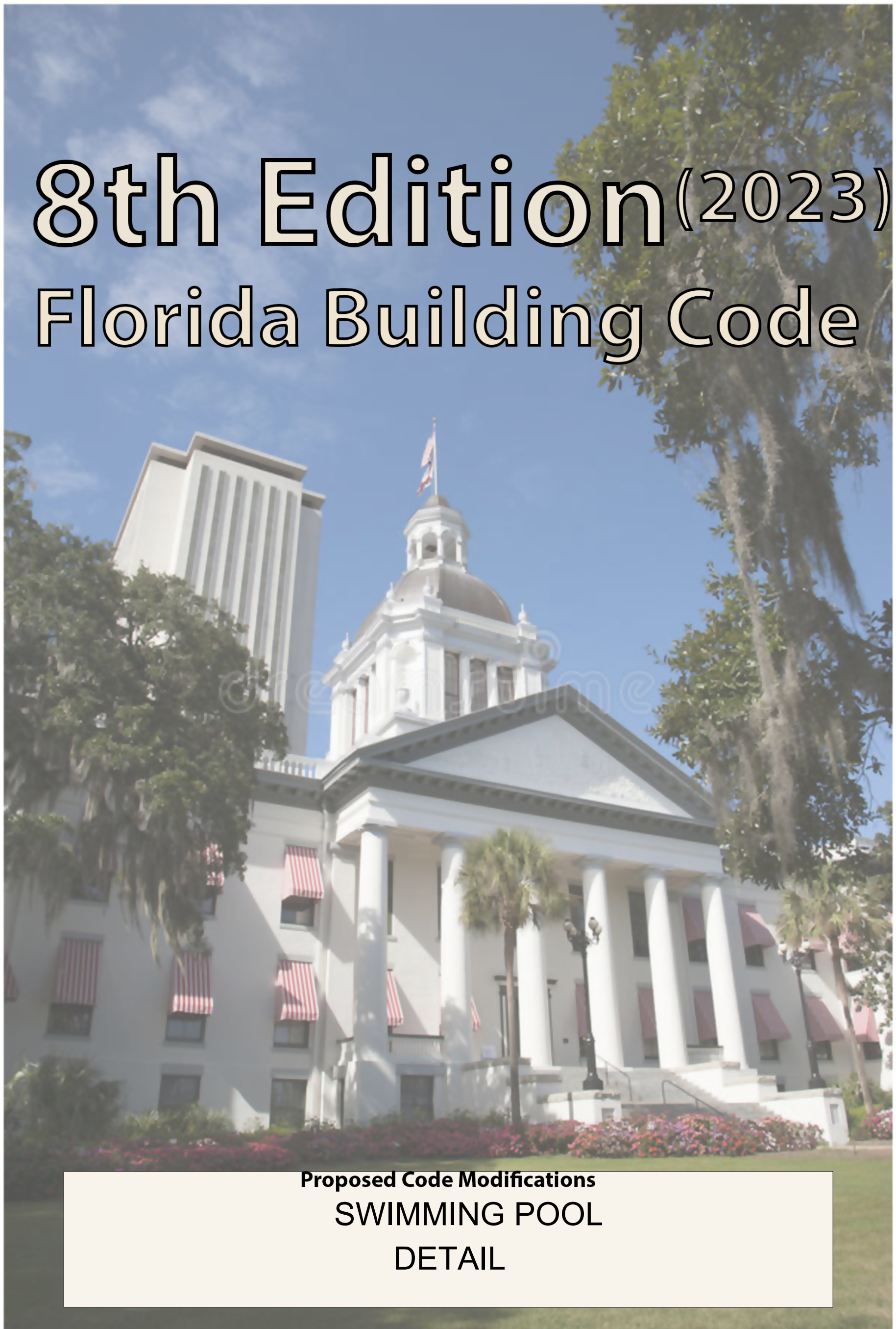


This document created by the Florida Department of Business and Professional Regulation -

850-487-1824

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9857

1

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

This would reduce the 15' minimum pool width to 10', and also clarify the rule.

Rationale

3. 454.1.2.2.2 – The 15ft pool width rule has many exceptions, but still trips up designers. We propose a 10-ft rule with fewer exceptions. It would eliminate the reference to "spa cove" which was not defined. Designers get around this code by turning their pool into a spa, which wastes energy because spas have to be turned over every 30 minutes. Width requirements are not found in other state codes and are not found in the ISPSC. This change also allows legal pools to fit in the envelope of a single wide trailer and go down the road, and allows pools to fit into structural grids better.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact, there is already a rule on this subject.

Impact to building and property owners relative to cost of compliance with code

Cost of compliance would go down. Owners who want narrower pools would be able to have them without imposing the turnover rate of a spa pool on them.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

We have not heard, from Florida or from any other state, reports of injuries from colliding with the opposite wall in a narrow pool.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This removes the undefined term "spa cove".

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This modification does not create any new exceptions.

Alternate Language

1st Comment Period History

SW9857-A1

Proponent Michael Weinbaum **Submitted** 4/13/2022 10:57:38 AM **Attachments** Yes

Rationale:

15' is not a requirement elsewhere in the United States, and we are not aware of any injuries associated with narrow pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Code becomes clearer.

Impact to building and property owners relative to cost of compliance with code

Code becomes more permissive.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade.

1st Comment Period History

SW9857-G1

Proponent Oliver Miranda Submitted 4/14/2022 12:01:55 PM Attachments No

Comment:

In the most recent code revision pool sizing allowed for smaller pools which has made maintaining those smaller pools with higher bather loads more difficult. This will certainly encourage the design of smaller pools at facilities intensifying the ongoing maintenance issues.

1st Comment Period History

SW9857-G2

Proponent Dallas Thiesen Submitted 4/14/2022 2:08:47 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification

1st Comment Period History

SW9857-G3

Proponent	bob vincent	Submitted	4/17/2022 12:20:10 PM	Attachments	Yes

Comment:

Life altering injuries have occurred from accidents in pools and will be worsened with obstructions and opposing walls less that 15 feet from perimeter entry points. Existing code can be clarified but existing setbacks are important for safety.

1st Comment Period History

SW9857-G4

Proponent	Gerald Robinson	Submitted	4/17/2022 7:25:42 PM	Attachments	No

Comment:

A quick internet search provides the average jumping distance of a human is approximately 10 feet. Public pools with a width at or near 10 feet would encourage daredevil jumping at distances near the average jumping distance. Individuals who choose to jump across would intersect the opposite side of the pool at or near the terminal distance and the risk of injury would greatly increase.

454.1.2.2.2 Walls and corners. All pool walls or obstructions shall have a clearance of ~~15~~ 10 feet (~~4572~~ 3048 mm) perpendicular to the ~~wall~~ edge (as measured at design water level from gutter lip to gutter lip, or on skimmer pools, from vertical wall to vertical wall). Offset steps, ~~spa coves,~~ sun shelves, spa pools and wading pools are exempt from this clearance requirement. Where interior steps or sun shelves protrude into the pool, the remaining width, from the junction of the step or shelf riser and the floorto the opposite wall, shall be 6 ft or more. ~~resulting in less than 15 feet (4572 mm) of clearance from any wall, such protrusion shall not exceed 6 feet (1828 mm) on any perpendicular line from a tangent to any pool wall from which the steps emanate.~~

Proposed Revision

454.1.2.2.2 Walls and corners. All pool walls or obstructions shall have a clearance of ~~15~~ 10 feet (~~4572~~ 3048 mm) perpendicular to the ~~wall~~ edge (as measured at design water level from gutter lip to gutter lip, or on skimmer pools, from vertical wall to vertical wall). Offset steps, ~~spa coves,~~ spa pools and wading pools are exempt from this clearance requirement. Where interior steps or a sun shelf protrude into the pool, the remaining width from the junction of the step riser and the floor to the opposite wall shall be 6 ft or more. ~~resulting in less than 15 feet (4572 mm) of clearance from any wall, such protrusion shall not exceed 6 feet (1828 mm) on any perpendicular line from a tangent to any pool wall from which the steps emanate.~~

…

454.1.2.6 Obstructions. The pool water area shall be unobstructed by any ~~type~~ structure ... Structures in accord with the above shall not be located in a diving bowl area.~~or within 15 feet (4572 mm) of any pool wall.~~

…

Exceptions:

…

3.

~~**…A sun shelf shall not protrude into the 15-foot (4572 mm) clearance requirement of Section 454.1.2.6.**~~

E910.8 - Accidental drowning in quenching

E910.8	2006	2007	2008	2009
Traumatic Brain Injury	6	6	4	5
Total Cost	$269,589.00	$319,652.00	$157,209.00	$211,253.00

E910.8	2006	2007	2008	2009
Spinal Cord Injury	1	2	3	3
Total Cost	$247,952.00	$57,140.00	$863,257.00	$736,696.00

E883.0 - Accident from diving or ju

E883.0	2006	2007	2008	2009
Traumatic Brain Injury	10	16	10	6
Total Cost	$359,480.00	$1,423,450.00	$306,982.00	$145,308.00

E883.0	2006	2007	2008	2009
Spinal Cord Injury	27	32	28	27
Total Cost	$5,310,091.00	$5,513,143.00	$3,458,059.00	$5,073,778.00

*Includes residents and non-residents and deaths. There are overlaps in traumatic brain
some patients have suffer both injuries. This w

tank or swimming pool

2010	2011	2012	2013	2014	Total
5	9	3	8	8	54
$113,662.00	$394,230.00	$492,994.00	$423,596.00	$250,181.00	$2,632,366.00

2010	2011	2012	2013	2014	Total
3	2	0	1	0	15
$906,878.00	$541,116.00	0	$75,098.00	0	$3,428,137.00

mping into water

2010	2011	2012	2013	2014	Total
13	11	11	9	6	92
$2,048,670.00	$1,914,174.00	$889,428.00	$486,880.00	$364,365.00	$7,938,737.00

2010	2011	2012	2013	2014	Total
33	26	21	22	19	235
$7,575,893.00	$6,679,815.00	$5,728,572.00	$3,542,963.00	$4,242,701.00	$47,125,015.00

injury and spinal cord injury for accidents from diving or jumping into water, meaning
'as not the case in the accidental drowning.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9858

2

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

This would reduce the 4 inch width of horizontal tile required for a sun shelf to 2 inches.

Rationale

454.1.2.6 – The code is repetitive regarding contrasting markings, and requires 4” of horizontal tile on sun shelves when 2” is sufficient for a bench and should be sufficient for a sun shelf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This makes the rules for similar situations the same, there is less for the local entity to remember.

Impact to building and property owners relative to cost of compliance with code

Cost of compliance would go down slightly, with a little less tile to buy and install.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

In pools, edges with steep drop-offs should be identified to warn users before they fall.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This makes the code clearer and less repetitive.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This modification does not create any new exceptions.

Alternate Language

1st Comment Period History

SW9858-A1

Proponent Michael Weinbaum **Submitted** 4/4/2022 2:41:18 PM **Attachments** Yes

Rationale:

In my original proposal, I didn't realize that the bench requirements include an allowance for a mere 3/4" of bullnose tile on the horizontal surface. This would not be enough. The requirement should be 2" of tile on the horizontal surface.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact

Impact to building and property owners relative to cost of compliance with code

Less tile is used, less cost.

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, we don't want people falling over the edge without a warning

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, four inches of stripe is excessive.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The code remains effective.

1st Comment Period History

SW9858-G1

Proponent Dallas Thiesen Submitted 4/14/2022 2:10:26 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification

1st Comment Period History

SW9858-G2

Proponent bob vincent Submitted 4/17/2022 2:21:45 PM Attachments No

Comment:

Florida Department of Health opposes this mod. Benches are 18" wide and are not intended to be used for children's play areas, so they are not similar to sun shelfs. Their contrasting bench edge marker is 11% of the width of the bench. Sun shelfs are defined as very shallow play and seating areas and have been designed up to 40 feet wide (commonly 15 feet), with a 4 foot water depth below the edge "cliff". Thus the larger edge markers are necessary for patrons to see from a greater distance before approaching the edge; this is similar to warning markers along pool perimeters for depth and no-diving, also 4" font. Compared to bench edge markers, these 4" edge markers on a 10 foot wide sun shelf are only 3% of the width of the shelf.

1st Comment Period History

SW9858-G3

Proponent	Gerald Robinson	Submitted	4/17/2022 7:38:25 PM	Attachments	No

Comment:

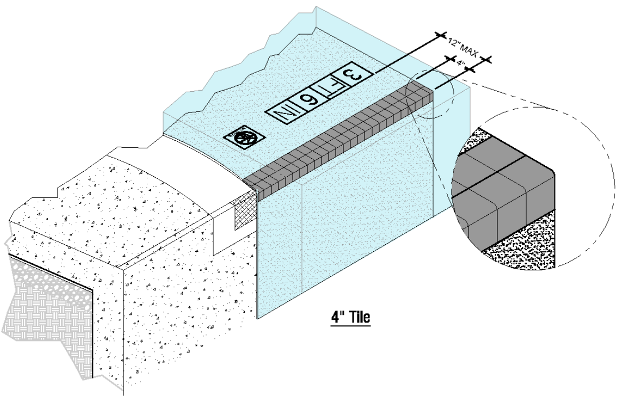
Benches and Sun Shelfs are different features with significant differences in use. Walking perpendicular to the edge of a bench, a pool user would expect and edge within a stride or 2. Walking on a sun shelf, the user would expect to be able to take several strides without the danger of a drop off. Additionally, the maximum bench width is 18 inches and 11% of that edge (2 out 18 inches) would be the contrasting tile, using a 4-inch tile there would be almost 20% of the bench edge and possible excessive. For an 8-foot sun shelf the 4-inch contrasting tiles would only be 4% of length and not excessive but visually contrasting.

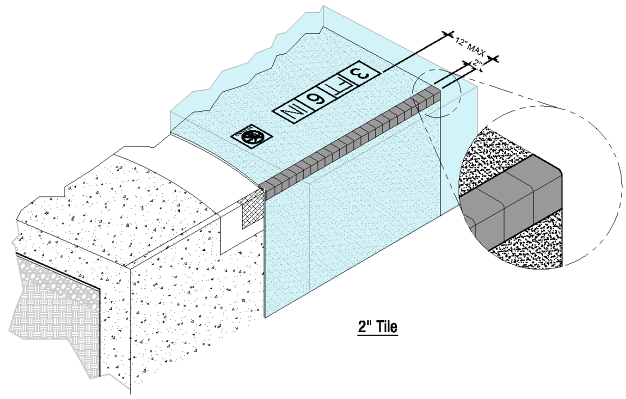
454.1.2.6 Obstructions. The pool water area shall be unobstructed …
Exceptions:
…

3. **3. … A sun shelf must have a dark contrasting slip-resistant tile marking at the edge of the shelf and the pool wall extending ~~4~~ 2 inches (~~102~~ 51 mm) from the horizontal shelf edge surface. Additionally, a 2-inch (51 mm) contrasting tile line is required on the vertical pool wall at the edge of the shelf. Vinyl liner, stainless steel and fiberglass pools may use other material for the sun shelf edge marking as detailed in Section 454.1.2.3.1, Item 7, provided the material is permanently secured, dark in color, nonfading and slip resistant. When the edge of a sun shelf uses stairs as a transition, the sun shelf edge tile markings shall comply with step edge requirements as provided in Section 454.1.2.5.3.…**

454.1.2.6 Obstructions. The pool water area shall be unobstructed ...
Exceptions:
...
3. ... A sun shelf must have ~~a dark contrasting slip-resistant tile marking at the edge of the shelf and the pool wall extending 4 inches (102 mm) from the horizontal shelf edge surface. Additionally, a 2-inch (51 mm) contrasting tile line is required on the vertical pool wall at the edge of the shelf. Vinyl liner, stainless steel and fiberglass pools may use other material for the sun shelf edge marking as detailed in Section 454.1.2.3.1, Item 7, provided the material is permanently secured, dark in color, nonfading and slip resistant. When the edge of a sun shelf uses stairs as a transition, the sun shelf edge tile markings shall comply with step edge requirements as provided in Section 454.1.2.5.3.~~the same markings at the edge as a bench. ...


3 FT 3 IN 1.0 M


12" MAX
4"
3 FT 6 IN
4" Tile


12" MAX
2"
3 FT 6 IN
2" Tile

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9859

3

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Eliminate minimum slope requirement

Rationale

Eliminating the minimum slope will simplify the design and checking of large pools. There are other provisions in the Code that ensure the floor is cleaned.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This gives the local entity one less thing to check.

Impact to building and property owners relative to cost of compliance with code

This reduces the cost of compliance for some pool types, and does not increase the cost for anyone.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The minimum slope is not needed to ensure that debris is removed from the floor, because 454.1.6.5.12 already requires a vacuum system.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This makes it easier and simpler to design safe pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

There are still required means of cleaning the pool floor.

1st Comment Period History

SW9859-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:11:20 PM	Attachments	No

Comment:

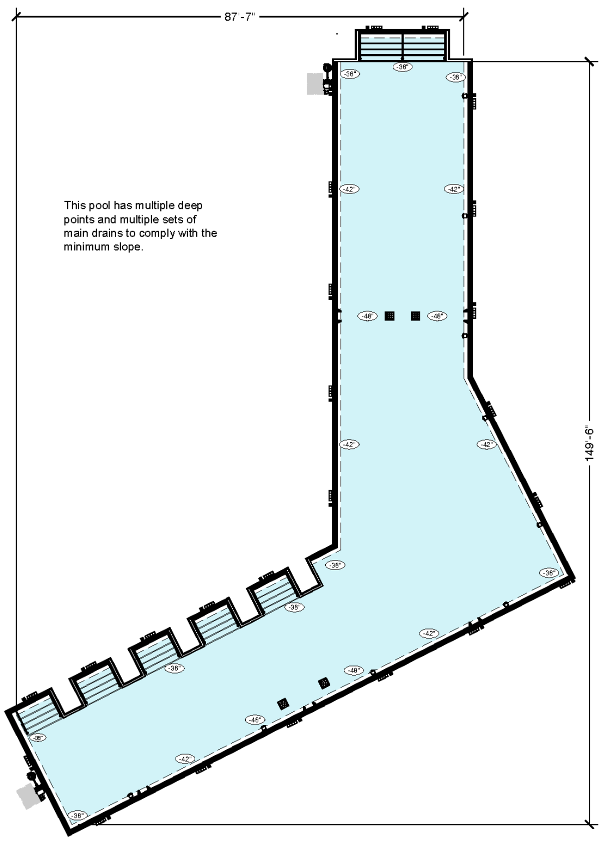
The Florida Swimming Pool Association (FSPA) Supports this Modification

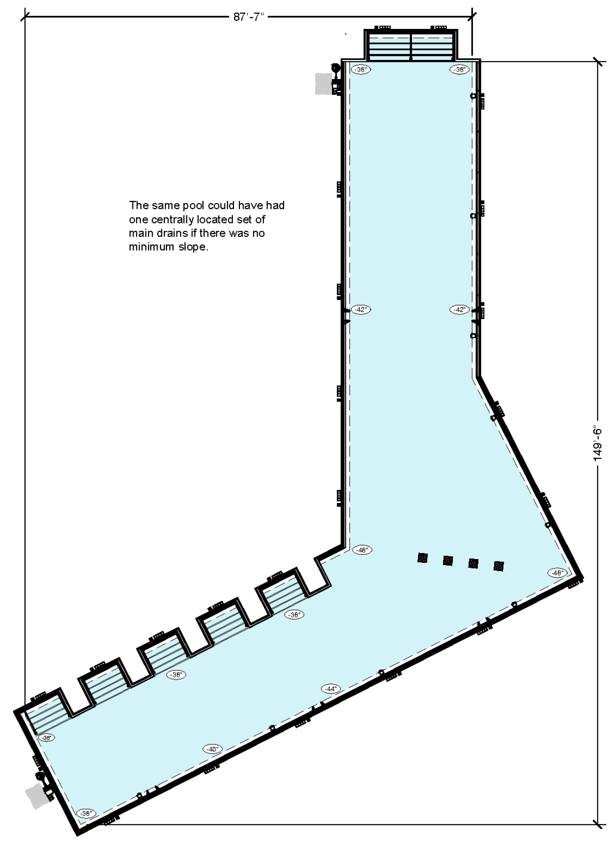
SW9859Text Modification

454.1.2.2.3.1 Floor slope shall be uniform. The floor slope shall be a maximum 1 unit vertical in 10 units horizontal ~~and a minimum of 1 unit vertical in 60 units horizontal~~ in areas 5 feet (1524 mm) deep or less. The floor slope shall be a maximum 1 unit vertical in 3 units horizontal in areas more than 5 feet (1524 mm) deep.

Mod_9859_TextOfModification.pdf Page: 1

SW9859Rationale





Page: 1

Mod_9859_Rationale_Change 6 - No Min Slope.pdf

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9860

4

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Eliminate minimum "deep area" depth.

Rationale

There is no need to require a part of the pool to be at least 4 ft deep.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This gives the local entity one less thing to check.

Impact to building and property owners relative to cost of compliance with code

This reduces the cost of compliance for some pool types, and does not increase the cost for anyone.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The current requirement has no reasonable connection with the health, safety, and welfare of the general public and should be removed.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This makes it easier and simpler to design safe pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This does not create any new exceptions.

1st Comment Period History

SW9860-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:12:24 PM	Attachments	No

Comment:

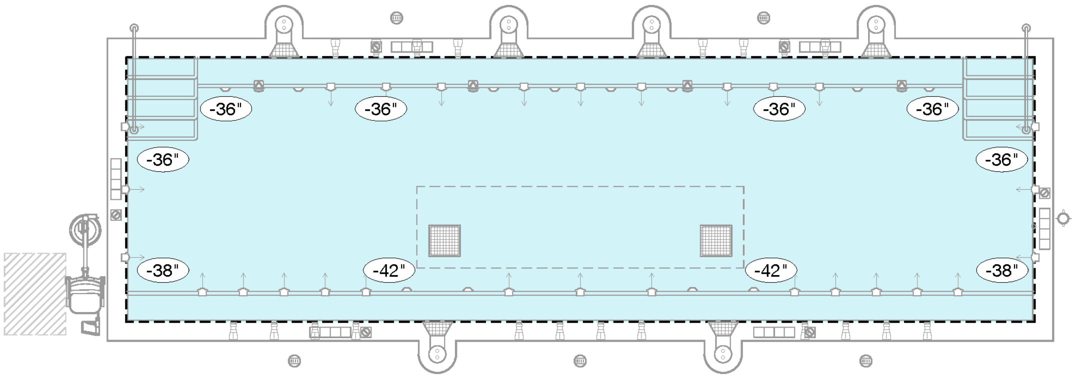
The Florida Swimming Pool Association (FSPA) Supports this Modification

~~**454.1.2.2.4 Pool depths.The minimum water depth shall be 3 feet (914 mm) in shallow areas and 4 feet (1219 mm) in deep areas.**~~

454.1.2.3 Markings.

454.1.2.3.1 Depth and markings. Depth and markings shall meet the following criteria:

1. The minimum water depth shall be 3 feet (914 mm)~~ in shallow areas and 4 feet (1219 mm) in deep areas~~.



The above pool would not comply with the pool code because its deep end is less than 48" deep.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9861

5

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Reducing the letter height of the sun shelf warning.

Rationale

The 4 inch tall letters are excessive. The warning about the overall depth of the pool is adequate at 2 inch letter height, so 2 inches should be sufficient for this warning as well.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There is no impact. They still have to verify that the signage exists, it just doesn't have to be as big.

Impact to building and property owners relative to cost of compliance with code

There would be a slight reduction in their costs.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The signs are meant to give fair warning to prevent someone from injuring themselves while stepping off the sunshelf edge.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

When the two similar warnings have the same letter height, there is less confusion for the enforcement official.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

The modification does not create any new exceptions.

1st Comment Period History

SW9861-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:13:24 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW9861-G2

Proponent	bob vincent	Submitted	4/17/2022 3:00:40 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod as written. Sun shelfs are rare in Florida pools so patrons may not be aware of them upon first arrival, and a pool signage warning for caretakers of children who cannot swim is warranted to be seen from all locations on the pool deck, thus larger letters are warranted. Commercial signs that are purchased now have already been produced with existing code language. Per manufacturer's letter visibility webpage, signazon.com, rule of thumb for best impact readability size and distance is 1" font for every 10' from sign. ANSI Z535.2-2011 Section specifies warning sign lettering sizes as 2.4" from 60', 3.2" from 80', 4" from 100' so reader can read the message panel text at a safe distance from the hazard. Recommend mod be edited to reassign a max. distance for all pool rules signs adjacent to pool, based upon using national standards.

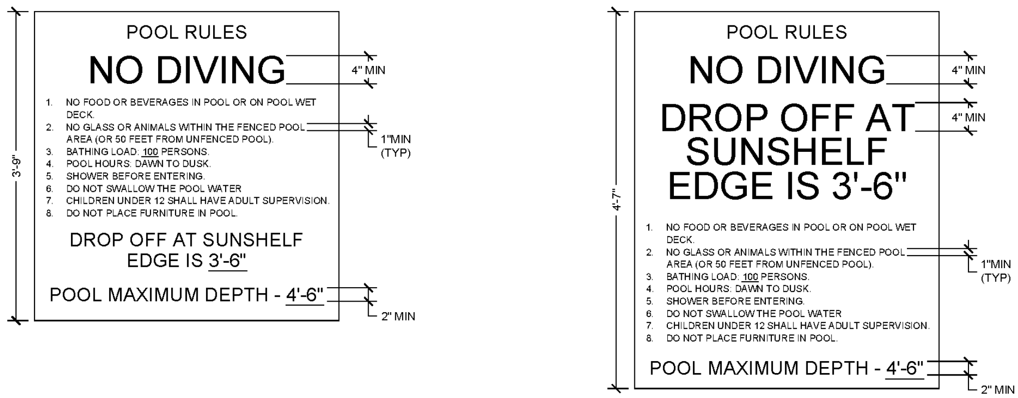
454.1.2.3.5 Rules and regulations signage Rules and regulations for bathers shall be installed in minimum 1-inch (25.4 mm) letters that must be legible from the pool deck, and shall contain the following:

…

8. If the pool includes a sun shelf, "WARNING: DROP OFF AT SUN SHELF EDGE IS ___ FEET DEEP" in 42-inch (102 mm) letters.

Proposal: 2" letters

Current Code: Requires 4" letters



Page: 1

Mod_9861_Text_Change 10 - Sunshelf Signage.pdf

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9862

6

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This modification would allow a sunshelf in the same water depths that a bench is allowed.

Rationale

Sun shelves and benches present similar hazards of people falling off the edge and injuring themselves. They should have similar rules about where they can be placed.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
This reduces possible confusion for the enforcing agent.
Impact to building and property owners relative to cost of compliance with code
There are no changes to costs.
Impact to industry relative to the cost of compliance with code
There are no changes to costs.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Having a maximum depth for pool areas that are adjacent to benches and sunshelves reduces the possibility of injury or drowning from a bather accidentally going over the edge.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
This makes the rules of the code easier to remember and less confusing.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination.

Does not degrade the effectiveness of the code
There are no new exceptions.

1st Comment Period History

SW9862-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:15:32 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

1st Comment Period History

SW9862-G2

Proponent	Gerald Robinson	Submitted	4/17/2022 8:17:57 PM	Attachments	No

Comment:
Sun shelfs with drop offs greater that 3 feet create difficultly for bathers going on and off the edge. Bathers returning from deep to shallow would have to transition a flat wall with little water deep on the shallow side to provide buoyance. Bathers going form shallow to deep would transition into a plunge pool or well rather than a swimming pool. Benches also have a deeper starting depth than a sun shelf.

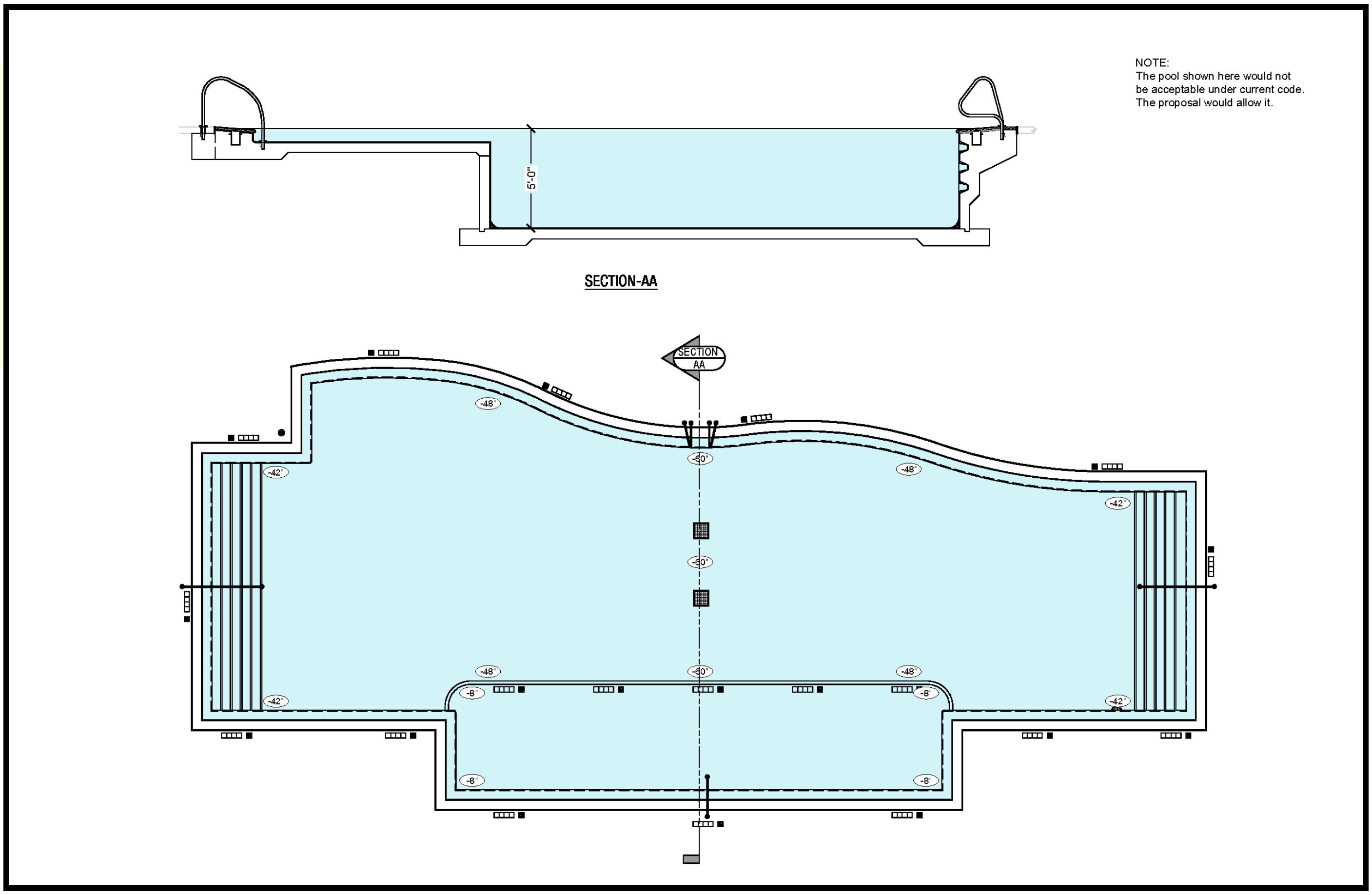
454.1.2.6 Obstructions.

...

Exceptions:

...

3. A sun shelf may be installed in pool areas less than 5 feet (1524 mm) deep.~~with no more than 4 feet (1219 mm) of water depth, or less.~~


NOTE:
The pool shown here would not
be acceptable under current code.
The proposal would allow it.
5'-0"
SECTION-AA
SECTION
AA
-48"
-42"
-50"
-8"

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9863

7

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This would clarify the decking requirements around plunge pools, and also clarify the difference between a swimming pool slide and a recreational water slide.

Rationale

The code imposes different requirements on recreational water slides vs. swimming pool slides but does not make it clear which is which. River Rides and Plunge Pools have similar needs for access and decking; they should use the same language for their deck requirements. This proposal does not change the requirements for River Ride decking, but applies those requirements to Plunge Pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This will reduce the confusion for code enforcement officials. Currently, the code says that deck has to go all the way around Plunge Pools. This is impossible because the flumes themselves will obstruct the deck. This change makes the code more enforceable.

Impact to building and property owners relative to cost of compliance with code

There is no impact.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This requires deck to be provided where deck is needed.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This eliminates the requirement to have the deck somehow wrap behind the slide flumes.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

This makes the code more effective by eliminating an impossible requirement.

1st Comment Period History

SW9863-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:16:41 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

"Recreational Water Slide" means a flume that carries riders with 100 gallons per minute or more of flow down the flume.

...

"Swimming pool slide" is a slide designed by its manufacturer to discharge over the sidewall of a swimming pool, and which uses no more than 100 gallons per minute of water to carry the riders.

...

454.1.9.2 Recreational Water slides. Recreational Water slides shall terminate in either a plunge pool or run out lanes.

454.1.9.2.1 ~~Water slide p~~Plunge pool. Plunge pools shall be constructed...

...

454.1.9.2.1.6 Plunge pool decks.

454.1.9.2.1.6.1Decking shall be provided at the entrance and exit points as necessary to provide safe patron access but shall not be smaller than 10 feet (3048 mm) in width and length. ~~Width. The minimum width of plunge pool decks along the exit side shall be 10 feet (3048 mm).~~

...

454.1.9.5.5Decking shall comply with 454.1.9.2.1.6.1.~~Decking shall be provided at the entrance and exit points as necessary to provide safe patron access but shall not be smaller than 10 feet (3048 mm) in width and length.~~ Additional decking along the ride course is not required except that decking shall be required at lifeguard locations and emergency exit points.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9864

8

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

9863

Summary of Modification

Clarifying that the 75ft rule for the spacing of access points does not apply to Plunge Pools.

Rationale

Code reviewers have attempted to enforce the 75 ft rule along plunge pool edges. A plunge pool should only be entered by the slide or points determined to be safe by the slide designer. The code should not mandate additional points.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This gives the code reviewer one less thing to check.

Impact to building and property owners relative to cost of compliance with code

This reduces the cost of compliance. Owners may be going for $300 variances to create safe plunge pools at this point.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This allows the designer to put exactly the number of exit points for the plunge pool to work as designed, rather than requiring extra points that would only confuse users.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This tailors the code better to a specific type of pool.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The 75ft rule would remain in place for all the other pools it currently applies to.

1st Comment Period History

SW9864-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:17:10 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

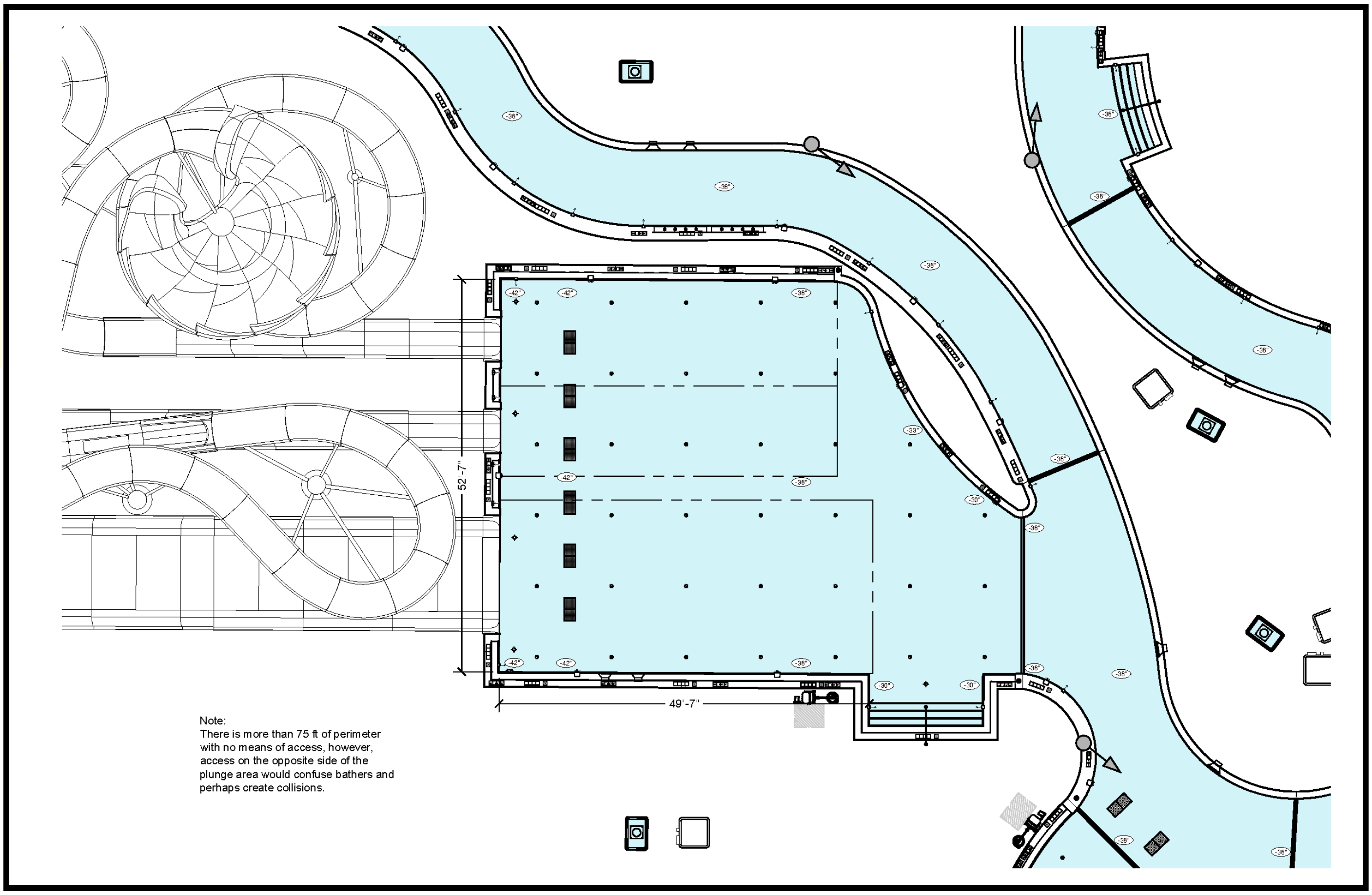
SW9864-G2

Proponent	bob vincent	Submitted	4/17/2022 3:59:56 PM	Attachments	No

Comment:

This proposed statement appears to say there is one point of ingress to the plunge pool, one slide flume, OR one point of egress, the exit: Only one entry or exit location shall be required, regardless of the plunge pool’s perimeter.

454.1.9.2.1.1 Adequate space at terminus. The slide design engineer must demonstrate to the jurisdictional building department's satisfaction that the water depth, clear area, distance between adjacent slides, floor slope, rope line placement, exit location, and pool floor surface finish are all adequate to prevent injury or harm to riders or other users of the pool, making reference to ASTM F2376, *Standard Practice for Classification, Design, Manufacture, Construction, and Operation of Water Slide Systems*, as appropriate. Only one entry or exit location shall be required, regardless of the plunge pool's perimeter.


52'-7"
49'-7"
Note:
There is more than 75 ft of perimeter
with no means of access, however,
access on the opposite side of the
plunge area would confuse bathers and
perhaps create collisions.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9865

9

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

454.1.6.5.3.1 – Allow gutters to wrap less than 90% of a perimeter as long as level control is provided. Level control language taken from IWF requirements.

Rationale

The requirement to have gutters on 90% of the pool perimeter is too restrictive and becomes the subject of variances. This revision would codify exactly what enhancements need to be made to a design to allow gutters to be on less than 90% of the pool perimeter.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The local entity may not be familiar with weirflow calculations that would be used to demonstrate that the remaining gutter length has sufficient capacity for the flow

Impact to building and property owners relative to cost of compliance with code

This would sometimes reduce their costs because tiled gutters are often one of the most expensive parts of the pool.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This revision ensures that designs that reduce the length of gutters still allow all of the required flow to go through the gutters

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Before, these designs would have gone through the variance process, and the variance board may not have used the weirflow calculation to check these designs.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This creates a new exception to the code but requires the designer to show the building department that the flow rate is maintained.

Alternate Language

1st Comment Period History

SW9865-A1

Proponent	Michael Weinbaum	**Submitted**	4/14/2022 4:45:31 PM	**Attachments**	Yes

Rationale:

This is an improvement on the prior submission, explains how to calculate the minimum gutter length instead of leaving it up to an unspecified calculation.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This ensures that a reasonable flow of water over the gutters will remain even as some gutters are eliminated.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This allows for an equivalently good method of gutter design to be employed.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

Does not degrade.

1st Comment Period History

SW9865-G1

Proponent	Oliver Miranda	Submitted	4/14/2022 12:16:56 PM	Attachments	No

Comment:

This code revision will leave far too much room for design flaws. Without equal surface skimming around the entire pool perimeter there are dead spots in the water that will collect surface debris and other contaminants. Even dispersion of chemicals will also be hindered.

1st Comment Period History

SW9865-G2

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:18:02 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

454.1.6.5.3.1 Perimeter overflow gutters. The lip of the gutter shall be uniformly level with a maximum tolerance of $^1/_4$ inch (6 mm) between the high and low areas. The bottom of the gutter shall be level or slope to the drains. The spacing between drains shall not exceed 10 feet (3048 mm) for 2-inch (51 mm) drains or 15 feet (4572 mm) for $2^1/_2$-inch (64 mm) drains, unless hydraulically justified by the design engineer. Gutters may be eliminated along pool edges, but if any edge without gutters exceeds 15 feet, or if the total edges without gutters exceed 10 percent of the perimeter, the following shall apply:

1. The remaining gutter length shall be indicated on the drawings. There shall be at least one 1 ft (305 mm) of remaining gutter length for each 5 gpm (0.32 L/s) of design recirculation flow.
2. An automatic water level controller shall be provided.
3. An overfill waste line with air gap shall be provided.

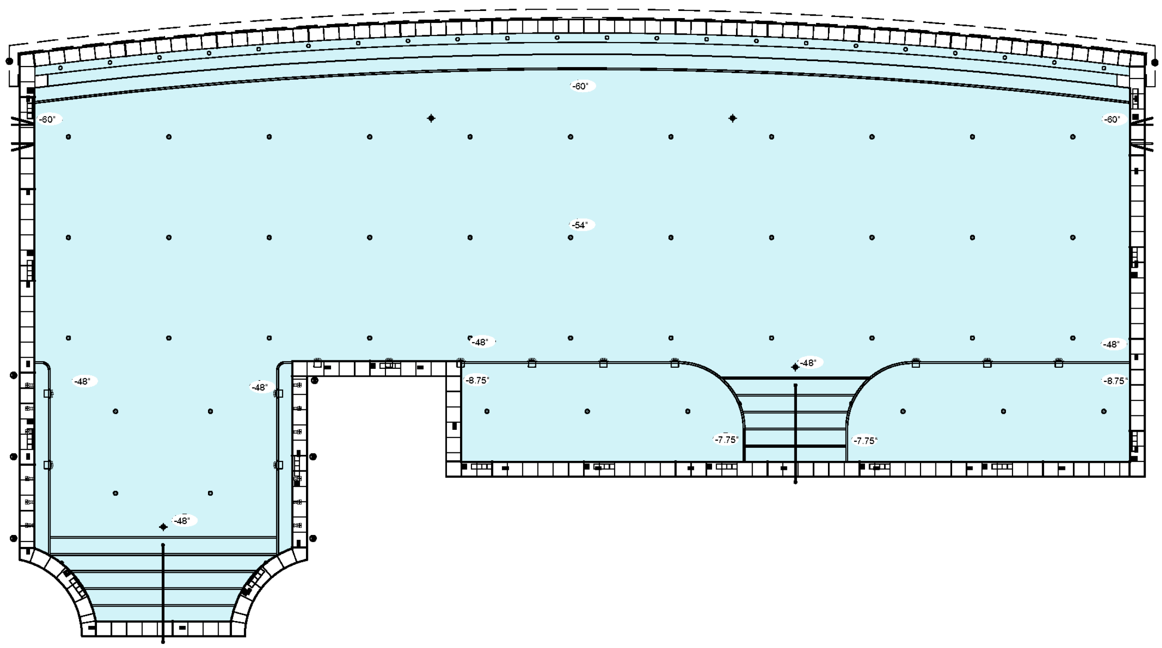
~~for no more than 15 feet (4572 mm) and this shall not exceed 10 percent of the perimeter (at least 90 percent of the perimeter shall be guttered).~~In areas where gutters are eliminated, handholds shall be provided within 9 inches (229 mm) of the water surface. Handhold design shall be approved by the jurisdictional building department prior to construction.

454.1.6.5.3.1 Perimeter overflow gutters. The lip of the gutter shall be uniformly level with a maximum tolerance of 1/4 inch (6 mm) between the high and low areas. The bottom of the gutter shall be level or slope to the drains. The spacing between drains shall not exceed 10 feet (3048 mm) for 2-inch (51 mm) drains or 15 feet (4572 mm) for 2 1/2-inch (64 mm) drains, unless hydraulically justified by the design engineer. Gutters may be eliminated along pool edges, but if any edge without gutters exceeds 15 feet, or if the total edges without gutters exceed 10 percent of the perimeter, the following shall apply:

1. The design engineer shall demonstrate to the jurisdictional building department that the remaining gutter length, in combination with the design water level over the gutter lip, is sufficient for the designrecirculation flow.
2. An automatic water level controller shall be provided.
3. An overfill waste line with air gap shall be provided.

for no more than 15 feet (4572 mm) and this shall not exceed 10 percent of the perimeter (at least 90 percent of the perimeter shall be guttered).In areas where gutters are eliminated, handholds shall be provided within 9 inches (229 mm) of the water surface. Handhold design shall be approved by the jurisdictional building department prior to construction.

NOTE:
This pool has an infinity type overflowing edge on one side only. This is not allowed under current code, but would be allowed under this proposal.



TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9866

10

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

This modification would require skimmers to be adequate for 100% of the design recirculation flow, rather than only 60%.

Rationale

This gives the plan reviewer a single flow rate to check for, rather than a 100% number and a 60% number.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This makes enforcement easier, one number to remember.

Impact to building and property owners relative to cost of compliance with code

This may occasionally require larger pipe sizes on skimmer suction lines.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This makes sure that the skimmers are doing as much pool cleaning work as possible.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This makes the code simpler and pools cleaner.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This eliminates a discrimination that favors skimmers, which allowed them to be installed with smaller pipes.

Does not degrade the effectiveness of the code

This eliminates a carve-out that currently exists for skimmers.

Alternate Language

1st Comment Period History

SW9866-A1

Proponent	Michael Weinbaum	**Submitted**	4/14/2022 1:55:58 PM	**Attachments**	Yes

Rationale:

Builders and designers would like to stay with a reduced flow requirement for skimmers, 60 percent rather than 100, but the Code should not imply that this is absolute. It's intended to be a minimum and designs allowing 100 percent through skimmers should be allowed also.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Code language is clearer

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, skimmers don't work unless the right amount of flow is directed through them.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

SW9866-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:18:43 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

454.1.6.5.3 System design. The design pattern of recirculation flow shall be 100 percent through the main drain piping and 100 percent through the perimeter overflow system or a minimum of 60 percent through the skimmer system.

...

454.1.6.5.3.2.1 Volume. The recessed automatic surface skimmer piping system shall be designed to carry a minimum of 60 percent of the pool total design flow rate with each skimmer carrying a minimum 30 gpm (2 L/s). One skimmer for every 400 square feet (37 m^2) or fraction thereof of pool water surface area shall be provided.

...

454.1.6.5.3 System design. The design pattern of recirculation flow shall be … 100 percent through the perimeter overflow system or ~~60 percent through~~ the skimmer system.
454.1.6.5.3.2.1 Volume. The recessed automatic surface skimmer piping system shall be designed to carry ~~60~~ 100 percent of the pool ~~total design~~ recirculation flow rate with each skimmer carrying a minimum 30 gpm (2 L/s). One skimmer for every 400 square feet (37 m^2) or fraction thereof of pool water surface area shall be provided.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9867

11

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

The code allows inlets to exceed 20 gpm if the manufacturer rates it for that. The code should also relax the inlet spacing and pool width requirements if such an inlet is specified.

Rationale

When an inlet has a faster flow rate, it is cleaning a greater area of the pool. This allows an inlet that has twice the flow rate to be credited as cleaning twice the floor area of the pool. It does so with a table that increases the allowable distances by the square root of the ratio of the new flow rate over the baseline 20 gpm value.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The local entity will have to get accustomed to using the table that is provided.

Impact to building and property owners relative to cost of compliance with code

This reduces the cost of compliance by allowing certain property owners to reduce the number of small pipes they have to use for their pool inlets.

Impact to industry relative to the cost of compliance with code

The industry is already providing these inlets that accept larger flow rates.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

It is reasonable to say that the inlets are cleaning the floor and walls of the pool, and they should be evenly distributed throughout the pool with no large gaps between them.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This adds new geometric rules to the code without requiring the reviewer to do more math or geometry.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This maintains the idea of a certain inlet flow rate per pool area.

Alternate Language

1st Comment Period History

SW9867-A1

Proponent Michael Weinbaum **Submitted** 4/14/2022 2:37:24 PM **Attachments** Yes

Rationale:

This equation gives the same results that the table in the original proposal gives. The equation may be easier to understand and use. The math assumes that an inlet is intended to clean a certain floor area. That floor area is the required spacing of inlets in one direction, multiplied by the required spacing in a perpendicular direction. If the flow rate in the inlet increases above 20 gpm, the floor area it can clean increases proportionally. The area is just the square of the spacing, so the spacing may increase by the square root of the increase in flow.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This is a calculation that the local entity may have to check on some pools

Impact to building and property owners relative to cost of compliance with code

The cost of new pools is reduced when fewer, larger inlets are used, when compared to many, smaller inlets. The chances for leaks developing is reduced, as well as the cost of resurfacing.

Impact to industry relative to the cost of compliance with code

No impact, industry is already making these high powered fittings.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This ensures that a certain flow per surface area of the pool is maintained, keeping the water just as clean as today's code requires.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This strengthens the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This eliminates discrimination against newer, larger inlets.

Does not degrade the effectiveness of the code

Does not degrade.

1st Comment Period History

SW9867-G1

Proponent Oliver Miranda Submitted 4/14/2022 12:22:03 PM Attachments No

Comment:

This decreases the even distribution of chemicals in the pool. Allowance of higher flow inlets is not a problem but the table provided allows for too far a span with the spacing for proper chemical mixing.

1st Comment Period History

SW9867-G2

Proponent Dallas Thiesen Submitted 4/14/2022 2:19:34 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

1st Comment Period History

SW9867-G3

Proponent	bob vincent	Submitted	4/17/2022 4:10:17 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod. Inlet spacing should be fluid dynamic modeled and field verified with dye tests before choosing possible separation distances and flow capacity for a building code change.

454.1.6.5.9.6 The flow rate through each inlet shall not exceed 20 gpm (1 L/s) except for inlets designed for higher flows as ~~specified~~ documented by the manufacturer and selected by the design engineer. If higher flow inlets are used, the allowable dimensions for inlet spacing and pool width may be increased in accordance with equation 454-1:

$$S_a = S_t \times (Q/20)^{0.5}$$

Equation 454-1

where:
S_a = allowable dimension, feet
S_t = allowable dimension as described in 454.1.6.5.9.1, feet
Q = inlet flow rate, gpm

454.1.6.5.9.6 The flow rate through each inlet shall not exceed 20 gpm (1 L/s) except for inlets designed for higher flows as ~~specified~~ documented by the manufacturer and selected by the design engineer. If higher flow inlets are used, the allowable dimensions for spacing and pool width may be increased as shown on this Table:

	Dimension specified in 454.1.6.5.9.1-5 (ft)				
Inlet Flow Rate (gpm)	10	15	20	25	30
30	12.2	18.4	24.5	30.6	36.7
50	15.8	23.7	31.6	39.5	47.4
70	18.7	28.1	37.4	46.8	56.1
100	22.4	33.5	44.7	55.9	67.1
150	27.4	41.1	54.8	68.5	82.2

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

12

SW9868

Date Submitted	01/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

454.1.6.5.17 – This revision loosens the 20% requirement for features that derive water from a filter, and clears up the ambiguity with the term “designed turnover rate.”

Rationale

Frequently, the pool builder would like to add deck sprays or film waterfalls to their pool. These features may require the water they receive to be filtered, to prevent clogging. This revision makes it easier to use the same filter that is already filtering the pool water to clean the water for these features. It changes the word "designed" to "minimum" to eliminate a recursion problem and to give the reviewer a definite value to use.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There is no impact, the rule remains in place.

Impact to building and property owners relative to cost of compliance with code

This allows new cost reducing options to be used when designing pools with water features attached. Rather than plan extra inlet pipes and inlets to accommodate extra flow when the feature is off, the designer can simply reduce the speed of the pump.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This is part of making sure that all pools meet their minimum flow rate so they have clean water.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This reduces the ambiguity about which flow rate the reviewer is supposed to check against, and eliminates a possible recursion issue if they pick the wrong one.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This makes the code more effective.

1st Comment Period History

SW9868-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:20:18 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.6.5.17 Water features such as waterfalls or fountains in pools may use up to ~~20~~ 50 percent of the return water ~~from the filter system~~coming out of the filter, however all waters used in the feature shall not be counted toward attaining the ~~designed~~ minimum turnover rate specified in 454.1.1.1, 454.1.6.5.2, or elsewhere in this Code. The ~~R~~return piping system shall be designed and capable of handling the additional feature flow when the feature is turned off, otherwise the pump speed shall be reduced automatically. ~~Features that require more than 20 percent of the flow rate shall be supplied by an additional pump that drafts from a suitable collector tank.~~ All water features that utilize water from the pool shall be designed to return the water to the pool…

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9869

13

Date Submitted	01/07/2022	**Section**	454.1	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Add a definition of "letters" to allow lower case lettering on signage around pools, above a certain size.

Rationale

Some believe that Pool Rules signs have to be in all capital letters. There is decades of research showing that ALL CAPS is not as easy to read as a mixture of upper and lower case. This would explicitly allow lower case letters on Pool Rules signs.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This gives the local entity a new guideline by which they could reject a font that is very hard to read, such as an unusual font with tall capital letters and very short lower case letters.

Impact to building and property owners relative to cost of compliance with code

There is no impact.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This will make Pool Rules signs easier to read.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This clarifies that lower case letters are allowed.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The code effectiveness remains the same.

1st Comment Period History

W9869-G1

Proponent	Oliver Miranda	Submitted	4/14/2022 1:39:27 PM	Attachments	No

Comment:

Either all caps or not should be allowed as long as the height of the letters meets the minimum code requirements for the rule (all the lowercase letters must measure 1" in height if used for that particular section of rule).

“Letters” refers to upper case letters where “C” is at least a specified height, or lower case letters where “c” is at least half the specified height.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9926

14

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Correct a units error, and remove a sentence that is redundant from 454.1.2.3.1

Rationale

The code converts length to millimeters, not cubic meters. The last sentence should be deleted because the requirement is stated more clearly in 454.1.6.5.10.1

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Code becomes easier to read

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, the deepest point in the pool should be indicated at the edge of the pool so that people know what they're getting into.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, this makes the code easier to read and understand.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The requirements stay the same, but the repetition is eliminated.

1st Comment Period History

SW9926-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:21:03 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.2.3.1

...

2. Permanent depth markings followed by the appropriate full or abbreviated words "FEET," "FT," or "INCHES," "IN," shall be installed in minimum 4-inch-high (102 mm) numbers and letters on a contrasting background. Depth markers shall indicate the actual pool depth, within 3 inches (76 mm), at normal operating water level when measured 3 feet (914 ~~m3~~mm) from the pool wall. ~~Symmetrical pool designs with the deep point at the center may be allowed provided a dual marking system is used which indicates the depth at the wall and at the deep point.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

15

SW9927

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarify when the sunshelf edge dropoff warning is required.

Rationale

A warning about a drop-off should not be required unless the drop-off actually exists.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The rule gets a little more complicated, because it has two conditions rather than one, but the outcome is more logical. Because the rule as written can create illogical outcomes, there might be problems with enforcement today.

Impact to building and property owners relative to cost of compliance with code

Fewer signs would be required in some situations.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes. Regardless, it is important to warn pool users about steep dropoffs.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, this makes the code more logical.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code
Makes the code more effective.

1st Comment Period History

SW9927-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:21:31 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW9927-G2

Proponent	bob vincent	Submitted	4/17/2022 3:09:31 PM	Attachments	No

Comment:
Florida Department of Health is not in favor of this mod as written. Pool floors have floor slope criteria plus step and sun shelf drop-off criteria to prevent injuries and to assure that patrons have immediate information on the depth below. A step will be no more than 10" below the sun shelf edge, so that is the suggested threshold for sign warning. Sun shelfs can be either 8" deep or 12" deep at drop-off edge, so depending on the type built, either 18" or 22" water depth below the sun shelf edge would be the threshold for the signage.

454.1.2.3.5 Rules and regulations signage. …

…

8. If the pool includes a sun shelf, and the depth in the pool directly adjacent to any part of the shelf is 3 feet (914 mm) deep or more, "WARNING: DROP OFF AT SUN SHELF EDGE IS ___ FEET DEEP"…

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9929

16

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

There will be a similar modification proposed to the section on remote vacuum assemblies.

Summary of Modification

Code officials are still not sure if skimmer equalizers are required or not. Skimmer equalizers should not be required by the code.

Rationale

The first sentence says that equalizer valves are optional, but truly the equalizer itself should also be optional. It does not make sense to require an equalizer. They create a direct suction situation that can harm people. The only benefit is that they might protect a pump from burning out. This is not worth the cost of potentially hurting someone if an equalizer grate breaks or comes off. Also, places where water leaves the pool are called outlets elsewhere in the Code, that should be the word here.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The language becomes clearer. This would be one less thing to check on a skimmer pool design.

Impact to building and property owners relative to cost of compliance with code

The cost of compliance would go down. Less pipes, less grates.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this is allowing owners to eliminate a potentially dangerous condition.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, there are other ways for owners to protect their pumps other than equalizers.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This removes a requirement that is not beneficial.

1st Comment Period History

SW9929-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:22:14 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

SW9929Text Modification

454.1.6.5.3.2.3 Equalizers. If installed, an equalizer valve shall be a spring-loaded vertical check valve that will not allow direct suction on the equalizer line. Float valves are prohibited. ~~The~~ If installed, the equalizer line ~~inlet~~ outlet shall be installed at least 1 foot (305 mm) below the normal pool water level and the equalizer line ~~inlet~~ outlet shall be protected by an ASME/ANSI A112.19.8 compliant cover/grate. ~~The equalizer line shall be sized to handle the expected flow with a 2-inch (51 mm) minimum line size.~~ Any equalizer line shall be 2 inches or larger. ~~Where an equalizer valve is not installed, the skimmer port may be plugged.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9930

17

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

The requirements for pool inlet spacing are repetitive and hard to understand. This shortens them from 331 words to 127 words, while requiring the same things.

Rationale

The language is very repetitive here. The Code already treats pools with some floor inlets the same regardless of their width. This revision would state that more clearly. Width only matters when only wall inlets are intended. The last sentence is a less strict version language at the beginning of 454.1.6.5.9, which is not included in this modification proposal.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This makes the code easier to read and learn.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Inlet spacing is important to lessen the possibility of stagnant water and organisms growing there.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The code becomes easier to read and understand.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The code still would require the same spacings.

Alternate Language

1st Comment Period History

SW9930-A1

Proponent	Michael Weinbaum	**Submitted**	3/22/2022 1:35:04 PM	**Attachments**	Yes

Rationale:

This alternate language explicitly says that there are three options for compliance with the code. It also adds that you can have inlets above and beyond what are required under the selected option. Previously, adding a single wall inlet to a design that otherwise has only floor inlets caused some code reviewers to say that all walls would need inlets on 20' spacing.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This makes enforcement easier

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, it is reasonable to ensure that inlets are as evenly spaced as possible.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, making the code easier to read makes it easier to enforce. It strengthens the code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade.

1st Comment Period History

SW9930-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:23:12 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW9930-G2

Proponent	Gerald Robinson	Submitted	4/17/2022 8:40:02 PM	Attachments	No

Comment:

The revision removes the floor inlet height restrictions and smooth feature details.

454.1.6.5.9 Inlets. All inlets shall be adjustable with wall-type inlets being directionally adjustable and floor-type inlets having a means of flow adjustment. Floor inlets shall be designed and installed such that they do not protrude above the pool floor and all inlets shall be designed and installed so as not to constitute sharp edges or protrusions hazardous to pool bathers. Floor inlets for vinyl liner and fiberglass pools, shall be smooth with no sharp edges, and shall not extend more than 3/8 inch (9.5 mm) above the pool floor. Wall inlets shall be installed a minimum of 12 inches (305 mm) below the normal operating water level unless precluded by the pool depth or intended for a specific acceptable purpose. The spacing of inlets shall comply with one of the following:

1. **~~454.1.6.5.9.1~~The pool is~~Pools~~ 30 feet (9144 mm) in width or lessand has wall inlets~~, with wall inlets only shall have enough inlets~~ such that the inlet spacing does not exceed 20 feet (6096 mm) ~~based on the~~ along the entire pool water perimeter.**
2. **~~454.1.6.5.9.2~~The pool has ~~Pools 30 feet (9144 mm) in width or less with~~ floor inlets ~~only shall have a number of inlets provided~~ such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the spacing between inlets and adjacent walls does not exceed 10 feet (3048 mm).**
3. **~~454.1.6.5.9.3A~~ The pool has a combination of wall and floor inlets ~~may be used~~such thatthe spacing between adjacent inlets of the same type does not exceed 20 feet (6096 mm), the spacing between a floor inlet and an adjacent wall without inlets does not exceed 10 feet (3048 mm), and the spacing between a floor inlet and an adjacent wall with inlets does not exceed 25 ft (7620 mm). ~~in pools 30 feet (9144 mm) in width or less only if the requirements of Section 454.1.6.5.9.1 or Section 454.1.6.5.9.2 are fully met.~~**

In each case, additional wall or floor inlets may be provided above and beyond these minimum requirements.

~~454.1.6.5.9.4Pools greater than 30 feet (9144 mm) in width shall have either floor inlets only, or a combination of floor inlets and wall inlets. Pools with floor inlets only shall have a number of floor inlets provided such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the spacing between inlets and an adjacent wall does not exceed 10 feet (3048 mm).~~

~~454.1.6.5.9.5Pools greater than 30 feet (9144 mm) in width with a combination of wall and floor inlets shall have the number of wall inlets such that the maximum spacing between the wall inlets is 20 feet (6096 mm) and floor inlets are provided for the pool water area beyond a 15 feet (4572 mm) perpendicular distance from all walls. The number of floor inlets shall be such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the distance from a floor inlet and an adjacent wall does not exceed 25 feet (7620 mm). Floor inlets shall be designed and installed such that they do not protrude more than 5/8 inch (16 mm) above the pool floor and all inlets shall be designed and installed so as not to constitute sharp edges or protrusions hazardous to pool bathers.~~

454.1.6.5.9.1 Pools 30 feet (9144 mm) in width or less may have wall inlets only, ~~with wall inlets only shall have enough inlets such that~~so long as the inlet spacing does not exceed 20 feet (6096 mm) based on the pool water perimeter.

454.1.6.5.9.2 Pools ~~30 feet (9144 mm) in width or less~~ with floor inlets only shall have a number of inlets provided such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the spacing between inlets and adjacent walls does not exceed 10 feet (3048 mm).

454.1.6.5.9.3 A combination of wall and floor inlets may be used as long as the spacing between adjacent inlets of the same type does not exceed 20 ft (6096 mm). The spacing between a floor inlet and an adjacent wall shall not exceed 25 ft (7620 mm). ~~in pools 30 feet (9144 mm) in width or less only if the requirements of Section 454.1.6.5.9.1 or Section 454.1.6.5.9.2 are fully met.~~

454.1.6.5.9.4~~Pools greater than 30 feet (9144 mm) in width shall have either floor inlets only, or a combination of floor inlets and wall inlets. Pools with floor inlets only shall have a number of floor inlets provided such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the spacing between inlets and an adjacent wall does not exceed 10 feet (3048 mm).~~Reserved

454.1.6.5.9.5~~Pools greater than 30 feet (9144 mm) in width with a combination of wall and floor inlets shall have the number of wall inlets such that the maximum spacing between the wall inlets is 20 feet (6096 mm) and floor inlets are provided for the pool water area beyond a 15 feet (4572 mm) perpendicular distance from all walls. The number of floor inlets shall be such that the spacing between adjacent inlets does not exceed 20 feet (6096 mm) and the distance from a floor inlet and an adjacent wall does not exceed 25 feet (7620 mm). Floor inlets shall be designed and installed such that they do not protrude more than 5/8 inch (16 mm) above the pool floor and all inlets shall be designed and installed so as not to constitute sharp edges or protrusions hazardous to pool bathers.~~Reserved

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9931

18

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Liquid chlorine tanks are routinely placed outdoors. This may cause the chlorine to degrade more rapidly, but as long as the area is inaccessible to the public there is no harm. The Code should not be requiring liquid Chlorine to be placed indoors.

Rationale

Chemicals have a longer shelf life when stored indoors, and storing them indoors is a best practice for the owner, but because outdoor storage of liquid chlorine is not hazardous to the public, this is not a topic for the Building Code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

The local authorities in general do not prevent liquid chemical tanks from being placed outside. This modification would confirm that practice.

Impact to building and property owners relative to cost of compliance with code

No impact, as it seems this part is not being enforced as written.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

It is reasonable to require liquid chemicals to be stored away from the public. This modification preserves that. It is not reasonable to require them to be placed under a roof.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This clarifies the code. Chlorine gas is much more hazardous and there are requirements in the code that were meant to apply to gas chlorine only, but since they only say "chlorine" someone may try to apply the rule to a liquid chlorine system.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

This part of the code is not being enforced as written.

1st Comment Period History

SW9931-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:23:46 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.3.3.4 A room or space shall be provided for chemicals to be stored ~~in a cool, dry, and well-ventilated area under a roof~~ and the area shall be inaccessible to the public.

...

454.1.6.5.16.1.1.1 Chlorine gas rooms shall have: continuous forced draft ventilation capable of a minimum of one air change per minute with an exhaust at floor level to the outside, a minimum of 30 footcandles (300 lux) of illumination with the switch located outside and the door shall open out and shall not be located adjacent to the filter room entrance or the pool deck. A shatterproof gas-tight inspection window shall be provided.

454.1.6.5.16.1.1.2 Chlorine gas areas shall have a roof and shall be enclosed by a chain-link-type fence at least 6 feet (1829 mm) high to allow ventilation and prevent vandalism.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9932

19

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

There are two references in the Code to turnover rates that could be interpreted as absolute requirements, but are intended to be minimums that may be exceeded. This should be corrected.

Rationale

All turnover rates mentioned in the Code should be clearly stated as minimums. It should be clear that going faster is OK.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact, the local authorities seem to understand this already.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Pool turnover times are critical to maintaining water quality.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This makes the code clearer.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

This makes the code clearer.

Alternate Language

1st Comment Period History

SW9932-A1

Proponent Michael Weinbaum **Submitted** 3/9/2022 1:32:12 PM **Attachments** Yes

Rationale:

The lap lane width is also a minimum. There is no reason harm if a lap lane is more than 7 feet wide.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

none

Impact to building and property owners relative to cost of compliance with code

none

Impact to industry relative to the cost of compliance with code

none

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

does not.

Does not degrade the effectiveness of the code

does not.

1st Comment Period History

SW9932-G1

Proponent Dallas Thiesen Submitted 4/14/2022 2:26:01 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.2.3.3 Lane markings. Pools that are not intended to be utilized for officially sanctioned competition may install lap lane markings provided they meet the following criteria: the markings must be 2 to 6 inches (51 to 152 mm) wide, they must terminate 5 feet (1524 mm) from the end wall in a "T" with the "T" bar at least 18 inches (457.2 mm) long, they must be placed at 7-foot (2134 mm) minimum intervals on center and be no closer than 4 feet (1219 mm) from any side wall, steps or other obstructions. Floating rope lines associated with lap lanes must not obstruct the entrance or exit from the pool and are prohibited when the pool is open for general use.

...

454.1.6.5.2 Volume. The recirculation system shall be designed to provide a minimum of four turnovers of the pool volume per day. Pools that are less than 1,000 square feet (93 m^2) at health clubs shall be required to provide a minimum of eight turnovers per day.

...

454.1.9.1 General. Water recreation attraction projects ... all pools listed in this section shall ~~have a~~ provide a minimum of one turnover every 2 hours ~~turnover rate~~ unless otherwise noted.

454.1.6.5.2 Volume. The recirculation system shall be designed to provide a minimum of four turnovers of the pool volume per day. Pools that are less than 1,000 square feet (93 m^2) at health clubs shall be required to provide a minimum of eight turnovers per day.

...

454.1.9.1 General. Water recreation attraction projects ... all pools listed in this section shall ~~have a~~provide a minimum of one turnover every 2 hours~~turnover rate~~ unless otherwise noted.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9933

20

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Wading pools are already required, per 454.1.7.1, to follow most requirements for swimming pools. There is no need to repeat these requirements in this section. Repetitive text should be removed.

Rationale

These requirements are already found for swimming pools and already apply to wading pools. Main drains discharge to collector tanks, 454.1.6.5.10.5. Main drain installed in deepest point, 454.1.6.5.10. Velocity not to exceed 1.5 fps, 454.1.6.5.10.2. Vacuum required, 454.1.6.5.12.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

All of these requirements help keep pools clean, and all of them already apply per 454.1.6.5.10 etc.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

A cleaner code is better.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

A cleaner code is better.

1st Comment Period History

SW9933-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:26:29 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.7.3 Recirculation Wading pools shall have a minimum of one turnover every hour. ~~Lines from main drains shall discharge into a collector tank.~~
454.1.7.3.1 Skimmer equalizer lines, when ~~required~~ installed, shall be plumbed into the main drain ~~installed in the pool floor with a grate covering~~.
~~454.1.7.3.2 The grate cover shall be sized so as not to allow the flow to exceed 1½ feet per second (457 mm/s) when the equalizer line is operating.~~
...
454.1.7.6 Reserved ~~Vacuuming. Wading pools with 200 square feet (19 m^2) or more of pool water surface area shall have provisions for vacuuming through the skimmer, a portable vacuum system or an alternative approved method that does not involve a direct suction port in the pool.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9934

21

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

The first two sentences of the spa steps requirements are repetitions of other parts of the Code. They should be deleted. The last sentence is also redundant.

Rationale

Section 454.1.2.5.5 already imposes a stricter version of these requirements.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
No impact
Impact to building and property owners relative to cost of compliance with code
No impact
Impact to industry relative to the cost of compliance with code
No impact
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
This does not change the requirements of the Code
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Eliminating redundancy makes the Code better
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination
Does not degrade the effectiveness of the code

The requirements are the same

Alternate Language

1st Comment Period History

SW9934-A1

Proponent Michael Weinbaum **Submitted** 4/15/2022 3:55:29 PM **Attachments** Yes

Rationale:

The definition of spa pool should be clarified, a "swim against the current" feature should not fall into the spa pool category. Currently spas with less than 120 sf can obstruct much more deck than a pool, while spas with 120 sf or more can't restrict as much deck as a pool can. The 120 sf is arbitrary so I propose replacing it with a 10 ft width threshold which is related to an ability to see and potentially assist people from the unobstructed deck. For larger spa pools, the deck requirements should default back to the pool requirements for simplicity. Lowered deck should be allowed for spas as well as pools. The number of inlets required should have nothing to do with perimeter. The language about combination spas/pools is not clear; many people think this is talking about separate pools when they first read it, but it is intended to talk about a spa within a pool. The requirement comes from a concern that if there is a pool with a bench and bubbler nozzles, people might not see the contrasting marking of the bench through the bubbles, and therefore they should be discouraged from entering the pool in this area. The updated language states this more clearly and also allows architects to select other types of obstructions if the stanchions are aesthetically objectionable. The spa portion of one of these combinations would be no more than 20' long, 3' wide, and 2.25' deep, giving 1,010 gallons. The two inlets required in 454.1.8.7, assuming 15 gpm each, gives a 34 minute turnover, close enough to 30 minutes without requiring the building official to do the math every time.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This deletes some requirements and introduces new ones, but the new requirements are simpler and fewer.

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, as described in the rationale

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

SW9934-G1

Proponent Dallas Thiesen Submitted 4/14/2022 2:27:05 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

"Spa pool" means a pool used in conjunction with high-velocity air or water coming from a nozzle in the back wall of a bench.

454.1.8.1 General. Spa pools shall meet the requirements of Sections 454.1.1 through 454.1.6.5, unless specifically indicated otherwise.

454.1.8.2 Color, pattern, finish. The color, pattern or finish of the pool interior shall not obscure the existence or presence of objects or surfaces within the pool.

454.1.8.3 Water depths. Spa-type pools shall have a minimum water depth of $2^1/_2$ feet (762 mm) and a maximum water depth of 4 feet (1219 mm), except that swim spa pools may have a maximum water depth of 5 feet (1524 mm). Depth markers and "NO DIVING" markers are not required on spa-type pools with 200 square feet (19 m^2) or less of water surface area.

454.1.8.4 Steps and handrails. Steps or ladders shall be provided and shall be located to provide adequate entrance to and exit from the pool. The number of sets of steps or ladders required shall be on the basis of one for each 75 feet (22 860 mm), or major fraction thereof, of pool perimeter. Step sets for spa-type pools with more than 200-square-feet (19 m^2) of pool water surface area shall comply with Section 454.1.2.5. Step sets for spa-type pools with 200 square feet (19 m^2) or less of pool water surface area shall comply with the following: Step treads shall have a minimum width of 10 inches (254 mm) for a minimum continuous tread length of 12 inches (305 mm). Step riser heights shall not exceed 12 inches (305 mm). Intermediate treads and risers between the top and bottom treads and risers shall be uniform in width and height, respectively. Contrasting markings on the leading edges of the submerged benches and the intersections of the treads and risers are required to be installed in accordance with Section 454.1.2.5.

~~**454.1.8.4.1** Handrails shall be provided for all sets of steps and shall be anchored in the bottom step and in the deck. Handrails shall be located to provide maximum access to the steps and handrails shall extend 28 inches (711 mm) above the pool deck.~~

~~**454.1.8.4.2** Where "figure 4" handrails are used, they shall be anchored in the deck and shall extend laterally to any point vertically above the bottom step. Handrails shall be located to provide maximum access to the steps and handrails shall extend 28 inches (711 mm) above the pool deck.~~

454.1.8.5 Decks. ~~Decks shall have a minimum 4-footwide (1219 mm) unobstructed width around the entire pool perimeter except that~~ Spa pools ~~of less than 120 square feet (11 m^2) of pool water surface area~~that are 10 feet (3048 mm) wide or less~~-~~shall have a minimum 4-foot-wide (1219 mm) unobstructed continuous deck around a minimum of 50 percent of the pool perimeter, with all points on the water surface within 10 feet (3048 mm) horizontally of the deck. ~~Decks less than 4 feet (1219 mm) wide shall have barriers to prevent their use.~~ Decks shall not be more than ~~10~~ 36 inches (~~254~~ 914mm) below the top of the pool. For spa pools ~~of 120 square feet (11 m^2) or~~ greater than 10 feet (3048 mm) in width, ~~10 percent of the deck along the pool perimeter may be obstructed~~ deck obstructions shall comply with 454.1.3.1.6.

454.1.8.6 Therapy or jet systems.

454.1.8.6.1 The return lines of spa-type therapy or jet systems shall be independent of the recirculation filtration and heating systems.

454.1.8.6.2 Therapy or jet pumps shall take suction from the collector tank. Collector tank sizing shall take this additional gallonage into consideration.

454.1.8.7 Filtration system inlets. Spa-type pools ~~with less than 20 feet (6096 mm) of perimeter~~ shall have a minimum of two equally spaced adjustable inlets.

454.1.8.8 Filtration recirculation. Spa-type pools shall have a minimum of one turnover every 30 minutes. The piping, fittings, and hydraulic requirements shall be in accordance with Section 454.1.6.5. All recirculation lines to and from the pool shall be individually valved with proportional flow-type valves in order to control the recirculation flow.

454.1.8.9 Vacuuming. Spa-type pools of over 200 square feet (19 m^2) of pool water surface area shall have provisions for vacuuming.

454.1.8.10 Combination spas/pools. When spa pools are part of a conventional swimming pool, the spa pool area shall be offset from the main pool area with the same water depth as the main pool area. The spa pool area shall meet all the spa pool requirements of this chapter454.1.8.6 and 454.1.8.7, and the deck area at the spa shall be protected by connected 30-inch-high (762 mm) stanchions, or other approved obstruction to prevent entry, wherever there is a bench with high velocity nozzles producing air bubbles. The deck perimeter at the offset spa area shall not exceed 20 feet (6096 mm)15 percent of the entire swimming pool perimeter. All benches shall have contrasting markings on the leading edges of the intersection of the bench seats. If tile is used, it shall be slip resistant.

454.1.8.4.1 ~~**Handrails shall be provided for all sets of steps and shall be anchored in the bottom step and in the deck. Handrails shall be located to provide maximum access to the steps and handrails shall extend 28 inches (711 mm) above the pool deck.**~~ **Reserved**

454.1.8.4.2 ~~**Where "figure 4" handrails are used, they shall be anchored in the deck and shall extend laterally to any point vertically above the bottom step. Handrails shall be located to provide maximum access to the steps and handrails shall extend 28 inches (711 mm) above the pool deck.**~~ **Reserved**

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9935

22

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Eliminate a redundant statement about IWF lighting

Rationale

3 footcandles is acceptable either way, the second clause never changes the outcome.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The requirements don't actually change.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Makes the code easier to understand.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The requirements stay the same.

1st Comment Period History

SW9935-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:27:49 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.9.8.4 If night operation is proposed, 3 footcandles (30 lux) of light shall be provided on the pool deck and the water feature area. ~~For IWFs that are operated with attendants or lifeguards, 3 footcandles (30 lux) of light is acceptable.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9936

23

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Correct a unit conversion error.

Rationale

Degrees should not be converted to mm. Degrees are already an SI unit.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
No impact
Impact to building and property owners relative to cost of compliance with code
No impact
Impact to industry relative to the cost of compliance with code
No impact
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
This is correcting an error in the Code
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
This is correcting an error in the Code
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination
Does not degrade the effectiveness of the code
This is correcting an error in the Code

Alternate Language

1st Comment Period History

SW9936-A1

Proponent Michael Weinbaum **Submitted** 4/4/2022 2:47:37 PM **Attachments** Yes

Rationale:

There are actually two errors here. 5 feet isn't given a metric conversion, and 5 degrees is given an incorrect metric conversion.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not.

Does not degrade the effectiveness of the code

Does not.

1st Comment Period History

SW9936-G1

Proponent Dallas Thiesen Submitted 4/14/2022 2:28:54 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.2.2.2

...

The upper part of pool walls in areas 5 feet (1524 mm) deep or less shall be within 5 degrees ~~(4572 mm)~~ vertical for a minimum depth of $2^1/_2$ feet (762 mm) from which point the wall may join the floor with a maximum radius equal to the difference between the pool depth and $2^1/_2$ feet.

...

454.1.2.2.2 Walls and corners.

The upper part of pool walls in areas 5 feet deep or less shall be within 5 degrees ~~(4572 mm)~~ vertical for a minimum depth of 21/2 feet (762 mm) from which point the wall may join the floor with a maximum radius equal to the difference between the pool depth and 21/2 feet.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9937

24

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Someone might think zero-depth means something different than zero depth. The Code should be consistent in its nomenclature.

Rationale

This is just replacing a dash with a space.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
No impact
Impact to building and property owners relative to cost of compliance with code
No impact
Impact to industry relative to the cost of compliance with code
No impact
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
There is no change to the meaning
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
This is correcting a minor error.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination.
Does not degrade the effectiveness of the code

This is correcting a minor error.

1st Comment Period History

SW9937-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:29:31 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.2.8.3Access to sun shelf.

For the purposes of Section 454.1.2.5, a sun shelf area shall be considered an entrance to or exit from the pool. If the vertical distance between the coping and the shelf floor adjacent to the wall is more than 10 inches (254 mm), stairs up to the deck or coping shall be provided which shall comply with Sections 454.1.2.5.3 and 454.1.2.5.5; or a zero-_depth entry area complying with Section 454.1.9.6 may be provided instead of stairs. For open gutter pools, where the gutter is used as a step, additional steps shall not be required where the distance from the gutter lip to the shelf floor is 10 inches or less. At least one handrail that is compliant with Section 454.1.2.5.5 must be provided at the sun shelf.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9938

25

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

This is correcting an error on a slope measurement in the Code.

Rationale

The intent of the deck is to provide access, but a 3:10 slope is not very accessible. The author clearly meant to say 3% as the minimum slope.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Removing errors from the Code makes their job easier.

Impact to building and property owners relative to cost of compliance with code

There is no impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

It is important to funnel rainwater away from the pump reservoir.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This corrects an error.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

This corrects an error.

Alternate Language

1st Comment Period History

SW9938-A1

Proponent	Michael Weinbaum	**Submitted**	4/15/2022 4:13:31 PM	**Attachments**	Yes

Rationale:

It has come to our attention that certain health departments are denying permits if they feel it is too difficult to observe the floor of a pump reservoir. There is currently no guideline for this in the Code, this would add one.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Gives a justification and math for something they are already doing

Impact to building and property owners relative to cost of compliance with code

Makes the actions of code officials more predictable.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

SW9938-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:30:41 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.9.2.3 Pump reservoirs. Pump reservoirs are only required for slides with run out lanes. Pump reservoirs shall be made of concrete or other impervious material with a smooth ~~slip-resistant~~ finish. Pump reservoirs shall be for the slide pump intakes, but where properly sized may also be used as a collector tank for the filter system. Pump reservoir designs shall meet the criteria of Sections 454.1.9.2.3.1 through 454.1.9.2.3.5.

...

454.1.9.2.3.3 Pump reservoir maintenance accessibility. Access decks or walkable grating shall be provided for the reservoir such that all areas are accessible for vacuuming, skimming, and maintenance. The decks shall have a minimum width of 3 feet (914 mm) and shall have a ~~minimum~~ slope of ~~3:10~~ 32-4% away from the reservoir. If any part of the pump reservoir has a permanent cover or roof, hatches or other openings for access to and observation of the floor must be provided with one hatch or openingper 150 square feet (13.9 m2) of tank floor area.

454.1.9.2.3.3 Pump reservoir maintenance accessibility. Access decks shall be provided for the reservoir such that all areas are accessible for vacuuming, skimming, and maintenance. The decks shall have a minimum width of 3 feet (914 mm) and shall have a minimum slope of ~~3:10~~ 3% away from the reservoir.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9939

26

Date Submitted	01/20/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

This is correcting a spelling error in the Code.

Rationale

This is a spelling error. Notice the "f" turns "or" into "for".

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
Removing errors from the Code makes their job easier.
Impact to building and property owners relative to cost of compliance with code
There is no impact.
Impact to industry relative to the cost of compliance with code
No impact.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
This is just a spelling error
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
This corrects an error.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination
Does not degrade the effectiveness of the code
This corrects an error.

1st Comment Period History

SW9939-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:31:16 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.2.20.1.1

...The circulation system and backwash piping shall be adequate for proper backwashing of said filter and shall provide backwash flow rates of at least 12 gpm per square foot (0.8 L/s) for rapid sand filters or 15 gpm per square foot (0.9 L/s) for high rate sand filters.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9940

27

Date Submitted	01/21/2022	**Section**	454.1.2.2.1	**Proponent**	Perry Walker
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Update handbooks referenced for competitive swimming to current issues.

Rationale

The currently referenced competitive handbooks are outdated. Note, some of the dates shown in this proposed modification may also have updated handbooks before the 8th edition of the FBC is issued.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

It will allow the new construction of competitive pools to comply with new standards.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

It will allow the new construction of competitive pools to comply with new standards.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This will not affect the materials or methods of construction.

Does not degrade the effectiveness of the code

This keeps the FBC current with referenced handbooks.

1st Comment Period History

SW9940-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:32:07 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

Dimensional standards for competition-type pools shall be those published by the National Collegiate Athletic Association, ~~1990~~ 2019-20 and 2020-21; Federation Internationale de Natation Amateur (FINA), ~~1998–2000~~ 2021 Handbook; ~~1998–1999 Official Rules of Diving & Code Regulation of United States Diving Inc.~~; ~~1998 United States Swimming Rules and Regulations,~~ USA Swimming, 2022; and National Federation of State High School Associations, ~~1997–1998~~ 2021-22, which are incorporated by reference in this code.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9941

28

Date Submitted	01/21/2022	**Section**	454.1.2.7	**Proponent**	Perry Walker
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes

Alternate Language No

Related Modifications

Summary of Modification

Update handbook referenced for competitive diving to current issue.

Rationale

The currently referenced competitive handbook is outdated. Note, the date shown in this proposed modification may also have an updated handbook before the 8th edition of the FBC is issued.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This will not change how the code is enforced.

Impact to building and property owners relative to cost of compliance with code

This will not have an affect on cost.

Impact to industry relative to the cost of compliance with code

This will not have an affect on cost.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

It will allow the new construction of competitive pools to comply with new standards.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

It will allow the new construction of competitive pools to comply with new standards.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This will not affect the materials or methods of construction.

Does not degrade the effectiveness of the code

This keeps the FBC current with the referenced handbook.

1st Comment Period History

SW9941-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:32:45 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

Diving facilities shall meet the minimum requirements of the FINA dimensions for diving facilities in accordance with the ~~2005 2009~~ 2021 FINA Handbook and include the following.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9942

29

Date Submitted	01/21/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Eliminate restriction on placing furniture in sun shelf

Rationale

Furniture is routinely placed in pools with and without sun shelves all over the world. Pool operators know to remove the furniture and clean it as part of the overall cleaning process of the pool.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
One less rule to check for.
Impact to building and property owners relative to cost of compliance with code
One less rule to print out on a sign.
Impact to industry relative to the cost of compliance with code
No impact.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
The existing rule does not have a reasonable connection with the health, safety, and welfare of the general public.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
This removes something that is not very reasonable.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
There is no discrimination.

Does not degrade the effectiveness of the code

The other mandatory rules have a much more reasonable connection to preventing disease and bodily harm.

1st Comment Period History

SW9942-G1

Proponent	bob vincent	Submitted	4/17/2022 4:20:36 PM	Attachments	No

Comment:

Florida Department of Health is opposed to this mod. Sun shelf is primarily for children play areas, and furniture is a safety entrapment hazard where children play (code requires safety barriers on play features). In all pools, furniture will more rapidly damage pool finish than bare feet will resulting in microbial infestation of pockets in the floor, trip hazards, will collect floating debris on the furniture, and is a water circulation and walk-about obstruction.

1st Comment Period History

SW9942-G2

Proponent	Gerald Robinson	Submitted	4/17/2022 9:07:25 PM	Attachments	No

Comment:

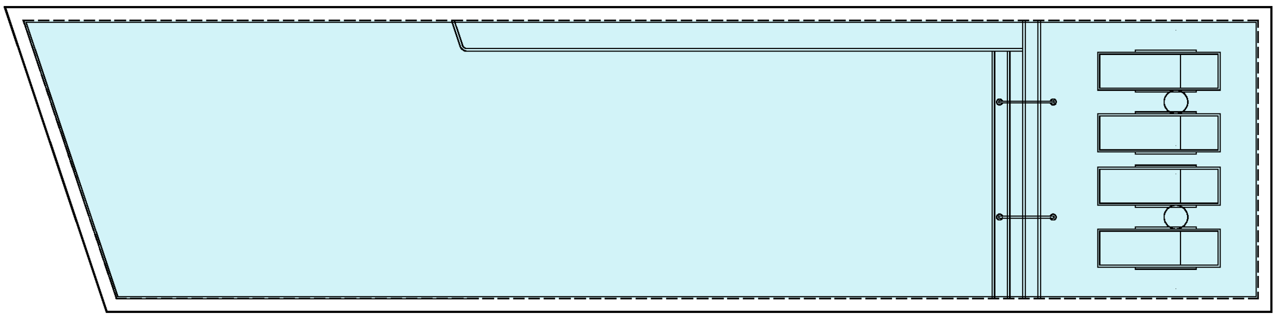
Pool Furniture from the pool deck into the water creature an obstruction for water flow and can introduce unapproved materials into the pool.

454.1.2.3.5 Rules and regulations signage. Rules and regulations for bathers ... shall contain the following:

1. ...

~~**9.** **If the pool includes a sun shelf, "DO NOT PLACE FURNITURE IN POOL."**~~

...



TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW9943

30

Date Submitted	01/21/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	Yes	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Allow permanent seating such as tables and stools to be part of the pool design.

Rationale

Benches are already allowed for seating. Other types of structures should be allowed for seating in pools intended for leisure. These structures would be marked similarly to a bench. Because overhanging surfaces can impede visibility and possibly entrap people, however, they should not be allowed unless a safety plan is approved.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This creates a new category of permissible things for the local entity to consider

Impact to building and property owners relative to cost of compliance with code

There is no impact

Impact to industry relative to the cost of compliance with code

There is no impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The requirements this imposes on permanent furniture minimize the trip or slip hazard that these features might otherwise create.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This allows a wider variety of features while still ensuring public safety.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination

Does not degrade the effectiveness of the code

The code remains effective.

1st Comment Period History

SW9943-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:34:22 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

1st Comment Period History

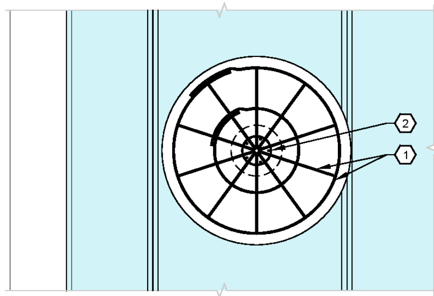
SW9943-G2

Proponent	bob vincent	Submitted	4/17/2022 1:15:44 PM	Attachments	No

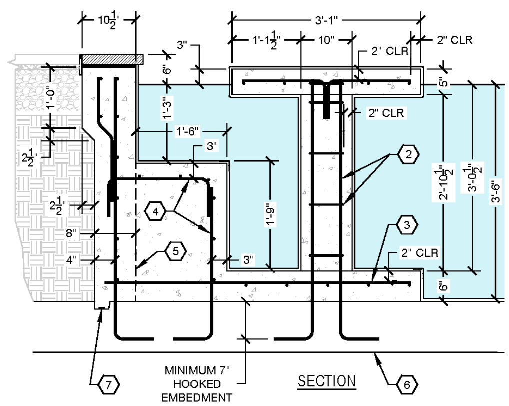
Comment:

Florida Department of Health is not in favor of this mod. Overhanging tables and stools in the pool water are an injury hazard.

454.1.2.6 Obstructions.The pool water area shall be unobstructed by any ... structure unless justified by engineering design as a part of the recirculation system, or intended for seating, such as tables and stools. Any structure intended for seating in the pool shall have 2" horizontal and 2" vertical markings in contrasting color, and be structurally rigid, impervious, non-toxic, smooth, and slip resistant. Engineering design and material specifications shall show that such structures will not endanger the pool patron, can be maintained in a sanitary condition and will not create a problem for sanitary maintenance of any part of the pool, pool water, or pool facilities. ... If any obstruction includes anoverhanging surface, a lifeguard safety plan shall be submitted to the health department for approval and implemented by the owner/operator.



PLAN



SECTION

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10109

31

Date Submitted	02/07/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

Increase maximum velocity on main drain pipes from 3 ft/s to 6 ft/s

Rationale

Main Drain systems typically have pre-fabricated pipe connections that have already been tested by the manufacturer for safe flow significantly above 3 ft/s in the pipe. The 3 ft/s speed limit was found in earlier national standards, but these standards have been replaced by APSP 16 which does not give a speed limit for pipes. A speed limit in the pipe is not needed for safety, but it is wise as a matter of limiting reduction of water level in the collector tank. For tanks that are within 100 ft of the pool, 6 ft/s is reasonable, and the engineer should be able to determine when to slow down the flow with larger pipes when the distance is farther.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact.

Impact to building and property owners relative to cost of compliance with code

The cost of building a pool would go down. In some situations, fewer drain sumps would be needed, along with fewer and smaller pipes. In other situations, the costs would be the same.

Impact to industry relative to the cost of compliance with code

Industry is already producing drain fittings designed to work well above 3 ft/s

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this change would preserve the 1.5 ft/s speed limit at grates which is still referenced in APSP 16.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, this preserves the idea that there is a speed limit in main drain pipes, it just raises that limit.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This eliminates a discrimination that already exists. Newer fixtures that are made to connect to smaller pipes should not be discriminated against.

Does not degrade the effectiveness of the code

Does not. This preserves the idea that there is a speed limit in main drain pipes, it just raises that limit.

Alternate Language

1st Comment Period History

SW10109-A1

Proponent Michael Weinbaum **Submitted** 3/3/2022 2:57:31 PM **Attachments** Yes

Rationale:

Same rationale as original proposal, but this alternate language brings in all of the references to a 3 ft/s speed limit on main drain pipes, and changes all of them to 6 ft/s for consistency.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None.

Impact to building and property owners relative to cost of compliance with code

Makes certain projects less expensive, does not increase the cost of any project.

Impact to industry relative to the cost of compliance with code

None.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

See original language

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

See original language

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

See original language

Does not degrade the effectiveness of the code

See original language

1st Comment Period History

SW10109-G1

Proponent Michael Weinbaum Submitted 4/13/2022 3:03:14 PM Attachments No

Comment:

The alternate language version has a minor conflict with SW10242. SW10242 would delete an item that SW10109-A1 is revising. If both are approved, the item should be deleted, not revised.

1st Comment Period History

SW10109-G2

Proponent Dallas Thiesen Submitted 4/14/2022 2:35:13 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

454.1.6.5.8 Flow velocity. Pressure piping shall not exceed 10-feet per second (2038 mm/s), except that precoat lines with higher velocities may be used when necessary for agitation purposes. The flow velocity in suction piping and main drain systems shall not exceed 6-feet per second (1829 mm/s) except that flow velocities up to 10-feet per second (3048 mm/s) in filter assembly headers will be acceptable. ~~Main drain systems and s~~Surface overflow systems which discharge to collector tanks shall be sized with a maximum flow velocity of 3-feet per second (914 mm/s).

454.1.9.2.1.4 Plunge pool main drains. The plunge pool shall have a minimum of one main drain with separate piping and valve to the filtration system collector tank. The velocity through the openings of the main drain grate shall not exceed $1^1/_2$ feet per second (457 mm/s) at the design flow rate of the recirculation pump. The main drain piping shall be sized to handle 100 percent of the design flow rate of the filtration system with a maximum flow velocity of ~~3~~ 6 feet (~~914~~ 1829 mm) per second.

454.1.9.2.3.5 Pump reservoir main drains. The pump reservoir shall have a minimum of one main drain with separate piping and valve to the filtration system collector tank unless the reservoir is used as the collector tank. Velocity through the openings of the main drain grates shall not exceed $1^1/_2$ feet per second (457 mm/s) at the design flow rate of the filtration system pump. The main drain piping shall be sized to handle 100 percent of design flow rate of the filtration system pump with a maximum flow velocity of ~~3~~ 6 feet per second (~~914~~ 1829 mm/s).

454.1.9.2.3.6 The pump reservoir shall be fed by main drains within the plunge pool itself (either in the floor or side wall). They shall have the maximum flow velocity of $1^1/_2$ feet per second (457 mm/s) through the main drain grating and ~~3~~ 6 feet per second (~~3962~~ 1829 mm/s) through the reservoir piping.

SW10109Text Modification

454.1.6.5.8 Flow velocity. Pressure piping shall not exceed 10-feet per second (2038 mm/s), except that precoat lines with higher velocities may be used when necessary for agitation purposes. The flow velocity in suction piping and main drain systems shall not exceed 6-feet per second (1829 mm/s) except that flow velocities up to 10-feet per second (3048 mm/s) in filter assembly headers will be acceptable. ~~Main drain systems and s~~Surface overflow systems which discharge to collector tanks shall be sized with a maximum flow velocity of 3-feet per second (914 mm/s).

A&A Manufacturing AVSC Drain Fitting

Area at grate, square inches	77.59		See top of second page of other attachment
	(2) 2.5" pipes	**(2) 3" pipes**	
Area at pipes, square inches	9.58	14.79	
Manufacturer rated flow, gpm	237	302	See top of third page of other attachment
Rated Flow, velocity at grate, ft/s	0.98	1.25	
Rated Flow, velocity in pipe, ft/s	7.94	6.55	
% of rated flow available at 3 ft/s	38%	46%	
% of rated flow available at 6 ft/s	76%	92%	

Conclusion: Increasing the speed limit from 3 ft/s to 6 ft/s would allow fewer of these fittings to be used, but would still be more conservative that eliminating the pipe's speed limit altogether.

Components

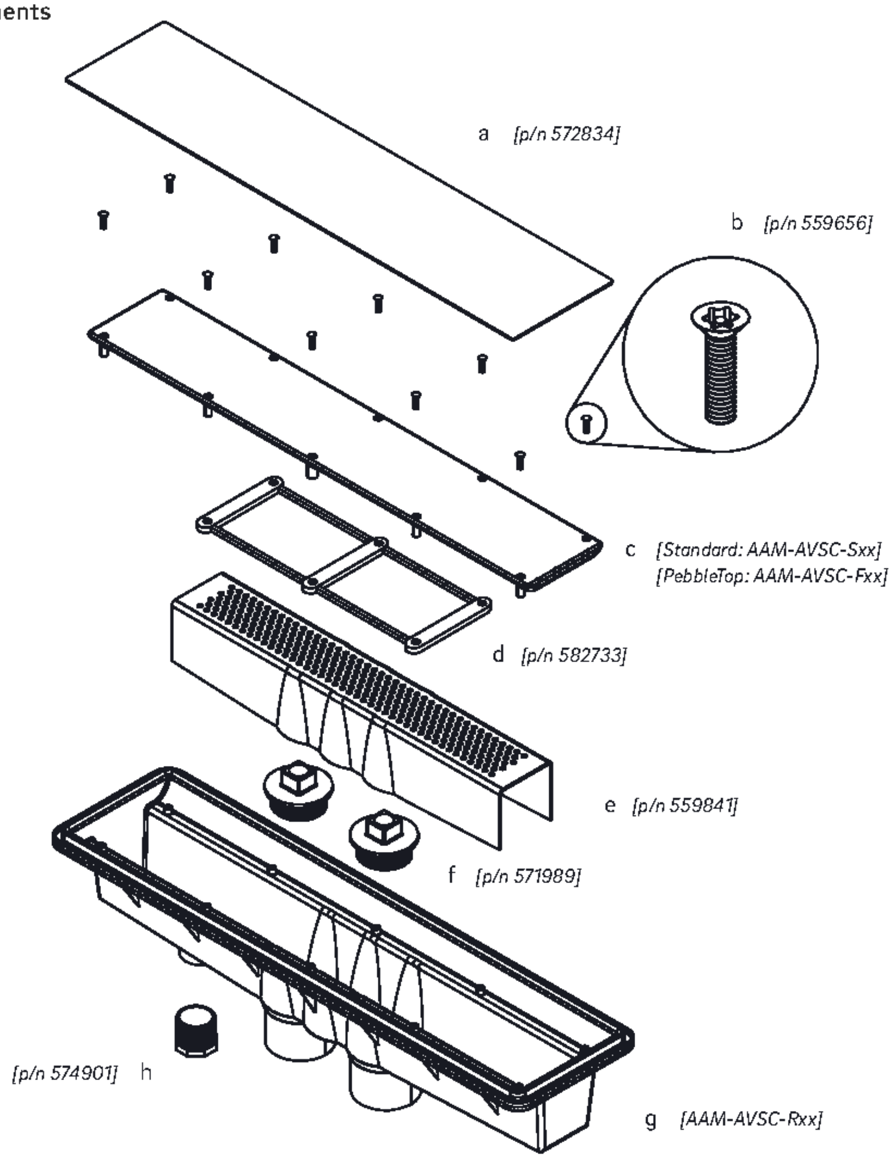


Figure 1

a. Construction cover (disposable)
b. 1-3/8", 316 stainless steel, Torx No.20 tamper-proof (qty. 10)
c. Standard cover (PebbleTop cover optional)
d. Anti-warp bar (disposable)
e. Baffle w/ adhesion packet
f. Pressure testing plugs, including O-rings (factory installed)
g. Sump (dual-port shown)
h. Hydrostatic port plug (hydrostatic valve optional)

AVSC Dimensions

The total effective suction area of the AVSC channel drain has been certified as 77.59 in^2 (1971 mm^2).

The ACSV drain suction ports are glue fittings that can be connected using either a 3" fitting on the outside or 2.5" pipe on the inside.

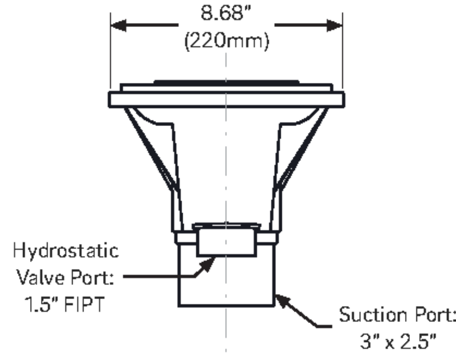


Figure 2

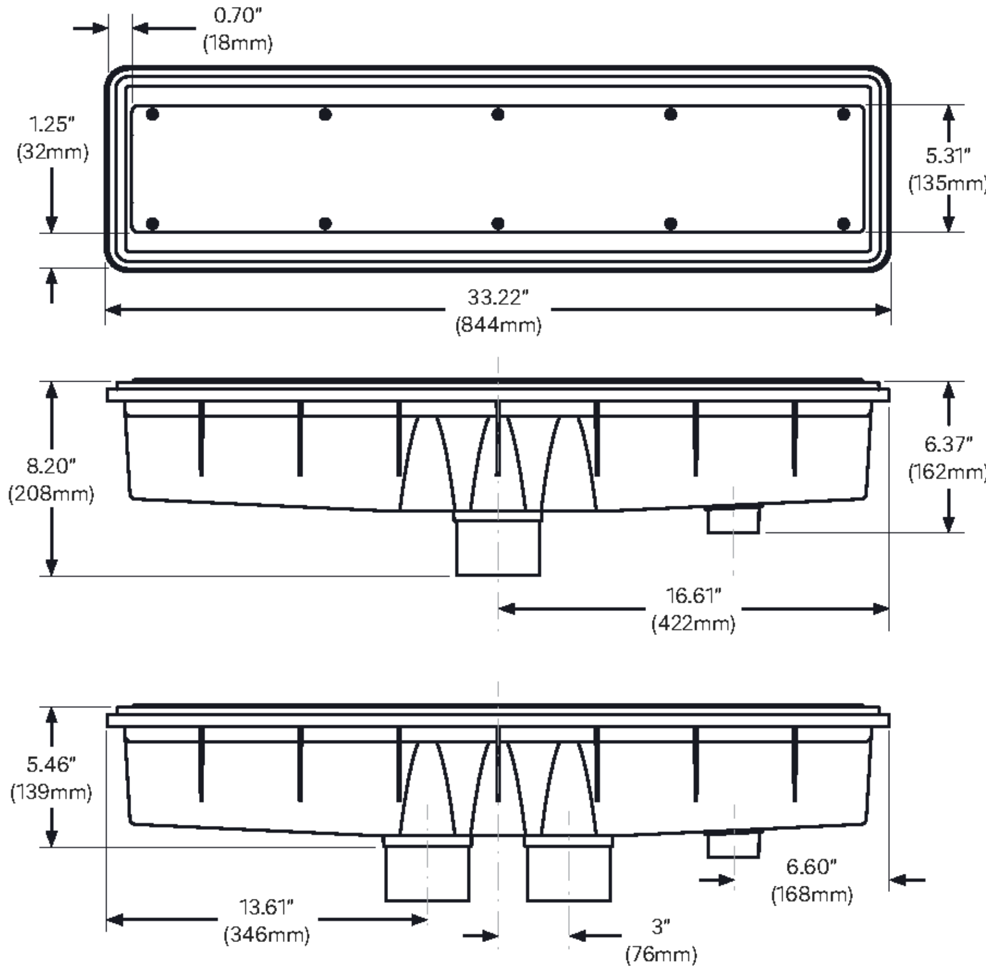


Figure 3

Specifications

Standard Cover

	2.5" pipe		3.0" pipe
FLOOR	237 gpm (single)	237 gpm (dual)	302 gpm (single & dual)
WALL	167 gpm (single)	184 gpm (dual)	302 gpm (single & dual)

PebbleTop Cover

	2.5" pipe		3.0" pipe
FLOOR	237 gpm (single)	237 gpm (dual)	302 gpm (single & dual)
WALL	184 gpm (single)	184 gpm (dual)	302 gpm (single & dual)

Return Methods & Installation Life

Depending on the desired placement, the AVSC drain has been certified as either a floor or wall return. Please follow the specifications above to identify which cover style is appropriate for the intended application.

Both Standard and PebbleTop covers for the AVSC drain have been certified for a maximum period of seven (7) years from the installation date. Upon the expiration of this designated period, the drain cover must be replaced. The sump has been certified for a period of 30 years. This is intended remain for the life of the structure in which it is installed. However, if at any point the sump becomes cracked or damaged, it is mandatory that the pool be shut down and all damaged components be removed and replace immediately. The installation life and installation date are stated on the Certificate of Compliance for the AVSC drain and will be provided by the installer.

If the cover exhibits any unnatural wear or extreme discoloration within its maximum lifespan the pool MUST be closed and the cover replaced, before bathers are allowed to reenter the pool.

Certified Part Numbers

"XX" denotes the color number code.

Standard Cover: AAM-AVSC-S*XX*
PebbleTop Cover: AAM-AVSC-F*XX*
Sump: AAM-AVSC-R*XX*

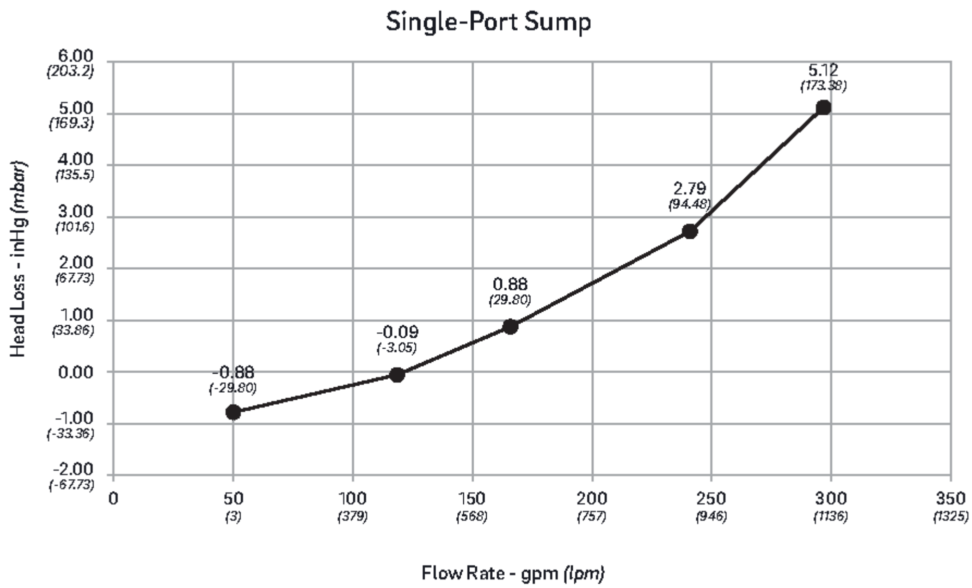
Color Number Codes

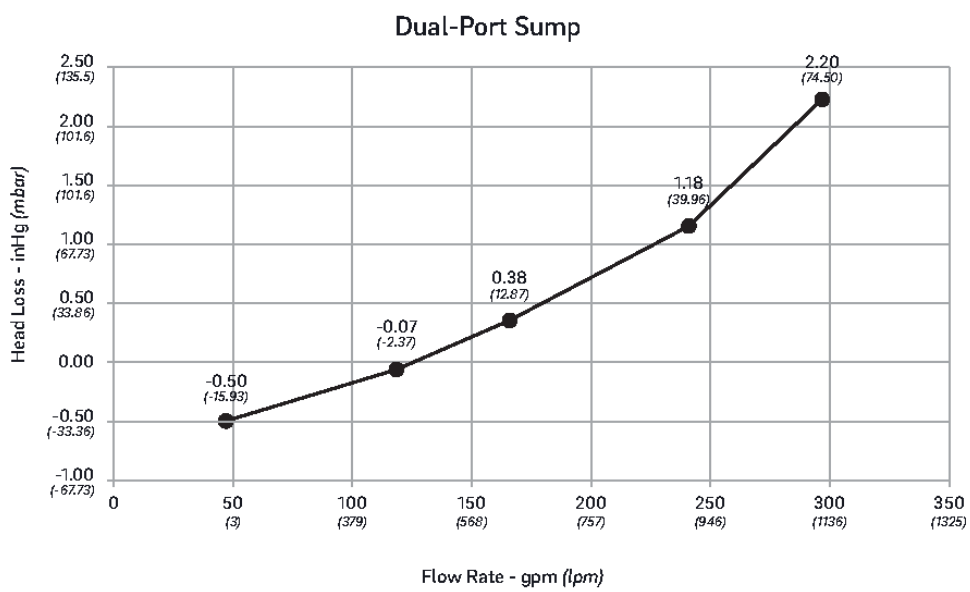
White - 01   Lt. Grey - 02   Grey - 03
Black - 04   Euro Blue - 05   Blue - 06
Tan - 07   Gold - 08

The assembly numbers listed below are for ordering purposes only.

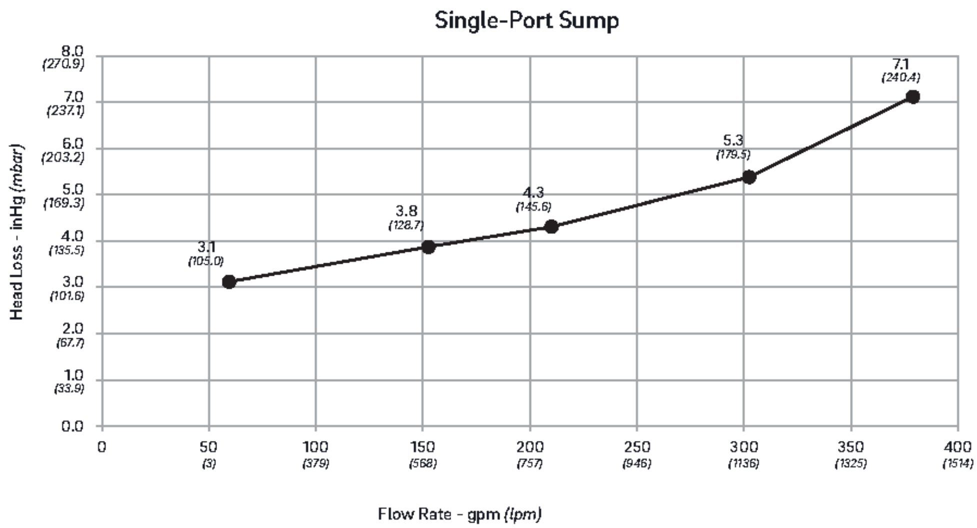
	w/ Standard Cover		w/ PebbleTop Cover	
	Single	Dual	Single	Dual
White	571840	571903	571444	571508
Light Grey	571891	571954	571495	571559
Grey	571858	571911	571452	571516
Black	571866	571920	571461	571524
Gold	571882	571946	571487	571541
Euro Blue	577512	571521	576317	576325
Dark Blue	571874	571938	571479	571532

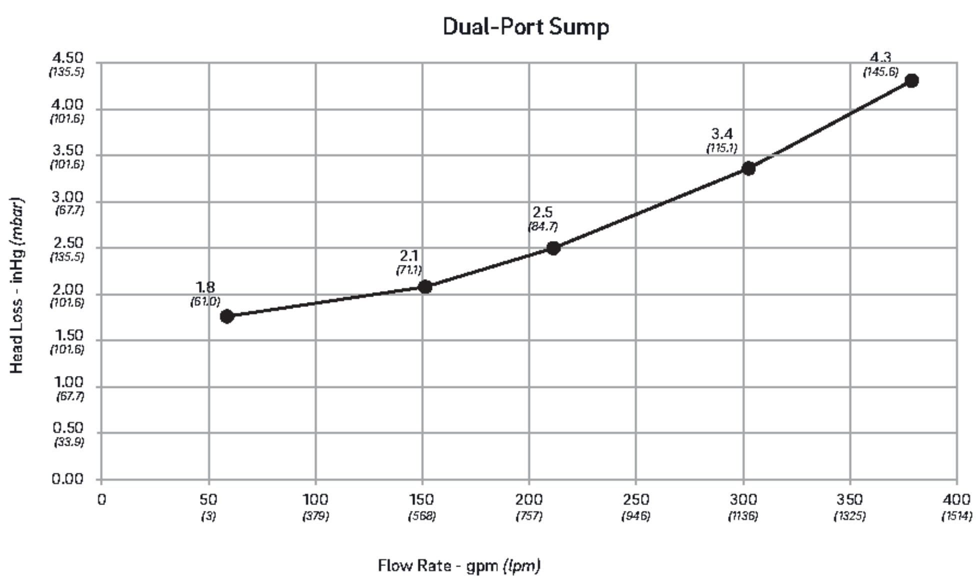
Head Loss Curves for 2.5" Pipe





Head Loss Curves for 3.0" Pipe





TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

32

SW10181

Date Submitted	02/11/2022	**Section**	454.1.1.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Simplifies the sizing calculation for public pools by basing pool size on minimum pool surface area. Increases the minimum size results for public pools proportionally to the number of units served by the swimming pool. Addresses water sanitation concerns presented by small/undersized pools.

Rationale

This modification simplifies the sizing calculation for public pools by basing pool size on minimum pool surface area and recirculation flow rate based on the type and a number of habitable units served. Increases the minimum size results for public pools proportionally to the number of units served by the swimming pool. Addresses water sanitation concerns presented by small/undersized pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None, simplifies public pool sizing calculation.

Impact to building and property owners relative to cost of compliance with code
None, owners have previously been required to follow sizing guidelines when building public pools.

Impact to industry relative to the cost of compliance with code
None, simplifies public pool sizing calculation.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
This modification addresses water sanitization concerns with small or undersized public pools allowed under the current code.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Simplifies the public pool sizing code making it easier for contractors, regulators, and inspectors to use and understand.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

1st Comment Period History

SW10181-G1

Proponent	bob vincent	Submitted	4/17/2022 1:24:33 PM	Attachments	Yes

Comment:

Florida Department of Health is not in favor of this mod. Previous 6th addition FBC code language submitted under SW10515 should be reverted to, with new edits for clarification. The 7th edition code language is understood by professional engineers using worksheet guidance attached.

454.1.1.1 Sizing.

Thepublic pools provided at a transient facility shall be able to accommodate one batherhave a minimum 6 square feet (0.56 m^2) of surface area and a minimum of 1 gpm (0.063 L/s) of recirculation flow per fiveliving units, whileThe public pools provided at nontransient facilities shall have a minimum 4.5 square feet (0.42 m^2) of surface area and a minimum of .75 gpm (0.047 L/s) of recirculation flow per living unit the bathing load at a nontransient facility shall be at least one bather per seven living units. Recreational vehicle sites, campsites and boat slips designated for live-aboards shall be considered a transient living unit. For properties with multiple pools, this requirement includes the cumulative total bathing load surface area and recirculation rate of all swimming pools, spas, wading pools and interactive water features. If the only pools at a facility are spa pools or interactive water features, this requirement does not apply.The bathing load for conventional swimming pools, wading pools, interactive water features, water activity pools and special purpose pools shall be computed either on the basis of one person per 5 gpm (0.32 L/s) of recirculation flow., or one person per each 20 square feet (1.9 m^2) of surface area, whichever is less. The bathing load for spa type pools shall be based on one person per each 10 square feet (0.9 m^2) of surface area. Where a pool's turnover rate is calculated to be less than 3 hours, that pool shall comply with Section 454.1.7.9 for automated controllers.

Mission:
To protect, promote & improve the health of all people in Florida through integrated state, county & community efforts.

Florida HEALTH

Ron DeSantis
Governor

Scott A. Rivkees, MD
State Surgeon General

Vision: To be the **Healthiest State** in the Nation

2020 Florida Building Code 454.1.1.1 Sizing (effective 12/31/2020)

The pools provided at a transient facility shall be able to accommodate one bather per five living units, while the bathing load at a non-transient facility shall be at least one bather per seven living units. Recreational vehicle sites, campsites and boat slips designated for live-aboards shall be considered a transient living unit. For properties with multiple pools, this requirement includes the cumulative total bathing load of all swimming pools, spas, wading pools and interactive water features. The bathing load for conventional swimming pools, wading pools, interactive water features, water activity pools and special purpose pools shall be computed either on the basis of one person per 5 gpm (0.32 L/s) of recirculation flow, or one person per each 20 square feet (1.9 m^2) of surface area, whichever is less. The bathing load for spa type pools shall be based on one person per each 10 square feet (0.9 m^2) of surface area. All other types of projects shall be sized according to the anticipated bathing load and proposed uses. Where a pool's turnover rate is calculated to be less than 3 hours, that pool shall comply with Section 454.1.7.9 for automated controllers.

The final Sizing code revision above passed the FBC Commission April 7 and means that we will have criteria for the Bathing Load, Recirculation Flow Rate (in GPM), and the Area of pool(s), but not specifically the water volume. Water volume is indirectly set by other requirements of the code: minimum / max. depths, minimum width, and for spas and IWFs by turnover period.

Steps required to determine sizing code compliance:

1. Calculate required bathing load (BL) using the transient ratio of 1 BL per 5 living units or the non-transient ratio of 1 BL per 7 (and there could be a mix of these at a living unit venue)
2. The cumulative BL count is spread across the cumulative total of four types of pools at a venue
3. The minimum cumulative pool surface area in sq. ft. & the minimum cumulative flow rate in GPM are calculated from the required BL (a spa pool's area:BL ratio is still unique)
4. The cumulative pool(s) at a living unit venue must meet the size and the flow rate minimums calculated in step #3
5. For the "whichever is less" sentence: If the owner chooses to increase the surface area or flow rate above the minimum required, the one resulting in the lesser BL is assigned to that pool.

Transient Facility Calculations:

of Living Units / 5 = **Minimum Required Bather Load** (For All Pools, Spas, etc. Combined)

Required Bather Load x 5 Gallons Per Minute Per Bather = **Minimum Required Flowrate** (For All Pools, Spas, etc. Combined)

Required Bather Load x 20 sq. ft. Surface Area = **Minimum Required Square Footage** (For All Pools, Wade pool & IWF. Combined)

Required Bather Load x 10 sq. ft. Surface Area = **Minimum Required Square Footage** (For only Spa pools)

Florida Department of Health
Division of Disease Control & Health Protection • Bureau of Environmental Health
4052 Bald Cypress Way, Bin A-08 • Tallahassee, FL 32399
PHONE: 850/245-4250 • FAX: 850/487-0864
FloridaHealth.gov

Non-Transient Facility Calculations:

of Living Units / 7 = **Minimum Required Bather Load** (For All Pools, Spas, Etc. Combined)

Required Bather Load x 5 Gallons Per Minute Per Bather = **Minimum Required Flowrate** (For All Pools, Spas, etc. Combined)

Required Bather Load x 20 sq. ft. Surface Area = **Minimum Required Square Footage** (For All Pools, Wade pool & IWF. Combined)

Required Bather Load x 10 sq. ft. Surface Area = **Minimum Required Square Footage** (For only Spa pools)

EXAMPLES:

Transient Pool with 1,000 Living Units-

STEP 1:

1,000 / 5 = **200 Bather Load Minimum Required**
200 x 5 = **1,000 Gallons Per Minute Minimum Required Flowrate**
200 x 20 = **4,000 Square Feet Water Surface Area Required**

If a facility decides to have a pool, spa and IWF the sizing can be split between all three bodies of water. Splitting the minimum requirements from Step 1 can give you the different requirements and sizes for Step 2

STEP 2:

150 Bathers for Pool
150 x 5 = **750 Gallons Per Minute Flowrate required**
150 x 20 = **3,000 Square Feet Water Surface Area**
10 Bathers for Spa
10 x 10 = **100 Square Feet Water Surface Area**, Spas must have a 30-minute turnover rate so flow will be determined based on the Volume but at a minimum the flowrate for this example would have to be **50 Gallons Per Minute** to ensure the total flow for all bodies of water meets the 1,000 gallons per minute required from Step 1.
40 Bathers for IWF
40 x 5 = **200 Gallons Per Minute Flowrate required**, 40 x 20 = **800 Square Feet Water Surface Area**. IWF must have a 30-minute turnover so the entire volume of the collector tank must be turned over at least once every 30 minutes.

Non-Transient Pool with 1,500 Living Units-

STEP 1:

1,500 / 7 = **214.28 Bather Load Minimum Required**
214.28 x 5 = **1,071.4 Gallons Per Minute Minimum Required Flowrate**
214.28 x 20 = **4,285.6 Square Feet Water Surface Area Required**

If a facility decides to have multiple pools, a spa and an IWF the sizing can be split between all three or more bodies of water. Splitting the minimum requirements from Step 1 can give you the different requirements and sizes for Step 2

STEP 2:

120 Bathers Family Pool
120 x 5 = **600 Gallons Per Minute Flowrate required**
150 x 20 = **2,400 Square Feet Water Surface Area**
45 Bathers Lap Pool
45 x 5 = **225 Gallons Per Minute Flowrate required**, 45 x 20 = **900 Square Feet Water Surface Area**
10 Bathers Spa
10 x 10 = **100 Square Feet Water Surface Area**, Spas must have a 30-minute turnover rate so flow will be determined based on the Volume but at a minimum the flowrate in this example would have to be **50 Gallons Per Minute** to ensure the total flowrate for all bodies of water meets the 1,000 gallons per minute required from Step 1.
40 Bathers for IWF
40 x 5 = **200 Gallons Per Minute Flowrate required**, 40 x 20 = **800 Square Feet Water Surface Area**. IWF must have a 30-minute turnover so the entire volume of the collector tank must be turned over at least once every 30 minutes.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10183

33

Date Submitted	02/11/2022	**Section**	454.1.2.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Removes Color Requirements from Pool Structure section of the code.

Rationale

The color requirements for swimming pool floors and walls is addressed more thoroughly in another code section. The color requirements language in this section is redundant. Furthermore section 454.1.2.1 addresses structural requirements for swimming pools, color requirements are out of place here.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Simplifies public pools color requirements by consolidating requirements in to one place. The color of public pools can impact bather safety by obscuring dangers or by preventing bathers in distress from being identified and assisted.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

None, simplifies code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.2.1 Pool structure.

Pools shall be constructed of concrete or other impervious and structurally rigid material. All pools shall be watertight, shall be free from structural cracks and shall have a nontoxic smooth and slip-resistant finish. All materials shall be installed in accordance with manufacturer's specifications unless such specifications violate Chapter 64E-9, Florida Administrative Code, rule requirements or the approval criteria of NSF/ANSI Standard 50 or NSF/ANSI Standard 60.

(a) ~~Floors and walls shall be white or pastel in color and shall have the characteristics of reflecting rather than absorbing light.~~ Tile used in less than 5 feet (1524 mm) of water must be slip resistant. A minimum 4-inch (102 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, shall be installed at the water line, but shall not exceed 12 inches (305 mm) in height if a dark color is used. Gutter-type pools may substitute 2- inch (51 mm) tile, each a minimum size of 1 inch (25 mm) on all sides, along the pool wall edge of the gutter lip.

(b) One-inch (25 mm) square tile may be used if the manufacturer has specified the adhesive for use underwater to adhere the type of tile used [vitreous (glass) or ceramic]. Tiles shall not have sharp edges exposed that could cause bather injury.

(c) The grout line is allowed to be included when meeting the 1-inch (25 mm) square tile requirements, if the tile is sold and distributed as nominal or trade size tile.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10184

34

Date Submitted	02/11/2022	**Section**	454.1.2.2.4	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Removes requirement for a minimum depth in deep areas. Clarifies that some areas of pool can have depth less than 3 feet in shallow areas.

Rationale

There is no reason that depths in deep areas of pools must be 4 feet minimum. Some pools can be restricted by size and minimum slopes such that 4 feet is not achievable. As long as the floor is sloped properly to the deep point, the maximum depth is irrelevant. Code change also clarifies that depths in sun shelfs and zero entry areas can be less than 3 feet, which is already allowed by code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Yes

Does not degrade the effectiveness of the code

Yes

1st Comment Period History

SW10184-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:36:25 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW10184-G2

Proponent	bob vincent	Submitted	4/17/2022 7:40:53 PM	Attachments	No

Comment:

Florida Department of Health suggests adding two other types pools to the exception list: wade and water activity pools.

The minimum water depth shall be 3 feet (914 mm) in shallow areas ~~and 4 feet (1219 mm) in deep areas~~ <u>except in sun shelfs and zero entry areas.</u>

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10185

35

Date Submitted	02/11/2022	**Section**	454.1.2.3.1	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

10184

Summary of Modification

Eliminates redundant language.

Rationale

This code is already included in the previous section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code

Yes

1st Comment Period History

SW10185-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:36:54 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

Depth and markings shall meet the following criteria:

1. ~~The minimum water depth shall be 3 feet (914 mm) in shallow areas and 4 feet (1219 mm) in deep areas.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10186

36

Date Submitted	02/11/2022	**Section**	454.1.2.3.5	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes

Alternate Language No

Related Modifications

Summary of Modification

Omits requirement to list depth at sun shelf where shelf transitions to steps on rules sign.

Rationale

The rule is intended to help the bather be aware of water depth at a sun shelf dropoff. There is no dropoff where the shelf transitions to steps, so this rule is unnecessary in that situation.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10186-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:37:45 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

8. If the pool includes a sun shelf, "WARNING: DROP OFF AT SUN SHELF EDGE IS ___ FEET DEEP" in 4-inch (102 mm) letters. Not required where sun shelfs transition to steps.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10187

37

Date Submitted	02/11/2022	**Section**	454.1.2.4	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Summary of Modification

Exempts slide landing areas from code color requirements. Allows swimming pool contractors and operators to use readily available slide area mats without obtaining a variance.

Rationale

Slide landing area mats that meet the color requirements of this section are not widely or readily available as a result many contractors and public pool operators are forced purchase darker slide landing area mats and obtain variance. It would be more efficient to allow for dark color schemes in certain areas. Furthermore, dark color schemes would not hinder the visual identification of a drowning person or the visibility of floor transitions in 24 inches or less of water.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Streamlines final approvals, as operators and contractors will not to first obtain variances to use readily available slide landing area mats.

Impact to building and property owners relative to cost of compliance with code

Reduces cost of compliance by eliminating the need to obtain variances for slide landing area mats that do not meet color requirements.

Impact to industry relative to the cost of compliance with code

None, eliminates the need to obtain variances for slide landing area mats that do not meet color requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Slide landing area mats ensure bathers physical safety when using water slides.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Allows for the use of more slide landing area mats without first obtaining a variance.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

Alternate Language

1st Comment Period History

SW10187-A2

Proponent Michael Weinbaum **Submitted** 4/15/2022 1:17:36 PM **Attachments** Yes

Rationale:

Just as slide landing areas become more safe when colored mats are placed, it is becoming common to place colored mats in other parts of pools intended for children to play and wade in.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Focuses the color requirement on the areas most likely to have bathers in distress.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

454.1.2.4 Color.

Pool floors and walls shall be white or light pastel in color and shall have the characteristic of reflecting rather than absorbing light. Floors and walls in slide landing areas, and in pools with a maximum depth of 24 inches (610 mm) or less, are exempt from this color requirement. The interior finish coating floors and walls shall be comprised of a nonpigmented white cementitious binder component together with a sand/aggregate component. The finish coating shall have a dry lightness level (CIE L value) of 80.0 or greater and a wet luminous reflectance value (CIE Y value) of 50.0 or greater, as determined by test results provided by the manufacturer, utilizing testing methodology from American Standard ASTM D4086, ASTM E1477, ASTM E1347. Pools constructed of fiberglass, thermoplastic, or stainless steel shall be subject to the same interior finish color requirements. A minimum 4-inch (102 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, shall be installed at the water line, but shall not exceed 12 inches (305 mm) in height if a dark color is used. Gutter-type pools may substitute a 2-inch (51 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, along the pool wall edge of the gutter lip.

454.1.2.4 Color.

Pool floors and walls shall be white or light pastel in color and shall have the characteristic of reflecting rather than absorbing light. Floors and walls in slide landing areas are exempt from this color requirement.The interior finish coating floors and walls shall be comprised of a nonpigmented white cementitious binder component together with a sand/aggregate component. The finish coating shall have a dry lightness level (CIE L value) of 80.0 or greater and a wet luminous reflectance value (CIE Y value) of 50.0 or greater, as determined by test results provided by the manufacturer, utilizing testing methodology from American Standard ASTM D4086, ASTM E1477, ASTM E1347. Pools constructed of fiberglass, thermoplastic, or stainless steel shall be subject to the same interior finish color requirements. A minimum 4-inch (102 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, shall be installed at the water line, but shall not exceed 12 inches (305 mm) in height if a dark color is used. Gutter-type pools may substitute a 2-inch (51 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, along the pool wall edge of the gutter lip.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10188

38

Date Submitted	02/11/2022	**Section**	454.1.2.5	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Increase allowable distance between means of access to 90 ft for pools with eight or more lap lanes

Rationale

Under the current 75 foot access requirement, pools with eight or more lap lanes must place means of access on the ends of the pools which interferes with lap lane starting block positions. This modifications increase allowable distance between means of access to 90 ft for pools with eight or more lap lanes. 90 ft would allow ladders on each side of a 25 meter wide lap pool, so the ladders do not interfere with the starting blocks. This modification creates a narrow exception for lap pools with eight or more lanes and does not change the general 75 foot means of access requirement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, clarifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, changing the means of access requirement for large lap pools add no additional costs.

Impact to industry relative to the cost of compliance with code

None, changing the means of access requirement for large lap pools add no additional costs.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Eliminates a potential danger to swimmers by allowing means of access to be place on the sides of the pool and not in a place where a ladder could interfere with swimming starting blocks.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.2.5 Access.

All pools shall have a means of access every 75 feet (22 860 mm) of pool perimeter with a minimum of two, located so as to serve both ends of the pool~~.~~, except for swimming pools with eight (8) or more lap lanes which shall have means of access every 90 feet (27432 mm) of pool perimeter in the lap lane area. In addition, an access point shall be provided at the deep portion, if the deep portion is not at one end of the pool. When the deep portion of the pool is over 30 feet (9144 mm) wide, both sides of this area shall have a means of access. Access shall consist of ladders, stairs, recessed treads or swimouts and may be used in combination. All treads shall have a slip-resistant surface.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10189

39

Date Submitted	02/11/2022	**Section**	454.1.2.5	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Includes sun shelves as pool accesses.

Rationale

Clarifies that sun shelfves qualify as pool access points.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10189-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 2:45:41 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.2.5 Access. All pools shall have a means of access every 75 feet (22 860 mm) of pool perimeter with a minimum of two, located so as to serve both ends of the pool. In addition, an access point shall be provided at the deep portion, if the deep portion is not at one end of the pool. When the deep portion of the pool is over 30 feet (9144 mm) wide, both sides of this area shall have a means of access. Access shall consist of ladders, stairs, recessed treads, sun shelves or swimouts and maybe used in combination. All treads shall have a slip resistant surface.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

40

SW10190

Date Submitted	02/11/2022	**Section**	454.1.2.6	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Summary of Modification

Clarifies that a sun shelf can be used in pools at points greater than 4 feet in depth if the shelf transitions to steps.

Rationale

Intent of the code is to limit the distance at a sun shelf dropoff for bather safety. With steps, there is no steep dropoff. The steps and associated handrail make apparent that there is no dropoff and the bather can safely access the steps with no threat of falling directly into deeper water. In addition, pools can be designed with a top step of up to 4 feet in width and not qualify as a sun shelf, with the lower steps allowed to run to any depth desired by the designer. In this case there is no difference between a wide step and a sun shelf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Yes

Does not degrade the effectiveness of the code

Yes

Alternate Language

1st Comment Period History

SW10190-A1

Proponent Dallas Thiesen **Submitted** 4/14/2022 2:53:43 PM **Attachments** Yes

Rationale:

The alternate language clarifies the original proposal. Maintains bather safety by ensuring the depth is not too deep where a sun shelf transitions to the pool.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Protects bather safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials.

Does not degrade the effectiveness of the code

Improves the code by clarifying code requirements.

3.A sun shelf may be installed in pool areas with no more than 4 feet (1219 mm) of water depth, or less, except where **the entire** sun shelf transitions to steps, where the depth at the bottom of the steps can exceed 4 feet (1219 mm).

3.A sun shelf may be installed in pool areas with no more than 4 feet (1219 mm) of water depth, or less, except where sun shelf transitions to steps, where the depth at the bottom of the steps can exceed 4 feet (1219 mm).

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

41

SW10191

Date Submitted	02/11/2022	**Section**	454.1.2.8.1	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies that radiused sun shelves are allowed by code. Allows for a minimum slope on sun shelves that do not originate from a zero entry.

Rationale

This code as written does not allow for radiused or hemispherical sun shelves along a pool edge, even though FDOH allows them all the time. The intent of the code was to prohibit a sun shelf that meets the pool edge on two ends but has drop-offs on two sides. That is why the sentence "the sun shelf edge that adjoins the pool edge must be continuous" was added during the previous code revision cycle. The sentence regarding three sides being adjacent to pool deck is unnecessary and would prohibit any sun shelf that only has one side adjacent to a deck. Contractors prefer there to be at least some slope on a sun shelf during the finishing process in order that acid used for final wash does not pool on the surface of the pool shell. The proposed code allows for a slight slope while still keeping the sun shelf near-horizontal so as to maintain bather safety.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Yes

Does not degrade the effectiveness of the code

Yes

1st Comment Period History

SW10191-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:02:48 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Proposed Modification SW10195 more completely addresses sunshelf dimensional requirements and allows for radiused sunshelf designs.

1st Comment Period History

SW10191-G2

Proponent	bob vincent	Submitted	4/17/2022 8:05:00 PM	Attachments	No

Comment:

Florida Department of Health concurs that a hemispherical (half moon-phase) sun shelf is code-compliant for continuous edge criteria and this corrected the previous code's safety hazard of a sun shelf with water on two sides. The shape of the "moon phase" must not leave narrow slivers of sun shelf at each end of the shelf; it must meet the 20" minimum width requirement at both ends.

Sun shelf areas must be a minimum of 20 inches (508 mm) wide and provide a minimum of 10 square feet (0.93 m^2) of horizontal surface adjoining on the edge of the pool ~~(three sides of shelf must be surrounded by pool deck)~~ over a distance of not less than 3 feet (914 mm). The sun shelf edge that adjoins the pool edge must be continuous. The sun shelf floor shall be horizontal or sloped at a maximum of 1 unit vertical in 60 units horizontal, or shall have uniform slope from a zero depth entry, and its maximum depth shall be between 8 inches (203 mm) and 12 inches (254 mm) below the water surface. In pools utilizing automatic recessed surface skimmers, there shall be at least one skimmer in each sun shelf area.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10192

42

Date Submitted	02/11/2022	**Section**	454.1.2.5.5	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Specifies handrail placement in sun shelves.

Rationale

When stairs are inset into a sun shelf, the handrail should serve as a boundary between the sun shelf and the stairs. The current code is not clear on handrail placement for stairs inset into sun shelves, this modification specifies handrail placement.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, handrails are already required. This modification only specifies the location of handrails under certain circumstances.

Impact to building and property owners relative to cost of compliance with code

None, handrails are already required. This modification only specifies the location of handrails under certain circumstances.

Impact to industry relative to the cost of compliance with code

None, handrails are already required. This modification only specifies the location of handrails under certain circumstances.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Handrails and where they are placed affect bather safety entering, exiting, and navigating swimming pools.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.2.5.5 Handrails and grabrails.

Handrails shall be provided for all stairs, shall be anchored in the bottom step and the deck. Where "figure 4" deck-mounted-type handrails are used, they shall be anchored in the deck and extend laterally to any point vertically above the bottom step. Grabrails must be mounted in the pool deck at each side of recessed steps. Handrails and grabrails shall extend between 28 and 40 inches (711 mm and 1016 mm) above the step edge and deck. Where stairs are used as an access point between a sun shelf and pool area, a handrail shall be provided. The hand rail shall be anchored into the bottom step and the sun shelf floor. Where such stairs are inset into the sun shelf, a handrail shall be placed adjacent to each edge of the sun shelf.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

43

SW10194

Date Submitted	02/11/2022	**Section**	454.1.7.5	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Allows for an alternative for rapid drainage of a wading pool in the event of a fecal discharge.

Rationale

Allows for an alternative to a quick opening valve with a simple and effective method for draining the wading pool.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10194-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:03:55 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

All wading pools shall have drainage to waste without a cross connection through a quick opening valve to facilitate emptying the wading pool should accidental bowel or other discharge occur. This can also be achieved utilizing a pump taking suction from the collector tank drain with immediate discharge to waste. The pump must be capable of draining all water in the pool and tank.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10195

44

Date Submitted	02/11/2022	**Section**	454.1.2.8.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Changes sunshelf dimensional requirements to allow for radiused shelfs and benches along sunshelf edges.

Rationale

Changes sunshelf dimensional requirements to allow for radiused shelfs and benches along sunshelf edges. The current code detailing sunshelf requirements is ambiguous. This modification clarifies the code to allow for radiused sun shelf designs that pose no risk to bathers and allow for the installation of benches along the pool edge of a sun shelf.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, this modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

None, this modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

None, this modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool design and structure substantially affect bather safety, this modification is specifying pool design criteria.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by clarifying requirements.

1st Comment Period History

SW10195-G1

Proponent	bob vincent	Submitted	4/17/2022 9:17:36 PM	Attachments	No

Comment:

Florida Department of Health is opposed to this mod. 3 inches of water on a horizontal sun shelf will cause a high disinfectant demand due to solar UV destruction rapidly, resulting in inadequate disinfectant residual, thus a greater pathogen survival and higher risk for illness outbreak. A bench below a sun shelf is not allowed because two code exceptions placed adjacent together was never envisioned when sun shelf code was adopted. There is a high potential for injury by patron stepping off sun shelf edge to bench since benches have no code-designated distance below water surface, and a variable width allowance. Whereas stairs below sun shelfs are code-designated, and are built with handrails; thus are the preferred choice for most designers for patrons to ingress/egress the pool area.

454.1.2.8.1Sun shelf dimensional requirements.

Sun shelf areas must be a minimum of 20 inches (508 mm) wide and provide a minimum of 10 square feet (0.93 m2) of horizontal surface adjoining on the edge of the pool ~~(three sides of shelf must be surronded by pool deck)~~over a ~~distance~~length of not less than 3 feet (914 mm) of unobstructed deck. The sun shelf edge that adjoins the pool edge must be continuous~~.~~ and equal to or shorter in length than the sunshelf edge along the pool deck. A bench may be installed along the edge of the sunshelf. The sun shelf floor shall be horizontal or ~~shall a have uniform slope from a~~zero depth entry, ~~and its~~ ~~maximum~~ with a depth ~~shall be~~ between ~~8~~3 inches (~~203~~77 mm) and 12 inches (254 mm) below the water surface. ~~In pools utilizing automatic recessed surface skimmers, there shall be at least one skimmer in each sun shelf area.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10196

45

Date Submitted	02/11/2022	**Section**	454.1.8.5	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Adds language requiring a barrier where spas directly abut a pool.

Rationale

Spas may be constructed adjacent to pools and share a common wall. This code would require a barrier that discourages bathers from moving from the spa to the pool over the wall, or vice versa.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
Minimal
Impact to industry relative to the cost of compliance with code
Minimal
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10196-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:07:18 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Jurisdictional authority to approve the proposed barrier will result inconsistent results and requirements from jurisdiction to jurisdictions.

Decks shall have a minimum 4-foot wide (1219 mm) unobstructed width around the entire pool perimeter except that pools of less than 120 square feet (11 m^2) of pool water surface area shall have a minimum 4-foot-wide (1219 mm) unobstructed continuous deck around a minimum of 50 percent of the pool perimeter. Decks less than 4 feet (1219 mm) wide shall have barriers to prevent their use. Decks shall not be more than 10 inches (254 mm) below the top of the pool. For pools of 120 square feet (11 m^2) or greater, 10 percent of the deck along the pool perimeter may be obstructed. Where a spa type pool abuts a swimming pool, a barrier approved by the jurisdictional building department shall be installed on top of the spa wall to discourage bathers from traversing between the pools.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10198

46

Date Submitted	02/11/2022	**Section**	454.1.9.8.4	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Corrects an error with light level at an IWF.

Rationale

Corrects an error with light levels for unsupervised IWFs.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10198-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:09:54 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

If night operation is proposed, ~~3~~ 6 foot candles (~~30~~ 60 lux) of light shall be provided on the pool deck and the water feature area. For IWFs that are operated with attendants or lifeguards, 3 footcandles (30 lux) of light is acceptable.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10199

47

Date Submitted	02/11/2022	**Section**	454.1.2.8.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Makes sunshelf depth marker requirements consistent with the rest of the code.

Rationale

This modification makes sunshelf depth marker requirements consistent with the rest of the code and specifies that there must be at lease two depth markers per sun shelf. This modification makes depth marker spacing consistent while ensuring adequate depth marker placement for sun shelfs.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool depth is important information for bathers to have to prevent injury. This modification address depth marker placement.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.2.8.2Depth markers at sun shelves.

Where a sun shelf is installed, wet deck-located depth and no diving markers shall be placed every ~~20~~25 feet (~~6096~~7620mm) or less~~.~~, with at least two (2) markers per sunshelf. If the vertical distance between the coping or wet deck and the shelf floor adjacent to the wall is 12 inches (305 mm) or less, these markers shall indicate the water depth of the sun shelf. For open-type gutter pools, the vertical distance shall be measured from the gutter lip to the shelf floor. Where vertical distance between the coping or wet deck and the shelf floor adjacent to the wall is more than 12 inches (305 mm), “No-Entry” markers as described in Section 454.1.9.6.4 shall be provided in the deck. When the sun shelf does not use stairs as a transition, depth markers of the adjacent pool depth at the sun shelf edge and no-dive markers shall be placed on the sun shelf floor, every 10 feet (3048 mm) or less, along a line no more than 1 foot (305 mm) back from the edge of the sun shelf above the deeper pool. All markers shall comply with Items 2, 6 and 7 of Section 454.1.2.3.1, except the distance between them as described in this section shall be followed.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10200

48

Date Submitted	02/11/2022	**Section**	454.1.9.8.6	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies filtration and UV requirements for IWFs.

Rationale

This code as written is very confusing. The proposed code clearly explains the three types of systems acceptable for IWF water treatment.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

1st Comment Period History

SW10200-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:13:00 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Proposed Modification SW10387 provide more clarity to this section of the code.

454.1.9.8.6.1

~~All (100 percent of the water from the collector tank must be first filtered, treated by an NSF Standard 50 certified UV disinfection unit with a minimum 40 mJ/cm2 dose, and then final treatment provided by disinfectant adjustment chemicals before any of this treated water is piped to the water features.~~

All water discharged to the water features must first be treated with UV disinfection with final treatment provided by disinfectant adjustment chemicals before any of this treated water is piped to the features. The recirculation system shall be sized to treat the contained volume of water in the tank and piping system based upon a 30 minute turnover with chlorine feeder/generators capable of producing a dosage of at least 12ppm; and the UV disinfection equipment shall be electrically interconnected such that whenever it fails to produce the required UV dosage, the water spray features pump(s) and flow will be immediately stopped. All pumps must draw suction from the collector tank.

454.1.9.8.6.2

~~In the design above and the alternative below: excess water not required by the water features shall be returned to the collector tank; the recirculation system shall be sized to treat the contained volume of water based upon a 30 minute turnover with a chlorine feeder/generator capable of producing a dosage of at least 12ppm; and the UV disinfection equipment shall be electrically interconnected such that whenever it fails to produce the required UV dosage, the water spray features pump(s) and flow will be immediately stopped.~~

There are three options for filtration and disinfection systems for a IWF as follows:

Option 1: A single pump may be used for water treatment and to supply the water features. Flow must be filtered, treated by an NSF Standard 50 certified UV disinfection unit with a minimum 40 mJ/cm^2 dose, then treated with disinfectant adjustment chemicals prior to discharge to the water features. Excess flow not required by the features must be directed back to the collector tank following UV treatment and must be treated with disinfectant and pH adjustment chemicals prior to discharge to the tank.

Option 2: Separate filter and feature pumps may be utilized. The filter flow must be filtered and treated with disinfectant and pH adjustment chemicals prior to discharge to the tank. All feature flow must be filtered, treated by a NSF Standard 50 certified UV disinfection unit with a minimum 40 mJ/cm^2 dose, then treated with disinfectant adjustment chemicals prior to discharge to the water features. UV flow capacity must meet the feature pump(s) flow capacity.

Option 3: Separate filter and feature pumps may be utilized. The filter flow must be filtered and treated with disinfectant and pH adjustment chemicals prior to discharge to the tank. All feature flow must be treated by a validated UV disinfection unit with a minimum 40 mJ/cm^2 dose described in Section 454.1.6.5.16.6(3), then treated with disinfectant adjustment chemicals prior to discharge to the water features. UV flow capacity must meet the feature pump(s) flow capacity.

454.1.9.8.6.3

~~In lieu of Section 454.1.9.8.6.1, the recirculation system must be designed to continuously return 100 percent of the water to the collector tank after all (100 percent) of the water is first filtered, treated by a validated UV disinfectant unit with a minimum 40 mJ/cm^2 dose described in Section 454.1.6.5.16.6 on each feature pump and then final treatment with disinfectant and pH adjustment chemicals, before any of this treated water is piped to the water features. UV flow capacity must meet the feature pump(s) flow capacity.~~

Reserved.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

49

SW10201

Date Submitted	02/11/2022	**Section**	454.1.6.5.16.6	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

10200

Summary of Modification

Clarifies UV equipment requirements in conjunction with new code proposed for Section 454.1.9.8.6.

Rationale

Makes clear the type of UV system required depending on the type of treatment protocol being used.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code

Yes

1st Comment Period History

SW10201-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:13:39 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Proposed Modification SW10387 provide more clarity to this section of the code.

3.UV equipment used in higher risk facilities such as interactive water features, wading pools, and activity pools shall be validated by a capable party that it delivers the required and predicted UV dose at the validated flow, lamp power and water UV transmittance conditions, and has complied with all professional practices summarized in the USEPA Ultraviolet Disinfectant Guidance Manual dated November 2006, which is publication number EPA 815-R-06-007 available from the department at http://www.floridashealth.org/Environment/water/swim/index.html or at http://www.epa.gov/safewater/disinfection/lt2/pdfs/guideit2_uguidance.pdf.

Exception: Not applicable when Section ~~454.1.9.8.6.1 alternative is used~~ 454.1.9.8.6.2 alternative Options 1 or 2 are used.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10202

50

Date Submitted	02/11/2022	**Section**	454.1.9.8.8	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Summary of Modification

This is a new section that includes code language for vanishing edge pools.

Rationale

Provides design and construction criteria for vanishing edge pools, which have been previously accepted in Florida through the variance process.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Yes
Does not degrade the effectiveness of the code
Yes

Alternate Language

1st Comment Period History

SW10202-A1

Proponent Michael Weinbaum **Submitted** 4/14/2022 4:41:35 PM **Attachments** Yes

Rationale:

This creates a workaround for the 60 foot length restriction on lowered deck. The length restriction is based on access out of the pool being every 75 ft. We want to expand the ability to create beautiful, long vanishing edges with standards that ensure bather safety. 454.1.9.8.8.4 is intended to make it as easy as possible to get out of the pool without actually requiring the designer to place stairs or ladders that would interrupt the edge itself.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Creates a new category for code enforcement to check

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Limiting the pool width and depth, and requiring access at both ends of the vanishing edge, are all intended to preserve bather safety

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not.

1st Comment Period History

SW10202-G1

Proponent Dallas Thiesen Submitted 4/14/2022 3:16:23 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. This modification is not needed, the current code sufficiently addresses vanishing edge swimming pools.

454.1.3.1.2

...

Lowered portions of wet deck shall be not more than 60 feet (18 288 mm) long and shall adjoin the rest of the wet deck via stairs or ramps at both ends, unless the pool meets all of the requirements of a Vanishing Edge Pool.

...

454.1.9.8.8 Vanishing edge pools

454.1.9.8.8.1 Vanishing edge pools shall be designed and constructed within the limits of sound engineering practice and shall meet the requirements of Sections 454.1.1 through 454.1.6.5, unless specifically indicated otherwise.

454.1.9.8.8.2 Vanishing edges and associated discharge trough or basin shall be constructed of concrete or other structurally rigid impervious materials with a non-toxic, and smooth finish.

454.1.9.8.8.3 The vanishing edge shall discharge into a trough or basin. The trough or basin must be covered with a lid or secure grating that has the capacity to support a responder outside the pool attending to a bather in distress adjacent to the vanishing edge. The trough or basin must be designed to deter access. The maximum height of the trough or basin wall above surrounding deck grade shall be 10 inches (254 mm).

454.1.9.8.8.4 Lowered deck complying with 454.1.3.1.2 must be provided along the vanishing edge. Means of access complying with 454.1.2.5 shall be provided at both ends of the vanishing edge, but are not required along the length vanishing edge if:

1. The pool width measured perpendicular to the vanishing edge does not exceed 82 feet (25 m).

2. The pool maximum depth does not exceed 4 feet (1219 mm)

Water line tile at the top of the edge wall as required by 454.1.2.1(a) does not need to be non-skid.

454.1.9.8.8.5 Depth markings for vanishing edges shall be in accordance with 454.1.2.3.1(5).

454.1.9.8.8 Vanishing edge pools

454.1.9.8.8.1 Vanishing edge pools shall be designed and constructed within the limits of sound engineering practice and shall meet the requirements of Sections 454.1.1 through 454.1.6.5, unless specifically indicated otherwise.

454.1.9.8.8.2

Vanishing edges and associated discharge trough or catch basin shall be constructed of concrete or other structurally rigid impervious materials with a non-toxic, smooth and slip-resistant finish.

454.1.9.8.8.3

The vanishing edge shall discharge into a trough or basin. The trough or basin must be covered with a lid or secure grating that has the capacity to support a responder attending to a bather in distress on the opposite side of the vanishing edge. The trough or basin must be designed to deter access. The maximum height of the trough or basin wall above surrounding grade shall be 10 inches. A wet deck in accordance with 454.1.3.1 must be provided around the trough or basin within 15 feet perpendicular from the vanishing edge wall.

454.1.9.8.8.4

The vanishing edge length shall not exceed 65 feet of pool perimeter. The maximum vertical distance from the top of the vanishing edge wall to the trough or catch basin cover or adjacent grade shall be 30 inches. The maximum water depth in the pool at the vanishing edge wall shall be 4 feet. The vanishing edge wall shall not be considered as a perimeter deck obstruction. Water line tile at the top of the edge wall as required by 454.1.2.1(a) need not be non-skid.

454.1.9.8.8.5

Depth markings for vanishing edges shall be in accordance with 454.1.2.3.1(5).

454.1.9.8.8.6

Surface treatment for vanishing edge pools must be provided in accordance with 454.1.6.5.3.1 or 454.1.6.5.3.2 as applicable. The vanishing edge feature pump must be operated at minimum 3-hour intervals when the pool is closed to provide skimming action. The feature pump must be operated for a minimum length of time as needed to completely skim the entire surface of the pool at least once.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10203

51

Date Submitted	02/11/2022	**Section**	454.1.3.1.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Allows for up to 40% of the swimming pool wet deck to be lowered.

Rationale

This modification allows for up to 40% of a swimming pool wet deck to be lowered and eliminates the current requirement that lower deck is only allowable with an overflowing edge design. Allowing for more portions of the wet deck to be lowered will improve swimming pool design options and will allow for the use of ADA transferrer rails without first obtaining a variance.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, clarifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, clarifies code requirements. Will also allow for more access ADA compliance options.

Impact to industry relative to the cost of compliance with code

None, clarifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Allows for more ADA access options for bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

1st Comment Period History

SW10203-G1

Proponent	bob vincent	Submitted	4/17/2022 8:29:35 PM	Attachments	No

Comment:

Florida Department of Health is opposed to this mod. By deleting the phrase "Where a perimeter overflowing edge is provided," this lowered deck allowance can be placed on any pool, spa and other types. By increasing the height of the edge wall from 36" above the wet deck to any pool with a curb height of 42" above wet deck, there are several serious safety hazards: • Elevated pools limit visibility into the pool from the deck. • An elevated pool limits areas to access into the pool in the event of an emergency. • With an elevated pool it can limit the areas to retrieve a victim or make it more hazardous to retrieve a victim to provide emergency care. • Elevated pools increase the risks of falls from the pool to the deck below. For both adults and children. • Where an ADA lift is used at an elevated pool the risk of severe injury is much higher if someone slips from the ADA lift.

454.1.3.1.2

Pool wet decks shall be uniformly sloped away from the pool or to deck drains to prevent standing water. The minimum slope for the wet deck is 2 percent, but in the portions of the deck intended to be accessible to disabled persons, it may be 1 percent less than the maximum allowable cross slope given by the Florida Building Code, Accessibility. The maximum slope is 4 percent. A minimum of 1 percent deck slope is allowable for paver-type decks. Textured deck finishes that provide pitting and crevices of more than 3/16 inch (4.8 mm) deep that accumulate soil are prohibited. If settling or weathering occurs that would cause standing water, the original slopes shall be restored or corrective drains installed. When a curb is provided, the deck shall not be more than 10 inches (254 mm) below the top of the curb.

Deck-level perimeter overflow systems may be sloped at a maximum of 4 percent toward trench or slot drains for a maximum distance of 18 inches (457 mm) where deck-level perimeter overflow systems are utilized. These must be slip resistant. This distance is not applicable to zero depth entries in Section 454.1.9.6.2. Wet deck area in accordance with Section 454.1.3.1.3 shall be provided beyond the trench grate or slot drain.

~~Where a perimeter overflowing edge is provided,~~ Up to 40 percent of the wet deck may be lowered. Lowered portions of wet deck shall be at least 10 inches (254 mm) but not more than 36 inches (914 mm) below the pool water level~~.~~, and not more than 42 inches (1067 mm) below the curb height. Lowered portions of wet deck shall be not more than 60 feet (18 288 mm) long and shall adjoin the rest of the wet deck via stairs or ramps at both ends.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

52

SW10204

Date Submitted	02/11/2022	**Section**	454.1.1	**Proponent**	James LePetrie
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

10202

Summary of Modification

Provides a definition for vanishing edge pools.

Rationale

Provides a definition for vanishing edge pools in conjunction with addition of a new code section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Yes

Does not degrade the effectiveness of the code

Yes

Alternate Language

1st Comment Period History

SW10204-A1

Proponent Dallas Thiesen **Submitted** 4/14/2022 3:53:27 PM **Attachments** Yes

Rationale:

Clarifies the proposed definition of vanishing edge.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
None
Impact to industry relative to the cost of compliance with code
None
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Specifies construction standards for commercial swimming pools used by the public.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Adds clarity to the building code.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Does not specify materials or products.
Does not degrade the effectiveness of the code
Adds clarity to the building code.

"Vanishing edge" means a pool wall structure that is designed in such a way that the top of the pool wall and adjacent deck are not visible from certain vantage points in the pool or from the opposite side of the pool. Water from the pool flows over the edge and is captured and reused through the normal pool circulation system. **Includes overflowing edge swimming pools with a lowered deck.** Also referred to as an infinity edge, negative edge, **overflowing edge,** or zero edge.

“Vanishing edge” means a pool wall structure that is designed in such a way that the top of the pool wall and adjacent deck are not visible from certain vantage points in the pool or from the opposite side of the pool. Water from the pool flows over the edge and is captured and reused through the normal pool circulation system. Also referred to as an infinity edge, negative edge, or zero edge.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10206

53

Date Submitted	02/11/2022	**Section**	454.1.3.1.6	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Simplifies swimming pool deck obstruction rules and calculation.

Rationale

This modification changes the deck obstruction limitation to standard of 20 feet, eliminating the need to calculate 10% of the swimming pool perimeter. The modification also allows obstructions on lower deck portions not exceeding 20 feet.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements and calculations.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements and calculations.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements and calculations.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool deck design can impact bather safety, this modification clarifies the limitations of deck obstructions on publics swimming pools.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

1st Comment Period History

SW10206-G1

Proponent	bob vincent	Submitted	4/17/2022 8:44:48 PM	Attachments	No

Comment:

Florida Department of Health opposes this mod. There is a significant additional safety risk for a person in distress when the rescue access points on the lowered wet deck is obstructed in any way. Both mod phrases proposed to be struck should be saved.

454.1.3.1.6

Twenty percent of the deck along the pool perimeter may be obstructed as long as any one obstruction does not exceed ~~10 percent of the pool perimeter or~~20 feet (6096 mm), ~~whichever is less,~~in any one area where water depth is 5 feet (1524 mm) or less. ~~No lowered portion of the wet deck may be obstructed.~~Obstructions shall have a wet deck area behind or through them, with the near edge of the walk within 15 feet (4572 mm) of the water except approved slide obstructions shall have the near edge of the walk within 35 feet (10 668 mm) of the water. These obstructions must be protected by a barrier or must be designed to discourage patron access. Obstructions shall not include pool exit points. When an obstruction exists in multiple areas around the pool, the minimum distance between obstructions shall be 4 feet (1219 mm).

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10209

54

Date Submitted	02/11/2022	**Section**	454.1.3.3.7	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Adds requirements and standards for the use of removable floor and wall padding.

Rationale

Padding is already widely used in river rides and kids' wet play areas. Arguably, it is already permitted in the Code, but not all reviewers agree. It sometimes goes in for a variance. Adding this provision, allowing padding on floors and walls, would eliminate the ambiguity.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

None, clarifies code requirements.

Impact to industry relative to the cost of compliance with code

None, clarifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Padding can be used to improve bather safety in river rides, slide areas, and other instances where a bather is likely to impact the pool floor or wall.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

454.1.3.3.7

To reduce the possibility of injury, removable padding may be installed over the walls and floors of the pool, in areas where impacts are likely, so long as the surface of the padding is impervious, non-toxic, smooth, and slip resistant. Such padding shall be installed and maintained according to the manufacturer's specifications. The surface underneath the padding must be structurally rigid, impervious, non-toxic, smooth, and slip resistant. The padding may be white or a contrasting color.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10232

55

Date Submitted	02/11/2022	**Section**	454.1.6.5.12	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Eliminates contradictory requirements for swimming pool cleaning systems.

Rationale

Clarifies remote vacuum system requirements. Fixes inlet/outlet contradictions in this section.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, clarifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, clarifies code requirements and simplifies compliance.

Impact to industry relative to the cost of compliance with code

None, clarifies code requirements and simplifies compliance.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool cleaning systems ensure a sanitary bathing environment.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

None, clarifies code requirements, removes unnecessary complications.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

None, clarifies code requirements, removes unnecessary complications.

454.1.6.5.12Cleaning system.

A portable, robotic or plumbed-in vacuum cleaning system shall be provided. All vacuum pumps shall be equipped with hair and lint strainers. When the system is plumbed in, the vacuum fittings shall be located to allow cleaning the pool with a 50-foot (15 240 mm) maximum length of hose. Vacuum fittings shall be located remotely in the pool deck. Remote vacuum assemblies shall be installed with ~~an equalizer valve and~~ an equalizer line when the vacuum piping system is connected directly to pump suction and the suction line shall be protected with a threaded plug when not in use. ~~The equalizer valve shall be a spring-loaded vertical check valve that will not allow direct suction on the equalizer line. Float valves are prohibited.~~ The equalizer line ~~inlet~~outlet shall be installed at least 1 foot (305 mm) below the normal pool water level and the equalizer line ~~inlet~~outlet shall be protected by an ANSI/APSP-16 compliant cover/grate. The equalizer line shall be sized to handle the expected flow with a 2-inch (51 mm) minimum line size. The provision of a filtered, chemically treated water supply to the equalizer piping shall be provided to assist in preventing algae from forming within the equalizer piping arrangement. Bag-type cleaners, which operate as ejectors on potable water supply pressure, shall be protected by a vacuum breaker. Cleaning devices shall not be used while the pool is open to bathers.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10235

56

Date Submitted	02/11/2022	**Section**	454.1.6.5.16.1.1.4	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Prohibits the use of chlorine gas on new public swimming pools.

Rationale

Chlorine gas is a dangerous sanitizer that should be phased out.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None.

Impact to building and property owners relative to cost of compliance with code

None, chlorine gas is rarely used on modern pools. This modification ensures it cannot be used in the future.

Impact to industry relative to the cost of compliance with code

None, chlorine gas is rarely used on modern pools. This modification ensures it cannot be used in the future.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Chlorine gas is unnecessarily dangerous.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Eliminates the use an unnecessarily dangerous sanitizer.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Eliminates the use an unnecessarily dangerous sanitizer.

Does not degrade the effectiveness of the code

Eliminates the use an unnecessarily dangerous sanitizer.

454.1.6.5.16.1.1.4

After December 31, 2023, new pools may not use chlorine gas.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10237

57

Date Submitted	02/11/2022	**Section**	454.1.6.5.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Updates equipment testing standards to the most current version of NSF/ANSI 50

Rationale

Updates equipment testing standards to the most current version of NSF/ANSI 50

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None, updates referenced testing standards.
Impact to building and property owners relative to cost of compliance with code
None, updates referenced testing standards.
Impact to industry relative to the cost of compliance with code
None, updates referenced testing standards.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Properly functioning equipment ensure bather safety at public pools.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Updates referenced testing standards to the most current standards.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Does not specify particular materials, products, methods, or systems of construction.
Does not degrade the effectiveness of the code
Updates referenced testing standards to the most current standards.

454.1.6.5.1Equipment testing.

Recirculation and treatment equipment such as filters, recessed automatic surface skimmers, ionizers, ozone generators, disinfection feeders and chlorine generators shall be tested and approved using the ~~NSF/ANSI Standard 50, Circulation System Components and Related Materials for Swimming Pool, Spas/Hot Tubs, dated April 2007~~NSF/ANSI 50 – 2017 Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities, which is incorporated by reference.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10241

58

Date Submitted	02/11/2022	**Section**	454.1.6.5.16.6	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes

Alternate Language No

Related Modifications

Summary of Modification

Removes dead web links in the code and simplifies explanation of UV sanitization.

Rationale

This is a critical code fix because there are dead links in this section of the code. We need to simplify the explanation of UV sanitization by referencing NSF 50 -2017. The requirements to use this equipment on certain types of pools should be moved to the sections discussing those types of pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Clarifies code requirements.

Impact to building and property owners relative to cost of compliance with code

Clarifies code requirements.

Impact to industry relative to the cost of compliance with code

Clarifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Sanitization systems are vital to bather health and safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Clarifies code requirements.

1st Comment Period History

SW10241-G1

Proponent	bob vincent	Submitted	4/17/2022 10:55:25 AM	Attachments	Yes

Comment:

This code section should remain the same with an edit to the source link. UV disinfection devices are fully understood by professional engineers required to design pools and drinking water systems. The NSF standard for UV devices does not have sufficiently strong criteria when these certified devices are used at high risk pools designed with indirect filtration, while the improved EPA Guidance-validated UV disinfection device does have adequate criteria for direct or indirect filtration. The current link to the EPA Ultraviolet Disinfection Guidance Manual has been changed to: https://www.epa.gov/dwreginfo/long-term-2-enhanced-surface-water-treatment-rule-documents and the direct link to the PDF attached here is: https://www.epa.gov/dwreginfo/long-term-2-enhanced-surface-water-treatment-rule-documents

454.1.6.5.16.6

Ultraviolet (UV) light disinfectant equipment may be used ~~as supplemental water treatment on public pools [and additional treatment on interactive water features (IWFs)]~~ subject to the conditions of this paragraph and manufacturer's specifications. UV is encouraged to be used to eliminate or reduce chlorine-resistant pathogens, especially the protozoan cryptosporidium.

1.UV equipment and electrical components and wiring shall comply with the requirements of the National Electrical Code and the manufacturer shall provide a certification of conformance to the jurisdictional building department.

2.UV equipment shall meet UL standards and shall be electrically interlocked with recirculation pump(s) on all pools and with feature pumps(s) on an IWF such that when the UV equipment fails to produce the required dosage as measured by an automated sensor, the feature pump(s) are disabled so the water features do not operate.

3.UV equipment ~~used in higher risk facilities such as interactive water features, wading pools, and activity pools~~ shall be certified forsecondary or supplemential disinfection per NSF 50 – 2017.~~validated by a capable party that it delivers the required and predicted UV dose at the validated flow, lamp power and water UV transmittance conditions, and has complied with all professional practices summarized in the USEPA Ultraviolet Disinfectant Guidance Manual dated November 2006, which is publication number EPA 815-R-06-007 available from the department at http://www.floridashealth.org/Environment/water/swim/index.html or at http://www.epa.gov/safewater/disinfection/lt2/pdfs/guideit2_uguidance.pdf.~~

~~Exception: Not applicable when Section 454.1.9.8.6.1 alternative is used.~~

4.UV equipment that is not cetifed for secondary disinfection per NSF 50 – 2017 shall be installed and configured to constantly produce a validated dosage of at least 40 mJ/cm2 (millijoules per square centimeter) at the end of lamp life.

5.The UV equipment shall not be located in a side stream flow and shall be located to treat all water returning to the pool or water features. Any treatment chemicals shall be injected downstream of the UV equipment.

United States
Environmental Protection
Agency

ULTRAVIOLET DISINFECTION GUIDANCE MANUAL FOR THE FINAL LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE

Office of Water (4601)
EPA 815-R-06-007
November 2006

U.S. Environmental Protection Agency
Office of Water (4601)
1200 Pennsylvania Avenue NW
Washington, DC 20460
EPA 815-R-06-007
http://www.epa.gov/safewater/disinfection/lt2/compliance.html
November 2006

Purpose:

The purpose of this guidance manual is solely to provide technical information on the application of ultraviolet light for the disinfection of drinking water by public water systems. This guidance is not a substitute for applicable legal requirements, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, states, or the regulated community. Interested parties are free to raise questions and objections to the guidance and the appropriateness of using it in a particular situation. Although this manual covers many aspects of implementing a UV disinfection system, it is not comprehensive in terms of all types of UV systems, design alternatives, and validation protocols that may provide satisfactory performance. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Authorship:

This manual was developed under the direction of EPA's Office of Water, and was prepared by Malcolm Pirnie, Inc., Carollo Engineers, P.C., The Cadmus Group, Inc., Dr. Karl G. Linden, and Dr. James P. Malley, Jr. Questions concerning this document should be addressed to:

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Glossary

The following definitions were derived from existing UV literature, standard physics textbooks, and/or industry standards and conventions. Some concepts have more than one acceptable term or definition, but for consistency within the document, only one term is used.

Absorption – the transformation of UV light to other forms of energy as it passes through a substance.

A_{254} (UV Absorbance at 254 nm)– a measure of the amount of UV light that is absorbed by a substance at 254 nm.

Action Spectra Correction Factor (CF_{as}) – a correction factor to account for greater proportional inactivation of a challenge microorganism compared to the target pathogen that results from differences in action spectra.

Action Spectrum – the relative efficiency of UV energy frequencies at inactivating microorganisms. Each microorganism has a unique action spectrum.

Bacteriophage – a virus that infects bacterial cells and can be used a microbial surrogate during validation testing.

Ballast – an electrical device that provide the proper voltage and current required to initiate and maintain the gas discharge within the UV lamp.

Beer's Law –an empirical equation describing the absorption of light as a function of the transmitting medium's properties; also know as the Beer-Lambert law.

Bioassay – in the context of this document, an empirical assessment of the inactivation response of a specific microorganism to a controlled dose of UV light, usually in UV reactors. Bioassay has been used in the UV disinfection literature in the same context as "biodosimetry" (see **Biodosimetry**).

Biodosimetry – a procedure used to determine the reduction equivalent dose (RED) of a UV reactor. Biodosimetry involves measuring the inactivation of a challenge microorganism after exposure to UV light in a UV reactor and comparing the results to the known UV dose-response curve of the challenge microorganism (determined via bench-scale collimated beam testing).

Calculated Dose Approach – See **Dose-monitoring Strategy**.

Challenge Microorganism – a non-pathogenic microorganism used in validation testing of UV reactors.

Collimated Beam Test – a controlled bench-scale test that is used to determine the UV dose-response of a challenge microorganism. Both time and UV light intensity are directly measured; the UV dose is calculated using the intensity of the incident UV light, UV absorbance of the water, and exposure time.

Dark Repair – an enzyme-mediated microbial process that removes and regenerates a damaged section of deoxyribonucleic acid (DNA), using an existing complimentary strand of DNA. Dark repair refers to all microbial repair processes not requiring reactivating light.

Design Flow Rate – the maximum flow that can be treated at the UV facility. See Section 3.4 for potential methods for determining design flow rate.

Design UVT – The minimum UVT that will typically occur at the design flow of the UV facility. The design UVT and design flow are typically used by the UV manufacturer to determine the appropriate UV equipment for a target pathogen inactivation. The design UVT may not necessarily be the minimum operating UVT (see **Minimum Operating UVT**).

Diffuse Reflection – that portion of light reflected by a rough surface that radiates in all directions.

Dose Distribution – see **UV Dose**.

Dose-monitoring Strategy – the method by which a UV reactor maintains the required dose at or near some specified value by monitoring UV dose delivery. Such strategies must include, at a minimum, flow rate and UV intensity (measured via **duty UV sensor**[s]) and lamp status. They sometimes include UVT and lamp power. Two common Dose-monitoring Strategies that are discussed in this manual are the UV Intensity Setpoint Approach and the Calculated Dose Approach.

- **The UV Intensity Setpoint Approach** relies on one or more "setpoints" for UV intensity that are established during validation testing to determine UV dose. During operations, the UV intensity as measured by the UV sensors must meet or exceed the setpoint(s) to ensure delivery of the required dose. Reactors must also be operated within validated operation conditions for flow rates and lamp status [40 CFR 141.720(d)(2)]. In the UV Intensity Setpoint Approach, UVT does not need to be monitored separately. Instead, the intensity readings by the sensors account for changes in UVT. The operating strategy can be with either a single setpoint (one UV intensity setpoint is used for all validated flow rates) or a variable setpoint (the UV intensity setpoint is determined using a lookup table or equation for a range of flow rates).

- **The Calculated Dose Approach** uses a dose-monitoring equation to estimate the UV dose based on operating conditions (typically flow rate, UV intensity, and UVT). The dose-monitoring equation may be developed by the UV manufacturers using numerical methods; however, EPA recommends that systems use an empirical dose-monitoring equation developed through validation testing. During reactor operations, the UV reactor control system inputs the measured parameters into the dose-monitoring equation to produce a calculated dose. The system operator divides the calculated dose by the Validation Factor (see Chapter 5 for more details on the Validation Factor) and compares the resulting value to the required dose for the target pathogen and log inactivation level.

Dose-pacing Strategy – the method by which a UV reactor maintains the required dose at or near some specified value that typically involves adjusting the lamp power or turning "on" or "off" banks of UV lamps or whole UV reactors to respond to changes in UVT, lamp intensity, or flow rate. A programmable logic controller (PLC) makes adjustments using an equation(s) developed during the UV reactor validation process.

Duty UV Sensor (or Duty Sensor) – the duty (on-line) UV sensor installed in the UV reactor that monitors UV intensity during UV equipment operations.

Emission Spectrum – the relative power emitted by a lamp at different wavelengths.

End-of-Lamp Life – The duration of lamp operations after which the lamp should be replaced

First-order Inactivation – in the context of this document, inactivation of a microorganism that is directly proportional to the UV dose.

Fluence – see the definition for **UV Dose**.

Fluence Rate – see the definition for **UV Intensity**.

Fouling/Aging Factor – a site-specific factor (the product of a fouling factor and aging factor) that is used to account for the decline in UV transmittance through the lamp sleeve due to fouling (e.g., by water quality parameters) and aging of the lamp and lamp sleeve. The lamp fouling portion of the factor is the estimated fraction of UV light passing through a fouled sleeve as compared to a new sleeve. The lamp aging portion of the factor is the fraction of UV light emitted from aged sleeves and lamps compared to new sleeves and lamps. It can be estimated by the lamp and sleeve aging characteristics obtained from the UV manufacturer.

Gas Discharge – a mixture of non-excited atoms, excited atoms, cations, and free electrons formed when a sufficiently high voltage is applied across a volume of gas. Most commercial UV lamps use mercury gas discharges to generate UV light.

Germicidal Effectiveness – the relative inactivation efficiency of each UV wavelength in an emission spectrum. This value is usually approximated by the relative absorbance of DNA at each wavelength.

Germicidal Range – the range of UV wavelengths responsible for microbial inactivation in water (200 to 300 nm).

Germicidal Sensor – A UV sensor with a spectral response that peaks between 250 and 280 nm and has less than 10 percent of its total measurement due to light above 300 nm when mounted on the UV reactor and viewing the UV lamps through the water that will be treated at the water treatment plant.

Inactivation – in the context of UV disinfection, a process by which a microorganism is rendered unable to reproduce, thereby rendering it unable to infect a host.

Lamp Burn-in – During the first few hours of mercury-vapor lamp operation, output will diminish rapidly, then stabilize as the impurities within the lamp are burned off. This initial "burn-in" period is typically assumed to be complete at 100 hours.

Lamp Envelope – the exterior surface of the UV lamp, which is typically made of quartz.

Lamp Sleeve – the quartz tube or thimble that surrounds and protects the UV lamp. The exterior is in direct contact with the water being treated. There is typically an air gap (approximately 1 cm) between the lamp envelope and the quartz sleeve.

Lamp Status – see **UV Lamp Status**

Light Pipe – a quartz cylinder that transmits light from the interior of the UV reactor to the photodetector of a UV intensity sensor.

Lignin Sulfonate – a commercially available liquid lignin mixture (typically procured from paper mills) used to adjust the UV transmittance of natural waters during validation testing.

Low-pressure (LP) Lamp – a mercury-vapor lamp that operates at an internal pressure of 0.13 to 1.3 Pa (2×10^{-5} to 2×10^{-4} psi) and electrical input of 0.5 watts per centimeter (W/cm). This results in essentially monochromatic light output at 254 nm.

Low-pressure high-output (LPHO) Lamp – a low-pressure mercury-vapor lamp that operates under increased electrical input (1.5 to 10 W/cm), resulting in a higher UV intensity than low-pressure lamps. It also has essentially monochromatic light output at 254 nm.

Medium-pressure (MP) Lamp – a mercury vapor lamp that operates at an internal pressure of 1.3 and 13,000 Pa (2 to 200 psi) and electrical input of 50 to 150 W/cm. This results in a polychromatic (or broad spectrum) output of UV and visible light at multiple wavelengths, including wavelengths in the germicidal range.

Microbial Repair – enzyme-mediated microbial process where damaged strands of deoxyribonucleic acid (DNA) are repaired. Energy for this process can be derived by light energy (photorepair) or chemical energy (dark repair).

Minimum Operating UVT: The lowest UVT expected to occur during lifetime of the UV facility. Understanding the minimum UVT is critical because the UV reactor should be designed and validated for the range of UVT and flow rate combinations expected at the WTP to avoid off-specification operation.

Monochromatic – light output at only one wavelength, such as UV light generated by low-pressure and low-pressure high-output lamps.

Monitoring Window – a quartz disc that transmits light from the interior of the UV reactor to the photodetector of a UV sensor.

MS-2 Bacteriophage – a non-pathogenic bacteriophage commonly used as a challenge organism in UV reactor validation testing.

Non-germicidal Sensor – A UV sensor with a spectral response that is not restricted to the germicidal range (see "Germicidal Sensor" for more details).

Off-line Chemical Clean (OCC) – a process to clean lamp sleeves where the UV reactor is taken off-line and a cleaning solution (typically a weak acid) is sprayed into the reactor through a service port. After the foulants have dissolved, the reactor is drained, rinsed, and returned to service. Also called "flush-and-rinse" systems.

Off-specification – A UV facility that is operating outside of the validated operating conditions (e.g., at a flow rate higher than the validated range or a UVT below the validated range).

On-line Mechanical Clean (OMC) – a process to clean lamp sleeves where an automatic mechanical wiper (e.g., O-ring) wipes the surface of the lamp sleeve at a prescribed frequency.

On-line Mechanical-Chemical Clean (OMCC) – a process to clean lamp sleeves where an automatic mechanical wiper (e.g., O-ring) with a chemical solution located within the cleaning mechanism wipes the surface of the lamp sleeve at a prescribed frequency.

Operating Strategy – the strategy used by the PWS to operate the UV equipment with the UV Intensity Setpoint Approach. Typically, single setpoint or variable setpoint operation is used.

Petri Factor – a ratio used in collimated beam testing that is equal to the average intensity measured across the surface of a suspension in a petri dish divided by the intensity at the center of a petri dish.

Photodetector – a device that produces an electrical current proportional to the UV light intensity at the detector's surface.

Photorepair– a microbial repair process where enzymes are activated by light in the near UV and visible range, thereby repairing UV induced damage. Photoreactivation requires the presence of light.

Polychromatic – light energy output at several wavelengths such as with MP lamps.

Polychromatic Bias – a potential bias in validation test data resulting from polychromatic differences between validation and operation of a UV reactor at a water system. Polychromatic bias can occur in MP reactors when non-germicidal sensors are used.

Quartz Sleeve – see **lamp sleeve**.

Radiometer – an instrument used to measure UV irradiance.

Rayleigh Scattering – light scattering by particles smaller than the wavelength of the light.

Reduction Equivalent Dose (RED) – see **UV Dose**.

Reduction Equivalent Dose (RED) Bias – a correction that accounts for the difference between the UV dose measured with a surrogate microorganism and the UV dose that would be delivered to a target pathogen due to differences in the microorganisms' inactivation kinetics.

Reference UV Sensor (or Reference Sensor) – a calibrated, off-line UV sensor used to monitor duty UV sensor calibration and to determine UV sensor uncertainty.

Required Dose – the UV dose required for a certain level of log inactivation. Required doses are set forth by the LT2ESWTR.

Sensor Correction Factor – a correction factor that may need to be temporarily applied during operations when duty sensor(s) fail a calibration check and can not be immediately replaced. The sensor correction factor allows the UV facility to remain in operation while the problem is resolved.

Setpoint (also called "operational setpoint") – a specific value for a critical parameter, such as UV intensity, that is related to UV dose. Setpoints are established during validation testing. During operations, the PWS compares the measured parameter to the setpoint to confirm performance.

Solarization – a change in the structure of a material due to exposure to UV light that increases light scattering and attenuation.

Spectral Response – A measure of the output of the UV sensor as a function of wavelength.

State – the agency of the state or Tribal government that has jurisdiction over public water systems. During any period when a state or Tribal government does not have primary enforcement responsibility pursuant to section 1413 of the Act, the term "state" means the Regional Administrator, U.S. Environmental Protection Agency.

Subpart H Systems – public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of subpart H of 40 CFR Part 141.

Target Log Inactivation - For the target pathogen, the specific log inactivation the PWS wants to achieve using UV disinfection. The target log inactivation is driven by requirements of the SWTR, LT1ESWTR, IESWTR, and LT2ESWTR.

Target Pathogen (also called "target microorganism") – For the purposes of this manual, the target pathogen is defined as the microorganism for which a PWS wants to obtain inactivation credit using UV disinfection.

UV Absorbance (A) – a measure of the amount of UV light that is absorbed by a substance (e.g., water, microbial DNA, lamp envelope, quartz sleeve) at a specific wavelength (e.g., 254 nm). This measurement accounts for absorption and scattering in the medium (e.g., water). Standard Method 5910B details this measurement method. However, for UV disinfection applications, the sample should not be filtered or adjusted for pH as described in Standard Methods.

UV Absorbance at 254 nm (A_{254}) – a measure of the amount of UV light that is absorbed by a substance at 254 nm.

UV Action Spectrum – the relative efficiency of UV energy at different wavelengths in inactivating microorganisms. Each microorganism has a unique action spectrum.

UV Dose – the UV energy per unit area incident on a surface, typically reported in units of mJ/cm^2 or J/m^2. The UV dose received by a waterborne microorganism in a reactor vessel accounts for the effects on UV intensity of the absorbance of the water, absorbance of the quartz sleeves, reflection and refraction of light from the water surface and reactor walls, and the germicidal effectiveness of the UV wavelengths transmitted. This guidance manual also uses the following terms related to UV dose:

- **UV dose distribution** – the probability distribution of delivered UV doses that microorganisms receive in a flow-through UV reactor; typically shown as a histogram. An example is shown in Figure 2-8.

- **Reduction Equivalent Dose (RED)** – The UV dose derived by entering the log inactivation measured during full-scale reactor testing into the UV dose-response curve that was derived through collimated beam testing. RED values are always specific to the challenge microorganism used during experimental testing and the validation test conditions for full-scale reactor testing.

- **Required Dose (D_{req})** – The UV dose in units of mJ/cm^2 needed to achieve the target log inactivation for the target pathogen. The required dose is specified in the LT2ESWTR and presented in Table 1.4 of this guidance manual.

- **Validated Dose (D_{val})** – The UV dose in units of mJ/cm^2 delivered by the UV reactor as determined through validation testing. The validated dose is compared to the Required Dose (D_{req}) to determine log inactivation credit.

- **Calculated Dose** - the RED calculated using the dose-monitoring equation that was developed through validation testing.

UV Dose-Response – the relationship indicating the level of inactivation of a microorganism as a function of UV dose.

UV Equipment – the UV reactor and related components of the UV disinfection process, including (but not limited to) UV reactor appurtenances, ballasts, and control panels.

UV Facility – all of the components of the UV disinfection process, including (but not limited to) UV reactors, control systems, piping, valves, and building (if applicable).

UV Intensity – the power passing through a unit area perpendicular to the direction of propagation. UV intensity is used in this guidance manual to describe the magnitude of UV light measured by UV sensors in a reactor and with a radiometer in bench-scale UV experiments.

UV Intensity Setpoint Approach – See **Dose-Monitoring Strategy**.

UV Irradiance – the power per unit area incident to the direction of light propagation at all angles, including normal.

UV Lamp Status – a parameter that is monitored during validation testing and long-term operation of UV reactors that indicates whether a particular UV lamp is on or off.

UV Light – light emitted with wavelengths from 200 to 400 nm.

UV Reactor – the vessel or chamber where exposure to UV light takes place, consisting of UV lamps, quartz sleeves, UV sensors, quartz sleeve cleaning systems, and baffles or other hydraulic controls. The UV reactor also includes additional hardware for monitoring UV dose delivery; typically comprised of (but not limited to): UV sensors and UVT monitors.

UV Reactor Validation – Experimental testing to determine the operating conditions under which a UV reactor delivers the dose required for inactivation credit of *Cryptosporidium*, *Giardia lamblia*, and viruses.

UV Sensitivity – the resistance of a microorganism to inactivation by UV light, expressed as mJ/cm^2 per log inactivation.

UV Sensor – a photosensitive detector used to measure the UV intensity at a point within the UV reactor that converts the signal to units of milliamps (mA).

UV Transmittance (UVT) – a measure of the fraction of incident light transmitted through a material (e.g., water sample or quartz). The UVT is usually reported for a wavelength of 254 nm and a pathlength of 1-cm. If an alternate pathlength is used, it should be specified or converted to units of cm^{-1}. UVT is often represented as a percentage and is related to the UV absorbance (A_{254}) by the following equation (for a 1-cm path length): $\% \text{ UVT} = 100 \times 10^{-A}$.

Validated Dose – see **UV Dose**.

Validation Factor – an uncertainty term that accounts for the bias and uncertainty associated with validation testing.

Validated Operating Conditions – the operating conditions under which the UV reactor is confirmed as delivering the dose required for LT2ESWTR inactivation credit . These operating conditions must include flow rate, UV intensity as measured by a UV sensor, and UV lamp status. Also commonly referred to as the “validated range” or the “validated limits.”

Validation Uncertainty – an uncertainty term that accounts for error in measurements made during validation testing to develop the UV intensity setpoint(s) (for the UV Intensity Setpoint Approach) or dose-monitoring equation (for the Calculated Dose Approach).

Visible Light – Wavelengths of light in the visible range (380 – 720 nm).

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List of Units, Abbreviations, and Acronyms

λ	wavelength
μg	microgram
μg/L	microgram per liter
μm	micrometer, micron
A_{254}	ultraviolet light absorbance at 254 nanometers
ACGIH	American Conference of Governmental Industrial Hygienists
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
AOC	assimilable organic carbon
APHA	American Public Health Association
ATCC	American Type Culture Collection
AWA	Australian Water Association
AWWA	American Water Works Association
B_{Poly}	polychromatic bias
°C	degree Centigrade
CCPP	calcium carbonate precipitation potential
CCWA	Clayton County Water Authority
CEC	Clancy Environmental Consultants
CF	correction factor
CF_{as}	action spectra correction factor
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfu	colony forming unit
cfu/mL	colony forming units per milliliter
cm	centimeter
cPEL	ceiling permissible exposure limit
CT	contact time
DBP	disinfection byproduct
DBPR	Stage 2 Disinfectants and Disinfection Byproducts Rule
DNA	deoxyribonucleic acid
DOC	dissolved organic carbon
D_{Req}	required UV dose
DVGW	Deutsche Vereinigung des Gas- und Wasserfaches
ENR BCI	Engineering News Record Building Cost Index
EOLL	end-of-lamp-life
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
°F	degree Fahrenheit
g	gram
g/L	gram per liter
g/mL	gram per milliliter
GAC	granular activated carbon
GFI	ground fault interrupter

gpm	gallon per minute
gpm/sf	gallon per minute per square foot
GWUDI	ground water under the direct influence of surface water
HAA	haloacetic acid
HAA5	five haloacetic acids (monochloroacetic, dichloroacetic, trichloroacetic, monobromoacetic, and dibromoacetic acids)
HazMat	hazardous materials
hr	hour
HSP	high-service pump
HVAC	heating, ventilating, and air conditioning system
Hz	Hertz
I&C	instrumentation and control
IDLH	Immediately Dangerous to Life or Health
IEEE	Institute of Electrical and Electronic Engineers
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFE	individual filter effluents
J	joule
J/m2	joule per meter squared
kVA	kilovolt ampere
kW	kilowatt
L	liter
LED	light emitting diode
LID	light intensity distribution
log I	log Inactivation
LP	low pressure
LPHO	low pressure high output
LRAA	locational running annual average
LSA	lignin sulfonic acid
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
M	molar
M^{-1} cm^{-1}	molar absorption coefficient
m/s^2	meter per second squared
mA	milliampere
mA/mW	milliampere per milliwatt
MCL	maximum contaminant level
mg	milligram
mg/cm	milligram per centimeter
mg/L	milligram per liter
mgd	million gallon per day
$mg\text{-}Hg/m^3$	milligrams mercury per meter cubed
min	minute
mJ	millijoule
mJ/cm^2	millijoule per centimeter squared
mL	milliliter
mm	millimeter

m-mhos/cm	millimhos per centimeter
MP	medium pressure
MS2	male-specific-2 bacteriophage
mW	milliwatt
mW/cm	milliwatt per centimeter
mW/cm^2	milliwatt per centimeter squared
mWs/cm^2	milliwatt second per centimeter squared
NEC	National Electric Code
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
nm	nanometer
NOM	natural organic matter
NPL	National Physical Laboratory
NSF	National Science Foundation
NTU	nephelometric turbidity unit
NWRI	National Water Research Institute
NYSERDA	New York State Energy Research and Development Authority
O&M	operation and maintenance
OCC	off-line chemical cleaning
OMC	on-line mechanical cleaning
OMCC	on-line mechanical-chemical cleaning
ÖNORM	Österreichisches Normungsinstitut
oocysts/L	oocysts per liter
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
Pa	pascal
PAC	powder activated carbon
PEL	permissible exposure limit
pfu	plaque forming unit
pfu/mL	plaque forming units per milliliter
PLC	programmable logic controller
psi	pounds per square inch
psig	pounds-force per square inch gauge
PTB	Physikalisch Technische Bundesanstalt
PWS	public water system
PWSID	public water system identification
QA/QC	quality assurance/quality control
RAA	running annual average
RCRA	Resource Conservation and Recovery Act
RED	reduction equivalent dose
RNA	ribonucleic acid
s	second
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
SUVA	specific ultraviolet absorbance

SWTR	Surface Water Treatment Rule
TCU	total color unit
THM	trihalomethane
TLV	threshold limit value
TNTC	too numerous to count
TOC	total organic carbon
TSA	tryptic soy agar
TSB	tryptic soy broth
TTHM	total trihalomethane
UPS	uninterruptible power supply
UV	ultraviolet
U_{Val}	Uncertainty in Validation
UV-A	ultraviolet range from 315 to 400 nm
UV-B	ultraviolet range from 280 to 315 nm
UV-C	ultraviolet range from 200 to 280 nm
U_{DR}	Uncertainty of the Dose-response Fit
U_{IN}	Uncertainty in Interpolation
U_S	Uncertainty in UV Sensor Measurements
U_{SP}	Uncertainty in the Setpoint Value
UVT	ultraviolet transmittance
VF	validation factor
VFD	variable frequency drive
W	watt
W/cm	watt per centimeter
W/cm^2	watt per centimeter squared
W/m^2	watt per meter squared
W/nm	watt per nanometer
WEF	Water Environment Federation
WTP	water treatment plant

1. Introduction

Interest in using ultraviolet (UV) light to disinfect drinking water is growing among public water systems (PWSs)[1] due to its ability to inactivate pathogenic microorganisms without forming regulated disinfection byproducts (DBPs). UV light has proven effective against some pathogens, such as *Cryptosporidium*, that are resistant to commonly used disinfectants like chlorine.

The United States Environmental Protection Agency (EPA) developed the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to further reduce microbial contamination of drinking water. The rule requires additional treatment for some PWSs based on their source water *Cryptosporidium* concentrations and current treatment practices. UV disinfection is one option PWSs have to comply with the additional treatment requirements.

The design, operation, and maintenance needs for UV disinfection differ from those of traditional chemical disinfectants used in drinking water applications. EPA has developed this guidance manual to familiarize states[2] and PWSs with these distinctions, as well as associated regulatory requirements in the LT2ESWTR. Particularly important design and operation considerations include monitoring, reliability, redundancy, lamp cleaning and replacement, and lamp breakage. Regulatory requirements include UV dose, UV reactor validation, monitoring, reporting, and off-specification compliance.

EPA developed the requirements for UV disinfection in the LT2ESWTR and the guidance in this manual solely for PWSs using UV light to meet drinking water disinfection standards established under the Safe Drinking Water Act (SDWA). EPA has not addressed and did not consider the extension of these requirements and guidance to other applications, including point-of-entry or point-of-use devices for residential water treatment that are not operated by PWSs to meet SDWA disinfection standards.

Chapter 1 covers:

[1] Throughout this document, the terms "PWS" and "water system" are used interchangeably.
[2] Throughout this document, the terms "state" and "states" are used to refer to all regulatory agencies, including both state and federal, with primary enforcement authority for PWSs.

1.1 Guidance Manual Objectives

This manual's objectives are as follows:

- Provide PWSs and designers with technical information and guidance on selecting, designing, and operating UV installations and complying with the UV disinfection-related requirements in the LT2ESWTR.
- Provide states with guidance and the necessary tools to assess UV installations during the design, start-up, and routine operation phases.
- Provide manufacturers with testing and performance standards for UV reactors and components intended for treating drinking water.

1.2 Organization

This manual consists of seven chapters and seven appendices:

- Chapter 1 – **Introduction.** The remainder of this chapter summarizes the microbial treatment and UV disinfection requirements of the LT2ESWTR.
- Chapter 2 – **Overview of UV Disinfection.** This chapter describes the principles of UV disinfection, dose-response relationships, water quality impacts, and UV reactors.
- Chapter 3 – **Planning Analyses for UV Facilities.** This chapter discusses planning for UV disinfection facilities, including disinfection goals, potential locations, basic design parameters, UV reactor evaluation, operational strategies, facility hydraulics, pilot- and demonstration-scale testing, and preliminary costs.
- Chapter 4 – **Design Considerations for UV Facilities.** This chapter discusses the key design features for UV disinfection facilities and presents some common approaches to facility design. Key design features include hydraulics, operational optimization, instrumentation and controls, electrical power considerations, facility layout, and specifications.
- Chapter 5 –**Validation of UV Reactors.** This chapter summarizes the LT2ESWTR requirements for validation testing and presents EPA's recommended validation protocol.
- Chapter 6 – **Start-up and Operation of UV Facilities.** This chapter discusses start-up and operation issues for UV disinfection facilities, recommended maintenance tasks, and monitoring requirements and recommendations.
- Chapter 7 – **Bibliography.** This chapter lists the references used in Chapters 1 through 6 and Appendices A through G.

- Seven appendices provide supplemental information to Chapters 1 – 6.

  Appendix A. Preparing and Assaying Challenge Microorganisms
  Appendix B. UV Reactor Testing Examples
  Appendix C. Collimated Beam Testing to Develop a UV Dose-response Curve
  Appendix D. Background to the UV Reactor Validation Protocol
  Appendix E. UV Lamp Break Issues
  Appendix F. Case Studies
  Appendix G. Reduction Equivalent Dose Bias Tables

1.3 Regulations Summary

This section summarizes general microbial treatment and specific UV disinfection requirements in the LT2ESWTR. The rule applies to all PWSs that use surface water or groundwater under the direct influence of surface water (GWUDI). It builds on existing regulations—the Surface Water Treatment Rule (SWTR), Interim Enhanced Surface Water Treatment Rule (IESWTR), and Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)—to improve control of *Cryptosporidium* and other microbial pathogens.

EPA has developed a Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) with the LT2ESWTR to address the risk-risk trade off between microbial disinfection and the DBPs formed by commonly used disinfectants. The Stage 2 DBPR aims to reduce peak DBP concentrations in the distribution system by modifying the Stage 1 DBPR monitoring requirements and procedures for compliance determination. Consequently, when a PWS assesses its disinfection strategy, it must consider both the disinfectant effectiveness against the target pathogen and the DBPs formed as a result of the disinfectant.

Table 1.1 highlights microbial treatment requirements and DBP maximum contaminant levels (MCLs) from the SWTR, IESWTR, LT1ESWTR, LT2ESWTR, Stage 1 DBPR, and Stage 2 DBPR. See the original regulations or the *Code of Federal Regulations* (CFR) for complete requirements. Details on the Stage 2 DBPR can be found in 40 CFR 141.600 – 141.629.

Table 1.1. Summary of Microbial and DBP Rules

Surface Water Treatment Rules – Minimum Treatment Requirements[1]			
Regulation	***Giardia***	**Virus**	***Cryptosporidium***
SWTR	3-log removal and/or inactivation	4-log removal and/or inactivation	Not addressed
IESWTR and LT1ESWTR	No change from SWTR		2-log removal
LT2ESWTR	No change from SWTR		0- to 2.5-log additional treatment for filtered systems[2]
			2- or 3-log inactivation for unfiltered systems[2]

DBP Rules – MCLs Based on Running Annual Averages (RAAs) or Locational RAAs (LRAAs)				
Regulation	**Total Trihalomethanes (TTHM) (μg/L)[3]**	**Five Haloacetic Acids (HAA5) (μg/L)[3]**	**Bromate (μg/L)[3]**	**Chlorite (μg/L)[3]**
Stage 1 DBPR	80 as RAA	60 as RAA	10	1000
Stage 2 DBPR[4]	80 as LRAA	60 as LRAA	No change from Stage 1	

[1] The term “log” means the order of magnitude reduction in concentration; e.g., 2-log removal equals a 99% reduction, 3-log removal equals a 99.9% reduction, and 4-log removal equals a 99.99-percent reduction.
[2] Specific requirements for each plant depend on source water monitoring results and current treatment practices (40 CFR 141.710 – 141.712).
[3] micrograms/liter (μg/L)
[4] Monitoring locations for LRAAs are identified from the Initial Distribution System Evaluation.

The following sections describe LT2ESWTR requirements for filtered and unfiltered PWSs.

1.3.1 Filtered PWSs

The LT2ESWTR requires filtered PWSs to conduct source water monitoring[3] to determine average *Cryptosporidium* concentrations. Based on the monitoring results, filtered PWSs will be classified in one of four possible treatment bins. A PWS’s bin classification determines the extent of any additional *Cryptosporidium* treatment requirements. The rule requires filtered PWSs to comply with additional treatment requirements by using one or more management or treatment techniques from a “microbial toolbox” of options (40 CFR 141.711). UV is one option in the microbial toolbox; see the LT2ESWTR for additional options (40 CFR 141.715).

[3] The full monitoring requirements are described in the *Source Water Monitoring Guidance Manual for Public Water Systems for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2006).

Filtered PWSs are exempt from *Cryptosporidium* monitoring if the PWS provides, or will provide, a total of at least 5.5-log *Cryptosporidium* treatment—the maximum treatment required by the LT2ESWTR for filtered PWSs[4]—by the treatment compliance date, which varies, depending on population (see Section 1.5 for compliance dates) [40 CFR 141.701(d)]. Installing a UV disinfection system that is validated for the appropriate inactivation credit in addition to filtration treatment can achieve this objective.

Treatment Bin Classification

Table 1.2 presents the bin classifications and their corresponding additional treatment requirements for filtered PWSs (40 CFR 141.711). PWSs with average *Cryptosporidium* concentrations of less than 0.075 oocysts per liter (oocysts/L) are placed in Bin 1 where no additional treatment is required. For concentrations of 0.075 oocysts/L or more, treatment beyond that required by existing rules is necessary. The additional treatment required for each bin, specified in terms of log removal, depends on the type of treatment the PWS already uses.

Table 1.2. Bin Requirements for Filtered PWSs [1]

***Cryptosporidium* Concentration (oocysts/L)**	**Bin Classification**	**And if the following filtration treatment is operating in full compliance with existing regulations, then the *additional* treatment requirements are[2]...**			
		Conventional Filtration Treatment (includes softening)	**Direct Filtration**	**Slow Sand or Diatomaceous Earth Filtration**	**Alternative Filtration Technologies**
< 0.075	**1**	No additional treatment	No additional treatment	No additional treatment	No additional treatment
≥ 0.075 and < 1.0	**2**	1 log treatment[3]	1.5 log treatment[3]	1 log treatment[3]	As determined by the state[3,5]
≥ 1.0 and < 3.0	**3**	2 log treatment[4]	2.5 log treatment[4]	2 log treatment[4]	As determined by the state[4,6]
≥ 3.0	**4**	2.5 log treatment[4]	3 log treatment[4]	2.5 log treatment[4]	As determined by the state[4,7]

1 From 40 CFR 141.711
2 Additional treatment requirements reflect a *Cryptosporidium* removal credit of 3 log for a conventional, slow sand, or diatomaceous earth filtration, and a 2.5-log credit for direct filtration plants.
3 PWSs may use any technology or combination of technologies from the microbial toolbox.
4 PWSs must achieve at least 1 log of the required treatment using ozone, chlorine dioxide, UV light, membranes, bag/cartridge filters, or bank filtration.
5 Total *Cryptosporidium* treatment must be at least 4.0 log.
6 Total *Cryptosporidium* treatment must be at least 5.0 log.
7 Total *Cryptosporidium* treatment must be at least 5.5 log.

4 Treatment requirements for filtered PWSs [40 CFR 141.711] are based on a determination that conventional, slow sand, and diatomaceous earth filtration plants in compliance with the IESWTR and LT1ESWTR achieve an average of 3-log removal of *Cryptosporidium*. EPA has determined that direct filtration plants achieve an average of 2.5-log removal of *Cryptosporidium* (their removal is less than in conventional filtration because they lack a sedimentation process).

1.3.2 Unfiltered PWSs

All existing requirements for unfiltered PWSs remain in effect, including disinfection to achieve at least 3-log inactivation of *Giardia* and 4-log inactivation of viruses. The LT2ESWTR requires 2- or 3-log inactivation of *Cryptosporidium*, depending on the source water concentration of *Cryptosporidium*, as shown in Table 1.3 [40 CFR 141.712)].

Table 1.3. Requirements for Unfiltered PWSs

Average *Cryptosporidium* Concentration (oocysts/L)	Additional *Cryptosporidium* Inactivation Requirements
≤ 0.01	2 log[1]
> 0.01	3 log[1]

[1] Overall disinfection requirements must be met with a minimum of two disinfectants [40 CFR 141.712(d)].

Unfiltered PWSs are exempt from *Cryptosporidium* monitoring if the PWS provides, or will provide, a total of at least 3-log *Cryptosporidium* inactivation—the maximum treatment required by the LT2ESWTR for unfiltered systems [40 CFR 141.701(d)]—by the treatment compliance date. (See Figure 1.1.) Installing a UV disinfection system that is validated for the appropriate inactivation credit can achieve this objective.

1.3.3 PWSs with Uncovered Finished Water Storage Facilities

The LT2ESWTR requires PWSs with uncovered finished water storage facilities to either cover the storage facility or treat the discharge of the storage facility that is distributed to consumers to achieve inactivation and/or removal of 4-log virus, 3-log *Giardia*, and 2-log *Cryptosporidium*. UV disinfection is a treatment option that can help water systems meet these requirements.

1.4 UV Disinfection Requirements for Filtered and Unfiltered PWSs

The LT2ESWTR has several requirements related to the use of UV disinfection. They address the UV doses for different levels of inactivation credit, performance validation testing of UV reactors, monitoring, reporting, and off-specification operation.

1.4.1 UV Dose and Validation Testing Requirements

EPA developed UV dose requirements for PWSs to receive credit for inactivation of *Cryptosporidium*, *Giardia*, and viruses (Table 1.4). The UV dose values in Table 1.4 are applicable only to post-filter applications of UV disinfection in filtered systems and to unfiltered systems.

Unlike chemical disinfectants, UV leaves no residual that can be monitored to determine UV dose and inactivation credit. The UV dose depends on the UV intensity (measured by UV sensors), the flow rate, and the UV transmittance (UVT).[5] A relationship between the required UV dose and these parameters must be established and then monitored at the water treatment plant to ensure sufficient disinfection of microbial pathogens.

Table 1.4. UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2) [1]

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1)

The UV dose requirements in Table 1.4 account for uncertainty in the UV dose-response relationships of the target pathogens but do not address other significant sources of uncertainty in full-scale UV disinfection applications. These other sources of uncertainty are due to the hydraulic effects of the UV installation, the UV reactor equipment (e.g., UV sensors), and the monitoring approach.

Due to these factors, the LT2ESWTR requires PWSs to use UV reactors that have undergone validation testing. This validation testing must determine the operating conditions under which the reactor delivers the required UV dose for treatment credit [40 CFR 141.720(d)(2)]. These operating conditions must include flow rate, UV intensity as measured by a UV sensor, and UV lamp status. Further, validation testing must meet the following requirements:

- Validated operating conditions must account for UV absorbance of the water, lamp fouling and aging, measurement uncertainty of online sensors, UV dose distributions arising from the velocity profiles through the reactor, failure of UV lamps or other critical system components, and inlet and outlet piping or channel configurations of the UV reactor [40 CFR 141.720(d)(2)(i)].

- Validation testing must involve full-scale testing of a reactor that conforms uniformly to the UV reactors used by the PWS, and it also must demonstrate inactivation of a test microorganism whose dose-response characteristics have been quantified with a low-pressure mercury vapor lamp [40 CFR 141.720(d)(2)(ii)].

Using the above requirements as a basis, Chapter 5 presents EPA's recommended validation protocol. Water systems are not required to follow this protocol but may follow alternatives that achieve compliance with the regulatory requirements as long as they are acceptable to the state. Also, states may have additional requirements than are provided in the federal rule.

[5] UV intensity measurements may account for UVT depending on sensor locations.

1.4.2 UV Disinfection Monitoring Requirements [40 CFR 141.720(d)(3)(i)]

The LT2ESWTR requires PWSs to monitor their UV reactors to demonstrate that they are operating within the range of conditions that were validated for the required UV dose. At a minimum, PWSs must monitor each reactor for flow rate, lamp status, UV intensity as measured by a UV sensor, and any other parameters required by the state. UV absorbance should also be measured when it is used in a dose-monitoring strategy. PWSs must verify the calibration of UV sensors and recalibrate sensors in accordance with a protocol the state approves. Section 6.4.1.2 of this guidance describes recommended frequencies for checking sensors.

1.4.3 UV Disinfection Reporting Requirements [40 CFR 141.721(f)(15])

The LT2ESWTR requires PWSs to report the following items:

- **Initial reporting** – Validation test results demonstrating operating conditions that achieve the UV dose required for compliance with the LT2ESWTR.
- **Routine reporting** – Percentage of water entering the distribution system that was not treated by the UV reactors operating within validated conditions on a monthly basis.

1.4.4 Off-specification Operational Requirement for Filtered and Unfiltered Systems [40 CFR 141.720(d)(3)(ii)]

To receive disinfection credit for UV, both filtered and unfiltered PWSs must treat at least 95 percent of the water delivered to the public during each month by UV reactors operating within validated conditions for the required UV dose. EPA views this 95-percent limit as a feasible minimum level of performance for PWSs to achieve, while ensuring the desired level of health protection is provided. For purposes of design and operation, PWSs should strive to deliver the required UV dose at all times during treatment.

In this manual, operating outside the validated limits is defined as off-specification. Off-specification compliance is based on the volume of water treated. Guidance for calculating off-specification is provided in Chapter 6.

1.5 Regulations Timeline

Figure 1.1 provides a timeline for LT2ESWTR initial source water monitoring and treatment installation. Compliance dates vary among the following PWS sizes:

- Systems serving 100,000 or more people
- Systems serving 50,000 to 99,999 people
- Systems serving 10,000 to 49,999 people
- Systems serving fewer than 10,000 people

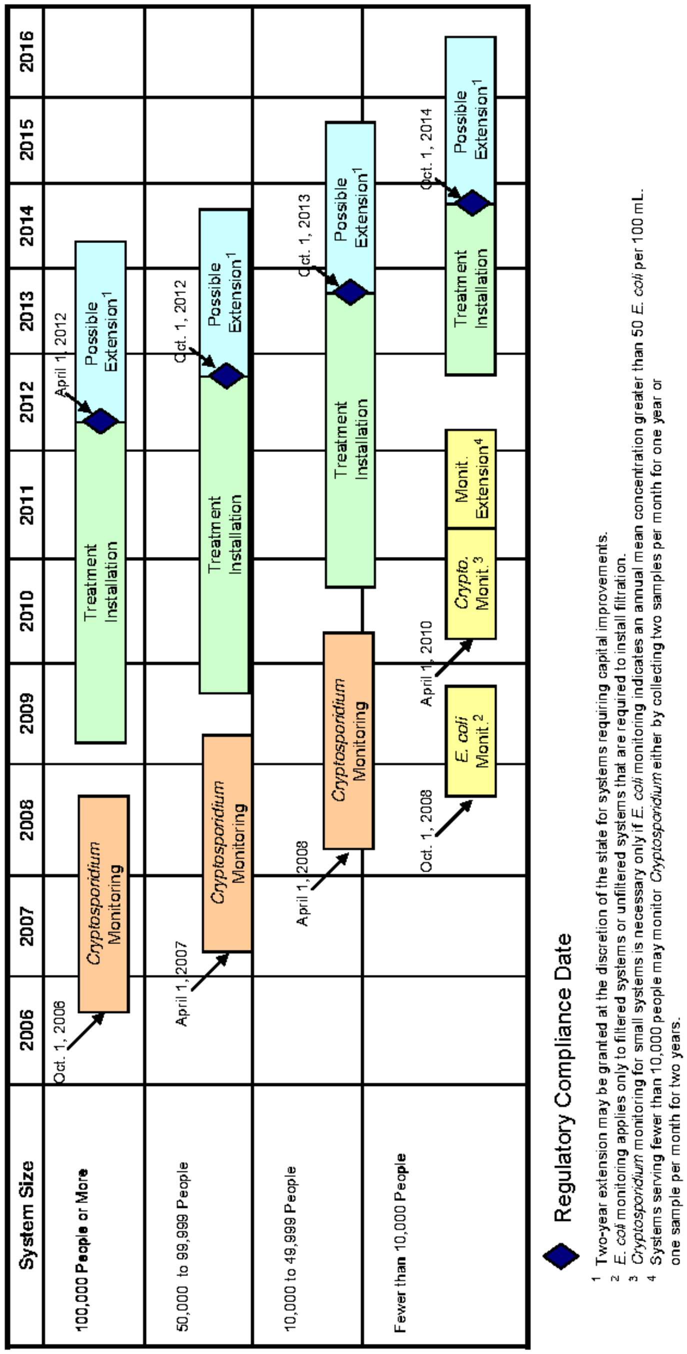
Treatment installation dates pertain only to PWSs that are required to provide additional treatment for *Cryptosporidium*. Further, the actual duration of the treatment installation phase will be contingent on a number of PWS-specific factors, including scope of design (i.e., new facility or retrofit); scale of design (size of facility); available in-house resources; procurement methods; and validation testing requirements (discussed in detail in Chapters 3, 4, and 5).

1.6 Alternative Approaches for Disinfecting with UV Light

This manual provides technical information about using UV disinfection for drinking water treatment. Although it covers many aspects of implementing a UV installation, it is not comprehensive in terms of all types of UV installations, design alternatives, and validation protocols that may provide satisfactory performance. For example, pulsed UV and eximer lamps are two types of UV technologies not included in this manual, but they may provide effective disinfection.

Currently, substantial research is being conducted on UV disinfection and its applications in various industries. As more information becomes available, UV equipment or methods of operation, design, and validation will evolve. Water systems are not limited by the information provided in this guidance manual but must meet the requirements of the LT2 and other drinking water rules, as well as any state-specific requirements. States may approve alternatives in UV installation design, operation, and validation that are not described in this manual.

Figure 1.1. LT2ESWTR Compliance Timeline for Initial Source Water Monitoring and Treatment Installation



2. Overview of UV Disinfection

Chapter 2 provides an overview of UV disinfection. This overview includes discussion of basic chemical and physical principles, the components of UV equipment, and performance monitoring for UV facilities. The overview material in Chapter 2 is intended to present generally accepted facts and research results related to UV disinfection. The material is not intended to provide guidance or recommendations for designing, validating, or installing UV disinfection facilities. Some guidance is included in this chapter to enhance the information presented, but any guidance that appears in this section is also documented in the appropriate subsequent chapters in this manual.

Chapter 2 covers:

2.1 History of UV Light for Drinking Water Disinfection
2.2 UV Light Generation and Transmission
2.3 Microbial Response to UV Light
2.4 UV Disinfection Equipment
2.5 Water Quality Effects and Byproduct Formation

2.1 History of UV Light for Drinking Water Disinfection

UV disinfection is an established technology supported by decades of fundamental and applied research and practice in North America and Europe. Downes and Blunt (1877) discovered the germicidal properties of sunlight. The development of mercury lamps as artificial UV light sources in 1901 and the use of quartz as a UV transmitting material in 1906 were soon followed by the first drinking water disinfection application in Marseilles, France, in 1910. In 1929, Gates identified a link between UV disinfection and absorption of UV light by nucleic acid (Gates 1929). The development of the fluorescent lamp in the 1930s led to the production of germicidal tubular lamps. Considerable research on the mechanisms of UV disinfection and the inactivation of microorganisms occurred during the 1950s (Dulbecco 1950, Kelner 1950, Brandt and Giese 1956, Powell 1959).

Although substantial research on UV disinfection occurred during the first half of the 20th century, the low cost of chlorine and operational problems with early UV disinfection equipment limited its growth as a drinking water treatment technology. The first reliable applications of UV light for disinfecting municipal drinking water occurred in Switzerland and Austria in 1955 (Kruithof and van der Leer 1990). By 1985, the number of such installations in these countries had risen to approximately 500 and 600, respectively. After chlorinated disinfection byproducts (DBPs) were discovered, UV disinfection became popular in Norway and the Netherlands with the first installations occurring in 1975 and 1980, respectively.

As of the year 2000, more than 400 UV disinfection facilities worldwide were treating drinking water; these UV facilities typically treat flows of less than 1 million gallons per day (mgd) (USEPA 2000). Since 2000, several large UV installations across the United States have been constructed or are currently under design. The largest of these facilities includes a 180-mgd facility in operation in Seattle, Washington, and a 2,200-mgd facility under design for the New York City Department of Environmental Protection (Schulz 2004). Because of the susceptibility of *Cryptosporidium* to UV disinfection and the emphasis in recent regulations on controlling *Cryptosporidium*, the number of public water systems (PWSs) using UV disinfection is expected to increase significantly over the next decade.

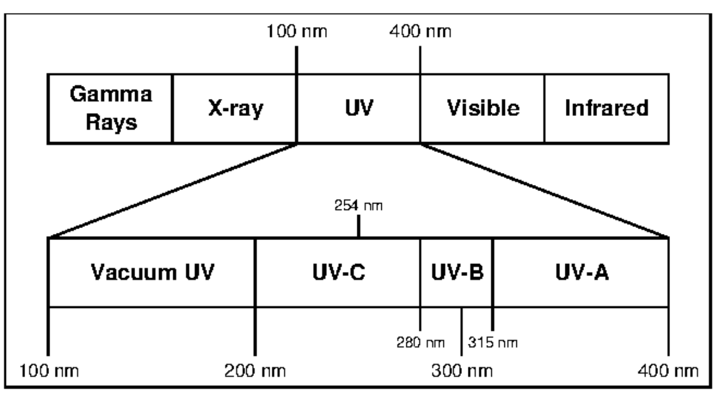
2.2 UV Light Generation and Transmission

The use of UV light to disinfect drinking water involves (1) generating UV light with the desired germicidal properties and (2) delivering (or transmitting) that light to pathogens. This section summarizes how UV light is generated and the environmental conditions that affect its delivery to pathogens.

2.2.1 Nature of UV Light

UV light is the region of the electromagnetic spectrum that lies between X-rays and visible light (Figure 2.1). The UV spectrum is divided into four regions: vacuum UV [100 to 200 nanometers (nm)]; UV-C (200 to 280 nm); UV-B (280 to 315 nm); and UV-A (315 to 400 nm) (Meulemans 1986). UV disinfection primarily occurs due to the germicidal action of UV-B and UV-C light on microorganisms. The germicidal action of UV-A light is small relative to UV-B light and UV-C light; therefore, very long exposure times are necessary for UV-A light to be effective as a disinfectant. Although light in the vacuum UV range can disinfect microorganisms (Munakata et al. 1991), vacuum UV light is impractical for water disinfection applications because it rapidly dissipates in water over very short distances. For the purposes of this manual, the practical germicidal wavelength for UV light is defined as the range between 200 and 300 nm. The germicidal range is discussed further in Section 2.3.1.

Figure 2.1. UV Light in the Electromagnetic Spectrum



Typically, UV light is generated by applying a voltage across a gas mixture, resulting in a discharge of photons. The specific wavelengths of light emitted from photon discharge depend on the elemental composition of the gas and the power level of the lamp. Nearly all UV lamps currently designed for water treatment use a gas mixture containing mercury vapor. Mercury gas is advantageous for UV disinfection applications because it emits light in the germicidal wavelength range. Other gases such as xenon also emit light in the germicidal range.

The light output from mercury-based UV lamps depends on the concentration of mercury atoms, which is directly related to the mercury vapor pressure. In low-pressure (LP) UV lamps, mercury at low vapor pressure [near vacuum; 2×10^{-5} to 2×10^{-3} pounds per square inch (psi)] and moderate temperature [40 degrees centigrade (°C)] produces essentially monochromatic (one wavelength) UV light at 253.7 nm. In medium-pressure (MP) UV lamps, a higher vapor pressure [2 – 200 psi] and higher operating temperature (600 – 900 °C) is used to increase the frequency of collisions between mercury atoms, which produces UV light over a broad spectrum (polychromatic) with an overall higher intensity. The characteristics of LP and MP lamps are discussed in Section 2.4.2 and summarized in Table 2.1.

2.2.2 Propagation of UV Light

As UV light propagates from its source, it interacts with the materials it encounters through absorption, reflection, refraction, and scattering. In disinfection applications, these phenomena result from interactions between the emitted UV light and UV reactor components (e.g., lamp envelopes, lamp sleeves, and reactor walls) and also the water being treated. When assessing water quality, UV absorbance or UV transmittance (UVT) is the parameter that incorporates the effect of absorption and scattering. This section briefly describes both the phenomena that influence light propagation and the measurement techniques used to quantify UV light propagation.

Absorption is the transformation of light to other forms of energy as it passes through a substance. UV absorbance of a substance varies with the wavelength (λ) of the light. The components of a UV reactor and the water passing through the reactor all absorb UV light to varying degrees, depending on their material composition. When UV light is absorbed, it is no longer available to disinfect microorganisms.

Unlike absorption, the phenomena of refraction, reflection, and scattering change the direction of UV light, but the UV light is still available to disinfect microorganisms.

Refraction (Figure 2.2) is the change in the direction of light propagation as it passes through the interface between one medium and another. In UV reactors, refraction occurs when light passes from the UV lamp into an air gap, from the air gap into the lamp sleeve, and from the lamp sleeve into the water. Refraction changes the angle that UV light strikes target pathogens, but how this ultimately affects the UV disinfection process is unknown.

Reflection is the change in direction of light propagation when it is deflected by a surface (Figure 2.3). Reflection may be classified as specular or diffuse. Specular reflection occurs from smooth polished surfaces and follows the Law of Reflection (the angle of incidence is equal to the angle of reflection). Diffuse reflection occurs from rough surfaces and scatters light in all directions with little dependence on the incident angle. In UV reactors, reflection will take place at interfaces that do not transmit UV light (e.g., the reactor wall) and also at UV transmitting interfaces (e.g., the inside of a lamp sleeve). The type of reflection and intensity of light reflected from a surface depends on the material of the surface.

Figure 2.2. Refraction of Light

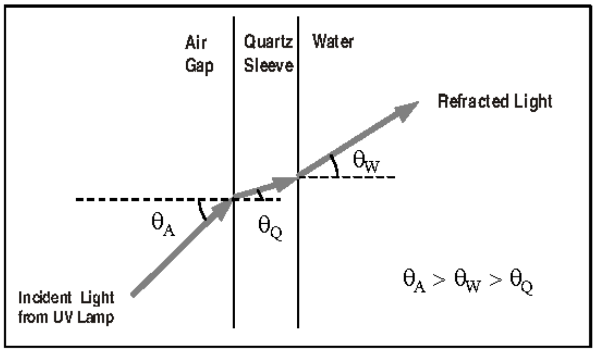
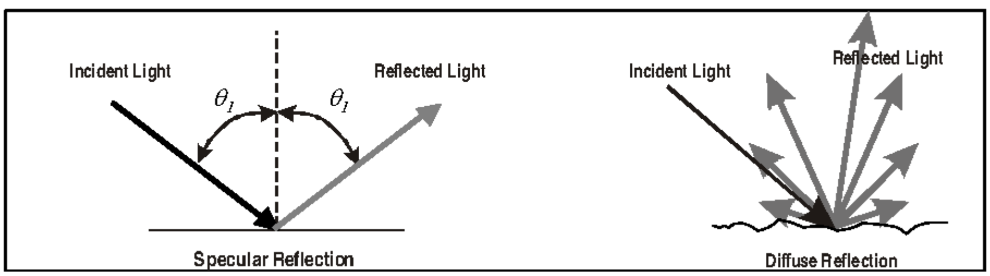


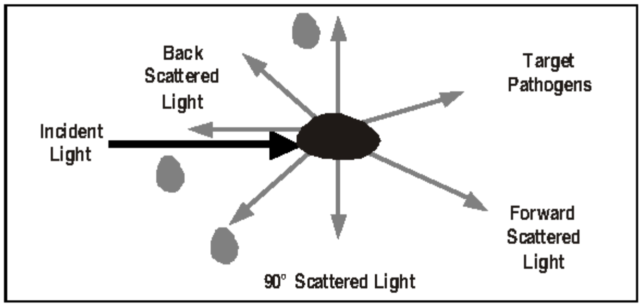
Figure 2.3. Reflection of Light



Scattering of light is the change in direction of light propagation caused by interaction with a particle (Figure 2.4). Particles can cause scattering in all directions, including toward the incident light source (back-scattering). Scattering of light caused by particles smaller than the wavelength of the light is called Rayleigh scattering. Rayleigh scattering depends inversely on wavelength to the fourth power ($1/\lambda^4$) and thus is more prominent at shorter wavelengths. Particles larger than the wavelength of light scatter more light in the forward direction but also cause some backscattering that is relatively independent of wavelength.

UV absorbance (A) quantifies the decrease in the amount of incident light as it passes through a water sample over a specified distance or pathlength. UV absorbance at 254 nm (A_{254}) is a water quality parameter commonly used to characterize the DBP formation potential of the water (e.g., specific UV absorbance calculations). In UV disinfection applications, A_{254} is used to measure the amount of UV light passing through the water and reaching the target organisms. A_{254} is measured using a spectrophotometer with 254 nm incident light and is typically reported on a per centimeter (cm^{-1}) basis.

Figure 2.4. Scattering of Light



Standard Method 5910B (APHA et al. 1998) calls for filtering the sample through a 0.45-µm membrane and adjusting the pH before measuring the absorbance. For UV disinfection applications, however, A_{254} measurements should reflect the water to be treated. Therefore, water samples should be analyzed without filtering or adjusting the pH. More information on collecting A_{254} data is provided in Section 3.4.4.1. Although Standard Methods defines this measurement as UV absorption, this manual refers to it as UV absorbance because the latter term is widely used in the water treatment industry.

UV Transmittance (UVT) has also been used extensively in the literature when describing the behavior of UV light. UVT is the percentage of light passing through material (e.g., a water sample or quartz) over a specified distance. The UVT can be calculated using Beer's law (Equation 2.1):

$$\%\ UVT = 100 * \frac{I}{I_0} \qquad \text{Equation 2.1}$$

where

- UVT = UV transmittance at a specified wavelength (e.g., 254 nm) and pathlength (e.g., 1 cm)
- I = Intensity of light transmitted through the sample [milliwatt per centimeter squared (mW/cm^2)]
- I_0 = Intensity of light incident on the sample (mW/cm^2)

UVT can also be calculated by relating it to UV absorbance using Equation 2.2:

$$\%\ UVT = 100 * 10^{-A} \qquad \text{Equation 2.2}$$

where

- UVT = UV transmittance at a specified wavelength (e.g., 254 nm) and pathlength (e.g., 1 cm)
- A = UV absorbance at a specified wavelength and pathlength (unitless)

UVT is typically reported at 254 nm because UV manufacturers and PWSs widely use A_{254}. This manual assumes UVT is at 254 nm unless specifically stated otherwise.

2.3 Microbial Response to UV Light

The mechanism of disinfection by UV light differs considerably from the mechanisms of chemical disinfectants such as chlorine and ozone. Chemical disinfectants inactivate microorganisms by destroying or damaging cellular structures, interfering with metabolism, and hindering biosynthesis and growth (Snowball and Hornsey 1988). UV light inactivates microorganisms by damaging their nucleic acid, thereby preventing them from replicating. A microorganism that cannot replicate cannot infect a host.

It is important that the assays used to quantify microorganism inactivation measure the ability of the microorganism to reproduce (Jagger 1967). For bacteria, assays measure the ability of the microorganism to divide and form colonies. For viruses, assays measure the ability of the microorganism to form plaques in host cells. For protozoan cysts, the assays measure the ability of the microorganism to infect a host or tissue culture. Assays that do not measure a response to reproduction may result in misleading information on the inactivation of microorganisms using UV light.

This section describes how UV light causes microbial inactivation, discusses how microorganisms can repair the damage, and introduces the concept of UV dose-response.

2.3.1 Mechanisms of Microbial Inactivation by UV Light

Nucleic acid is the molecule responsible for defining the metabolic functions and reproduction of all forms of life. The two most common forms of nucleic acid are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA and RNA consist of single- or double-stranded polymers comprising building blocks called nucleotides (Figure 2.5). In DNA, the nucleotides are classified as either purines (adenine and guanine) or pyrimidines (thymine and cytosine). In RNA, the purines are the same as in DNA, but the pyrimidines are uracil and cytosine.

As shown in Figure 2.6, the nucleotides absorb UV light at wavelengths from 200 to 300 nm. The UV absorption of DNA and RNA reflects their nucleotide composition and tends to have a peak near 260 nm and a local minimum near 230 nm.

All purines and pyrimidines strongly absorb UV light, but the rate of UV-induced damage is greater with pyrimidines (Jagger 1967). Absorbed UV light induces six types of damage in the pyrimidines of nucleic acid (Setlow 1967, Snowball and Hornsey 1988, Pfeifer 1997). The damage varies depending on UV dose. The following three types of damage contribute to microorganism inactivation:

Figure 2.5. Structure of DNA and Nucleotide Sequences within DNA

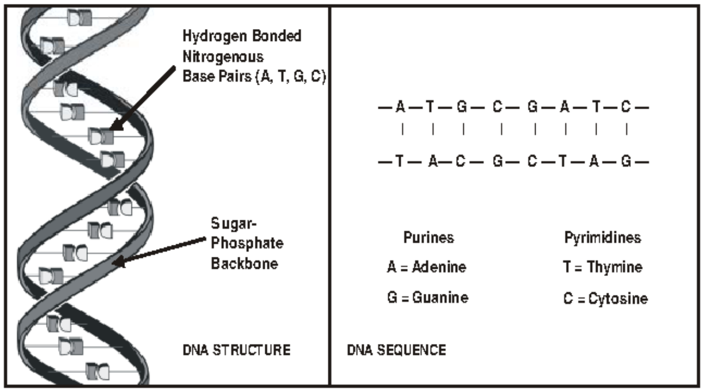
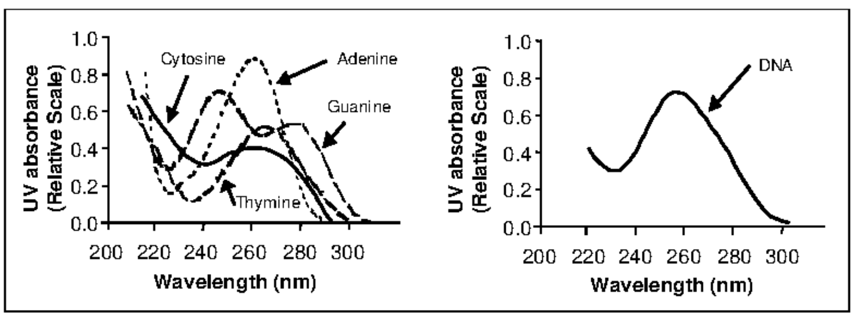


Figure 2.6. UV Absorbance of Nucleotides (left) and Nucleic Acid (right) at pH 7



Source: Adapted from Jagger (1967)

- **Pyrimidine dimers** form when covalent bonds are present between adjacent pyrimidines on the same DNA or RNA strand, and they are the most common damage resulting from UV disinfection.

- **Pyrimidine (6-4) pyrimidone photoproducts** are similar to pyrimidine dimers and form on the same sites.

- **Protein-DNA cross-links** are covalent bonds between a protein and a DNA strand, and they may be important for the disinfection of certain microorganisms.

The other three types of damage do not significantly contribute to UV disinfection: pyrimidine hydrates occur much less frequently than dimers, and single- and double-strand breaks and DNA-DNA cross-links occur only at doses that are several orders of magnitude higher than the doses typically used for UV disinfection (Jagger 1967).

Pyrimidine dimers are the most common form of nucleic acid damage, being 1000 times more likely to occur than strand breaks, DNA-DNA cross-links, and protein-DNA cross-links. Of the three possible pyrimidine dimers that can form within DNA (thymine-thymine, cytosine-cytosine, and thymine-cytosine), thymine-thymine dimers are the most common. For RNA, because thymine is not present, uracil-uracil and cytosine-cytosine dimers are formed. Microorganisms with DNA rich in thymine tend to be more sensitive to UV disinfection (Adler 1966).

Pyrimidine dimer damage and other forms of nucleic acid damage prevent the replication of the microorganism. The damage, however, does not prevent the metabolic functions in the microorganism such as respiration. UV doses capable of causing oxidative damage that prevent cell metabolism and kill the microorganism (similar to the damage caused by chemical disinfectants) are several orders of magnitude greater than doses required to damage the nucleic acid and prevent replication.

2.3.2 Microbial Repair

Many microorganisms have enzyme systems that repair damage caused by UV light. Repair mechanisms are classified as either photorepair or dark repair (Knudson 1985). Microbial repair can increase the UV dose needed to achieve a given degree of inactivation of a pathogen, but the process does not prevent inactivation.

Even though microbial repair can occur, neither photorepair nor dark repair is anticipated to affect the performance of drinking water UV disinfection, as described below:

- Photorepair of UV irradiated bacteria can be prevented by keeping the UV disinfected water in the dark for at least two hours before exposure to room light or sunlight. Treated water typically remains in the dark in the piping, reservoirs, and distribution system after UV disinfection. Most facilities also use chemical disinfection to provide further inactivation of bacteria and virus and protection of the distribution system. Both of these common practices make photorepair unlikely to be an issue for PWSs.

- Dark repair is also not a concern for PWSs because the required UV doses shown in Table 1.4 are derived from data that are assumed to account for dark repair.

2.3.2.1 Photorepair

In photorepair (or photoreactivation), enzymes energized by exposure to light between 310 and 490 nm (near and in the visible range) break the covalent bonds that form the pyrimidine dimers. Photorepair requires reactivating light and repairs only pyrimidine dimers (Jagger 1967).

Knudson (1985) found that bacteria have the enzymes necessary for photorepair. Unlike bacteria, viruses lack the necessary enzymes for repair but can repair using the enzymes of a host cell (Rauth 1965). Linden et al. (2002a) did not observe photorepair of *Giardia* at UV doses typical for UV disinfection applications (16 and 40 mJ/cm^2). However, unpublished data from the same study show *Giardia* reactivation in light conditions at very low UV doses (0.5 mJ/cm^2, Linden 2002). Shin et al. (2001) reported that *Cryptosporidium* does not regain infectivity after inactivation by UV light. One study showed that *Cryptosporidium* can undergo some DNA photorepair (Oguma et al. 2001). Even though the DNA is repaired, however, infectivity is not restored.

2.3.2.2 Dark Repair

Dark repair is defined as any repair process that does not require the presence of light. The term is somewhat misleading because dark repair can also occur in the presence of light. Excision repair, a form of dark repair, is an enzyme-mediated process in which the damaged section of DNA is removed and regenerated using the existing complementary strand of DNA. As such, excision repair can occur only with double stranded DNA and RNA. The extent of dark repair varies with the microorganism. With bacteria and protozoa, dark repair enzymes start to act immediately following exposure to UV light; therefore, reported dose-response data are assumed to account for dark repair.

Knudson (1985) found that bacteria can undergo dark repair, but some lack the enzymes needed for dark repair (Knudson 1985). Viruses also lack the necessary enzymes for repair but can repair using the enzymes of a host cell (Rauth 1965). Oguma et al. (2001) used an assay that measures the number of dimers formed in nucleic acid to show that dark repair occurs in *Cryptosporidium*, even though the mircroorganism did not regain infectivity. Linden et al. (2002a) did not observe dark repair of *Giardia* at UV doses typical for UV disinfection applications (16 and 40 mJ/cm^2). Shin et al. (2001) reported *Cryptosporidium* does not regain infectivity after inactivation by UV light.

2.3.3 UV Intensity, UV Dose, and UV Dose Distribution

UV intensity is a fundamental property of UV light and has the units of watts per meter squared (W/m^2) (Halliday and Resnick 1978). UV intensity has a formal definition that is derived from Maxwell's equations, which are fundamental equations that define the wavelike properties of light. The total UV intensity at a point in space is the sum of the intensity of UV light from all directions.

UV dose is the integral of UV intensity during the exposure period (i.e., the area under an intensity versus time curve). If the UV intensity is constant over the exposure time, UV dose is defined as the product of the intensity and the exposure time. Units commonly used for UV dose are joule per meter squared (J/m^2), mJ/cm^2, and milliwatt seconds per centimeter squared (mWs/cm^2), with mJ/cm^2 being the most common units in North America and J/m^2 being the most common in Europe.[5]

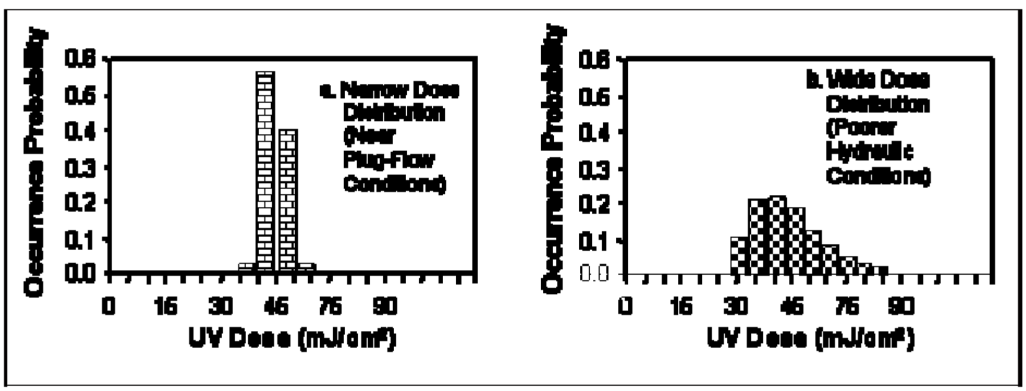
In a completely mixed batch system, the UV dose that the microorganisms receive is equal to the volume-averaged UV intensity within the system. An example of a completely mixed batch system is the collimated beam study in which a petri dish containing the stirred

[5] 10 J/m^2 = 1 mJ/cm^2 = 1 mWs/cm^2

microbial solution is irradiated by a collimated UV light beam (see Appendix C for details). In this case, the average UV intensity is calculated from the measured UV intensity incident on the surface of the microbial suspension, the suspension depth, and the UV absorbance of the water (see Appendix C for details). When using polychromatic light sources (e.g., MP lamps), UV dose calculations in batch system also incorporate the intensity at each wavelength in the germicidal range and the germicidal effectiveness at the associated UV wavelengths.

Dose delivery in a continuous flow UV reactor is considerably more complex than in a completely mixed batch reactor. Some microorganisms travel close to the UV lamps and experience a higher dose, while others that travel close to the reactor walls may experience a lower dose. Some microorganisms move through the reactor quickly, while others travel a more circuitous path. The result is that each microorganism leaving the reactor receives a different UV dose. Accordingly, UV dose delivered to the microorganisms passing through the reactor is best described using a dose distribution (Cabaj et al. 1996) as opposed to a single dose value. A dose distribution can be defined as a histogram of dose delivery (see Figure 2.7). Alternatively, the dose distribution can be defined as a probability distribution that a microorganism leaving a UV reactor will receive a given dose.

Figure 2.7. Hypothetical Dose Distributions for Two Reactors with Differing Hydraulics



The width of the dose distribution is indicative of the dose delivery efficiency of the reactor. A narrow dose distribution (Figure 2.7a) indicates a more efficient reactor, and a wider dose distribution (Figure 2.7b) indicates a less efficient reactor. In particular, the average log inactivation a reactor achieves with a given microorganism is strongly affected by microorganisms that receive the lowest UV doses.

The dose distribution a UV reactor delivers can be estimated using mathematical models based on computational fluid dynamics (CFD) and the light intensity distribution (LID). CFD is used to predict the trajectories of microorganisms as they travel through the UV reactor. LID is used to predict the intensity at each point within the UV reactor. UV dose to each microorganism is calculated by integrating the UV intensity over the microorganism's trajectory through the reactor. Biodosimetry (discussed below) is often used to verify these modeling results.

Currently, dose delivery is measured using a technique termed biodosimetry. With biodosimetry, the log inactivation of a surrogate microorganism is measured through the UV reactor and related to a dose value termed the reduction equivalent dose (RED) using the UV dose-response curve of the surrogate microorganism. Methods for conducting biodosimetry are presented in Chapter 5. Although alternatives to biodosimetry are being developed (e.g., the use of actinometric microspheres) for measuring the dose distribution of a reactor, such methods have not yet been proven for measuring dose delivery in UV reactors.

2.3.4 Microbial Response (UV Dose-Response)

Microbial response is a measure of the sensitivity of the microorganism to UV light and is unique to each microorganism. UV dose-response is determined by irradiating water samples containing the microorganism with various UV doses using a collimated beam apparatus (as described in Appendix C of this manual) and measuring the concentration of infectious microorganisms before and after exposure. The microbial response is calculated using Equation 2.3.

$$Log\ \ Inactivation = \log_{10} \frac{N_0}{N} \qquad \text{Equation 2.3}$$

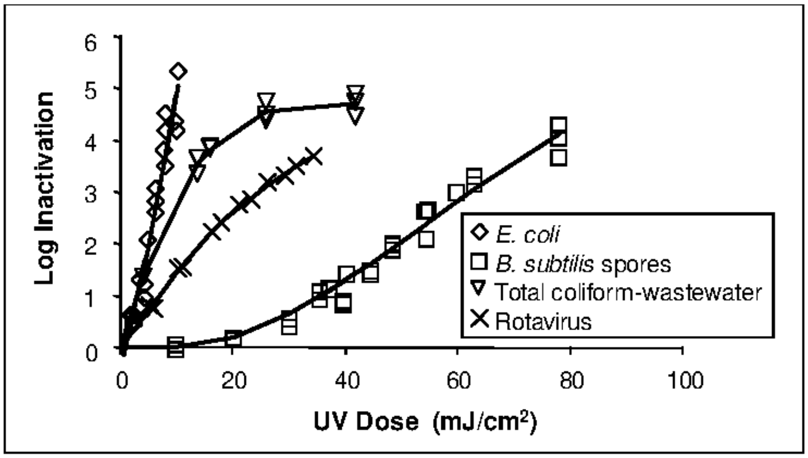
where

N_0 = Concentration of infectious microorganisms before exposure to UV light
N = Concentration of infectious microorganisms after exposure to UV light

UV dose-response relationships can be expressed as either the proportion of microorganisms *inactivated* or the proportion of microorganisms *remaining* as a function of UV dose. Microbial inactivation has a dose-response curve with a positive slope, while microbial survival has a dose-response curve with a negative slope. This manual presents microbial response as log inactivation because the terminology is widely accepted in the industry. Therefore, all dose-response curves presented (log inactivation as a function of dose) have a positive slope with log inactivation on a logarithmic (base 10) scale and UV dose on a linear scale.

Figure 2.8 presents examples of UV dose-response curves. The shape of the UV dose-response curve typically has three regions. At low UV doses, the UV dose-response shows a shoulder region where little if any inactivation occurs (e.g., *Bacillus subtilis* curve, Figure 2.8). The shoulder region has been attributed to dark repair (Morton and Haynes 1969) and photorepair (Hoyer 1998). Above some threshold dose level, the dose-response shows first-order inactivation where inactivation increases linearly with increased dose. In many cases, the dose-response shows first-order inactivation without a shoulder (e.g., *E. coli* curve, Figure 2.8). At higher UV doses, the dose-response shows tailing, a region where the slope of the dose-response decreases with increased dose (e.g., rotavirus and total coliform curves, Figure 2.8). Tailing has been attributed to the presence of UV-resistant sub-populations of the microorganism and the presence of particulate-associated and clumped microorganisms (Parker and Darby 1995). The shape of the dose-response curve can affect validation results, and information on how to account for tailing and shoulders in validation testing is included in Section C.6.

Figure 2.8. Shapes of UV Dose-Response Curves



Source: Adapted from Chang et al. (1985)

Microbial response to UV light can vary significantly among microorganisms. The UV sensitivity of viruses and bacteriophage can vary by more than two orders of magnitude (Rauth 1965). With bacteria, spore-forming and gram-positive bacteria are more resistant to UV light than gram-negative bacteria (Jagger 1967). Among the pathogens of interest in drinking water, viruses are most resistant to UV disinfection followed by bacteria, *Cryptosporidium* oocysts, and *Giardia* cysts.

UV dose-response is generally independent of the following factors:

- **UV intensity:** In general, UV dose-response follows the Law of Reflectivity over an intensity range of 1 – 200 mW/cm^2, where the same level of inactivation is achieved with a given UV dose regardless of whether that dose was obtained with a high UV intensity and low exposure time or vice versa (Oliver and Cosgrove 1975, Rice and Ewell 2001). Non-reciprocity has been observed at low intensities where repair may compete with inactivation (Sommer et al. 1998, Setlow 1967).

- **UV absorbance:** UV absorbance of the suspension is considered when calculating UV dose. Increasing intensity or exposure time, however, may be necessary to achieve a constant UV dose as the absorbance of a suspension changes.

- **Temperature:** Temperature effects on dose-response are minimal and depend on the microorganism. For male-specific-2 (MS2) bacteriophage, inactivation is not temperature-dependent (Malley 2000). Severin et al. (1983) studied three microorganisms to determine the dose required to achieve 2-log inactivation as a function of temperature. For *E. coli* and *Candia parapsilosis*, the dose requires decreases by less than 10 percent as the temperature increases from 5 to 35 °C, and for f2 bacteriophage, the dose requires decreases by less than 20 percent over the same temperature interval (Severin et al. 1983).

- **pH:** Dose-response is independent of the suspension pH from pH 6 to pH 9 (Malley 2000).

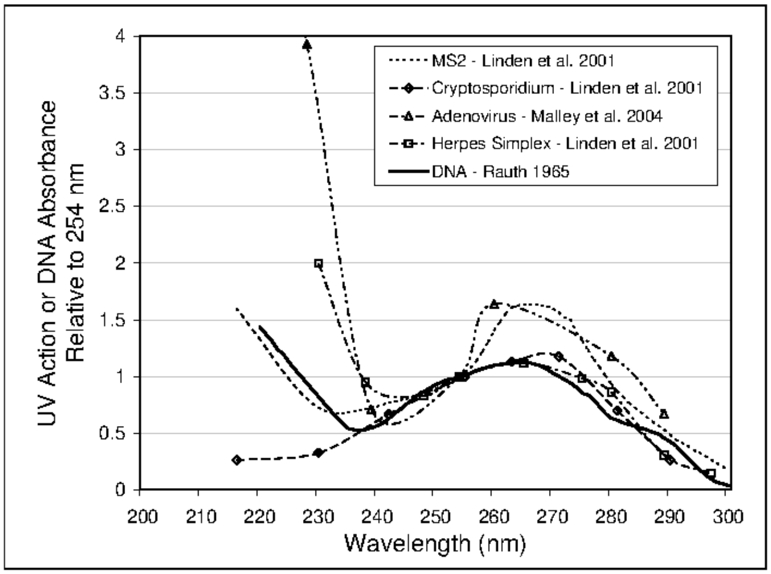
Particle association and clumping of microorganisms affects UV dose-response. Small floc particles can enmesh and protect MS2 bacteriophage, and potentially other viruses, from exposure to UV light (Templeton et al. 2003). Similarly, the inactivation rate of particle-associated coliforms is slower than that of non-particle-associated coliforms (Örmeci and Linden 2003). The shielding effect of clumping or particle association can cause a tailing or flattening of the dose-response curve at higher inactivation levels (Figure 2.8, total coliform curve).

Several studies have examined the effect of particles on UV disinfection performance. Research by Linden et al. (2002b) indicated that the UV dose-response of microorganisms added to filtered drinking waters is not altered by variation in turbidity that meets regulatory requirements for filtered effluents. For unfiltered waters, source water turbidity up to 10 nephelometric turbidity units (NTU) did not affect the UV dose-response of separately added (seeded) microorganisms (Passantino et al. 2004, Oppenheimer et al. 2002). The effect of particle enmeshment on the UV dose-response of seeded microorganisms in water has been studied by adding clays or natural particles. When coagulating suspensions containing kaolinite or montmorillonite clay using alum or ferric chloride, no difference was observed in the log inactivation of the seeded microorganisms (Templeton et al. 2004, Mamane-Gravetz and Linden 2004). When humic acid particles and a coagulant were added to the suspensions, however, significantly less inactivation was achieved (Templeton et al. 2004). Further research is needed to understand fully the effect of coagulation and particles on microbial inactivation by UV light.

2.3.5 Microbial Spectral Response

Microbial response varies as a function of wavelength of the UV light. The action spectrum (also called UV action) of a microorganism is a measure of inactivation effectiveness as a function of wavelength. Figure 2.9 illustrates the UV action spectrum for three microbial species and the UV absorbance of DNA as a function of wavelength. Because of the similarity between the UV action and DNA absorbance spectra and because DNA absorbance is easier to measure than UV action, the DNA absorbance spectrum of a microorganism is often used as a surrogate for its UV action spectrum. In Figure 2.9, the scale of the y-axis represents the ratio of inactivation effectiveness at a given wavelength to the inactivation effectiveness at 254 nm.

Figure 2.9. Comparison of Microbial UV Action and DNA UV Absorbance



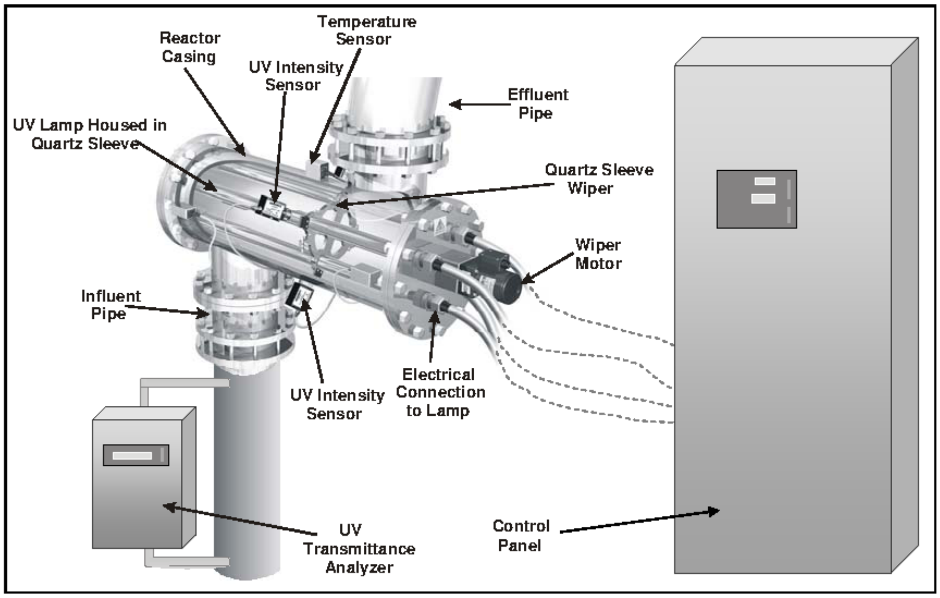
Source: Adapted from Rauth (1965), Linden et al. (2001), and Malley et al. (2004)

For most microorganisms, the UV action peaks at or near 260 nm, has a local minimum near 230 nm, and drops to zero near 300 nm, which means that UV light at 260 nm is the most effective at inactivating microorganisms. Because no efficient way to produce UV light at 260 nm is available and mercury produces UV light very efficiently at 254 nm, however, the latter has become the standard. Although the action spectrum of various microorganisms is similar at wavelengths above 240 nm, significant differences occur at wavelengths below 240 nm (Rauth 1965).

2.4 UV Disinfection Equipment

The goal in designing UV reactors for drinking water disinfection is to efficiently deliver the dose necessary to inactivate pathogenic microorganisms. An example of UV equipment is shown in Figure 2.10. Commercial UV reactors consist of open or closed-channel vessels, containing UV lamps, lamp sleeves, UV sensors, and temperature sensors. UV lamps typically are housed within the lamp sleeves, which protect and insulate the lamps. Some reactors include automatic cleaning mechanisms to keep the lamp sleeves free of deposits. UV sensors, flow meters, and, in some cases, UVT analyzers, are used to monitor dose delivery by the reactor. This section briefly describes the components of the UV equipment and its monitoring systems.

Figure 2.10. Example of UV Disinfection Equipment

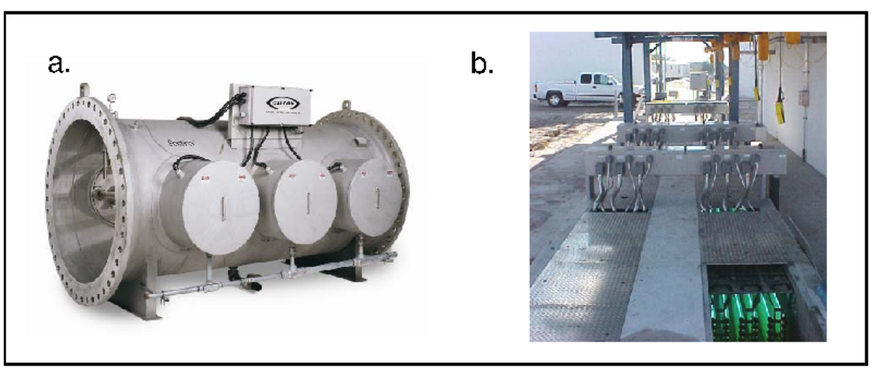


Source: Courtesy of and adapted from Severn Trent Services
Note: Not to scale

2.4.1 UV Reactor Configuration

UV reactors are typically classified as either closed or open channel. Water flows under pressure (i.e., no free surface) in closed-channel reactors (Figure 2.11a). Drinking water UV applications have used only closed reactors to date. Open-channel reactors (Figure 2.11b) are open basins with channels containing racks of UV lamps and are most commonly used in wastewater applications.

Figure 2.11. Examples of UV Reactors: (a) Closed-channel and (b) Open-channel



Source: (a) Courtesy of Calgon Carbon Corporation and (b) Courtesy of WEDECO UV Systems

UV equipment manufacturers design their UV reactors to provide efficient and cost-effective dose delivery. Lamp placement, baffles, and inlet and outlet conditions all affect mixing within a reactor and dose delivery. Individual reactor designs use various methods to optimize dose delivery (e.g., higher lamp output versus lower lamp output and improved hydrodynamics through increased head loss).

The lamp configuration in a reactor is designed to optimize dose delivery. In a reactor with a square cross-section, lamps are typically placed with lamp arrays perpendicular to flow. This pattern may be staggered to improve disinfection efficiency. With a circular cross-section, lamps typically are evenly spaced on one or more concentric circles parallel to flow. However, UV lamps may be oriented parallel, perpendicular, or diagonal to the flow direction. Depending on the reactor installation, lamps may consequently be oriented horizontally, vertically, or diagonally relative to the ground surface. Orienting MP lamps parallel to the ground prevents overheating at the top of the lamps and reduces the potential for lamp breakage due to temperature differentials.

The thickness of the water layer between lamps and between the lamps and the reactor wall influences dose delivery. If the water layer is too thin, the reactor wall and adjacent lamps will absorb UV light. If the water layer is too thick, water will pass through regions of lower UV intensity and experience a lower UV dose. The optimal spacing between lamps depends on the UVT of the water, the output of the lamp, and the hydraulic mixing within the reactor.

The flow through UV reactors is turbulent. Residence times are on the order of tenths of a second for MP lamps and seconds for LP lamps. In theory, optimal dose delivery is obtained with plug flow hydraulics through a UV reactor. In practice, however, UV reactors do not have such ideal hydrodynamics. For example, turbulence and eddies form in the wake behind lamp sleeves oriented perpendicularly to flow. Some manufacturers insert baffles to improve hydrodynamics in the reactor. Improvements to the hydraulic behavior of a reactor are often obtained at the expense of head loss.

Inlet and outlet conditions can significantly affect reactor hydrodynamics and UV dose delivery. For example, changes in flow direction of 90 degrees at inlets and outlets promote short-circuiting, eddies, and dead zones within the reactor. Straight inlet configurations with gradual changes in cross-sectional area will help create flow conditions for optimal dose delivery.

2.4.2 UV Lamps

UV light can be produced by the following variety of lamps:

- LP mercury vapor lamps
- Low-pressure high-output (LPHO) mercury vapor lamps
- MP mercury vapor lamps
- Electrode-less mercury vapor lamps
- Metal halide lamps

- Xenon lamps (pulsed UV)
- Eximer lamps
- UV lasers
- Light emitting diodes (LEDs)

Full-scale drinking water applications generally use LP, LPHO, or MP mercury vapor lamps. Therefore, this manual limits discussion to these UV lamp technologies. Table 2.1 lists characteristics of these lamps, and Table 2.2 lists operational advantages of the lamp types.

Table 2.1. Typical Mercury Vapor Lamp Characteristics

Parameter	Low-pressure	Low-pressure High-output	Medium-pressure
Germicidal UV Light	Monochromatic at 254 nm	Monochromatic at 254 nm	Polychromatic, including germicidal range (200 – 300 nm)
Mercury Vapor Pressure (Pa)	Approximately 0.93 (1.35×10^{-4} psi)	0.18 – 1.6 (2.6×10^{-5} – 2.3×10^{-4} psi)	40,000 – 4,000,000 (5.80 – 580 psi)
Operating Temperature (°C)	Approximately 40	60 – 100	600 – 900
Electrical Input [watts per centimeter (W/cm)]	0.5	1.5 – 10	50 – 250
Germicidal UV Output (W/cm)	0.2	0.5 – 3.5	5 – 30
Electrical to Germicidal UV Conversion Efficiency (%)	35 – 38	30 – 35	10 – 20
Arc Length (cm)	10 – 150	10 – 150	5 – 120
Relative Number of Lamps Needed for a Given Dose	High	Intermediate	Low
Lifetime [hour (hr)]	8,000 – 10,000	8,000 – 12,000	4,000 – 8,000

Note: Information in this table was compiled from UV manufacturer data.

Table 2.2. Mercury Vapor Lamp Operational Advantages

Low-pressure and Low-pressure High-output	Medium-pressure
• Higher germicidal efficiency; nearly all output at 254 nm • Smaller power draw per lamp (less reduction in dose if lamp fails) • Longer lamp life	• Higher power output • Fewer lamps for a given application

LP, LPHO, and MP lamps consist of the following elements, arranged as shown in Figure 2.12:

- **Lamp Envelope:** The envelope of the lamp is designed to transmit germicidal UV light, act as an electrical insulator, and not react with the lamp's fill gases. A non-crystalline form of quartz, vitreous silica, is often used for the lamp envelope because of its high UVT and its resistance to high temperatures. The UVT of the envelope affects the spectral output of lamps, especially with MP lamps at lower wavelengths. Because of this, lamp envelopes can be made from doped quartz (quartz that is altered to absorb specific wavelengths) to prevent undesirable non-germicidal photochemical reactions. Envelopes are approximately 1 – 2 millimeters (mm) thick, and the diameter is selected to optimize the UV output and lamp life.

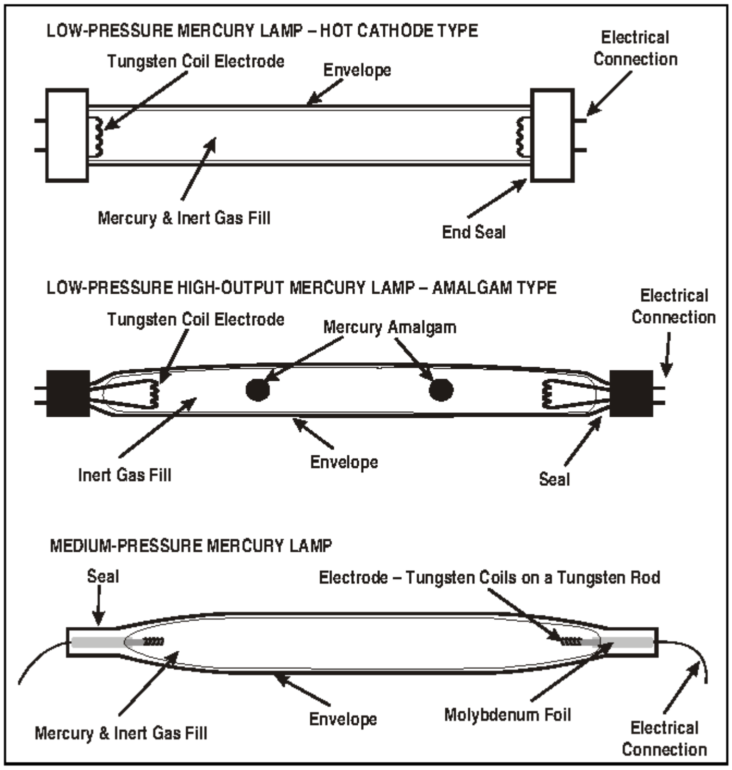
- **Electrodes:** Electrode design and operation are critical for reliable long-term operation of lamps. Electrodes promote heat transfer so that lamps can operate at an appropriate temperature. The electrodes in LP and LPHO lamps are made of a coil of tungsten wire embedded with oxides of calcium, barium, or strontium. In MP lamps, electrodes consist of a tungsten rod wrapped in a coil of tungsten wire.

- **Mercury Fill:** The mercury fill present in UV lamps can be in the solid, liquid, or vapor phase. Amalgams (alloys of mercury and other metals such as indium or gallium in the solid phase) are typically used in LPHO lamps, while LP and MP lamps contain liquid elemental mercury. As the lamps heat, the vapor pressure of mercury increases. LP and LPHO lamps operate at lower temperatures and have lower mercury vapor pressures than MP lamps. In MP lamps, the concentration of mercury in the vapor phase is controlled by the amount of mercury in the lamp. In LPHO lamps, an excess of mercury is placed in the lamp, and the amount of mercury entering the vapor phase is limited by either a mercury amalgam attached to the lamp envelope, a cold spot on the lamp wall, or a mercury condensation chamber located behind each electrode.

- **Inert Gas Fill:** In addition to mercury, lamps are filled with an inert gas (typically argon). The inert gas aids in starting the gas discharge and reduces deterioration of the electrode. The vapor pressure of the inert gas is typically 0.02 – 1 psi.

In addition to amalgam LPHO lamps, another method is used to increase the output from LP lamps. In this application, a standard LP lamp with reinforced filaments is used, allowing for an increase in current through the lamp. The higher current increases the output from the lamp.

Figure 2.12. Construction of a UV Lamp



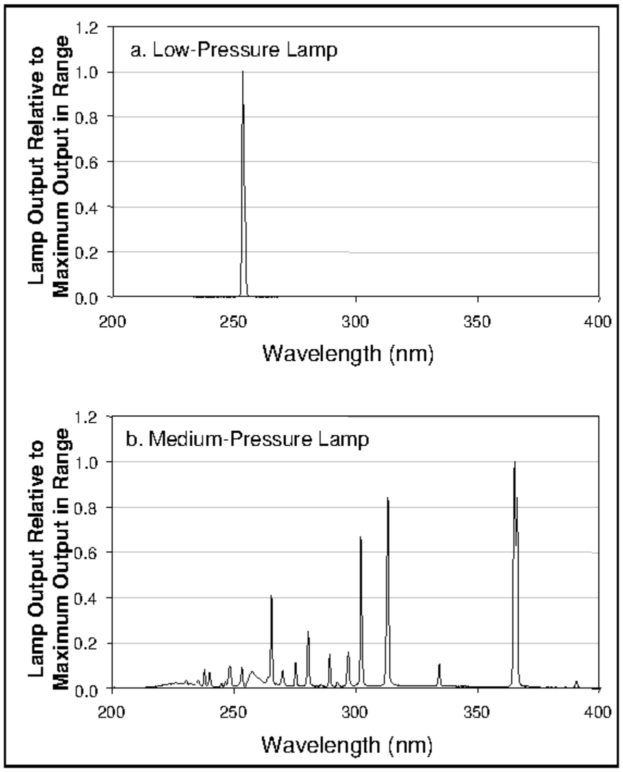
2.4.2.1 Lamp Start-up

As lamps start up, the following series of events occurs to generate an arc (i.e., produce UV light). First, the electrode emits electrons that collide with the inert gas atoms, causing the inert gas to ionize. This creates a plasma that allows current to flow, which heats the gas. The mercury in operating lamps vaporizes in the presence of the hot inert gas, and collisions between the vapor-phase mercury and high-energy electrons in the plasma cause the mercury atoms to reach one of many excited states. As the mercury returns from a given excited state to ground state, energy is released (according to the difference in the state energies) in the wavelength range of the UV spectrum.

2.4.2.2 Lamp Output

The light that LP and LPHO lamps emit is essentially monochromatic at 253.7 nm (Figure 2.13a) in the ultraviolet range and is near the maximum of the microbial action spectrum. These lamps also emit small amounts of light at 185, 313, 365, 405, 436, and 546 nm due to higher energy electron transition in the mercury. Lamp output at 185 nm promotes ozone formation. Because ozone is corrosive, toxic, and absorbs UV light, LP and LPHO lamps used in water disinfection applications are manufactured to reduce the output at 185 nm.

Figure 2.13. UV Output of LP (a) and MP (b) Mercury Vapor Lamps



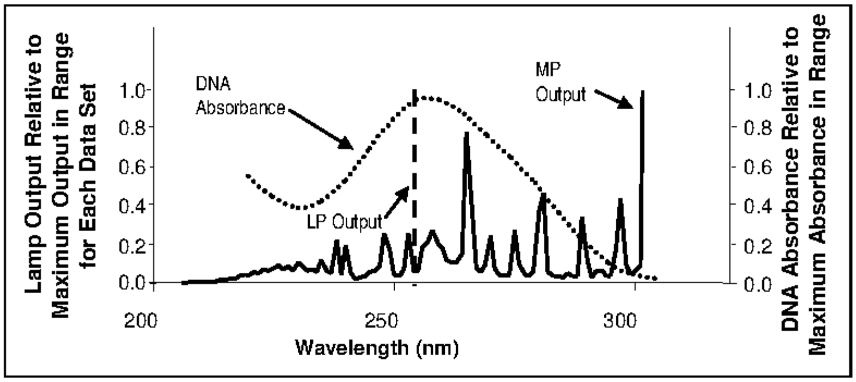
Source: Sharpless and Linden (2001)

MP lamps emit a wide range of UV wavelengths from 200 to 400 nm (Figure 2.13b). The combination of free electrons and mercury in the lamp creates a broad continuum of UV energy below 245 nm. Electron transitions in the mercury cause the peaks in the spectrum.

All UV lamps also emit light in the visible range. Visible light can promote algal growth as discussed in Section 2.5.1.5.

Figure 2.14 shows the output of LP and MP lamps superimposed on the DNA absorption spectrum. In Figure 2.14, the DNA absorbance is plotted relative to the maximum absorbance in the range (260 nm), and the lamp outputs are presented on a relative scale. In absolute terms, however, the intensity and power of LP and MP lamps differ significantly (see Table 2.1 for more information on lamp operating characteristics).

Figure 2.14. UV Lamp Output and its Relationship to the UV Absorbance of DNA



Source: Courtesy of Bolton Photosciences, Inc.

2.4.2.3 Lamp Sensitivity to Power Quality

A UV lamp can lose its arc if a voltage fluctuation, power quality anomaly, or power interruption occurs. For example, voltage sags that vary more than 10 – 30 percent from the nominal voltage for as few as 0.5 – 3 cycles (0.01 – 0.05 seconds) may cause a UV lamp to lose its arc.

The most common sources of power quality problems that may cause UV lamps to lose their arcs are as follows:

- Faulty wiring and grounding
- Off-site accidents (e.g., transformer damaged by a car accident)
- Weather-related damage
- Animal-related damage
- Facility and equipment modifications
- Starting or stopping equipment with large electrical needs on the same circuit at the water plant
- Power transfer to emergency generator or alternate feeders

LP lamps generally can return to full operating status within 15 seconds after power is restored. LPHO and MP reactors that are more typically used in drinking water applications, however, exhibit significant restart times if power is interrupted. The start-up time for lamps should be considered in the design of UV disinfection systems as start-up time can contribute to off-specification operations (see Section 3.4.1). The start-up and restart behaviors for LPHO and MP lamps are summarized in Table 2.3.

Table 2.3. Typical Start-up and Restart Times for LPHO and MP Lamps [1]

Lamp Type	Cold Start[2]	Warm Start[3]
LPHO	total time: 4 – 7 minutes (min) (0 – 2 min warm-up plus 4 – 5 min to full power)	total time: 2 – 7 min (0 – 2 min warm-up plus 2 – 5 min to full power)
MP	total time: 1 – 5 min (No warm-up or cool down plus 1 – 5 min to full power[4])	total time: 4 – 10 min (2 – 5 min cool down plus 2 – 5 min to full power[4])

[1] Information shown in table is compiled from Calgon Carbon Corporation, Severn Trent, Trojan, and WEDECO. Contact the manufacturer to determine the start-up and restart times for specific equipment models.
[2] A cold start occurs when UV lamps have not been operating for a significant period of time.
[3] A warm start occurs when UV lamps have just lost their arcs (e.g., due to voltage sag).
[4] 60 percent intensity is reached after 3 min.
Source: Cotton et al. (2005)

The effects of temperature can increase or decrease the times listed in Table 2.3 and should be discussed with the UV manufacturer. Individual manufacturers report that colder water temperatures (below 10 °C) can result in slower start-ups for LPHO lamps than those listed in Table 2.3. Conversely, MP manufacturers report shorter restart times with colder temperatures because the cold water accelerates the condensation of mercury (i.e., cool down), which is necessary for re-striking the arc.

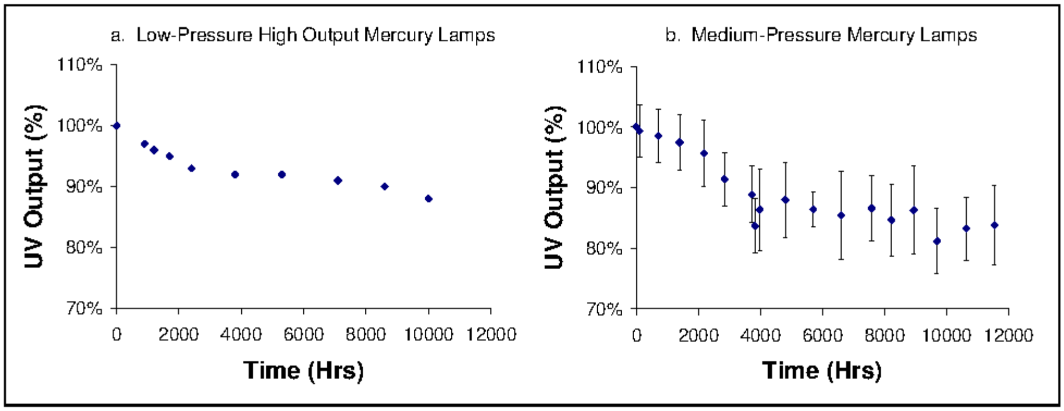
2.4.2.4 Lamp Aging

UV lamps degrade as they age, resulting in a reduction in output that causes a drop in UV dose delivery over time. Lamp aging can be accounted for with the fouling/aging factor (described in Section 3.4.5) in the design of the UV facility.

Lamp degradation occurs with both LP and MP lamps and is a function of the number of lamp hours in operation, number of on/off cycles, power applied per unit (lamp) length, water temperature, and heat transfer from lamps. The rate of decrease in lamp output often slows as the lamp ages (Figure 2.15). The reduction in output occurs at all wavelengths across the germicidal range as shown in Figure 2.16, which is an example of MP lamp output reduction after 8,220 hours of operation.

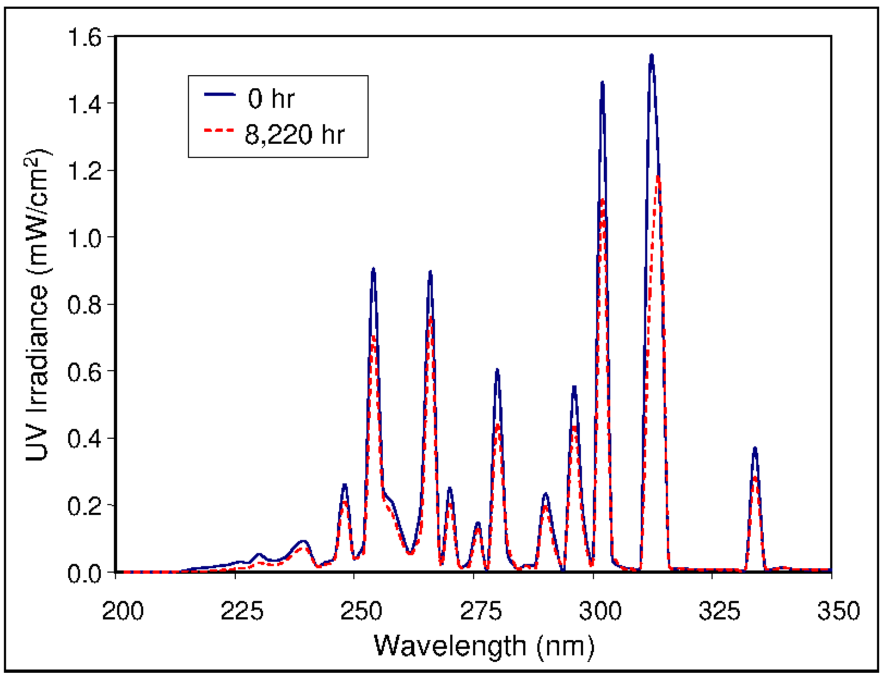
Preliminary findings from ongoing research into lamp aging at water and wastewater UV facilities shows that LPHO and MP lamp aging is non-uniform with respect to axial and horizontal output and varies greatly from lamp to lamp (Mackey et al. 2005). The lamp aging study by Mackey et al. is still ongoing, and any future findings from this or other studies should be evaluated and considered once results are available.

Figure 2.15. Reduction in UV Output of (a) LPHO and (b) MP Lamps Over Time



Source: (a) Adapted from WEDECO, (b) adapted from Linden et al. (2004)

Figure 2.16. Lamp Aging for an MP Lamp



Source: Adapted from Linden et al. (2004)

Any deposits on the inner or outer surfaces of the lamp envelope and metallic impurities within the envelope can absorb UV light and cause premature lamp aging. In LP and LPHO lamps using UV-transmitting glass, mercury may combine with sodium in the glass to create a UV-absorbing coating. Electrode sputtering during start-up can also coat the inside surface of the lamp envelope with tungsten as the lamp ages. The tungsten coating is black, non-uniform, concentrated within a few inches of the electrode, and can absorb UV light (Figure 2.17). If the lamps are not sufficiently cooled during operation, electrode material in MP lamps may evaporate and condense on the inside of the envelope.

Figure 2.17. Aged UV Lamp (right) Compared to a New UV Lamp (left)

Source: Mackey et al. (2004)

UV lamp manufacturers can reduce electrode sputtering by designing lamps that pre-heat the electrode before applying the start voltage, are driven by a sinusoidal current waveform, or have a higher argon (inert gas) content. Electrode sputtering can be reduced by minimizing the number of lamp starts during operation.

2.4.3 Ballasts

Ballasts are used to regulate the incoming power supply at the level needed to energize and operate the UV lamps. Power supplies and ballasts are available in many different configurations and are tailored to a unique lamp type and application. UV reactors typically use magnetic ballasts or electronic ballasts.

Electronic and magnetic ballasts each have specific advantages and disadvantages. UV reactor manufacturers consider these advantages and disadvantages when determining what technology to incorporate into their equipment designs. Electronic and inductor-based magnetic ballasts can provide almost continuous adjustment of lamp intensity. Most transformer-based magnetic ballasts, however, allow only step adjustment of lamp intensity. Transformer-based magnetic ballasts are typically more electrically efficient than inductor-based ballasts but are less efficient than electronic ballasts. However, higher efficiency and additional features can increase the electronic ballast cost. UV lamps that are powered by magnetic ballasts tend to have more lamp end-darkening (i.e., electrode sputtering) and have shorter lives compared to lamps powered by electronic ballasts due to the higher frequencies used by electronic ballasts. Electronic ballasts are generally more susceptible to power quality problems (Section 2.4.2.3) compared to magnetic ballasts; however, the power quality tolerances of both ballast types depend on the electrical design. A comparison of magnetic and electronic ballast technologies is shown in Table 2.4.

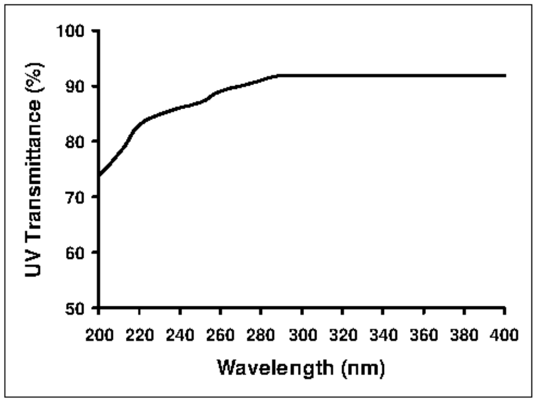
Table 2.4. Comparison of Magnetic and Electronic Ballasts

Magnetic Ballast	Electronic Ballast
• Less expensive • Continuous power adjustment occurs with inductor-based magnetic ballast (but not with transformer-based magnetic ballast) • More resistant to power surges • Proven technology (in use for nearly 70 years) • Greater separation distance allowed between the UV reactor and control panel	• Continuous power adjustment and ability to adjust to lower power levels (e.g., 30 %) • More power efficient • Lighter weight and smaller size • Allows for longer lamp operating life and less lamp end-darkening

2.4.4 Lamp Sleeves

UV lamps are housed within lamp sleeves to help keep the lamp at optimal operating temperature and to protect the lamp from breaking. Lamp sleeves are tubes of quartz (vitreous silica) that are open at one or both ends. The sleeve length is sufficient to include the lamp and associated electrical connections. The sleeve diameter is typically 2.5 – 5.0 cm for LP and LPHO lamps and 3.5 – 10.0 cm for MP lamps. The distance between the exterior of the lamp and interior of the lamp sleeve is approximately 1 cm. The positioning of the UV lamp along the length of the sleeve can vary, depending on reactor configuration. Lamp sleeves absorb some UV light (Figure 2.18), which may influence dose delivery by the reactor.

Figure 2.18. UVT of Quartz that is 1 mm Thick at a Zero-degree Incidence Angle



Source: GE Quartz (2004a)

The lamp sleeve assemblies are sealed to prevent water condensation within the sleeve and contain any ozone formed between the lamp envelope and lamp sleeve. Components within the sleeve should withstand exposure to UV light, ozone, and high temperatures. If the components are not made of the appropriate material, UV light exposure can cause component deterioration and off-gassing of any impurities present in the quartz sleeve. Off-gassed materials can form UV-absorbing deposits on the inner surfaces of the lamp sleeve. Off-gassing and ozone formation are of greater concern with MP lamps because they operate at a higher temperature and emit low-wavelength ozone-forming UV light. Off-gassing can be minimized through proper manufacturing of the lamp sleeves.

Lamp sleeves are vulnerable to fractures. Fractures can occur from internal stress and external mechanical forces such as wiper jams, water hammer, resonant vibration, and impact by objects. Fractures may also occur if lamp sleeves are not handled properly when removed for manual cleaning. Most lamp sleeves are designed to withstand continuous positive pressures of at least 120 pounds per square inch gauge (psig) (Roberts 2000, Aquafine 2001, Dinkloh 2001). However, pressures of negative 1.5 psig have been shown to adversely affect sleeve integrity (Dinkloh 2001). Section 4.1.4 discusses design considerations to reduce the potential for pressure-related incidents. If a lamp sleeve fractures while in service, water can enter the sleeve. The temperature difference between the hot lamp and cooler water may cause the lamp to break. Lamp breaks are undesirable due to the potential for mercury release. Appendix E discusses the lamp sleeve and lamp breaks. The tolerance level of the sleeve depends on the quality of the quartz and the sleeve's thickness and length.

Lamp sleeves can also foul, decreasing the UVT of the lamp sleeve. Fouling on the internal lamp sleeve surface arises from the deposition of material from components within the lamp or sleeve due to temperature and exposure to UV light. The UV reactor manufacturer can control internal lamp sleeve fouling through appropriate material selection. For example, some UV reactors using LP or LPHO lamps have sleeves made of Teflon® or Teflon-coated quartz. Teflon sleeves have a lower UVT, however, and their transmittance reduces faster than quartz sleeves without Teflon. Deposition of compounds in the water on the lamp sleeve surface cause fouling on external surfaces. A combination of thermal effects and photochemical processes causes the external fouling (Derrick and Blatchley 2005). Some compounds that may contribute to fouling are discussed in Section 2.5.1. External fouling can be removed by cleaning.

Solarization can also decrease the UVT of the sleeve. Solarization is photo-thermal damage to the quartz that increases light scattering and attenuation (Polymicro Technologies 2004). Quartz solarizes if exposed to prolonged high energy radiation such as UV light. Resistance to this type of solarization increases as the purity of the quartz increases. Solarization on quartz can be reversed by heating the quartz to about 500 °C (GE Quartz 2004b).

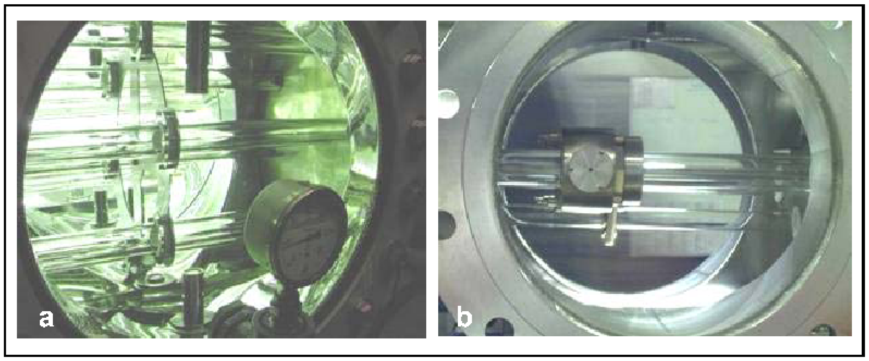
2.4.5 Cleaning Systems

UV reactor manufacturers have developed different approaches for cleaning lamp sleeves, depending on the application. These approaches include off-line chemical cleaning (OCC), on-line mechanical cleaning (OMC), and on-line mechanical-chemical cleaning (OMCC) methods.

For OCC systems, the reactor is shut down, drained, and flushed with a cleaning solution. Solutions used to clean lamp sleeves include citric acid, phosphoric acid, or a solution the UV reactor manufacturer provides that is consistent with National Sanitation Foundation International/American National Standards Institute (NSF/ANSI) 60 Standard (Drinking Water Treatment Chemicals – Health Effects). The reactor is filled with the cleaning solution for a time sufficient to dissolve the substances fouling the sleeves (approximately 15 minutes), rinsed, and returned to operation. The entire cleaning cycle typically lasts approximately 3 hours. Alternatively, instead of rinsing the UV reactor with a cleaning solution, the sleeves can be removed and manually cleaned. Some LPHO UV equipment uses OCC systems. The frequency of OCC can range from monthly to yearly and depends on the site-specific water quality and degree and frequency of fouling.

OMC and OMCC systems use wipers that are attached to electric motors or pneumatic piston drives. In OMC systems, mechanical wipers may consist of stainless steel brush collars or Teflon rings that move along the lamp sleeve (Figure 2.19a). In OMCC systems, a collar filled with cleaning solution moves along the lamp sleeve (Figure 2.19b). The wiper physically removes fouling on the lamp sleeve surface while the cleaning solution within the collar dissolves fouling materials.

Figure 2.19. Examples of (a) Mechanical Wiper System and (b) Mechanical-chemical Wiper System



Source: (a) Courtesy of Infilco Degremont, (b) Courtesy of Trojan Technologies

Draining the reactor is unnecessary when mechanical and mechanical-chemical wipers are used. Therefore, the reactor can remain on-line while the lamp sleeves are cleaned. MP equipment typically uses OMC or OMCC systems because the higher lamp temperatures can accelerate fouling under certain water qualities. The cleaning frequency for these OMC and OMCC systems ranges from 1 – 12 cycles per hour (Mackey et al. 2004).

2.4.6 UV Sensors

UV sensors measure the UV intensity at a point within the UV reactor (Figure 2.20) and are used with measurements of flow rate and, potentially, UVT to indicate UV dose delivery. The measurement responds to changes in lamp output due to lamp power setting, lamp aging, lamp sleeve aging, and lamp sleeve fouling. Depending on sensor position, UV sensors may also respond to changes in UVT of the water being treated. UV sensors comprise optical components, a photodetector, an amplifier, its housing, and an electrical connector. The optical components may include monitoring windows, light pipes, diffusers, apertures, and filters. Monitoring windows and light pipes deliver light to the photodetector. Diffusers and apertures reduce the amount of UV light reaching the photodetector, thereby reducing the sensor degradation that UV light causes. Optical filters modify the spectral response such that the sensor responds only to germicidal wavelengths (i.e., 200 – 300 nm). Verification of sensor performance is described in Chapter 5.

Figure 2.20. Example of a Dry UV Sensor Mounted on a UV Reactor

Source: Courtesy of WEDECO

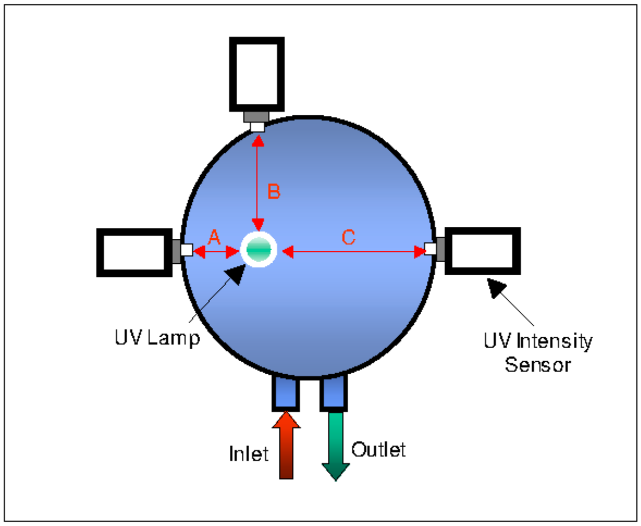
UV sensors can be classified as dry or wet. Dry sensors monitor UV light through a monitoring window, whereas wet UV sensors directly contact the water flowing through the reactor. Monitoring windows and the wetted ends of wet sensors can foul over time and may require cleaning similar to lamp sleeves.

2.4.7 UVT Analyzers

As stated previously, UVT is an important parameter in determining UV dose delivery. UVT analyzers are essential if UVT is part of the dose-monitoring strategy (see Section 2.4.9 for a discussion of dose monitoring approaches). If UVT is not part of the dose-monitoring strategy, analyzers may be provided for the purpose of monitoring water quality and helping to diagnose operational problems. Several commercial UV reactors use the measurement of UVT to calculate UV dose in the reactor and, if necessary, change lamp output or the number of energized lamps to maintain appropriate UV dose delivery.

Two types of commercial on-line UVT analyzers are available. One analyzer calculates UVT by measuring the UV intensity at various distances from a lamp. This type of analyzer is schematically displayed in Figure 2.21. In this analyzer, which is external to the UV reactor, a stream of water passes through a cavity containing an LP lamp with three UV sensors located at various distances from the lamp. The difference in sensor readings is used to calculate UVT.

Figure 2.21. Example UVT Analyzer Design



Source: Courtesy of Severn Trent Services

The other type of on-line UVT analyzer is a flow-through spectrophotometer that uses a monochromatic UV light source at 253.7 nm. The instrument measures the A_{254} and calculates and displays UVT.

2.4.8 Temperature Sensors

The energy input to UV reactors that is not converted to light (approximately 60 – 90 percent, depending on lamp and ballast assembly) is wasted as heat. As it passes through a reactor, water can absorb the heat, keeping the reactor from overheating. Nevertheless, temperatures can increase when either of the following events occurs:

- Water level in the reactor drops and lamps are exposed to air.
- Water stops flowing in the reactor.

UV reactors can be equipped with temperature sensors that monitor the water temperature within the reactor. If the temperature is above the recommended operating range, the reactor will shut off to minimize the potential for the lamps to overheat. Because of the high operating temperature of MP lamps, dissipating heat can be more difficult than in reactors that use LP or LPHO lamps. As such, UV reactors with MP lamps typically have temperature sensors; however, reactors with LP or LPHO lamps may not because of the lower lamp operating temperature.

2.4.9 UV Reactor Dose-Monitoring Strategy

The dose-monitoring strategy establishes the operating parameters used to confirm UV dose delivery. This guidance manual focuses on UV reactors that use one of these two strategies, described below. Other existing dose-monitoring strategies or new strategies developed after this manual is published, however, may also be suitable for reactor operations provided they meet minimum regulatory requirements.[6]

1. **UV Intensity Setpoint Approach.** This approach relies on one or more "setpoints" for UV intensity that are established during validation testing to determine UV dose. During operations, the UV intensity as measured by the UV sensors must meet or exceed the setpoint(s) to ensure delivery of the required dose. Reactors must also be operated within validated operation conditions for flow rates and lamp status [40 CFR 141.720(d)(2)]. In the UV Intensity Setpoint Approach, UVT does not need to be monitored separately. Instead, the intensity readings by the sensors account for changes in UVT. The operating strategy can be with either a single setpoint (one UV intensity setpoint is used for all validated flow rates) or a variable setpoint (the UV intensity setpoint is determined using a lookup table or equation for a range of flow rates).

2. **Calculated Dose Approach.** This approach uses a dose monitoring equation to estimate the UV dose based on the flow rate, UV intensity, and UVT, as measured during reactor operations. The dose monitoring equation may be developed by the UV manufacturers using numerical methods; however, EPA recommends that water systems use an empirical dose monitoring equation developed through validation testing. During reactor operations, the UV reactor control system inputs the measured parameters into the dose monitoring equation to produce a calculated dose. The water system operator divides the calculated dose by the Validation Factor (see Chapter 5 for more details on the Validation Factor) and compares the resulting value to the required dose for the target pathogen and log inactivation level.

The dose-monitoring strategies are described in more detail in Section 3.5.2. Any dose monitoring strategy must be evaluated during reactor validation (as described in Section 5.1), and the outputs measured during validation will be part of the monitoring requirements described in Section 6.4.1 [40 CFR 141.720(d)].

2.5 Water Quality Effects and Byproduct Formation

Constituents in the water to be treated can affect the performance of UV disinfection. Additionally, all disinfectants can form byproducts, and the goal of the overall disinfection process is to maximize disinfection while controlling byproduct formation. This section

[6] At a minimum, water systems must monitor flow rate, lamp status, and UV intensity plus any other parameters required by the State to show that a reactor is operating within validated conditions [40 CFR 141.720(d)(3)(i)].

discusses water quality characteristics affecting UV disinfection performance and the byproducts that may form during the UV disinfection process.

2.5.1 Effect of Water Quality on UV Reactor Performance

UVT, particle content, upstream water treatment processes, constituents that foul reactor components, and algae affect the performance of UV reactors. These effects can be adequately addressed through proper design of the UV disinfection equipment. The design guidelines are discussed in Section 3.4.

2.5.1.1 UVT

UVT has a strong effect on the dose delivery of a UV reactor. As UVT decreases, the intensity throughout the reactor decreases, which reduces the dose the reactor delivers. UV reactors are typically sized to deliver the required UV dose under specified UVT conditions for the application. Section 3.4.4.1 discusses approaches for selecting the UVT for UV facility design.

UV absorbers in typical source waters include soluble and particulate forms of humic and fulvic acids; other aromatic organics (e.g., phenols); metals (e.g., iron); and anions (e.g., nitrates and sulfites) (Yip and Konasewich 1972, DeMers and Renner 1992). UV absorbance will vary over time due to changing concentrations of these compounds and seasonal effects—rainfall, lake stratification and destratification (turnover), and changes in biological activity of microorganisms within the water source.

2.5.1.2 Particle Content

As described in Section 2.3.4, particle content can also affect UV disinfection performance. Particles in source waters are diverse in composition and size and include large molecules, microorganisms, clay particles, algae, and flocs. Sources of particles include wastewater discharges, erosion, runoff, microbial growth, and animal waste. The particle concentration will vary over time both seasonally and over the short term. Storm events, lake turnover, and spring runoff are some events that increase the concentration of particles.

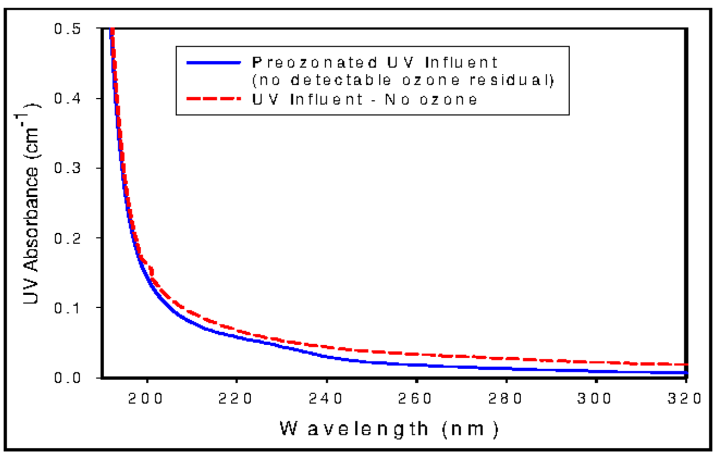
2.5.1.3 Upstream Water Treatment Processes

Unit processes and chemical addition upstream of UV reactors can significantly affect UV reactor performance because they can change the particle content and UVT of the water. Additionally, when UV disinfection is used in combination with another disinfectant, synergistic disinfection potentially may occur (i.e., the combination of disinfectants may be more effective than either disinfectant acting alone).

Water treatment processes upstream of the UV reactors can be operated to maximize UVT, thereby optimizing the design and costs of the UV reactor (Section 3.2.2). For example, coagulation, flocculation, and sedimentation remove soluble and particulate material, and filtration removes particles. Activated carbon absorption also reduces soluble organics.

Adding oxidants (such as chlorine and ozone) can increase the UVT (APHA et al. 1998) by degrading natural organic matter, reducing soluble material, and precipitating metals. An example of the effect ozone has on decreasing UV absorbance is shown in Figure 2.22. Ozone is also a strong absorber of UV light, however, and will decrease the UVT if an ozone residual is present in significant concentrations in the water passing through a UV reactor. Quenching agents that do not absorb UV light (such as sodium bisulfite) can be used to destroy the ozone residual upstream of the UV reactors. Thiosulfate is not recommended as a quenching agent because it absorbs UV light and can decrease the UVT.

Figure 2.22. Example Effect of Ozonation on UV Absorbance if Ozone is Quenched Prior to UV Disinfection



Source: Malley (2002)

In addition to ozone, other chemicals used in water treatment such as ferric iron and permanganate also absorb UV light and can decrease UVT. Table 2.5 lists the UV absorption coefficients at 254 nm of several common water treatment chemicals along with their "impact threshold concentration," which is the concentration that will decrease the UVT at 254 nm from 91 to 90 percent (Bolton et al. 2001). Note that these data are only for 254 nm, and the effect these chemicals have on UVT may be significantly different at other wavelengths generated by MP or other polychromatic lamps. The following chemicals were also evaluated in the same study (Bolton et al. 2001) and were found to have no significant absorbance: ammonia (NH_3), ammonium ion (NH_4^+), calcium ion (Ca^{2+}), hydroxide ion (OH^-), magnesium ion (Mg^{2+}), manganese ion (Mn^{2+}), phosphate species, and sulfate ion (SO_4^{2-}).

UV disinfection is often used in combination with other disinfectants, and the interaction of the disinfectants can affect the overall inactivation achieved. Research shows that applying ozone prior to UV disinfection is beneficial: the ozone increases the UVT, while the UV disinfection provides *Cryptosporidium* inactivation (Malley et al. 2003, Crozes et al. 2003).

Whether the effects of multiple disinfectants are synergistic (i.e., more inactivation observed when processes are used in combination than is expected from the sum of

Table 2.5. UV Absorbance Characteristics of Common Water Treatment Chemicals

Compound[1]	Molar Absorption Coefficient (M^{-1} cm^{-1})	Impact Threshold Concentration[2] (mg/L)
Ozone (O_3) (aqueous)	3,250	0.071
Ferric iron (Fe^{3+})	4,716	0.057
Permanganate (MnO_4^-)	657	0.91
Thiosulfate ($S_2O_3^{2-}$)	201	2.7
Hypochlorite (ClO^-)	29.5	8.4
Hydrogen peroxide (H_2O_2)	18.7	8.7
Ferrous iron (Fe^{2+})	28	9.6
Sulfite (SO_3^{2-})	16.5	23
Zinc (Zn^{2+})	1.7	187

[1] The following chemicals were also evaluated in the same study (Bolton et al. 2001) and were found to have no significant absorbance: ammonia (NH_3), ammonium ion (NH_4^+), calcium ion (Ca^{2+}), hydroxide ion (OH^-), magnesium ion (Mg^{2+}), manganese ion (Mn^{2+}), phosphate species, and sulfate ion (SO_4^{2-})

[2] Concentration in mg/L resulting in UVT decrease from 91 % to 90 % (A_{254} increase from 0.041 cm^{-1} to 0.046 cm^{-1})

Source: Adapted from Bolton et al. (2001)

the disinfectants acting alone) is currently under debate. Two studies reported synergistic effects when using UV disinfection and free chlorine, monochloramine, or chlorine dioxide (Ballester et al. 2003, Lotierzo et al. 2003), while others did not observe synergism (Coronell et al. 2003, Oppenheimer et al. 2003). The importance of the sequence of the disinfectants is also a subject of debate. Ballester et al. (2003) obtained improved disinfection with UV disinfection followed by monochloramine addition than with chloramination followed by UV disinfection, while the sequence of disinfectants did not affect the disinfection effectiveness in the study by Lotierzo et al. (2003).

2.5.1.4 Fouling Potential

Compounds in the water can foul the external surfaces of the lamp sleeves and other wetted components (e.g., monitoring windows of UV sensors) of UV reactors. Fouling on the lamp sleeves reduces the transmittance of UV light through the sleeve into the water, thereby reducing the output from the UV lamp into the water. Also, fouling on the monitoring windows affects measured UV intensity and dose monitoring. Sleeve fouling can be accounted for with the fouling/aging factor (described in Section 3.4.5) in the design of the UV facility.

Hardness (as $CaCO_3$), alkalinity, temperature, ion concentration, oxidation reduction potential (ORP), and pH all influence the rate of fouling and, subsequently, the necessary frequency of sleeve cleaning. Fouling can occur for the following reasons:

- Compounds for which the solubility decreases as temperature increases may precipitate [e.g., $CaCO_3$, $CaSO_4$, $MgCO_3$, $MgSO_4$, $FePO_4$, $FeCO_3$, $Al_2(SO_4)_3$]. These compounds will foul MP lamps faster than LP or LPHO lamps because MP lamps operate at higher temperatures.

- Photochemical reactions that are independent of sleeve temperature may cause sleeve fouling (Derrick 2005).

- Compounds with low solubility may precipitate [e.g., $Fe(OH)_3$, $Al(OH)_3$].

- Particles may deposit on the lamp sleeve surface due to gravity settling and turbulence-induced collisions (Lin et al. 1999a).

- Organic fouling can occur when a reactor is left off and full of water for an extended period of time (Toivanen 2000).

- Inorganic constituents can oxidize and precipitate (Wait et al. 2005).

Fouling rate kinetics has been reported as independent of time following a short induction period (Lin et al. 1999b). Depending on the water quality and UV lamp type, significant fouling may occur in hours or take up to several months.

Pilot studies lasting 5 – 12 months using UV reactors with LP, LPHO and MP lamps found that standard cleaning protocols and wiper frequencies (1 – 12 cleaning cycles per hour) were sufficient to overcome the effect of sleeve fouling with water that had total and calcium hardness levels less than 140 milligrams per liter (mg/L) and iron less than 0.1 mg/L (Mackey et al. 2001, Mackey et al. 2004).

Inorganic fouling is a complex process, however, and is not related only to hardness and iron concentrations. The solubility of inorganic constituents depends on whether they are in an oxidized or reduced state, which can be affected by both the ORP and pH of the water (Wait et al. 2005). ORP is a measurement of the water's ability to oxidize or reduce constituents in the water. Both pH and ORP are needed to predict the oxidation state of an inorganic constituent. Studies have found that fouling rates increase as ORP increases (Collins and Malley 2005, Wait et al. 2005, Derrick 2005). In some waters with high ORP, however, fouling rates can be minimized if the iron and manganese are removed through oxidation, precipitation, and filtration (Wait et al. 2005, Derrick 2005, Jeffcoat 2005). Although ORP can provide valuable information, measuring it can be challenging and may not be possible in all instances.

Ultimately, the fouling potential is difficult to predict, but standard cleaning equipment can remove fouling and may need to be included. Also, pilot-scale or demonstration-scale testing can determine the fouling tendencies and cleaning regime if the PWS is concerned about fouling.

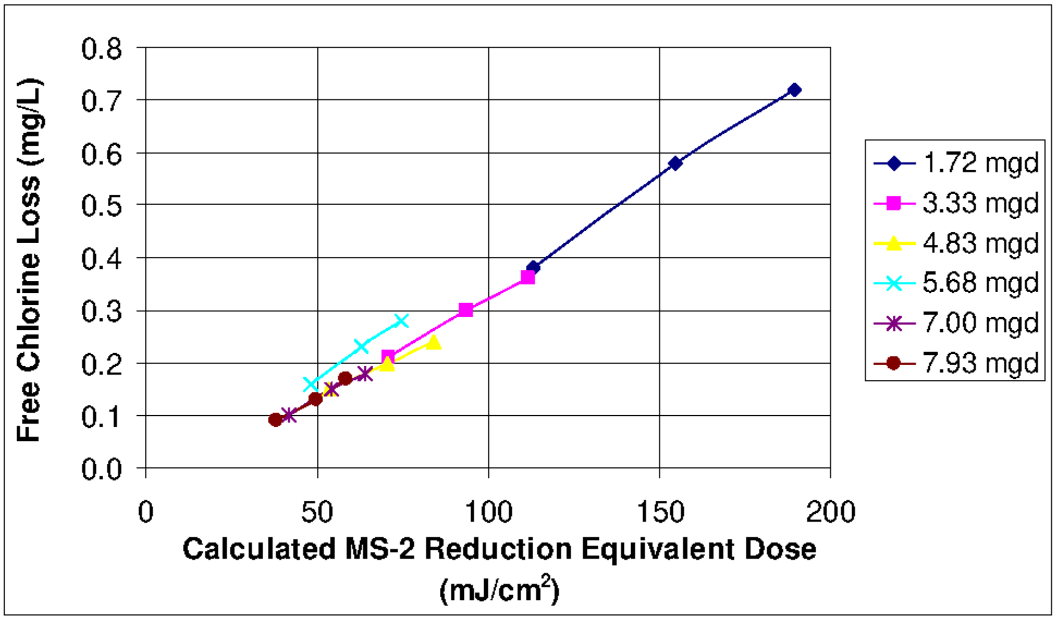
2.5.1.5 Algal Occurrence and Growth

The presence of algae in the water being treated may reduce UVT and interfere with the UV disinfection process. Algae also may grow upstream or downstream of UV reactors, which has been observed in MP pilot studies (Mackey et al. 2004). Visible light emitted from the lamps is transmitted through water farther than germicidal wavelengths. Algal growth depends on the concentration of nutrients in the water, hydraulics (i.e., dead spaces), and the amount of visible light transmitted beyond the reactor.

2.5.2 Chlorine Reduction through UV Reactors

When UV disinfection is applied to water with a free or total chlorine residual, some reduction of the residual may occur. The reduction in free chlorine residual is proportional to the delivered dose and independent of flow rate (Brodkorb and Richards 2004). The reduction in total chlorine residual is also proportional to the delivered dose (Wilczak and Lai, 2006). The reduction in chlorine residual further depends on the chlorine species, UV light source, and water quality characteristics (Örmeci et al. 2005, Venkatesan et al. 2003). An example of the effect of UV light on the free chlorine residual is shown in Figure 2.23. In other evaluations, a loss of about 0.3 mg/L of the free chlorine residual was observed in a WTP at a dose between 80 and 120 mJ/cm^2 (Kubik 2005), and a loss of 0.2 mg/L of the total chlorine residual was observed in bench-scale testing at doses up to 40 mJ/cm^2 (Wilczak and Lai 2006).

Figure 2.23. Example Effect of UV Disinfection on Free Chlorine Residual Loss



Source: Brodkorb and Richards (2004)

2.5.3 Byproducts from UV Disinfection

Studies indicate that UV disinfection at UV doses up to 200 mJ/cm^2 do not change the pH, turbidity, dissolved organic carbon level, UVT, color, nitrate, nitrite, bromide, iron, or manganese of the water being treated (Malley et al. 1996). Byproducts from UV disinfection, however, can arise either directly through photochemical reactions or indirectly through reactions with products of photochemical reactions. Photochemical reactions occur only when a chemical species absorbs UV light and the resulting excited state reacts to form a new species. The resulting concentration of new species depends on the concentration of the reactants and the UV dose. In drinking water, research on potential byproducts of UV disinfection has focused on the effect of UV light on the formation of halogenated DBPs after subsequent chlorination, the transformation of organic material to more degradable components, and on the potential formation of other DBPs (e.g., biodegradable compounds, nitrite, mutagenicity, and other byproducts).

2.5.3.1 Trihalomethanes, Haloacetic Acids, and Total Organic Halides

Trihalomethanes (THMs) and haloacetic acids (HAAs) are two categories of halogenated DBPs that EPA currently regulates. UV light at doses less than 400 mJ/cm^2 has not been found to significantly affect the formation of THMs or HAAs upon subsequent chlorination (Malley et al. 1996, Kashinkunti et al. 2003, Zheng et al. 1999, Liu et al. 2002, Venkatesan et al. 2003).

2.5.3.2 Biodegradable Compounds

Several studies have shown low-level formation of non-regulated DBPs (e.g., aldehydes) as a result of applying UV light at doses greater than 400 mJ/cm^2 to wastewater and raw drinking water sources (Liu et al. 2002, Venkatesan et al. 2003). At the doses typical for UV disinfection in drinking water (< 140 mJ/cm^2), however, no significant change was observed (Kashinkunti et al. 2003). UV disinfection has not been found to significantly increase the assimilable organic carbon (AOC) of drinking water at UV doses ranging from 18 – 250 mJ/cm^2 (Kruithof and van der Leer 1990, Akhlaq et al. 1990, Malley et al. 1996).

2.5.3.3 Nitrite

The conversion of nitrate to nitrite is possible with MP lamps that emit at wavelengths below 225 nm [von Sonntag and Schuchmann (1992), Mack and Bolton (1999), IJpelaar et al. (2003), Peldszus et al. (2004)]. Sharpless and Linden (2001) reported a conversion rate from nitrate to nitrite of approximately 1 percent. Therefore, the nitrate-to-nitrite conversion is unlikely to be a significant issue for PWSs under current regulations. The nitrate levels would have to be higher than the nitrate MCL of 10 mg/L for the nitrite MCL of 1 mg/L to be exceeded.

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3. Planning Analyses for UV Facilities

This chapter provides information on the elements that should be addressed during the UV disinfection planning or preliminary design phase.

Chapter 3 covers:

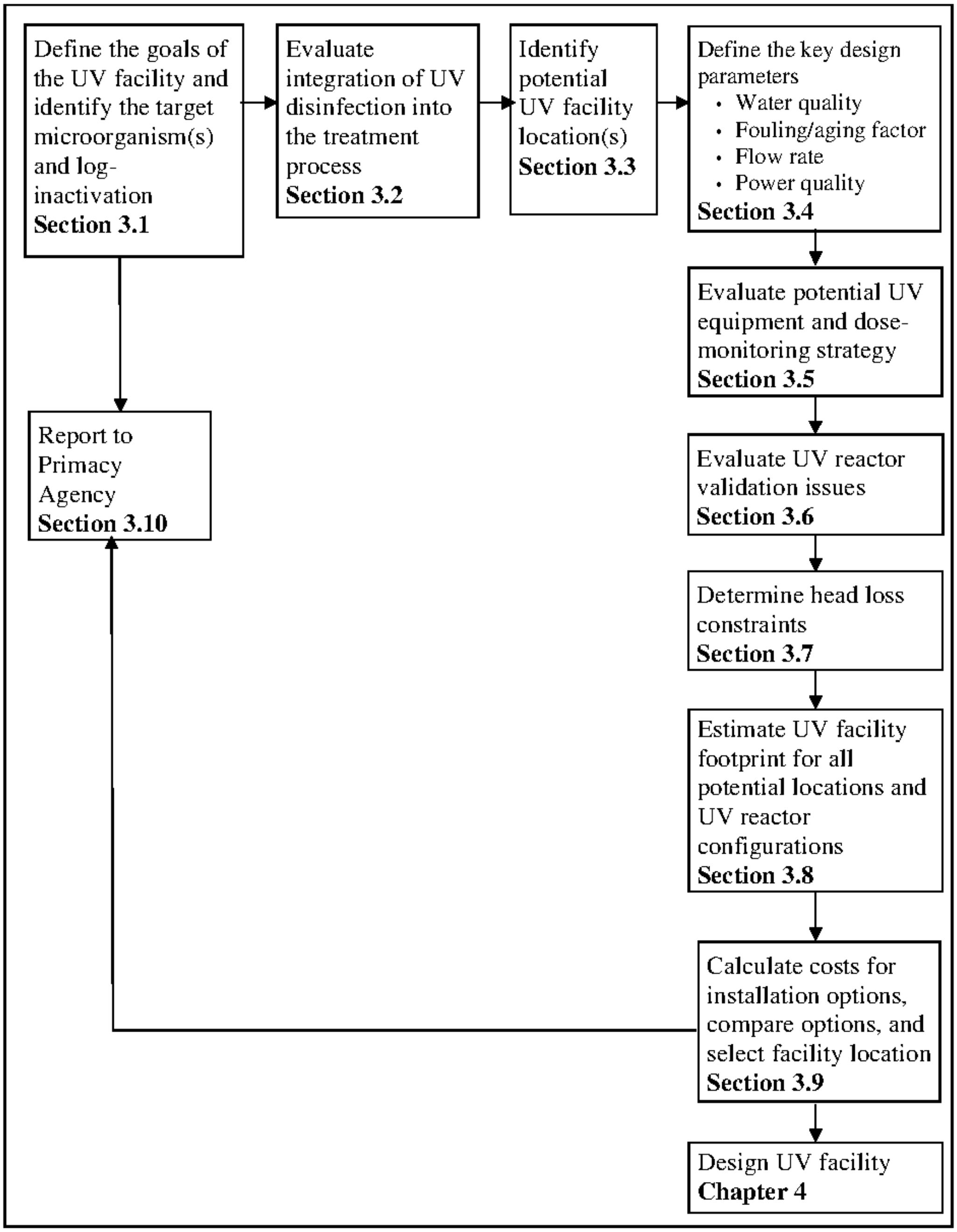
The planning for any UV facility is site-specific. Given the wide range of possible treatment scenarios, a guidance document such as this one cannot address or anticipate all possible treatment conditions. The information presented here should be used within the context of sound engineering judgment and applied appropriately on a case-by-case basis. Appendix F presents case studies that illustrate how various public water systems (PWSs) have implemented UV disinfection in their water systems. Additionally, this manual was written with the understanding that UV technology will continue to expand and evolve, so the information presented is current only as of the publication date. Furthermore, unless otherwise stated, throughout Chapter 3 the water to be disinfected is assumed to be from ***surface water systems*** [(i.e., filtered water, an unfiltered source water, or groundwater under the direct influence (GWUDI)], meeting applicable regulatory requirements that pre-date the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

The process of planning and designing a UV facility is presented in Figure 3.1. Once the design parameters are defined and the implementation issues are identified, they are incorporated into the detailed design phase, which is discussed in Chapter 4.

3.1 UV Disinfection Goals

The first step in planning a UV disinfection facility is to define the goals for the facility as part of a comprehensive disinfection strategy for the entire treatment process. Additionally, the target pathogen(s), target log-inactivation, and corresponding required UV dose should be identified.

Figure 3.1. Example Flowchart for Planning UV Facilities



- **Comprehensive Disinfection Strategy:** A comprehensive disinfection strategy provides multiple barriers to reduce microbial risk, while minimizing disinfectant byproduct (DBP) formation. UV disinfection is a tool that can contribute to a comprehensive disinfection strategy by providing a cost-effective method of inactivating pathogens that are more resistant to traditional disinfection methods. Also, UV disinfection can replace chemicals for primary disinfection of chlorine-resistant pathogens (e.g., *Cryptosporidium* and *Giardia*), thereby reducing DBP formation. Note that PWSs that plan to significantly change their disinfection process, including adding UV disinfection, must prepare a disinfection benchmark[1] (40 CFR 141.708) and consult with the state before making any changes. Further, PWSs must continue to provide 2-log *Cryptosporidium* removal by meeting filtered water turbidity requirements (40 CFR 141.173 for PWSs serving at least 10,000 people and 40 CFR 141.551 for PWSs serving fewer than 10,000 people) unless they meet the filtration avoidance criteria.

- **Target Pathogen and Log Inactivation:** The required UV doses for *Cryptosporidium* and *Giardia* inactivation are lower than those needed to inactivate viruses. (See Table 1.4.) Accordingly, the capital and operational costs for inactivating *Cryptosporidium* and *Giardia* should be lower than for viruses. One study estimated capital costs for *Cryptosporidium* and *Giardia* inactivation by UV disinfection on a log removal basis to be about half the cost associated with the UV inactivation of viruses (Cotton et al. 2002). Additionally, most viruses can be easily inactivated with chlorine so UV disinfection for virus inactivation may not be necessary. The target log inactivation also should be considered because higher target inactivation requires higher UV doses that will affect the design and cost of the UV facility. Therefore, the target microorganism(s) and their log-inactivation level should be determined early in the planning process.

3.2 Evaluating Integration of UV Disinfection into the Treatment Process

When installed, UV disinfection will typically be one of several treatment processes to help meet water quality goals. Accordingly, UV disinfection should be evaluated in the context of the complete treatment process, and the impacts on UV disinfection on other treatment processes should be considered. These issues are summarized in this section.

3.2.1 UV Disinfection Effects on Treatment

Typically, UV disinfection cannot entirely replace chemical disinfectants used in the treatment process. Some of the reasons are listed below.

- Surface water systems must maintain a disinfectant residual in the distribution system (40 CFR 141.72).

[1] More information on completing a disinfection benchmark can be found in *Disinfection Profiling and Benchmarking Guidance Manual* (EPA 1999).

- UV disinfection is not as efficient in inactivating viruses as more traditional, chlorine-based disinfection processes.
- Chemical disinfectants may also be needed to oxidize other constituents present in the water (e.g., iron, manganese, or taste- and odor-causing compounds).
- Some water systems apply chlorine to reduce algal growth in sedimentation basins.

Consequently, some level of chlorine-based disinfectant (chlorine or chloramines) usually will be needed even when UV disinfection is implemented. Therefore, any reduction in chlorine-based disinfectants should be evaluated in the context of other water quality and treatment goals.

When UV disinfection is applied to water having a chlorine residual, some chlorine residual reduction may occur, depending on the UV dose, chlorine species, UV light source, and water quality characteristics (Brodkorb and Richards 2004, Örmeci et al. 2005, Venkatesan et al. 2003). Brodkorb and Richards (2004) reported chlorine residual reduction between 0.1 and 0.7 milligrams per liter (mg/L) at a wide range of UV doses (described in Section 2.5.2). Significant chlorine reduction could occur inadvertently if the UV equipment cannot provide enough power modulation capacity and actually operates at much higher doses than designed. Two options are available to avoid chlorine reduction by UV disinfection:

1. Consider moving the chlorine addition point to after the UV facility if possible, especially when targeting viruses (because their required UV doses are higher).
2. Procure the UV equipment that has adequate power modulation to prevent overdosing and subsequent chlorine reduction.

In addition, UV disinfection of water having a chlorine residual, which results in a higher oxidation-reduction potential (ORP), could result in sleeve fouling (Section 2.5.1.4) if iron or manganese are present even at low levels and a proper cleaning system is not in place (Malley et al. 2001). Several studies have shown that fouling occurs at iron levels below the secondary maximum contaminant level (SMCL) when the water has a high oxidation-reduction potential (ORP) (Collins and Malley 2005, Derrick 2005, Wait et al. 2005). Again, moving the point of chlorination to after the UV facility can possibly reduce sleeve fouling (Section 3.4.4.2). Alternatively, oxidation and removal of iron and manganese (e.g., by adding potassium permanganate upstream of the sedimentation basin) reduces the fouling potential.

3.2.2 Upstream Treatment Process Effect on UV Disinfection

Water treatment processes upstream of the UV reactors can be operated to maximize the ultraviolet transmittance (UVT), thereby optimizing the design and costs of the UV equipment (Section 3.4.4.1). For example, coagulation, flocculation, and sedimentation remove soluble and particulate material, and optimizing coagulation for organics removal will increase the UVT, which could reduce the UV facility costs. Also, upstream chemicals may affect UV disinfection performance as described in Sections 2.5.1.3 and 3.4.4.1.

3.3 Identifying Potential Locations for UV Facilities

The UV dose tables (see Table 1.4) in the LT2ESWTR apply to post-filter applications of UV disinfection in filtration plants and to unfiltered systems that meet filtration avoidance criteria. In general, installing UV disinfection prior to filtration in conventional water treatment plants (WTPs) is not recommended because of the potential particle interference in raw and settled waters. As such, only post-filter locations are discussed for filtered systems in this section.

After the potential locations are identified, design criteria, hydraulics, validation issues, and footprint estimations should be evaluated at each location to identify which location is most feasible for the UV facility. These evaluations are described in subsequent sections.

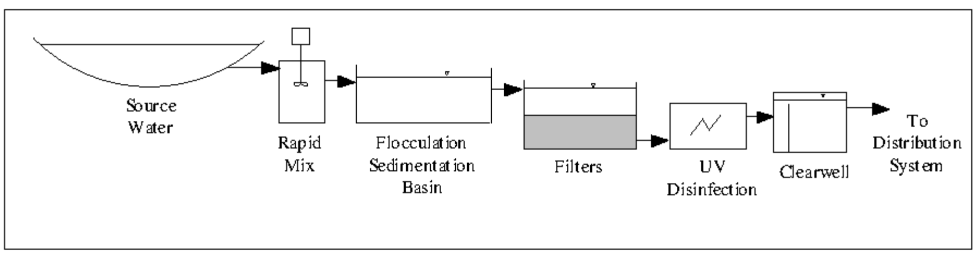
3.3.1 Installation Locations for Filtered Systems

In conventional WTPs, the three most common installation locations are downstream of the combined filter effluent (upstream of the clearwell), on the individual filter effluent piping (upstream of the clearwell), and downstream of the clearwell.

3.3.1.1 Combined Filter Effluent Installation (Upstream of the Clearwell)

A combined filter effluent installation is defined as the application of UV disinfection to the filtered effluent after the effluent from individual filters has been combined (as opposed to applying UV disinfection to the individual filter effluents) and ahead of the clearwell, as shown in Figure 3.2. For retrofits on existing WTPs, these installations are usually housed in a separate building.

Figure 3.2. Schematic for UV Facility Upstream of the Clearwell



This type of design and installation has several advantages:

- The UV reactor operation is largely independent of the operation of individual filters, which provides flexibility for design and operation.

- If the entire UV facility failed, a WTP can continue to disinfect by adding a chemical disinfectant to the clearwell. (Note that backup chemical disinfection will likely not provide *Cryptosporidium* inactivation.)
- Surge and pressure fluctuations typically are not a concern for this installation location unless membrane filtration, pressure filters, or intermediate booster pumps are used.
- Because this type of UV facility is typically constructed in a new building, there may be greater flexibility to maintain the recommended inlet and outlet hydraulic conditions for the UV reactors (Section 3.6.2).

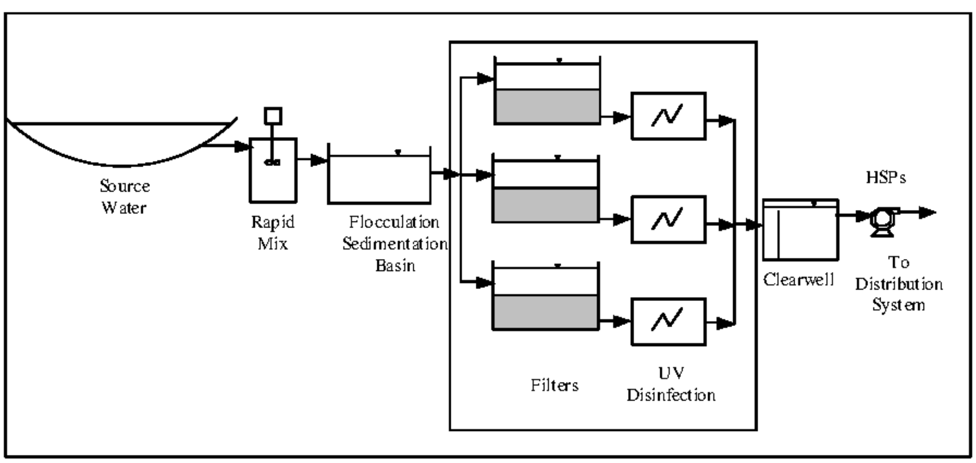
The primary disadvantages of this type of installation are:

- An additional building and space may be necessary.
- The piping and fittings may result in greater head loss than alternative configurations, which may result in the need for intermediate booster pumps.

3.3.1.2 Individual Filter Effluent Piping Installation

Individual filter effluent piping installations are defined as UV reactors installed on each filter effluent pipe (Figure 3.3). This type of installation is typically located within an existing filter gallery.

Figure 3.3. Schematic of Individual Filter Effluent Piping Installation in Filter Gallery



The primary advantages of this type of installation are:

- A new building is not necessary, which will decrease construction costs.
- The hydraulic effect of the UV facility is less because the only additional head loss is from the UV reactors (most necessary valves and appurtenances are already present in the filter gallery).
- If the UV reactors fail, a WTP can continue to disinfect by adding a chemical disinfectant to the clearwell. (Note that backup chemical disinfection likely will not provide *Cryptosporidium* inactivation.)

This installation location, however, has several disadvantages:

- Many filter galleries have insufficient space within existing effluent piping to accommodate the UV reactors.
- Sufficient space is needed in the filter gallery or nearby for the control panels and electrical equipment.
- Access to existing equipment may be impeded by the UV reactor, and access to UV reactor components for maintenance may be more restricted than for a combined filter effluent installation.
- Environmental conditions (e.g., moisture) in the filter gallery may not be appropriate for the installation of the UV reactors, associated control panels, and electrical equipment. This situation would necessitate improvements to the heating, ventilating, and air conditioning (HVAC) system.
- The existing piping may constrain how the UV reactor is validated because of the unique inlet and outlet conditions that may be present (Section 3.6.2).
- Surge and pressure fluctuations would need to be investigated if UV reactors are installed directly downstream of pressure filters or membrane filtration because water hammer can damage lamp sleeves.

Additionally, the individual filter effluent installation may also complicate treatment plant operations and limit operational flexibility, as described below:

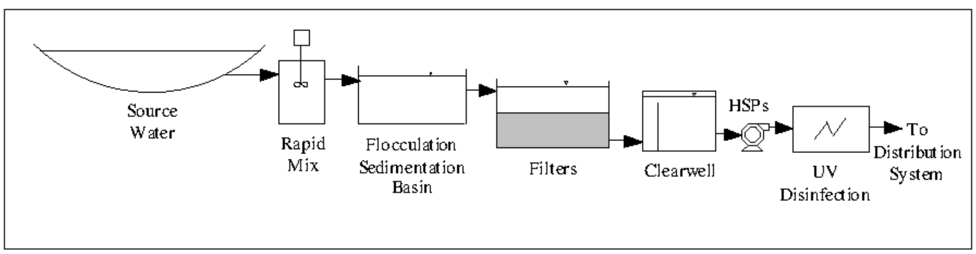
- In general, this option increases the number of UV reactors required compared to a combined filter installation because the number of filters dictates the number of UV reactors. More reactors may increase operation and maintenance costs.
- The head loss of the UV reactors may affect the operation of the filters and the clearwell.
- The operations of the UV reactor and the filter are closely related. If one reactor or one filter is off-line, the other process may not be operable.

- When a UV reactor goes off-line, the corresponding filter also should be taken off-line to minimize off-specification operation.
- The filter backwash cycle can complicate UV reactor operation.
  - Lamps that remain energized during a backwash may require cooling water because some lamps should not be energized in stagnant water. ***The designer should consult the UV manufacturer to determine whether the UV reactor requires cooling water during start-up.***
  - If a UV reactor is off-line during a backwash, the UV reactor may be operating outside of its validated limits (i.e., off-specification—discussed in Section 3.4.1) if water is being treated during lamp warm-up. If the piping configuration permits, energizing the UV reactors during the filter-to-waste period and having the filter-to-waste water pass through the reactors during the warm-up period would cool the lamps and reduce the volume of the off-specification water.

3.3.1.3 UV Disinfection Downstream of the Clearwell

A WTP may be able to locate the UV facility downstream of the clearwell, either upstream or downstream of the high-service pumps (HSPs), as shown in Figure 3.4. In many WTPs, the HSPs pump water directly from the clearwell, which limits space and the availability of suitable piping for installing the UV facility upstream of the HSPs. Installation downstream of the HSPs may provide greater space and flexibility in locating the UV facility.

Figure 3.4. UV Disinfection Downstream of High Service Pumps



The primary advantage of this type of installation is that UV reactor installation is possible even if the space or available head is insufficient to allow installation of the UV equipment between the filters and the clearwell. However, these options have significant disadvantages:

- UV facilities located downstream of the clearwell may experience greater fluctuations in flow rate because the flow rate is more closely related to demand changes.

Accommodating flow rate fluctuations may necessitate increasing the UV reactor size or number of UV reactors.

- Post-clearwell installation locations are more prone to water hammer because of their proximity to the HSPs and subsequent high pressures, and water hammer could damage lamp sleeves and the lamps. Hydropneumatic tanks or pressure-relief valves may be needed to avoid water hammer.

- In the event of a lamp break, post-clearwell installations may have less ability to contain mercury and quartz resulting from the break in a low-velocity collection area (depending on the distribution system configuration).

- In post-HSP installations, the water is at distribution system pressure. The UV reactor housing may need reinforcement to accommodate high pressure, which would increase the cost of the UV reactors.

- A UV facility located after the HSPs will reduce the discharge pressure to the distribution system, and a UV facility located between the clearwell and HSPs will reduce the suction head available for the pumps. As a result, discharge pressures and storage utilization could be affected at these two locations unless the HSPs are upgraded to account for the UV facility hydraulic needs.

- When UV disinfection is applied to water with a free or total chlorine residual, some reduction of the residual may occur, which may necessitate increasing the chlorine dose in the clearwell or moving the chlorination point to downstream of the UV facility.

3.3.2 Unfiltered System Installation Locations

In an unfiltered system, UV facilities can be located either before or after a storage reservoir. If the storage is covered, UV disinfection facilities can be installed in either location. If the storage reservoir is uncovered, however, the PWS is subject to the uncovered reservoir requirements of the LT2ESWTR and as such should install UV disinfection on the discharge side of the reservoir to provide the necessary treatment. Most unfiltered systems flow to the distribution system by gravity; however, water hammer may still be a concern if the facility is located near HSPs (if applicable). This installation location is similar to installations downstream of the clearwell, and as such, the items described in Section 3.3.1.3 also apply to this location.

More debris may be present in the influent to UV reactors in unfiltered applications than in post-filter applications. Debris entering the UV reactor with sufficient momentum can cause the lamp and sleeve to break. The mass and size of an object that might cause damage are installation-specific and depend on UV reactor configuration (e.g., horizontal versus vertical reactor orientation) and water velocity through the reactor. Methods of addressing debris are described in Section 4.5.1, and additional information on lamp breakage is presented in Appendix E.

3.3.3 Groundwater System Installation Locations

For groundwater applications of UV disinfection, UV facilities may be installed either at each well in a production system or at a centralized facility. If installed at or near well pumps, the hydraulic and water hammer considerations described in Section 3.3.1.3 will also apply. An engineering cost analysis can be conducted to compare centralized versus wellhead UV disinfection treatment, as well as any other treatment needs, such as removing iron, manganese, or sulfides.

3.3.4 Uncovered Reservoir Installation Locations

The LT2ESWTR requires PWSs with uncovered finished water storage facilities to either cover the storage facility or treat the discharge of the storage facility that is distributed to consumers to achieve inactivation and/or removal of 4-log virus, 3-log *Giardia*, and 2-log *Cryptosporidium* [40 CFR 141.714(c)]. When applying UV disinfection to uncovered reservoirs, the UV facility should be on the outlet of the uncovered reservoir. In some cases, the inlet and outlet to the uncovered reservoir is the same pipe, and the UV facility should be designed so it operates when the water flows from the uncovered reservoir to the customer. Water from most uncovered reservoirs flows by gravity to the distribution system; however, water hammer may still be a concern if the UV reactors are located close to HSPs. As such, the items described in Section 3.3.1.3 also apply to this location.

3.4 Defining Key Design Parameters

Off-specification requirements (see Section 3.4.1 below), target pathogen inactivation, flow, water quality, the fouling/aging factor, and power quality affect the sizing of the UV reactors and associated support facilities. Specifically, UV manufacturers use the design flow, design UVT, the range of UVT expected, and the fouling/aging factor to determine the appropriate number of UV reactors to achieve the required UV dose.

Pilot- and demonstration-scale testing for UV disinfection systems can be helpful in determining key design parameters but typically are unnecessary. For example, pilot- or demonstration-scale testing may be warranted when bench-scale analysis cannot determine the design criteria (e.g., prediction of fouling/aging factor in waters with high inorganic constituents). This section also describes some pilot- or demonstration-scale testing that can be used to determine key design criteria if deemed necessary by the PWS or design engineer.

3.4.1 Off-specification Requirements

The LT2ESWTR requires validation of UV reactors to demonstrate that they achieve the required UV dose [40 CFR 141.720(d)]. Validation testing establishes the conditions under which the UV reactors must be operated to ensure the required UV dose delivery [40 CFR 141.720(d)].

Receiving log inactivation credit to meet the treatment requirement of the LT2ESWTR requires that at least 95 percent of the water delivered to the public during each month is treated by UV reactors operating within validated limits [40 CFR 141.720(d)(3)]. In other words, the UV reactors cannot be operated outside of their validated limits for more than 5 percent of the volume of water that is treated each month. Operating outside of the validated limits is defined in this manual as off-specification operation.

Determining the appropriate design criteria related to flow, water quality (UVT and fouling), the fouling/aging factor, and power quality is important to comply with LT2ESWTR off-specification requirements. These design criteria also define the conditions under which the UV reactors must be validated and then operated. If the design parameters are not sufficiently conservative, the UV reactors may often operate off-specification and be out of compliance.

The UV reactors are off-specification when any of the following conditions occur:

- The flow rate is higher than the validated range.
- The UVT is lower than the validated range [if the Calculated Dose Approach is used (see Section 3.5.2)].
- The UV intensity is below the validated setpoint [if the UV Intensity Setpoint Approach is used (see Section 3.5.2)].
- The validated dose [2] is less than the required UV dose at a given flow rate [if the Calculated Dose Approach is used (see Section 3.5.2)].
- One or more lamps are not energized unless the UV reactor was validated with these lamps off.
- All UV lamps are off because of a power interruption or power quality problem, and water is flowing through the reactors.
- One or more UV sensors are not within calibration criteria, and the remedial actions are not taken. (See Section 6.4.1.1).
- A UVT analyzer is needed for the dose-monitoring strategy; the UVT analyzer is out of calibration; and a corrective action was not taken. (See Section 6.4.1.2.)
- The UV equipment includes installed or replaced components (or both) that are ***not*** equal to or better than the components used during validation testing unless the UV equipment was re-validated. (See Section 5.13.)

[2] For the purposes of this manual, the "Validated Dose" is the UV dose in units of mJ/cm^2 delivered by the UV reactor as determined through validation testing. The validated dose is compared to the required dose to determine log inactivation credit. For the Calculated Dose Approach, the validated dose equals the calculated dose from the dose-monitoring equation, divided by the Validation Factor. The Validation Factor accounts for key uncertainties and biases resulting from validation testing.

3.4.2 Target Pathogen Inactivation and Required UV Dose

As described in Section 3.1, the UV facility design criteria should include the target pathogen, log inactivation level, and corresponding required UV dose. The required UV dose (D_{Req}) for the various pathogens and inactivation are shown in Table 1.4; however, the PWS may consider increasing the required dose beyond those listed in Table 1.4 by 10 to 20 percent to provide flexibility and conservatism. Similar approaches are commonly used by many PWSs with chlorine disinfection where they provide higher chlorine residuals and contact times (CT) than required.

3.4.3 Design Flow Rate

The UV facility design criteria should identify the average, maximum, and minimum flow rates that the UV reactors will experience. Methods for determining the design flow rate for the installation locations described previously are listed in Table 3.1.

Table 3.1. Potential Method to Determine Design Flow

Installation Location	Design Flow Basis
Combined Filter Effluent	Combined rated capacity of all duty filters[1]
Individual Filter Effluent	Rated design flow for individual filter
Downstream of the Clearwell	Rated capacity of the HSP station
Unfiltered Application	Rated capacity of the treatment facility
Groundwater Application	Rated capacity of the well pump or well field
Uncovered Reservoir Application	Maximum reservoir outflow

[1] Does not include redundant filters

3.4.4 Water Quality

As highlighted in Chapter 2, the following water quality parameters and issues affect UV dose delivery and should be considered in UV facility planning:

- UVT at 254 nanometers (nm)
- UV transmittance scan from 200 – 300 nm (i.e., germicidal range)
- Sleeve and UV sensor window fouling, including
  - Calcium
  - Alkalinity
  - Hardness
  - Iron
  - Manganese
  - pH

- Lamp temperature
- ORP

- Particle content and algae (unfiltered and uncovered reservoir applications)

Water quality data should be collected from locations that are representative of the potential UV facility location(s). The duration of sampling, numbers of samples collected, and data analyses used to evaluate water quality for UV disinfection are similar to the approaches used for other water treatment technologies. The data collection should capture typical water quality and any water quality variation due to storm events, reservoir turnover, seasonal changes, source water blends, and variations in upstream treatment. The data collection frequency should be based on flow rate variability, the consistency of the source and treated water qualities, and the potential for obtaining cost and energy savings by refining the design criteria. The extent of water quality data to be collected and the data analysis should be left to the discretion of the PWS and the design engineer based on experience and professional judgment.

Water quality information should be communicated to the UV manufacturers, so they can determine the applicable UV reactors for the target pathogen inactivation. This section provides more details on the data collection and analysis recommendations.

3.4.4.1 UVT and UVT Scans

The most important water quality characteristic affecting UV facility design is UVT[3,4] because the UVT of the water directly influences UV dose delivery, as discussed in Chapter 2. Overly conservative design UVT values (i.e., low UVT) can result in over-design and increased capital costs. Conversely, inappropriately high design UVT values can result in frequent UV reactor off-specification operation, which could violate LT2ESWTR requirements.

Quantifying both a design UVT and the full range of UVT expected during operation is essential. Understanding the full range of UVT is critical because the UV reactor should be validated for the range of UVT and flow combinations expected at the WTP to avoid off-specification operation. Specifying a matrix of flow and UVT conditions for the UV reactors to meet the required UV dose may be appropriate. Also, the UV manufacturers may use the UVT range at the WTP to help determine the turndown (i.e., power modulation) needs of the UV reactors.

This section discusses the issues with using existing UVT data and describes the data collection, UVT measurement, and data analysis that can be used to determine design UVT and UVT range. Table 3.2 summarizes the recommendations for collecting and analyzing UVT data.

[3] UVT in this section implies UVT measurement specifically at 254 nm and 1 cm pathlength unless otherwise noted.

[4] $A_{254} = -\log\left(\frac{UVT(\%)}{100}\right)$

Table 3.2. Summary of UVT Data Collection and Analysis[1]

Issue	Recommendation
Water Quality Events to Capture in Data Collection	• Typical/average water quality conditions • Rainfall effects on source water • Reservoir turnover • Seasonal variations • Possible water quality blends if multiple source waters are used • Variation in upstream water treatment
Water Quality Sampling Locations	Locations that are representative of potential UV facility location(s)
Sample Type for Various Installation Options[2]	• Composite samples from operating filters or grab samples from the combined filtered water header should be collected for combined filter effluent installations • Grab samples from representative filter(s) for individual filter piping effluent installations • Grab samples from any locations downstream of clearwell under consideration
Collection Frequency and Period	• Weekly for 1 – 2 months if water quality is stable • Weekly[3] for 6 – 12 months (or more) if water quality changes seasonally
Existing Data for Potential Use	A_{254} is often collected in filtered waters to determine the specific UV absorbance (SUVA), and these measurements could be used in the data analysis. However, ultraviolet light absorbance at 254 nm (A_{254}) is typically filtered for the SUVA calculation, which would bias the A_{254} low (high UVT). Therefore, such data should only be used with this understanding.
Recommended Data Analysis	• Cumulative frequency analysis • UVT occurrence with flows
Recommended Data to Provide to UV Manufacturer	• Matrix of flows with corresponding UVTs • Target pathogen(s) and log inactivation • Design UVT[4] (corresponding to design flow) • Range of operating UVTs

[1] Existing A_{254} or UVT data may be available, which would reduce the sampling and analysis needed.
[2] The potential installation locations are described in detail in Section 3.3.1.
[3] More frequent samples may be needed to capture a water quality event (e.g., storm events).
[4] The design UVT is the UVT that will typically occur at the location of the facility.

Availability of Existing UVT Measurements

UVT data collection may not be necessary if sufficient filtered water UVT data are available to perform the recommended data analysis described subsequently. Additionally, filtered water A_{254} is often collected to determine the SUVA, and these measurements could be used in the data analysis. However, the water sample is typically passed through a 0.45-micrometer (μm) filter for the A_{254} measurement needed for the SUVA calculation, which may bias the A_{254} low (high UVT). If the only available A_{254} measurements are on water that has been passed through a 0.45- μm) filter, they can still provide input to the planning process, but additional UVT data collection may be necessary to understand the magnitude of the bias.

Data Collection

UVT measurements should be collected from locations that are representative of the potential facility location(s). UVT data can be collected using grab or composite samples, and the type of sample collected depends on the potential UV facility locations under consideration. For example, composite samples from operating filters or a grab sample from a combined filter effluent header should be collected for combined filter effluent UV facilities. For individual filter effluent pipe installations, grab samples from representative filters at the beginning and the end of filter runs are recommended. Grab samples from any location(s) downstream of the clearwell under consideration should be collected.

As with most engineering designs, the larger the data set, the more refined the design UVT can be. If UVT data are not available, weekly UVT measurement is recommended, but the duration of the sampling period depends on the source water quality. For example, a PWS with very stable UVT measurements may need only one or two months of data. A PWS that experiences seasonal changes, however, would benefit from more frequent data collection during seasonal events and over a longer period (6 to 12 months or more). If seasonal UVT decreases occur regularly, increased sampling frequency (e.g., daily) during these periods will better capture the magnitude and duration of the decreases. The possible effect of upstream processes on UVT should be assessed by collecting UVT data during the various operating conditions (e.g., a range of alum doses). If different sources or combinations of sources are used during the year, the UVT of the potential source water blends should be characterized to properly identify the representative water quality conditions.

UVT Measurement

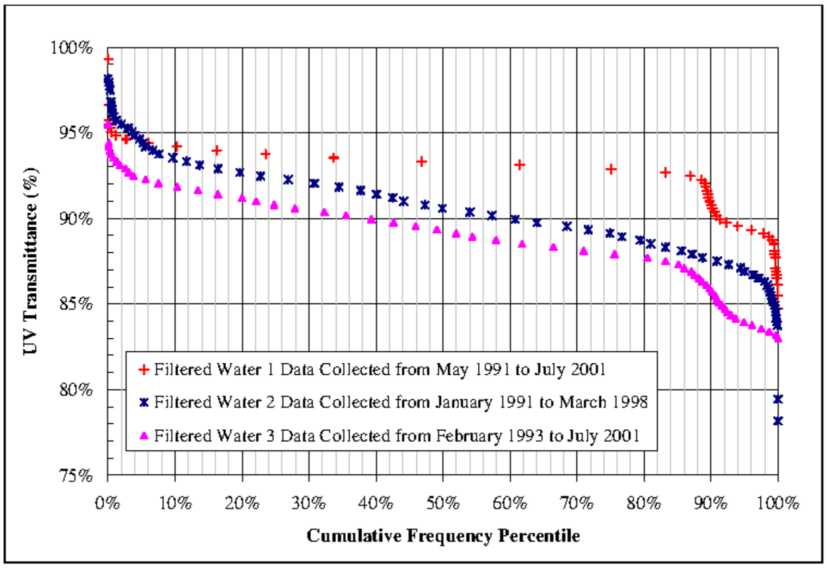
UVT can be measured with a bench-top spectrophotometer or can be continuously measured by an on-line UVT analyzer. During planning, UVT is typically measured using a spectrophotometer and is typically reported as a percent. The wavelength of the spectrophotometer should be set to 254 nm, and the pathlength of the quartz cuvette used to measure UVT is usually 1 centimeter (cm). If the UVT is high, however, longer pathlengths can be used to improve measurement resolution. When longer pathlengths are used, the A_{254} measured on the spectrophotometer should be normalized by the specific pathlength to calculate the A_{254} on a per cm basis, and then the UVT should be calculated based on the A_{254} with the converted 1-cm pathlength. Because particles can affect the absorbance of UV light, samples for UVT should ***not*** be passed through a 0.45-μm filter before analysis. The sample pH also should not be adjusted.

Data Analysis

A cumulative frequency diagram of the UVT data can help the PWS determine its design UVT value and will also illustrate the UVT range. Cumulative frequency diagrams can be prepared by ranking UVT results from lowest to highest and then calculating the percentile for each value. Figure 3.5 presents an example cumulative frequency diagram for three filtered waters; the cumulative frequency percentile (x-axis) shows the percentage of the dataset that is less than a given value of UVT over the data collection period. For example, if the 90^{th} percentile UVT is 91 percent, then 90 percent of the measurements are greater than 91 percent, and 10 percent of the UVT measurements are less than 91 percent.

In Figure 3.5, the UVT data for Filtered Waters 1, 2, and 3 display different characteristics. Filtered Water 1 has a relatively stable UVT, while Filtered Waters 2 and 3 have gradually increasing cumulative frequency slopes that indicate greater variability. Selection of an appropriate UVT design value for these waters should consider the variability in UVT and flow values and the maximum allowable volume of off-specification finished water at different UVT design levels. The water supply's preferred level of conservatism should also be taken into account in this comparison.

Figure 3.5. Example Cumulative Frequency Diagram for Three Filtered Waters

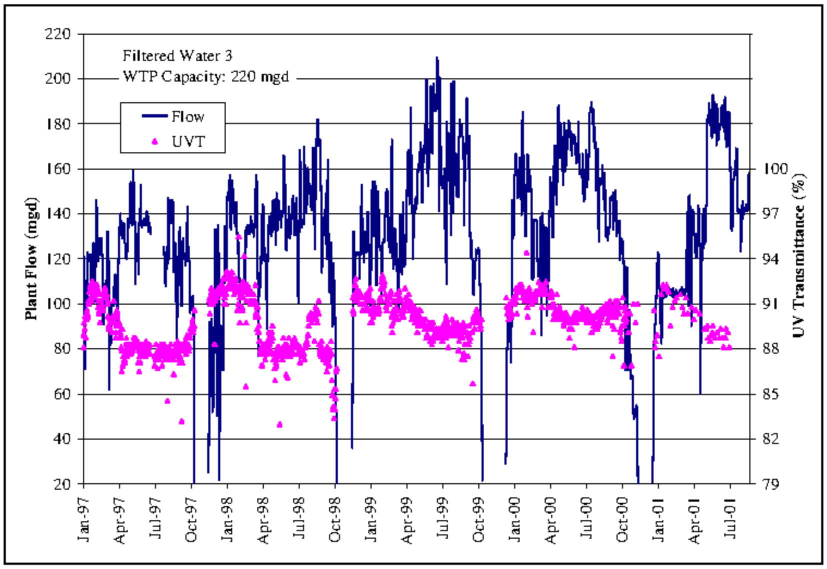


Additionally, the minimum operating UVT may not correspond to the period with the highest flow rates. The relationship between seasonal flow rates and UVT data should be considered when selecting a design UVT value and the matrix of UVT and flow conditions to be defined for the UV manufacturer. Figure 3.6 presents flow rate and UVT variations and seasonal patterns for Filtered Water 3. For this example WTP, the low UVT typically occurs in September and October and not during the high flow rate period in the summer. In this example, the following conditions for UVT and flow could be communicated to the UV manufacturers, so they can determine the applicable UV reactors for the required UV dose:

A 90th-percentile design UVT value of 86 percent at the design 220-million gallons per day (mgd) capacity

Minimum UVT of 83 percent coupled with a flow of 140 mgd

Figure 3.6. Example Flow Rate and UVT (at 254 nm) Data



Upstream Treatment Chemicals Effect on UVT

As described in Section 2.5.1.3 and Bolton et al. (2001), the following chemicals alone will not significantly affect UVT under typical filtered water conditions: alum, aluminum, ammonia, ammonium, zinc, phosphate, calcium, hydroxide, ferrous iron (Fe^{+2}), hypochlorite (ClO^-), ferric iron (Fe^{+3}), and permanganate. However, ozone residual affects UVT, as described below. If other chemicals of concern are present, the effect of water treatment chemicals on UV absorbance can be assessed by preparing solutions of various concentrations and measuring their UV absorbance using a standard spectrophotometer.

If ozone is added before UV disinfection, the UVT of the water can be increased measurably, thereby improving the efficiency of UV disinfection. Ozone also absorbs UV light, however, so if residual ozone enters the UV reactor, the resulting decrease in UVT can be significant and should be considered when determining the design UVT. To address this issue, PWSs can monitor the ozone residual and add an ozone-reducing chemical prior to the UV reactor to maintain the ozone residual below a specified setpoint value. Several chemicals can quench ozone, but some (such as sodium thiosulfate) also have a high UV absorbance value and can decrease UVT. Such chemicals should not be used prior to UV disinfection unless their application causes no residual concentration. Sodium bisulfite is an alternative to sodium thiosulfate that does not significantly affect UVT.

UVT Scans

If MP lamps are being considered, measuring the UVT at the wavelengths in the germicidal range (in addition to 254 nm) may also be important. A UVT scan is used to determine the UVT of the water over 200 – 300 nm (i.e., germicidal range). In a UVT scan, the absorbance at each wavelength is measured and converted to UVT using Equation 2.2 ($\%UVT = 100 \times 10^{-A}$). The UV absorbance of water typically decreases with increasing wavelength over the germicidal range. Thus, the UV light attenuation in a UV reactor and the corresponding disinfection performance depend on the absorbance at each emitted wavelength. Some UV manufacturers use site-specific UVT scans in their UV dose monitoring and control systems. UVT scans can also vary seasonally; therefore, UVT scans could be measured at different times during the year to account for this variation. Also, the UVT scans can be used to determine the appropriate UV-absorbing chemical for validating the UV reactors that will be installed.

3.4.4.2 Water Quality Parameters That Affect Fouling

Water quality can affect the amount and type of lamp sleeve fouling that occurs in UV reactors. The factors that affect fouling pertain to all UV equipment.

Fouling is typically caused by precipitation of compounds on the lamp sleeve, as described in Section 2.5.1.4. The rate of fouling and the consequent frequency of sleeve cleaning depend on ORP, hardness, alkalinity, lamp temperature, pH, and the presence of certain inorganic constituents (e.g., iron and calcium). If significant seasonal shifts in any of the parameters or coagulant doses are expected, the duration of the monitoring period should be sufficiently long to capture the variations.

Although fouling should not be a significant problem for most PWSs, the water quality parameters listed below should be monitored before the UV facility is designed, unless adequate water quality data are available. A summary of the data collection and analysis related to fouling parameters is provided in Table 3.3. Providing these data to UV manufacturers is recommended to help them qualitatively assess the fouling potential for their UV reactors and to assist designers in determining whether a particular cleaning system should be specified. These data will also help determine the fouling/aging factor, which is discussed in Section 3.4.5. (Note that ORP can be challenging to measure, so the data collected may have limited value.)

- Calcium
- Alkalinity
- Hardness
- Iron
- Manganese
- pH
- ORP

Table 3.3. Summary of Fouling Data Collection and Analysis

Issue	Fouling Parameters[1]
Collection Location	Locations that are representative of potential UV facility location(s)
Collection Frequency[2] and Period	• Monthly for 1 – 2 months if water quality is stable • Monthly for 6 – 12 months (or more) if water quality changes seasonally
Recommended Data Analysis	Based on design engineer's and PWS' best professional judgment
Recommended Data to Provide to UV Manufacturer	Median and maximum values

[1] Fouling parameters include calcium, alkalinity, hardness, iron, manganese, pH, and ORP.
[2] More frequent samples may be necessary to capture a water quality event (e.g., storm events).

Pilot tests of waters with total hardness levels less than 140 mg/L and iron less than 0.1 mg/L found that standard cleaning protocols and wiper frequencies (one sweep every 15 – 60 minutes) addressed the effect of sleeve fouling at the sites tested (Mackey et al. 2001, Mackey et al. 2004). Recent research has shown, however, that the addition of a chemical oxidant directly upstream of UV reactors (i.e., downstream of filters) will increase the ORP and potential for fouling (Derrick 2005, Wait et al. 2005). Therefore, moving the chemical oxidation point from immediately upstream of the UV reactors to downstream of the UV reactors should be considered to reduce the potential for fouling. It should be noted that if oxidation and filtration occur prior to UV disinfection, the iron and manganese are typically oxidized and then filtered out prior to the UV reactor, and fouling will be minimal (Derrick 2005, Wait et al. 2005, Jeffcoat 2005).

If the ORP, pH, and inorganic constituent concentrations are low, fouling is not likely to be an issue, and a cleaning system may not be necessary. However, a cleaning system should be considered if iron and manganese are present. Also, if the chemical oxidation point cannot be moved from immediately upstream of the UV equipment and iron and manganese are present, pilot testing (Section 3.4.5.1) may be necessary to determine the fouling rate and effectiveness of sleeve cleaning.

3.4.4.3 Additional Water Quality Considerations for Unfiltered Supplies and Treatment of Uncovered Reservoir Water

Water supplies are susceptible to variable water quality, turbidity spikes, reservoir turnover, and seasonal algal blooms. Typically, water treatment processes at filtered WTPs dampen the effects of such variations on UV disinfection. Unfiltered supplies, however, generally do not have upstream treatment that mitigates these variations. Specifically, the presence of particles and algae may affect UV dose delivery, and water quality and UVT may fluctuate more in unfiltered supplies and thus should be a consideration in the water quality data analysis.

Uncovered reservoirs have similar water quality issues as unfiltered supplies. In most cases, however, the problems are less severe because the water has been treated before it enters the uncovered reservoir and the operation of uncovered reservoirs is more controlled (e.g., smaller volumes, storm water control, concrete lining, and bird control). One exception is that algal blooms may be more prevalent in uncovered reservoirs than in unfiltered supplies if phosphate-based corrosion inhibitors are added at the WTP. Phosphates can promote algal growth.

Issues that should be considered in the water quality data analysis for unfiltered supplies and uncovered reservoirs are described in this section and summarized in Table 3.4.

Table 3.4. Summary of Particle and Algal Data Collection and Analysis

Issue	Particles and Algae
Collection Location	Locations that are representative of potential UV facility location(s)
Collection Frequency[1] and Period	• Monthly for 1 – 2 months for an Unfiltered PWS • Bi-weekly for the summer months[2] for Uncovered Reservoirs
Recommended Data Analysis	Based on design engineer's and PWS' best professional judgment
Recommended Data to Provide to UV Manufacturer	Median and maximum values

[1] More frequent samples may be needed to capture a water quality event (e.g., storm events).
[2] Algal blooms often occur in summer months in uncovered reservoir supplies.

Water Quality Fluctuations from Reservoir Turnover

Reservoir turnover in unfiltered supplies and uncovered reservoirs may cause water quality changes that affect UV disinfection. The UVT and parameters that affect fouling should be monitored over a complete reservoir cycle to account for these issues in the design criteria. For example, reservoir turnover can cause increased iron levels, which is a factor that should be considered when assessing fouling potential. If the potential for increased iron levels is not assessed, the appropriate sleeve cleaning technology may not be installed, and UV dose delivery may be affected.

Particle Content and UVT Variability

For unfiltered systems, the Surface Water Treatment Rule (SWTR) allows turbidity up to 5 nephelometric turbidity units (NTU) immediately prior to the first point of disinfection application (40 CFR 141.71). Storm-related turbidity spikes are more prevalent in unfiltered supplies than in filtered supplies because no upstream treatment is available to remove the particles. Particles in water absorb and scatter UV light to varying degrees based on their size and composition. Particles affect the disinfection process in two ways:

1. Particles can decrease the UVT of water and thereby affect UV dose delivery.

2. Microorganisms can associate with particles and be shielded from UV light, thereby changing the characteristics of the UV dose-response curve that is obtained using collimated beam studies.

Several studies have found that the effects of turbidity up to 10 NTU on UV disinfection can be accounted for in the UVT measurements (Passantino et al. 2004, Christensen and Linden 2002). However, the most commonly used spectrophotometer (bench-top direct reading) may underestimate the UVT of water with turbidity greater than 3 NTU (Christensen and Linden 2002). To reduce this underestimation, all unfiltered systems and uncovered reservoir applications should use a bench-top UV spectrophotometer with an integrating sphere to provide more accurate UVT measurements for planning purposes.

For unfiltered waters susceptible to turbidity fluctuations, the UVT sampling should occur during these events and be accounted for in the design UVT and UVT range. If the design UVT is appropriate, the UV reactor will be able to respond to changes in UVT that arise due to particles.

As described previously, particle content and UVT variability will probably be less prevalent in uncovered reservoirs compared to unfiltered supplies. The UVT sampling, however, should be conducted during a period sufficient to include seasonal events (e.g., rainstorms and runoff) that will affect the design UVT and the UVT range.

Algae

Previous research with male-specific-2 bacteriophage (MS2) has shown that algal counts up to 70,000 cells/mL do not affect disinfection performance (Wobma et al. 2004). Whether algal counts greater than 70,000 cells/mL affect the UV disinfection process is unknown. Therefore, for both unfiltered supplies and uncovered reservoirs, UVT sampling should be conducted during algal blooms to enable their effects on UVT to be assessed. At high algal concentrations, bench-, pilot-, or demonstration-scale testing may be warranted to determine if UV disinfection is significantly affected.

3.4.5 Fouling/Aging Factor

Sleeve fouling, sleeve aging, lamp aging, and UV sensor window fouling (if applicable) affect long-term UV reactor performance, as described in Sections 2.4.2 and 2.4.4. The fouling/aging factor accounts for these issues.

An acceptable fouling/aging factor and guaranteed lamp life should be determined based on experience and professional judgment. Alternatively, pilot- or demonstration-scale testing can be used to estimate the fouling factor and aging factor if deemed necessary by the PWS, as described in Sections 3.4.5.1 and 3.4.5.2, respectively.

The lamp-fouling portion of the factor (i.e., fouling factor) is the estimated fraction of UV light passing through a fouled sleeve as compared to a new sleeve. A lamp sleeve can become fouled when inorganics (e.g. iron) precipitate onto a lamp sleeve and reduce the UV transmittance of the sleeve. Water quality parameters that affect fouling are described in Section 3.4.4.2.

The lamp aging portion of the factor (i.e., aging factor) is the fraction of UV light emitted from aged sleeves and lamps compared to new sleeves and lamps and can be estimated by the lamp and sleeve aging characteristics obtained from the UV manufacturer. The lamp aging factor is important because as UV lamps age, the output of the lamps decrease.

The fouling/aging factor is calculated by multiplying the fouling factor by the aging factor and typically ranges from 0.4 (NWRI 2003) to 0.9. The fouling/aging factor is typically used in validation testing to ensure the UV equipment can meet the required dose in a fouled and/or aged condition. (See Equation 3.1.)

$$\textit{UV Dose with Clean Lamps} * \textit{Fouling Factor} * \textit{Aging Factor} \geq \textit{Required UV Dose} \quad \text{Equation 3.1}$$

When purchasing a pre-validated reactor, the PWS should determine if validation testing was conducted under conditions of reduced lamp output (e.g., 70 percent) that is equal to or less than reduced lamp output expected for fouled/aged conditions at its water treatment plant (e.g., 0.75, or 75 percent). If the site-specific fouling/aging factor is lower (e.g., 0.5, or 50 percent) than considered during validation testing, adjustments in validation test results or additional testing should be considered.

Selection of a fouling/aging factor coupled with a guaranteed lamp life is a trade-off between maintenance costs (the frequency of lamp replacement or chemical cleanings necessary) and capital costs (the size of the UV reactors). Both a fouling/aging factor and a guaranteed lamp life should be selected because doing so will guarantee that the fouling/aging factor will not be exceeded within the guaranteed lamp life. Lamps for a UV reactor with a lower fouling/aging factor will require less frequent replacement because the UV reactors are designed with more or higher powered lamps to achieve the necessary UV output at the guaranteed lamp life. This strategy, however, may necessitate an increase in the size of the UV reactor and facility. Conversely, the use of an insufficiently conservative factor may underestimate the reduction in the lamp output and potentially result in off-specification operation or more frequent lamp replacement.

3.4.5.1 Testing to Determine the Fouling Factor

The specific fouling rate and optimal cleaning protocol for any given application cannot be predicted with existing empirically-proven, mathematical equations. A proper cleaning protocol and sleeve-fouling factor, however, can be adequately estimated for most water sources without pilot- or demonstration-scale testing and then adjusted during normal operation.

Alternatively, fouling rates can be evaluated on a site-specific basis through pilot- or demonstration-scale testing or during UV reactor start-up. Testing could consist of the following test elements:

- **Test setup:** The UV sensors, lamp and sleeve type, power system, and cleaning system tested in a pilot- or demonstration-scale system should be identical to the full-scale reactor. Differences in lamp and lamp sleeve geometry can lead to erroneous conclusions based on pilot data alone.

- **Flow and UV equipment conditions:** Water should flow through the reactor at the minimum flow rate, and the lamps should be operated at maximum power.

- **Establishment of cleaning settings:** UV equipment with on-line chemical cleaning (OCC) systems should be operated for a prescribed length of time (e.g., 2 weeks) without a chemical cleaning to evaluate fouling. With water systems using on-line mechanical cleaning (OMC) and on-line mechanical-chemical cleaning (OMCC), the cleaning systems should be operated at the manufacturer's recommended frequency to assess fouling. One sleeve should be unwiped, however, for the entire testing period to serve as a control to verify that fouling is occurring.

- **Assessment of fouling factor:** Fouling is assessed by placing a new lamp inside a fouled sleeve, igniting it, and measuring the UV intensity. The UV intensity should be compared to a similar measurement made using a new, clean sleeve. The ratio of these two measurements (UV light passing through the fouled sleeve to that passing through the new sleeve) is the fouling factor.

- **Evaluation of sleeve cleaning efficiency:** A sleeve cleaning assessment can also be performed to determine if more frequent cleaning could reduce the fouling factor.

- **Sensor window fouling (if applicable):** To assess fouling on the UV sensor windows, the windows should be cleaned with phosphoric or citric acid at varying time intervals, and the change in UV sensor readings recorded. The fouling rate of the lamp sleeves is likely to be greater than the fouling rate of the sensor windows because the sleeves are hotter than the windows, and higher temperatures accelerate fouling.

- **Quality assurance:** The fouled sleeve should be manually cleaned, which should restore the sleeve UV intensity value to very near that of a new, clean sleeve after the fouling factor has been determined. If not, the inside of the sleeve should be manually cleaned and the UV intensity measured again. If the UV intensity is still low, the sleeve material has likely degraded, and the test should be performed with a new sleeve to ensure that the test results indicate fouling only and not sleeve degradation.

The fouling factor data can be analyzed to determine the water system's preferred fouling factor under the observed sleeve cleaning efficiencies.

3.4.5.2 Testing to Determine the Aging Factor

The aging factor is the fraction of UV light emitted from aged sleeves and lamps compared to the fraction emitted from new sleeves and lamps. The lamp aging factor is typically between 0.5 and 0.8. In most cases, the aging factor can be determined from manufacturer data with existing empirically proven, mathematical equations. The PWS, however, may desire testing to better understand lamp aging characteristics. Lamp aging tests assess the reduction and variance in lamp germicidal output over time under defined worst-case operating conditions. Factors to consider in designing the test(s) include lamp batch, lamp assembly, electrical characteristics of the ballasts, heat transfer from the lamps to the water, and lamp operation. Because lamps are manufactured in batches, lamps from several different lots should be evaluated to ensure that collected data are representative.

Lamp age can be tested with either a pilot- or demonstration-scale UV reactor or a test stand designed to simulate the UV lamp aging in full-scale operation. For either setup, lamps should be operated in an environment that reflects conditions expected when the UV equipment is installed at a WTP (e.g., use lamp sleeves, ballasts, and cleaning systems that will be used in the final application).

During testing, the following activities should be considered:

- Monitor the UV intensity, UVT, electrical power delivered to the ballast, electrical power delivered to the lamp, and water temperature over the lamp life.

- Visually inspect the lamp sleeves at regular intervals to document any degradation of the lamp assembly, including electrodes and seals, and any darkening of the lamp envelope.

- Document any fouling on the internal surfaces of the lamp sleeves.

- Using either a radiometer equipped with a germicidal filter or a reference UV sensor, measure the germicidal output of the lamp under fixed conditions of ballast operation (e.g., power setting); heat transfer (e.g., lamp sleeves); and environment (water temperature and transmission). The following procedure should be used:

  - Take one measurement with lamps that have been aged 100 hours (“new”).

  - Measure the output from various positions along the lamp based on visual inspection (i.e., the pattern of darkening on the lamp).

  - Measure lamp output as a function of lamp power setting if lamp power is variable.

  - Assess the output from lamps of different lots.

The lamp output measured under fixed operating conditions can be plotted over time and fit to estimate the mean expected performance for various lamp ages. To determine the aging factor, measure the output of a new lamp and the output at the end-of-lamp life. The aging factor is the ratio of the output at the guaranteed lamp life to new lamp output and is expressed as a fraction.

Although it does not impact reactor design, studies have shown that non-uniform lamp aging can occur. Non-uniform lamp aging should be considered during validation testing. (See Section 5.4.6)

3.4.6 Power Quality Evaluations

UV lamps can turn off if a voltage fluctuation, power quality anomaly, or a power interruption occurs. Power quality tolerances depend on the UV equipment design and vary significantly among UV manufacturers (Table 3.5). The UV manufacturer should be contacted to determine the power quality tolerance and the length of time for the equipment to reach full power after a power quality event. (See Section 2.4.2.3.)

Table 3.5. Power Quality Triggers for UV Reactors[1]

Power Quality Event		LPHO Manufacturer #1	LPHO Manufacturer #2	MP Manufacturer #1	MP Manufacturer #2
Voltage Sag/Swell Tolerance	Voltage[2]	± 20%	± 10%	± 30%	± 20%
	Duration[3]	2 seconds (s)	> 0.03 s	> 0.02 s	2 s
Power Interruption Tolerances[4]	Duration[3]	> 0.05 s	> 0.03 s	> 0.009 s	> 0.05 s

[1] Information shown in the table is compiled from Calgon Carbon Corporation, Trojan Technologies, and WEDECO.
[2] Percent of line voltage. For example, a 10-percent voltage loss is when the voltage is at 90% of the line voltage.
[3] 1 cycle is 0.017 s.
[4] Power interruption assumes total voltage loss.
Source: Cotton et al. (2005)

Studies have shown that the typical industrial power user experiences an average of eight power quality events per month (Grebe et al. 1996). Accordingly, power quality problems alone likely will not cause UV reactors to exceed the maximum off-specification requirements even though UV reactors are sensitive to power quality (Cotton et al. 2005). Therefore, a power quality assessment is probably necessary only when the installation site is (1) known to have power quality problems (e.g., 30 power interruptions and/or brownouts per month); or (2) located in a remote area and the power quality is unknown.

If power quality may be a problem at the intended installation location, a power quality assessment can be performed to quantify and understand the potential for off-specification operation, which consists of the following five steps:

1. Estimate the power quality at the potential location(s) of the UV facility. Local power suppliers often can provide data on power quality and reliability and should be the first source of information. Other sources of information are operating records of power quality incidents (if available), power interruptions, or Supervisory Control and Data Acquisition (SCADA) information for the existing plant.

2. Understand the power quality tolerance of the UV equipment under consideration by contacting the UV manufacturer or consulting published data.

3. Contact the UV manufacturer to determine how long it will take their equipment to be functioning at full power after a power quality event.

4. Estimate the off-specification time for the potential UV equipment-based information gathered in Steps 1 through 3. Examples of how to estimate off-specification based on this information are presented in Cotton et al. (2005).

5. Determine if backup power or power conditioning equipment is needed to reduce off-specification time or to improve UV equipment reliability.

Generally, personnel with a working knowledge of electrical supply and installation will be able to review power supply data and determine if power quality problems exist. More advanced assessments can include the installation of power quality monitors or the retention of an outside consultant to conduct a detailed power quality assessment.

3.5 Evaluating UV Reactors, Dose Monitoring Strategy, and Operational Approach

Selecting the appropriate UV reactor depends on the installation locations under consideration and the design parameters discussed in Section 3.4. The UV reactor manufacturer is a valuable resource for such evaluations and can determine what UV reactors are most appropriate for the installation locations under consideration. Evaluating the available UV reactors in the planning process is important because each manufacturer's UV reactors are unique and proprietary, and installation needs (e.g., power requirements) differ. UV reactors can generally be characterized based on lamp type with low-pressure high-output (LPHO) lamps and medium-pressure (MP) lamps applicable to most WTPs. This section discusses the general characteristics of LPHO and MP reactors and describes the various control strategies. UV manufacturers should be contacted directly to gain a better understanding of the available and appropriate UV reactors.

3.5.1 Characteristics of LPHO and MP Reactors

The fundamental difference between LPHO and MP reactors is the lamp intensity output (which influences the UV reactor configuration and size), lamp life and replacement, power use, power modulation capabilities, and sleeve cleaning.

- **UV reactor configuration and size:** Several UV reactor configurations are available. Reactors can be in-line (i.e., shaped like a pipe), S-shaped, or U-shaped, depending on the UV manufacturer and the site constraints of the specific installation location. Typically, LPHO reactors have a larger footprint than MP reactors because more UV lamps are needed to deliver the same required UV dose. MP reactor footprints will also vary, depending on lamp orientation (e.g., parallel versus perpendicular to flow).

- **Lamp life and replacement:** Lamp life also varies between LPHO and MP reactors. Most manufacturers provide warranties of 8,000 – 12,000 hours for LPHO lamps and 4,000 – 8,000 hours for MP lamps. Although the lamp life for LPHO reactors is greater than that for MP reactors, more lamps are needed for an LPHO reactor. The actual number of lamps replaced during a given period, therefore, may be less for MP reactors.

- **Power use:** Even though LPHO reactors typically have more lamps, they require less power input than similarly sized MP reactors because LPHO lamps are more efficient in converting the power to germicidal UV light for disinfection. This decreased energy efficiency results in higher power needs and increases in overall power consumption for MP reactors compared to LPHO reactors.

- **Power modulation capabilities:** The ability of the UV equipment to adjust lamp power or number of UV lamps energized will affect the energy use. Unlike the other issues described, power modulation capabilities depend on the UV equipment design and not the lamp type.

- **Sleeve Cleaning:** The lamp sleeve cleaning systems for LPHO and MP reactors can also differ. LPHO reactors typically have OCC systems, and MP reactors typically have OMC systems. Although OCC systems tend to be more labor intensive than OMC systems, OMC systems typically have more parts to replace. The extent of fouling will determine the amount of maintenance (labor and parts) that is needed on a routine basis and will affect the overall maintenance costs.

As described, the PWS should evaluate the differences between LPHO and MP reactors and determine any preferences based on the different characteristics and site-specific constraints. If one technology is precluded, it should not be evaluated further in the planning analyses.

3.5.2 Dose-monitoring Strategy and Operational Approach

The dose-monitoring strategy establishes the operating parameters used to confirm UV dose delivery. It affects how a reactor is validated, how instrumentation and controls are designed, and how the reactor is operated. In the planning phase, the water system should evaluate the various dose-monitoring strategies to determine whether a particular approach is preferable based on the ease of integration into their existing operation and control system. If a particular dose-monitoring strategy is preferred, the water system should select a UV equipment that has been validated for that strategy. The effect of the dose-monitoring strategy on the instrumentation and controls design is described in Section 4.3.

UV manufacturers commonly design their reactors to operate using either:

- The UV Intensity Setpoint Approach or
- The Calculated Dose Approach

This guidance manual focuses on the design, validation, and operation of UV reactors that use one of these two approaches. Another existing dose-monitoring strategy or a new strategy developed after this manual is published, however, may also be suitable for reactor operations as long as they meet minimum regulatory requirements.[5] Alternative strategies should be considered on a case-by-case basis.

Table 3.6 summarizes key characteristics of the two dose-monitoring approaches discussed in this manual. The next two sections provide an overview of how the approaches operate. Advantages and disadvantages of each are discussed in Section 3.5.2.3, and Section 6.4 provides additional guidance on monitoring frequency and reporting requirements for these control strategies.

Table 3.6. Dose-monitoring Approaches – Key Characteristics

Dose-monitoring Strategy	Parameter Used as the Operational Setpoint	Parameters Monitored During Operations to Confirm Dose Delivery
UV Intensity Setpoint Approach	UV Intensity	Flow rate Lamp status UV intensity
Calculated Dose Approach	Calculated or Validated dose [1]	Flow rate Lamp status UV intensity UVT

[1] As noted in Section 3.4.1, the calculated dose is estimated using a dose-monitoring equation. For the Calculated Dose Approach, the validated dose is equal to the calculated dose divided by a Validation Factor, which accounts for biases and experimental uncertainty.

3.5.2.1 UV Intensity Setpoint Approach

As indicated by its name, the UV Intensity Setpoint Approach relies upon one or more "setpoints" for UV intensity that are established during validation testing. During operations, the UV intensity, as measured by UV sensors, must meet or exceed the setpoint(s) to ensure delivery of the validated dose. Importantly, reactors must also be operated within the validated range of flow rates and lamp statuses (i.e., the "validated operating conditions") [40 CFR 141.720(d)(2)].

One key characteristic of the UV Intensity Setpoint Approach is that water systems ***need not monitor UVT*** during operations to confirm dose delivery. Instead, the approach relies on UV intensity readings by UV sensors to account for changes in UVT. In order for UV sensors to efficiently monitor dose delivery, they should be as close as possible to the "ideal" location. This means that they should be positioned so that the UV intensity is proportional to the UV dose, irrespective of changes in UVT and lamp output. If the sensor is too close to the lamp, changes in lamp output will disproportionately impact the measured UV intensity. If the sensor is too far from the lamp, changes in UVT of the water will disproportionately impact the measured UV

[5] Systems must monitor flow rate, lamp status, and UV intensity, plus any other parameters required by the state at a minimum to show that a reactor is operating within validated conditions [40 CFR 141.720(d)(3)(i)].

intensity. Water systems can check if sensors are in the ideal location by reviewing validation test data. (See Chapter 5.)

The recommended validation protocol in Chapter 5 will produce conservatively high UV intensity setpoint(s) under many water quality and lamp output conditions if the sensor is not in the ideal location, resulting in overdosing during operations. In some cases, UV manufacturers have developed modifications to the UV Intensity Setpoint Approach to account for non-ideal sensor placement.

Water systems can use one of the following operating strategies for the UV Intensity Setpoint Approach: single-setpoint operation or variable-setpoint operations. Table 3.7 describes these operating strategies and summarizes the advantages and disadvantages of each.

Table 3.7. Advantages and Disadvantages of Single-setpoint and Variable-setpoint Operations for the UV Intensity Setpoint Approach

Operating Strategy	Description	Advantages	Disadvantages
Single-setpoint	One UV intensity setpoint is used for all flow rates that were validated	Simplest to operate and control	When flow rate is variable, not energy efficient under most conditions because reactor is overdosing at low flow rates
Variable-setpoint [1]	The UV intensity setpoint is determined using a lookup table or equation for a range of flow rates	Lamp output can be reduced at low flow conditions to reduce energy costs	More validation data are needed. More complex operation compared to single-setpoint approach. Necessitates more advanced UV reactor monitoring and control.

[1] For the purposes of this guidance manual, variable-setpoint operations refers to variations based on flow rate only, as this is the most common application. In theory, multiple setpoints could also be established for different lamp statuses and UVT ranges.

3.5.2.2 Calculated Dose Approach

The Calculated Dose Approach uses a ***dose-monitoring equation*** to estimate the UV dose based the parameters measured during reactor operations. The most common operational parameters in dose-monitoring equation are:

- Flow rate,
- UV intensity, and
- UVT

Some manufacturers also consider lamp status as a variable in the dose-monitoring equation.

UV manufacturers may develop a theoretical dose-monitoring equation using numerical models (e.g., computational fluid dynamics [CFD]). Although the theoretical equations can be used as a starting point, EPA strongly recommends that water systems use an empirical dose-monitoring equation developed through ***validation testing***. To generate the empirical dose-monitoring equation, validation tests are performed over a wide range of flow rates, UVT values, and lamp power combinations. Regression analysis is used to fit the observed validation data to an equation. Chapter 5 of this manual provides detailed guidance on how to derive an empirical dose-monitoring equation through validation testing.

During reactor operations, the UV reactor control system (i.e., the internal reactor electronics) typically inputs the measured parameters into the dose-monitoring equation to produce a calculated dose. The system operator divides the calculated dose by a Validation Factor that accounts for uncertainties and biases to determine the validated dose.[6] The operator compares the validated dose to the required dose for the target pathogen and log inactivation level.

3.5.2.3 Advantages and Disadvantages

The principal operating advantage of the UV Intensity Setpoint Approach compared to the Calculated Dose Approach is that UVT monitoring is not needed to confirm dose delivery. Another important advantage is that the UV Intensity Setpoint Approach, single-setpoint operation is straightforward and simple to control with one operational setpoint and one maximum value for flow rate. For these reasons, EPA believes this option is good for small water systems. Other advantages are that the UV Intensity Setpoint requires fewer validation tests than the Calculated Dose Approach and data analyses are relatively straightforward. Data analyses to develop the dose-monitoring equation for the Calculated Dose Approach can be complex.

Water systems may favor the Calculated Dose Approach over the UV Intensity Setpoint Approach because it offers significant flexibility to reduce operating costs by manipulating lamp power (e.g., turning off banks of lamps or powering down lamps when the UVT increases and/or the flow rate decreases). This process is also called "dose pacing." Another potential advantage is that operations are more intuitive because the calculated dose, adjusted for uncertainties and biases, can be directly compared to the required dose for the target pathogen and log inactivation.

Manufacturers may favor the Calculated Dose Approach because they have more flexibility in UV sensor positioning (i.e., because internal analyzers monitor UVT during operations instead of relying on sensors to respond to changes in UVT, positioning sensors as close as possible to the "ideal" location offers no advantages). As noted in Section 3.5.2.1, UV Intensity Setpoint Approach operations will be more efficient if the UV sensors are at or near the ideal location.

6 In some cases, the UV reactor control system will perform this step as well, outputting the validated dose automatically.

3.6 Assessing UV Equipment Validation Issues

For disinfection credit, the LT2ESWTR requires UV reactors to be validated [40 CFR 141.720(d)]. A water system's approach to UV reactor validation and to UV facility design is interrelated. The issues to consider are whether equipment will be validated on-site or off-site and the hydraulic conditions of the UV reactor validation and installation. This section describes how these issues affect the design and the relationship between the validation and hydraulic installation approaches. Chapter 5 details the UV reactor validation guidelines.

3.6.1 Off-site Versus On-site Validation

UV reactors can be validated either off-site or on-site. With off-site validation, the UV reactors are validated before installation (i.e., pre-validated), typically at a third-party validation test center or a UV manufacturer facility. With on-site validation, the UV reactors are validated at the PWS after they have been installed. Many PWSs will use off-site validation to meet the LT2ESWTR requirements. In some cases, however, on-site validation may be appropriate (e.g., when the full UVT range was not tested in off-site validation). The advantages and disadvantages of off-site and on-site validation are presented in Table 3.8.

Table 3.8. Advantages and Disadvantages of Off-site and On-site Validation

	Advantages	Disadvantages
Off-site	• Broader ranges of flow and water quality are tested so a reactor can be validated for more than one application • Installation hydraulics are general, allowing for installation at most WTPs • Process is simpler for utilities because testing is conducted at a remote location • Cost is usually lower • Reactor performance is known before facility is designed and constructed	• Re-validation or additional on-site validation testing may be necessary if site-specific hydraulics and water quality are not within the tested ranges • Water quality and hydraulics may not match the installation location, potentially resulting in less efficient operation
On-site	• Exact hydraulics of the installation are used • Water quality tested is specific to the installation • Having provisions for on-site testing (e.g., feed and sample ports and static mixers) enables flexibility for future testing to optimize performance	• Facility may be designed and constructed before reactor performance is verified • Water quality is limited to the highest UVT at the facility during the testing period • Testing logistics can be complex, including isolation of the test reactor, assessment of additive mixing, and challenge microorganism stability • Cost may be higher • Disposal of test water may require special permits

The PWS should determine whether off-site or on-site validation will be used to meet the LT2ESWTR requirements. If on-site validation is preferred, the UV facility design should be adapted to enable testing. The UV reactor design should incorporate feed and sample ports, static mixers, space for tanks near the UV facility for adding the challenge microorganism and UV absorbing chemical, and a method to discharge the validation test water. If off-site validation is preferred, the UV facility need not incorporate provisions for on-site validation testing.

If pre-validated reactors that were validated off-site are chosen, the PWS should confirm that the validation hydraulic recommendations in Section 3.6.2 can be met without additional on-site validation or PWS-specific off-site validation.

3.6.2 Validation and Installation Hydraulics Recommendations

The inlet and outlet piping to the UV reactor in the UV facility should result in a UV dose delivery that is equal to or greater than the UV dose delivered when the UV reactor was validated. If off-site validation is used, the three preferred options for meeting this condition are presented below.

1. **Minimum five pipe diameters of straight pipe upstream of UV reactor:** The length of straight pipe upstream of each UV reactor at the UV facility is the length of straight pipe used in the validation testing plus a minimum of five (5) pipe diameters. During validation testing, the inlet piping to the reactor consists of either a single 90-degree bend, a "T" bend, or an "S" bend, followed by a length of straight pipe if necessary. See Figure 3.7 for validation and installation configuration options.

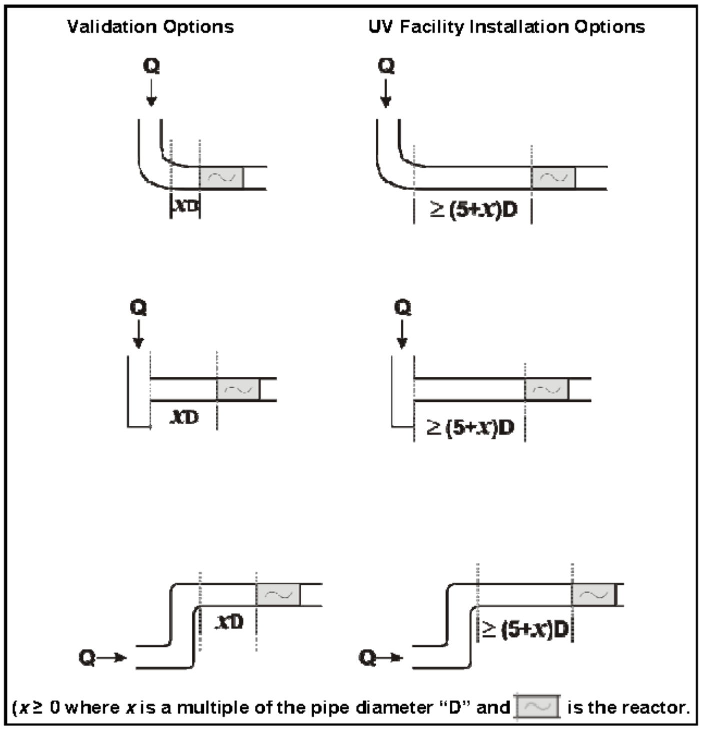
2. **Identical inlet and outlet conditions:** Inlet and outlet conditions used during validation match those used at the WTP for at least ten (10) pipe diameters upstream and five (5) pipe diameters downstream of the UV reactor.

3. **Velocity profile measurement:** Velocity of the water measured at evenly spaced points through a given cross-section of the flow upstream and downstream of the reactor is within 20 percent of the theoretical velocity with both the validation test stand and the WTP installation (NWRI 2003). The theoretical velocity is defined as the flow rate divided by the cross-sectional area.

Jetting and swirling flow will impact the assumptions for Options 1 and 3. To avoid jetting flow, the inlet piping should have no expansions for at least ten (10) pipe diameters upstream of the reactor. Also, any valves located in that length of straight pipe should always be fully open during UV reactor operation. To avoid swirling flow, the validation piping should not include two out-of-plane 90°-bends in series.

The most suitable validation option depends on the site-specific layout and piping constraints and on the validation data. Option 1 is more generally applicability for validation and installation of UV reactors. For example, the inlet and outlet piping configuration for installations in a new building could be designed based on how the procured UV reactor was validated. Option 2 is most applicable when unique piping configurations are needed or if the inlet and outlet conditions validated in Option 1 cannot be achieved because of site constraints. For example, Option 2 may be the only validation option for an individual filter effluent location, which likely will not have 5 diameters of straight pipe before the UV reactors (Option 1) because of existing site constraints. Option 3 also provides flexibility but may have the practical limitation of measuring the velocity through a cross-section at the installation.

Figure 3.7. Schematic of Hydraulic Option #1 (90°-Bend, T-Bend, S-Bend Inlet Piping Scenarios)



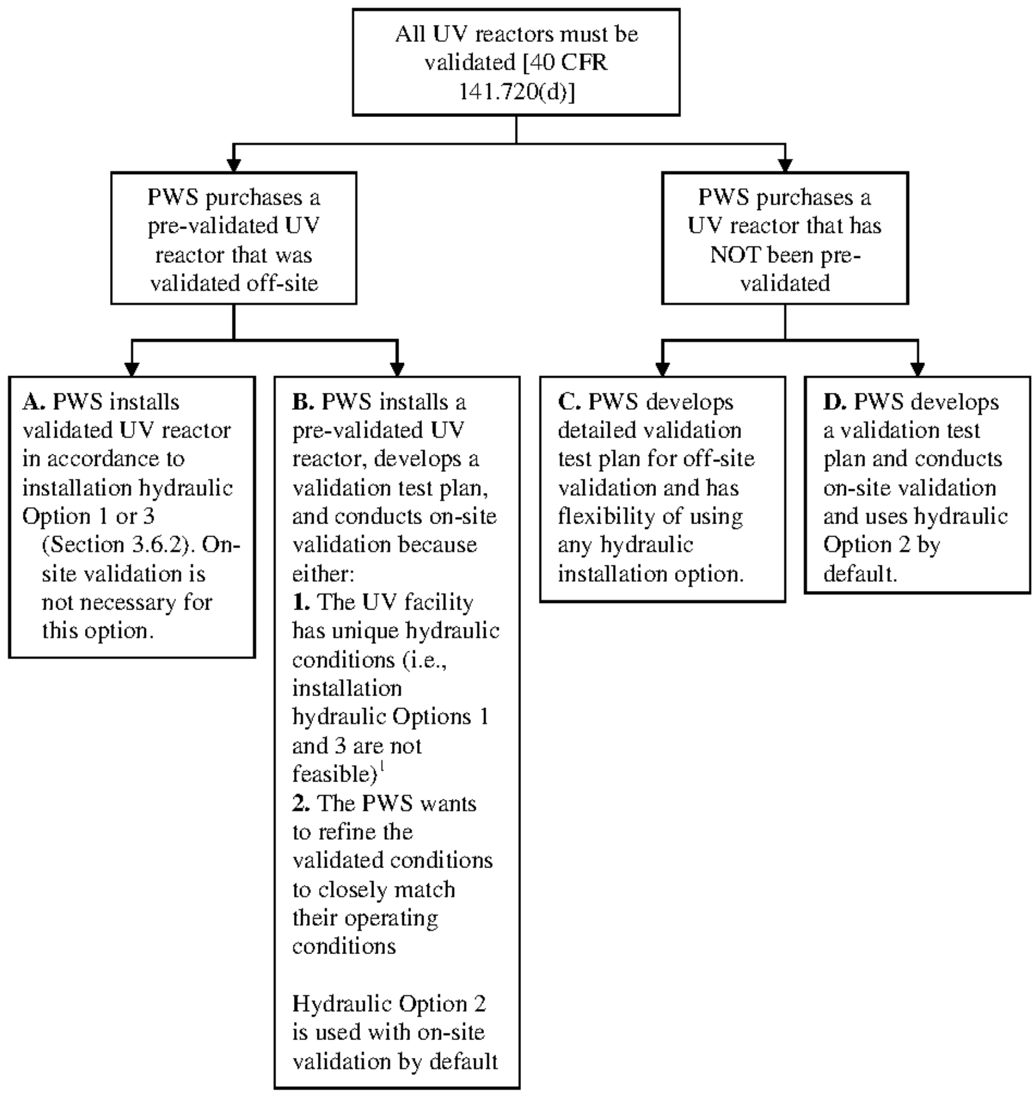
If available, the validation report for pre-validated UV equipment under consideration should be reviewed to determine what the inlet/outlet conditions were during validation, which will help determine if Option 1 is feasible. The method for meeting these recommended inlet/outlet constraints should be determined in the planning stage and considered when developing the UV facility layout (Section 3.8.2).

CFD modeling and CFD-based UV dose modeling of inlet and outlet conditions may be used to assess whether UV dose delivery at the WTP installation is better than UV dose delivery achieved during validation for given conditions of flow rate, UVT, and lamp output. The state should approve such models and their reliability should be properly evaluated before their results are accepted. Appendix D provides guidance on evaluating CFD models.

3.6.3 Selection of Validation and Hydraulic Approach

Whether or not the UV reactor was pre-validated off-site affects the inlet/outlet piping options for the UV facility. Completing on-site validation provides more inlet/outlet piping flexibility, but on-site validation means additional design considerations and testing at the water treatment plant. If the selected UV equipment is not pre-validated, the PWS can choose either off-site or on-site validation based on their site-constraints and preferences. These options are described in Figure 3.8.

Figure 3.8. UV Reactor Validation Options and How They Affect Installation Hydraulics



[1] PWS could contract with an off-site validation center to perform validation testing with specific hydraulic conditions rather than perform on-site validation.

3.7 Assessing Head Loss Constraints

When selecting a feasible location for UV reactors, the hydraulic requirements should be met. Head loss through a UV reactor is specific to the equipment and flow rate and generally varies from 0.5 – 3 feet (UV reactor only). Characteristic head loss data should be obtained from the UV manufacturer(s) for all candidate UV reactors. In addition to the head loss associated with the UV reactor itself, the head loss associated with piping, valves, flow meters, and flow distribution devices (e.g., baffles) should be considered when assessing the feasibility and location of the installation. When selecting a reactor that has been validated off-site (Options A of Figure 3.8), the UV reactor inlet/outlet piping used to estimate the head loss through the facility should be consistent with the validation recommendations described in Section 3.6.2. The head loss through the entire UV facility (i.e., piping, valves, joints, and UV reactors) can be between 1 and 8 feet.

If the head loss through the UV facility is greater than the available head, the plant design or operation, or both, may require modification. Some potential modifications, alone or in combination, that may be considered to address hydraulic limitations are listed below, and details for each are provided in the sections that follow:

- Eliminating existing hydraulic inefficiencies within the facility to improve head conditions (e.g., replacing undersized or deteriorated piping and valves)
- Modifying the operation of the clearwell
- Modifying the operation of the filters
- Installing intermediate booster pumps
- Modifying the operation of the HSPs

3.7.1 Eliminating Existing Hydraulic Inefficiencies

Replacing undersized piping and valves with larger diameter piping and valves may increase the available head for the proposed UV facility. Older piping can also produce excessive head loss if the inner pipe surface is pitted or scaled or if the pipe material has a high coefficient of friction. Slip-lining the interior of existing pipe with material having a lower coefficient of friction (e.g., high-density polyethylene) is one method of reducing friction losses. Re-lining the existing pipe interior with a smooth coating will also reduce head loss.

3.7.2 Modifying Clearwell Operation

A PWS may increase head available to a UV facility by lowering the surface water level of the clearwell. This strategy, however, decreases the storage volume available to meet peak demands, reduces the contact time available in the clearwell for chemical disinfectants, and may affect the pump discharge head and distribution system pressure. Evaluating any potential reduction in disinfection credit is important if contact time in the clearwell is used for calculating chlorine disinfectant requirements (i.e., CT). The UV facility, however, may reduce the *Giardia* CT requirements sufficiently to offset the reduction in CT.

3.7.3 Modifying Filter Operation

A treatment facility can alter the operation of its filters (e.g., increase the water elevation above the filters) to increase the head available for the UV facility. This approach, however, can reduce filter run times and reduce unit filter run volumes, resulting in a need for more frequent backwashing. If conditions upstream of the filters are such that additional freeboard and hydraulic head are available, a second option is to increase the water surface elevation above the filters to help minimize the reduction in head as the water is filtered.

3.7.4 Installing Intermediate Booster Pumps

When modifications to the existing facility or operations do not provide adequate head for the UV reactors, intermediate booster pumps can be installed. Booster pumping increases flexibility in locating the UV reactors. Installing booster pumps, however, increases facility operation and maintenance costs and space requirements. The reliability of the pumps should also be considered in the evaluation because they become a critical operating component. More information on intermediate booster pumps is presented in Section 4.1.6.

3.7.5 Modifying Operation of HSPs

When UV disinfection is installed close to the HSPs (e.g., after the clearwell in a filtration plant or after an unfiltered reservoir), one option to increase the head available for the UV facility is to modify the pumping operation of the HSPs. Modifications may not be practical, however, if they change the distribution system pressure.

3.8 Estimating UV Facility Footprint

The process footprint should be estimated in the planning phase to help determine feasible UV facility locations. The critical components for estimating the UV facility footprint are UV equipment constraints and UV facility layout.

3.8.1 UV Equipment Constraints

The UV equipment constraints that affect the footprint estimation are the number of UV reactors needed to meet the design criteria, the UV reactor orientation, and the control panel location constraints.

- **Number of UV reactors:** The number of UV reactors depends on the redundancy chosen and the power modulation capabilities of the UV reactor. UV reactor redundancy should be determined using sound engineering approaches similar to those used for other major equipment (e.g., capacity to provide full treatment with the largest UV reactor out-of-service). The ability of the UV equipment to modulate lamp power or change the number of lamps energized also should be considered, so that energy efficient operation is possible at the operating range of flows and UVTs expected for the UV reactors. The UV manufacturer should be contacted to determine a particular UV reactor's power modulation capabilities.

- **UV reactor orientation:** UV reactors can be oriented either parallel or perpendicular to the ground. Two advantages of vertical orientation (i.e., flow perpendicular to the ground) are that (1) the footprint will be smaller and (2) the potential for lamp breaks due to debris may be reduced (as described in Appendix E).

- **Control panel location constraints:** Maximum allowable separation distance between the UV reactors and electrical controls should be considered in the UV facility layout and footprint estimation. This information is unique to each UV reactor and should be obtained from the UV manufacturer.

- **Validation hydraulic restrictions:** Section 3.6.2 describes how the validation piping configuration can dictate the possible UV facility piping configurations.

3.8.2 Develop UV Facility Layout

The UV facility layout is dictated by site constraints and the UV equipment constraints described in the previous section. The following items should be considered when developing the UV reactor and piping configuration and estimating the UV facility footprint in the planning phase:

- Number, capacity, dimensions, and configuration of the UV reactors (including redundancy and connective piping)

- Vertical or horizontal orientation of the UV reactor

- Maximum allowable separation distance between the UV reactors and electrical controls if distance limitations apply

- Adequate distance between adjacent reactors to afford access for maintenance tasks (e.g., lamp replacement)

- Configuration of the connection piping and the inlet/outlet piping necessary before and after each UV reactor, based on validated hydraulic conditions (see Section 3.6.2) and UV manufacturer recommendations

- Space and piping for booster pumps and wetwells (if necessary)

- Space for electrical equipment, including control panels, transformers, ballasts, backup generators, and possible uninterruptible power supplies

- Room for storing spare parts and chemicals (if needed)
- Lifting capability for heavy equipment
- Provisions for on-site validation (if applicable)

The dimensions of UV reactors and associated electrical equipment vary depending on the UV manufacturer. Installation footprint and layout should therefore be estimated for all UV manufacturers being considered. Once the UV facility footprint is estimated, feasible site locations can be determined based on the available land and buildings.

3.9 Preparing Preliminary Costs and Selecting the UV Facility Option

The amount of analysis necessary to determine the appropriate application point for a UV facility is site-specific. Some options clearly will be infeasible, while others may necessitate a more detailed comparison of the installation options. Once feasible alternatives are identified, development of life-cycle costs and consideration of the non-monetary factors (e.g., ease of UV facility operation) can be useful in selecting among alternatives.

Preliminary life-cycle cost estimates should include capital costs and operation and maintenance (O&M) costs. Capital costs include the cost of the UV reactors; building (if necessary); piping; pumping (if necessary); electrical and instrumentation provisions; site work; contractor overhead and profit; pilot-testing (if necessary); validation costs; and engineering, legal, and administrative costs. The O&M costs should include the estimated labor, energy, and equipment replacement costs. The LPHO equipment and MP equipment have different O&M needs (Section 3.5.1) that should be considered in the O&M costs.

Selection of the best option should be based on the disinfection and design objectives and consideration of the following and other PWS-specific criteria:

- Cost-effectiveness and ability to meet the water system's disinfection and design objectives
- Ease of installation (where applicable)
- Operational flexibility and reliability
- Specific maintenance needs
- Flexibility for future treatment expansion (if applicable)

3.10 Reporting to the State

Interaction with the state throughout the planning and design phases is recommended to ensure that the objectives of both the PWS and the state are met. This interaction may require several months and can have a significant effect on the implementation schedule, particularly when the state requires modifications. Given the relatively limited use of UV disinfection in the

United States to date, drinking water treatment, and the unique technical characteristics of this technology, state agencies may not have developed approval requirements specifically for UV disinfection. As such, PWSs are urged to consult with their state early in their UV disinfection planning process to understand the approvals and documentation that will be required for the use of UV disinfection.

The state may require that a preliminary design report be submitted that summarizes the decision logic used to identify, evaluate, and select UV disinfection. The following items may be addressed in the preliminary design report:

- Disinfection objectives (target organism and inactivation)
- Overall disinfection strategy
- Summary of reasons for incorporating UV disinfection
- Description of the overall process train
- Description of the proposed UV reactors
- Water quality data
- Design criteria
- Validation Test Plan (if performing on-site or off-site validation- See Section 5.11 for guidance on developing a Validation Test Plan)

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4. Design Considerations for UV Facilities

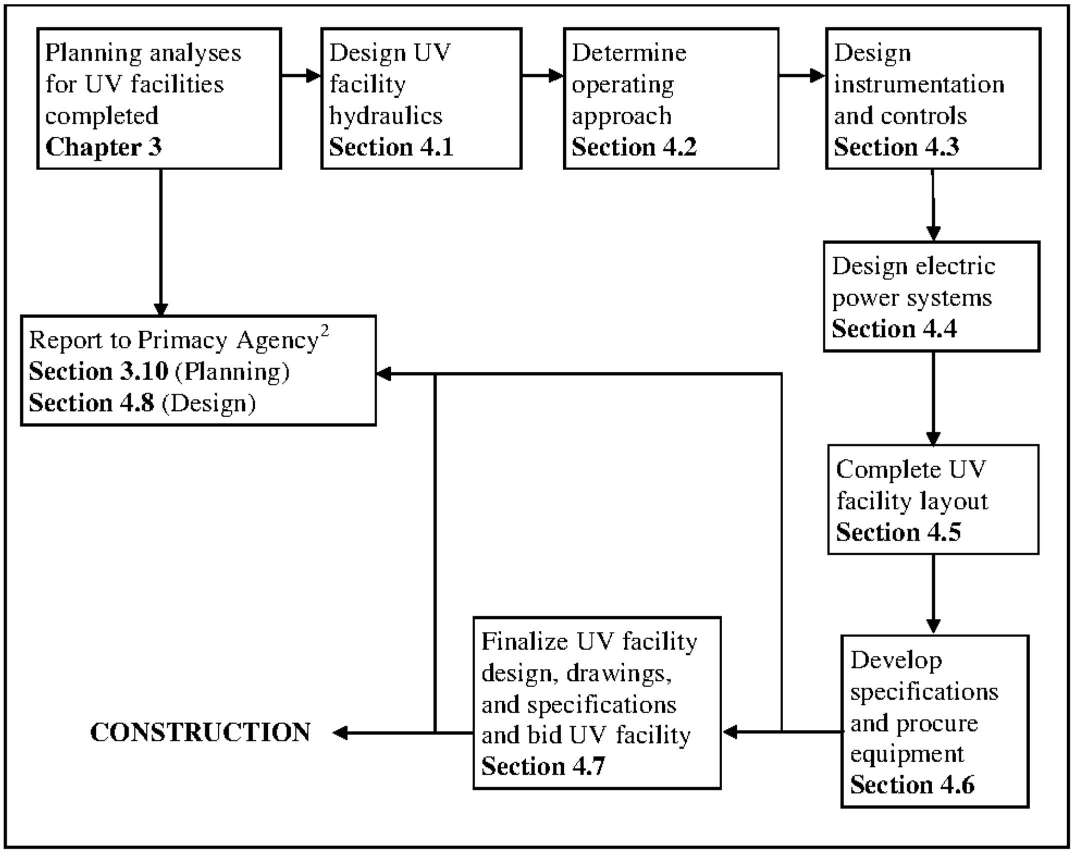
This chapter presents the key factors that should be considered during the detailed design phase and is written under the premise that the necessary planning and evaluation work discussed in Chapter 3 has been completed. This chapter focuses primarily on the design of UV disinfection applications for filtered surface water. Most of the information presented, however, also applies to unfiltered systems, groundwater under the direct influence (GWUDI), and uncovered finished water reservoirs. Additional design issues specifically associated with unfiltered, GWUDI, and uncovered finished water reservoir systems are also described.

Chapter 4 covers:

In the United States, most public water systems (PWSs) purchase or select the UV equipment before the UV facility design is complete. Pre-purchase or pre-selection of the UV equipment enables the designer and the UV manufacturer to coordinate during the detailed, final design phase to consider manufacturer-specific design recommendations. Sometimes the equipment is pre-selected and the UV equipment manufacturer is included in the construction contract. Other procurement methods (e.g., base-bid and contractor selection of equipment) are also used, but these methods are less common.

The process for designing a UV facility is presented as a flowchart in Figure 4.1. The illustrated process is based on pre-purchasing or pre-selecting the UV equipment using a traditional design-bid-build approach. Any of the equipment procurement and contractor selection approaches currently available within the industry, however, can be used to build UV facilities. The PWS and the engineer are responsible for selecting the most appropriate approach for their specific project. The order of the steps for other procurement approaches may differ from that shown in Figure 4.1, but the analyses completed are likely to be very similar. The steps described in this chapter follow the order presented in Figure 4.1. Some states may have design and plan review requirements that could impact the timing or sequence of steps shown in Figure 4.1. The appropriate state regulatory agency should be contacted early in the design process to discuss specific design requirements, plan review fees, and review scheduling.

Figure 4.1. Flowchart for Planning, Design, and Construction of UV Facilities[1]



[1] Flowchart is based on pre-purchase of UV reactors that have undergone validation testing and equipment installation using a traditional design-bid-build approach.

[2] Additional state coordination may be necessary.

4.1 UV Facility Hydraulics

After the facility location and UV equipment are selected during the planning phase, a more detailed evaluation of system hydraulics for the UV facility layout developed in Section 3.8 should be conducted. In most cases, the UV facility will be designed with multiple, parallel UV reactor trains of the same capacity. Each train consists of the lateral piping, UV reactor, valves, and flow meter (if applicable) and is joined to the other trains by the distribution and recombination channel or manifold. The hydraulic evaluation should include upstream and downstream processes for free water surfaces, the inlet/outlet piping configuration, flow control and distribution, flow rate measurement, level control, air and pressure controls, valving, and, where applicable, intermediate booster pumps.

4.1.1 Inlet and Outlet Piping Configuration

The recommended inlet and outlet conditions for validation and for the UV facility are described in detail in Section 3.6.2. If validation is conducted at an off-site testing facility, the designer should refer to the validation report to determine the validated inlet and outlet conditions, and then use the recommendations in Section 3.6.2 to determine the recommended inlet and outlet piping for the UV facility. If on-site validation or custom off-site validation is planned, the inlet and outlet hydraulics should be designed according to manufacturer recommendations and to accommodate any site-specific constraints. In addition, to avoid jetting flow, the inlet piping should have no expansions for at least ten (10) pipe diameters upstream of the reactor.

4.1.2 Flow Distribution, Control, and Measurement

Regulations specify flow rate, UV intensity, and lamp status as the minimum operating conditions that a PWS must routinely monitor [40 CFR 141.720(d)(3)]. Accordingly, proper flow distribution and measurement are essential for compliance monitoring of the UV reactors. This section discusses various methods for designing proper flow distribution and measurement through the UV reactors.

4.1.2.1 Flow Distribution and Control

The lateral piping for each UV reactor train should be sized and configured to provide approximately equal head loss through each UV reactor train over the range of flow rates. Importantly, flow rate through each reactor must conform to the validated operating conditions, [40 CFR 141.729(d)] as described in the validation report.

Two approaches for flow distribution and control are generally used. The first is active flow control and distribution, in which a dedicated flow meter and modulating control valve are installed for each UV reactor. Active flow control provides the greatest hydraulic control in applications with widely varying flow rates. The second method is passive flow distribution. For the passive approach, equal flow split is monitored with flow meters.

For PWSs that use distribution and recombination channels (instead of influent and effluent manifolds), designers typically have two basic choices to achieve passive flow distribution (Figure 4.2): (1) a series of individual weirs set at the same elevation or (2) a series of orifices submerged in the individual UV reactor laterals.

4.1.2.2 Flow Rate Measurement

The method of flow rate measurement selected should be based on the variability in plant flow rate, the type of flow split used, and any state requirements. Selection of the flow rate measurement method should be at the discretion of the PWS and the design engineer based on experience and professional judgment. Generally, each UV reactor should have a dedicated flow meter (as described in Table 4.1) to confirm that the reactor is operating within the validated flow rate. The state, however, may approve other methods (e.g., one flow meter coupled with pressure differential measurements).

Figure 4.2. Open-channel Flow Distribution Options

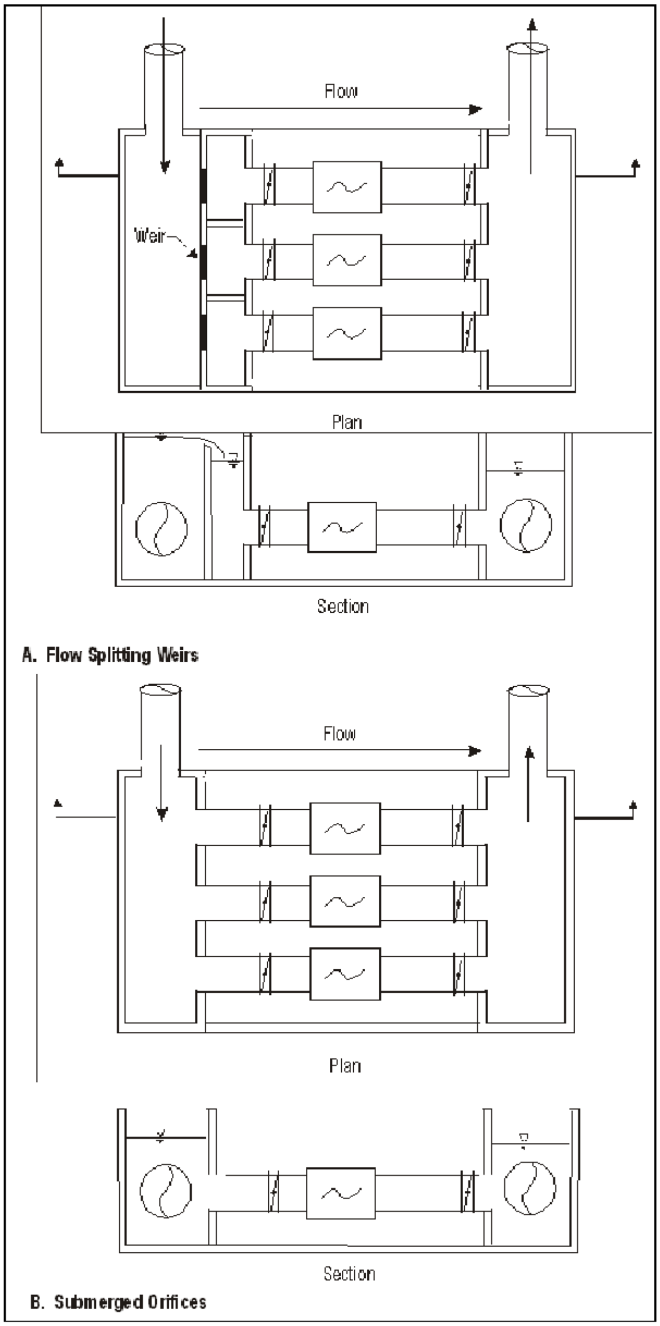


Table 4.1. Comparison of Techniques for UV Facility Flow Rate Measurement for Combined Filter Effluent and Post-clearwell UV Facilities [1]

Flow Rate Measurement Method	Flow Control Method	Advantages	Disadvantages
Individual UV Reactor Flow Rate Measurement	Passive flow control such as a weir or an orifice	• Measures individual UV reactor flow rates accurately	• May have unequal flow distribution • Cannot control the UV reactor flow rate
Individual UV Reactor Flow Rate Measurement and Control	Individual flow control (valve) for each UV reactor	• Measures individual UV reactor flow rates accurately • Does not rely on passive flow distribution	• Increases capital cost • May increase facility footprint due to hydraulics of UV reactor, meter, and valves

[1] For individual filter effluent installations, the flow rate from the filters can be used to determine the flow rate through the UV reactors.

When selecting a flow meter, the flow meter's effect on the inlet/outlet hydraulics of the UV reactor should be considered. Magnetic or other types of flow meters (such as Doppler) that do not protrude into the flow path exert the least effect on the velocity profile, which minimizes the potential effect on reactor inlet or outlet hydraulics.

4.1.3 Water Level Control

The UV lamps in the UV reactor should be submerged at all times to prevent overheating and UV equipment damage. This is accomplished by installing the UV reactors at an elevation below the hydraulic grade line elevation. Two common methods for keeping the UV lamps submerged are to:

1. Install a flow control structure (e.g., weir or orifice) immediately downstream of the UV reactor or at another location that ensures full pipe conditions through the UV reactors.

2. Use flow control valves to monitor and maintain the hydraulic grade line.

Damage to UV lamps caused by operation in air is specific to each lamp type and size. Low-pressure (LP) lamps can typically operate in air for up to 24 hours with minimal damage. Low-pressure high-output (LPHO) lamps will begin experiencing damage as a result of dislodged amalgam or mercury adsorption to the inner surface of the lamps in 6 – 12 hours (Lawal 2006). Medium-pressure (MP) lamps can experience advanced aging or solarization in fewer than 6 hours and can break (see Appendix E).

4.1.4 Air Relief and Pressure Control Valves

UV reactors should be kept free of air to prevent lamp overheating. Negative gauge pressures or surge effects within the UV reactors should also be prevented to avoid damage to the lamps and lamp sleeves. Quartz sleeves are designed to accommodate continuous positive pressures of at least 120 pounds per square inch gauge (psig) but have been shown to break at negative pressures of 1.5 (Roberts 2000, Aquafine 2001, Dinkloh 2001). Negative pressures can result from line breaks or accidental dewatering of the reactor. The use of air release valves, air/vacuum valves, or combination air valves may be necessary to prevent air pockets and negative gauge pressure conditions. The UV manufacturer should be contacted to determine any equipment-specific air release and pressure control valve needs. The valve locations will be dictated by the specific configuration of the facility and should be determined during design.

4.1.5 Flow Control and Isolation Valves

Each UV reactor should be capable of being isolated and removed from service. Isolating or shutting down a UV reactor will require valves, gates, or similar devices upstream and downstream of the UV reactor. Valves are recommended because they provide a tighter seal. During design, the inlet and outlet valve configuration should be discussed with the UV manufacturer to ensure that UV reactor performance will not be adversely affected and that the required inlet conditions used during validation are met, as discussed in Section 3.6.

If the isolation valves are also used for flow control, the flow control valve should be located downstream of the UV reactor to limit the disturbance of the flow entering the UV reactor. Valves downstream of the UV reactor can be equipped with an actuator to open or close automatically on a critical alarm occurrence and to enable start-up sequencing.

Valve seats and other in-pipe seals and fittings within the straight pipe lengths adjacent to the UV reactors should be constructed of materials that are resistant to UV light and chemicals that may be used for reactor cleaning. Resistant materials will help avoid valve degradation.

4.1.6 Installation of Intermediate Booster Pumps

A detailed evaluation and design of a booster pumping system is recommended if head constraints indicate a pumping system is necessary. Pumps common in water treatment plants (i.e., vertical turbine, end-suction centrifugal, and split-case centrifugal pumps) tend to have higher discharge pressures than needed for intermediate pumping applications and are generally not appropriate. Mixed- or axial-flow pumps with high-flow and low-head operating characteristics are usually better choices for intermediate pumping applications because typically only 1 – 8 feet of additional hydraulic head is needed to overcome the head loss through the UV facility.

Pumps can be installed before or after the UV reactors, allowing more flexibility in the UV facility's design elevations and the location of the UV reactors. Regardless of pump location, some form of wetwell should be provided upstream of the pump station. Existing clearwells, recombination channels, or dedicated pump wetwells may be used.

Booster pump operation may be controlled by the water level within the upstream wetwell. The use of variable frequency drives or a rate-of-flow controller with a modulating valve to dampen flow rate peaks is recommended, especially if the pump station is upstream of the UV reactors. By minimizing hydraulic peaks, the UV reactors can be sized to more closely match the flow rate through the water treatment plant (WTP).

4.1.7 Evaluating Existing Pumps and Potential Water Hammer Issues

In some WTPs, the most feasible location for installing the UV reactors may be immediately upstream or downstream of existing high-service pumps (HSPs) (Section 3.3.1.3). The HSP discharge curves should be analyzed to determine the effect of the increased head loss through the UV reactors and whether HSP modifications are necessary.

If pumps are located adjacent to the UV reactors, the impact of surge conditions should be evaluated. Of particular concern is the potential for surge if the pumps are operating and power is lost. Pump start-up procedures should be carefully defined, including procedures for pump control valves. Control of individual UV reactor isolation valves should be coordinated with pump starts and stops and with pump control valves where appropriate. Likewise, the warm-up time associated with the start-up of the UV reactors should be taken into account with the sequencing of the pump operation.

4.1.8 Groundwater System Hydraulic Issues

Common hydraulic issues associated with groundwater systems include high operating pressures, air entrainment, and the potential for water hammer events.

Lamp sleeves are designed to resist high external operating pressures. Before selecting equipment, however, the designer should determine the maximum expected operating pressure, which may occur during a failure event (e.g., downstream valve closes), and confirm that the proposed equipment can withstand that pressure.

Pressure surge events (water hammer) near the UV reactor may be more likely with groundwater systems than surface water systems because of the UV reactor's proximity to the well pumps. Surge events can cause positive or negative pressure transients in the well discharge piping and potentially break the sleeves and lamps. A surge analysis is recommended to determine if surge protection is necessary. Many well sites and distribution systems are already equipped with surge control tanks to dampen surge effects. These tanks may provide sufficient protection for the UV reactors, depending on their location relative to the UV reactors.

Air binding can interfere with the UV disinfection process or cause the lamps to overheat. UV reactors should be located downstream of any existing or planned air removal equipment (if necessary). Otherwise, the UV facility design should include a means for automatically releasing air prior to the UV reactor. The UV reactor may have air release valves or valve ports, or air release valves can be installed in the inlet piping.

4.1.9 Uncovered Finished Water Reservoir Hydraulic Issues

Many uncovered finished water reservoirs serve as distribution storage and are directly affected by the water system demand. Others may be used solely as an emergency supply or may function as both distribution storage and emergency supply. The specific hydraulic considerations that a PWS and designer should consider will vary depending on the function of the uncovered finished water reservoir. Regardless of reservoir function, however, specific hydraulic issues that should be considered when designing UV facilities at uncovered finished water reservoirs include widely varying flow rates, bi-directional flow (under certain piping configurations), and the effect a UV facility will have on system pressure.

- **Variable flow rate:** The methodology described in Section 3.4 should be followed to determine the flow rate and UVT that are used to design the UV facility. Most UV facilities at uncovered finished water reservoirs should be designed to handle the peak instantaneous demand that must be met by the reservoir. The instrumentation and control (I&C) design must consider how the PWS will sequence the UV reactors with highly variable flow conditions, especially warm-up times for UV lamps (Section 2.4.2.3).

- **Bi-directional flow:** In some cases, the inlet and outlet to the uncovered finished water reservoir is the same pipe, and the UV facility should be designed so that disinfection continues when the water is flowing from the uncovered finished water reservoir. The PWS may also consider operating the UV reactors at a minimum level as the water flows into the reservoir so that the UV lamps are energized and ready for UV disinfection if the flow direction changes suddenly. The necessity for this latter approach depends on the number of directional changes per day in the context of meeting off-specification requirements.

- **UV facility effect on system pressure:** As discussed in Section 3.7, head loss through a UV reactor generally varies from 0.5 to 3 feet, with the overall head loss through a UV facility typically about 1 to 8 feet. This head loss could affect the distribution system pressure. As discussed in Chapter 3, a hydraulic assessment should be completed to determine if head loss constraints occur for the UV facility or if booster pumping is needed.

4.2 Operating Approach Selection

The operating approach is the method of operating a UV reactor based on the **dose-monitoring strategy (Section 3.5.2) and validation report data** and should be determined before the I&C design is complete. The operating conditions for each UV reactor must be based on validation testing results [40 CFR 141.720(d)(3)].

As described in Section 3.5.2, this guidance manual focuses on two dose-monitoring strategies: UV Intensity Setpoint Approach and Calculated Dose Approach. The UV Intensity Setpoint Approach can be used with a single or variable setpoint operation; variable setpoint operation allows for some energy savings. The Calculated Dose Approach typically uses a single setpoint (e.g., the required dose), and the UV equipment automatically compensates based on the UVT, UV sensor measurements, and flow rate, which increases energy savings.

When considering the dose-monitoring strategy and operating approach, the operational complexity should be compared to the potential for energy savings. The UV manufacturer should be contacted to determine the potential energy savings with the available dose-monitoring strategies and operating approaches. For small water systems, the UV Intensity Setpoint Approach with a single setpoint may be the best option because the energy savings with a more complex operating approach may not be worth the additional operational needs. Detailed examples of how to determine the operational setpoints from validation reports for these operating strategies are described in Section 6.1.4.

4.3 Instrumentation and Control

The necessary level of I&C depends on the selected techniques for flow control and distribution, flow rate measurement, and the operating approach. For example, passive flow distribution with the UV Intensity Setpoint Approach that uses a single setpoint is simple and demands limited I&C but may result in reduced operating flexibility and energy efficiency. More complex control strategies, such as the use of dedicated flow meters and flow control valves with the Calculated Dose Approach, necessitate a higher level of I&C, but improve operating flexibility and enable optimization of disinfection performance. The control system complexity and operating flexibility should be balanced to meet the needs of the PWS.

Most of the manufacturers' equipment has similar I&C attributes and alarm conditions incorporated in the UV reactor designs. The designer should identify the

- Elements that are preprogrammed in the UV reactor control panel
- Necessary supplemental controls to coordinate the operations of the UV reactor trains
- Actions necessary for each alarm condition.

At a minimum, UV lamp intensity, flow rate, and lamp status must be monitored (40 CFR 141.720(d)(3)). The final I&C design can be modified as needed after UV equipment is selected. The following sections describe the elements that should be considered in I&C design.

4.3.1 UV Reactor Start-up and Sequencing

This section describes the typical UV reactor start-up protocol, strategies for sequencing the start-up of multiple UV reactors, and considerations for groundwater UV facility start-up.

4.3.1.1 UV Reactor Start-up

The UV reactor start-up sequence depends on whether the UV reactor requires cooling water while the UV lamps warm up. Some reactors require cooling water (Leinberger 2005, Larner 2005) and some do not (Larner 2005, Bircher 2005). Without water flow, some UV lamps may heat the water above the safe operating temperatures of 30 – 49 °C in 2.5 – 15 minutes, causing the reactor's internal safety devices to shut the reactor off (Leinberger 2005, Bircher 2005). LP and LPHO reactors typically do not and some MP reactors do not need cooling water as the UV lamps are warming up (Haubner 2005). UV lamp breaks (discussed in detail in Appendix E) can occur if the lamps become overheated because of no flow or minimal cooling water flow. **The designer should consult the UV manufacturer to determine whether the UV reactor requires cooling water during start-up.**

The potential start-up sequences for UV reactors that do and do not need cooling water and are starting cold (i.e., previously off as opposed to shut down for a very short period) are summarized below:

- **UV reactors that do not require cooling water:** The potential control sequence will ignite the lamps, get the UV reactor to its validated conditions, and open the isolation valves. With this strategy, the UV reactor will be "on" for some time when no water is flowing through it. Flow should be established in the UV reactor within an hour to prevent fouling of the quartz sleeves.

- **UV reactors that do require cooling water:** The potential control sequence will open the isolation valves to allow the minimal cooling water flow, ignite the lamps, get the UV reactor to its validated conditions, and then fully open the isolation valves to allow the full flow through the UV reactor. The I&C should be designed to reduce the amount of off-specification water by providing the minimal flow necessary to keep the lamps cool during start-up. If the amount of off-specification water should be limited, methods are available to design the UV facility piping to minimize off-specification water (e.g., cooling water being diverted to waste).

For facilities that do not operate continuously, the designer should discuss the specific operating schedule with the manufacturer to identify any special provisions that should be included in the design or the operating procedures (e.g., automatic cleaning before each start-up, draining for extended periods of downtime).

4.3.1.2 UV Reactor Sequencing

UV facilities with multiple UV reactors should develop two types of UV reactor start-up sequences in I&C loop descriptions:

- **Routine operation:** The UV reactor sequencing should be developed based on the validated conditions and the operational approach.

- **Start-up after a power quality event:** The control system should monitor the power input to the UV reactors and the UV reactor status. LPHO and MP reactors have different start-up characteristics after a power quality event (Section 2.4.2.3) and should have different start-up sequences to minimize warm-up and corresponding off-specification time.

- **LPHO reactors** – UV reactors that were on-line (i.e., operating) before the power quality event and shut-down should be restarted first after normal power is restored.

- **MP reactors** – UV reactors that were off-line before a power quality event that shuts down UV rectors should be started first when normal power is restored.

4.3.1.3 Groundwater Pump Cycling Effects on UV Reactor Start-up

Groundwater well cycling can adversely affect UV reactor performance, causing an increase in off-specification water. An analysis should be performed to estimate off-specification volume based on the current well cycling frequency. The well cycling approach may need to be changed if off-specification requirements cannot be met under current well cycling frequency. Two approaches that can minimize the effects of well cycling, depending on whether the UV reactors require cooling water, are discussed below.

- **UV reactors that do not require cooling water:** A time delay can be incorporated in the I&C loops that prevents the well pump from starting until the UV reactor reaches its validated conditions. As described in Section 4.3.1.1, the UV reactor will be "on" for some time when no water is flowing through it.

- **UV reactors that do require cooling water:** The I&C programming would supply the minimum water flow through the UV reactor until the reactor reaches validated conditions. Then, the groundwater flow can be increased to meet system demand. If desired, the cooling water can be discharged to waste if site conditions permit.

4.3.2 UV Equipment Automation

UV equipment operation can range from manual to fully automatic, depending on the reactor's size and complexity. Manual operation includes manually initiating lamp start-up and shut-down, and activating the appropriate valves. Various levels and types of automation are typically part of the internal UV equipment controls and can be added to the manual sequence. A first level of automation includes the sequencing of lamp start-up and valve actuation to bring individual UV reactors on-line after manual initiation. Further levels of automation include starting UV reactors, activating rows of lamps, or making lamp intensity adjustments based on UV intensity, UVT, or flow rate. Automatic UV reactor shut-down under critical alarm conditions (e.g., high temperature, lamp or sleeve failure, loss of flow) is essential for all operating approaches, including manual operation.

4.3.3 Alarms and Control Systems Interlocks

Many UV reactor signals and alarms are specific to the UV facility and the level of automation used. Alarms may be designated as minor, major, or critical, depending on the severity of the condition being indicated.

- A **minor alarm** generally indicates that a UV reactor requires maintenance but that the UV reactor is operating in compliance. Minor alarms also can be set for conditions just short of failure conditions so that major alarm conditions are not reached. For example, a minor alarm would occur when the UVT is within 1 percent UVT of the minimum allowed UVT or when the end-of-lamp-life based on hours of operation is reached, indicating the possible need for lamp replacement.

- A **major alarm** indicates that the UV reactor requires immediate maintenance (e.g., the UV sensor value has dropped below the validated setpoint) and that the unit may be operating off-specification. Based on the water system's disinfection objectives, this condition may also be handled as a critical alarm.

- A **critical alarm** typically shuts the unit down until the cause of the alarm condition is remedied. An example of a critical alarm is the UV reactor's temperature exceeding a pre-determined maximum value, resulting in automatic shut-down to prevent overheating and equipment damage.

The same alarm condition may represent a different level of severity depending on the validated conditions, the type of UV reactor, the operating approach, and the disinfection objectives of the PWS. For example, if a UV reactor was validated with one lamp out of service, a single lamp failure alarm may trigger a minor alarm. Had the reactor been validated with all lamps in operation, a single lamp failure may trigger a major alarm. Table 4.2 summarizes typical UV reactor monitoring and alarms that would likely be integral to the UV reactor control panel.

4.3.4 UV Reactor Control Signals

The designer should coordinate with the UV manufacturer to determine what elements of the control system are integral to the UV reactor and what elements should be addressed with supplemental controls and equipment (i.e., supervisory control and data acquisition or SCADA). For installations with multiple UV reactors, a common, master control panel may be necessary to optimize UV reactor operations. Typically, each UV reactor has a dedicated control panel, and the plant's SCADA system receives control signals from each control panel to control the entire UV facility. The SCADA system also monitors and records the process parameters. Recommended monitoring and recording frequencies are provided in Chapter 6, and the designer should coordinate with the state to determine if expected frequencies differ. This section describes the control signals that could be transferred from each reactor's control panel to the SCADA system.

4.3.4.1 UV Intensity

Signals from UV sensors should be displayed locally on the UV reactor control panel and in the plant's SCADA system screen (if applicable).

Table 4.2. Typical Alarm Conditions for UV Reactors [1]

Sensor	Alarm Type	Purpose/Description
Lamp Age	Minor alarm	Run-time for lamp indicates end of defined operational lamp life.
Calibration Check of UV sensor	Minor alarm	UV sensor requires calibration check based on operating time.
Low UV Validated Dose	Major alarm	Indicated validated UV dose (based on UV reactor parameters, i.e., flow rate, UV intensity, and UVT) falls below required UV dose.
Low UV Intensity	Major alarm	Intensity falls below validated conditions.
Low UV Transmittance	Major alarm	UVT falls below validated conditions.
High Flow Rate (Not Integral to UV Reactor—Relies on Flow Meters)	Major alarm[2]	Flow rate falls outside of validated range.
Mechanical Wiper Function Failure (If Applicable)	Major alarm	Wipe function fails.
Lamp/Ballast Failure	Major alarm	Single lamp/ballast failure identified.[3]
	Critical alarm	Multiple lamp/ballast failures identified.
Low Liquid Level	Critical alarm	Liquid level within the UV reactor drops and potential for overheating increases.
High Temperature	Critical alarm	Temperature within the UV reactor or ballast exceeds a setpoint.

[1] Alarm conditions and relative severity shown above may vary depending on the specific validated conditions, type of UV reactor, manufacturer, dose-monitoring strategy, and disinfection objectives of the PWS.
[2] Based on measurement from dedicated flow meters or calculated based on total flow rate divided by number of UV reactors operating.
[3] Coordinate with UV manufacturer to determine if a lamp/ballast failure could indicate a sleeve and lamp break, which should be classified as a critical alarm.

4.3.4.2 UV Transmittance

If the Calculated Dose Approach is used, the UVT must be known to ensure that it is within the validated range. An on-line UVT analyzer or a bench-top spectrophotometer may be used to monitor UVT. Output from an on-line UVT analyzer can be input directly into a control loop for most UV reactors, a SCADA system, or both. Results from a bench-top spectrophotometer can be manually input into a SCADA system or UV reactor control panel(s).

4.3.4.3 Flow Rate Measurement

To maintain regulatory compliance, the flow rate through a UV reactor must be known to ensure that it is within the validated range [40 CFR 141.720 (d)(2)]. Section 4.1.2 discusses flow rate measurement and control options. The flow rate signal should be displayed locally or be input directly into a control loop for the UV reactor, a SCADA system, or both.

4.3.4.4 Calculated and Validated UV Dose (If Applicable)

If the Calculated Dose Approach is used, the calculated and validated doses should be displayed locally and transmitted to the SCADA system. The validated dose is equal to the calculated dose divided by the Validation Factor (See Section 5.10 for details).

4.3.4.5 Operational Setpoints

The operational setpoints should be displayed locally and remotely in the SCADA system. These setpoints will depend on the specific dose-monitoring strategy, operating approach (Section 4.2), and the validation data, and may include UV intensity, UVT, flow rate, calculated dose, and validated dose.

4.3.4.6 Lamp Age

The operating time of each lamp should be monitored, displayed locally, and transmitted to the SCADA system to facilitate O&M and lamp replacement, as discussed in Section 6.3.2.6.

4.3.4.7 Lamp Power, Lamp Status, and Reactor Status

Water systems must monitor lamp status to verify that UV reactors are operating within validated conditions [40 CFR 141.720(d)(3)]. Lamp status refers to whether the lamp is "on" or "off." The operating power level should also be monitored and displayed at the control panel and remotely in the SCADA system. Each reactor's on-line or off-line status should also be monitored and indicated locally and remotely, which can be accomplished by monitoring power and valve status.

4.3.4.8 UV Reactor Sleeve Cleaning

Sleeve cleaning information should be displayed locally and communicated between the local control panels and the SCADA system. This information should include the date and time of the last cleaning for off-line chemical cleaning (OCC) systems and the wiping frequency for on-line mechanical cleaning (OMC) or on-line mechanical-chemical cleaning (OMCC) systems.

4.3.4.9 Alarms

At a minimum, alarm conditions should be displayed locally. The use of visual or audible alarms is also recommended. If the UV facility will frequently be unstaffed or a SCADA system is already in place, provisions should also be included in the design to allow remote monitoring and display through the SCADA system.

4.4 Electrical Power Configuration and Back-up Power

The electrical power configuration should take into account the power requirements of the selected equipment, the disinfection objectives, and power quality issues, if applicable. (See Section 3.4.6.)

4.4.1 Considerations for Electrical Power

The proper supply voltage and total load requirements should be coordinated with the UV manufacturer, considering the available power supply. In addition, the power needs for each UV reactor component may differ. For example, the UV reactor may require 3-phase, 480-volt service, while the on-line UVT analyzer may need single-phase, 110-volt service. Excluding high service pumping, the electrical load from UV reactors will typically be among the larger loads at the WTP.

Due to the varying nature of UV reactor loads, current and voltage harmonic distortion can be induced. Such disturbances can cause electrical system problems, including overheating of some power supply components and can affect other critical systems, such as variable frequency drives (VFDs), programmable logic controllers (PLCs), and computers. Selection of the UV reactors should be based on a thorough analysis of the potential for the equipment to induce harmonic distortion. Additionally, the UV facility design and UV equipment should meet the Institute of Electrical and Electronic Engineers (IEEE) 519 Standard that addresses harmonics.

One method for controlling harmonics is to use a transformer with Delta Wye connections to isolate the UV reactor from the remainder of the WTP power system. The Delta-connected primary feed can be designed and sized to trap and moderate any induced harmonics. The Wye-connected secondary should be solidly grounded so that the ballasts are powered from a grounded source in accordance with electrical code requirements. If a separate transformer for the UV reactors is impractical, harmonic filters can be added to the UV reactor power supply to control distortion.

4.4.2 Back-up Power Supply and Power Conditioning

The continuous operation of the UV reactor is highly dependent on the power supply and its quality (Section 3.4.6). If the power reliability requirements and, consequently, the disinfection objectives cannot be met by relying solely on the commercial power supply, the use of back-up power, power conditioning equipment, or both may be necessary.

4.4.2.1 Back-up Power Supply

A simple backup power supply (e.g., generator) may be sufficient if power quality issues are infrequent. If an existing backup power supply is in place, its load capacity should be assessed to determine whether it can accept the additional load associated with the UV facility. The time necessary for switching from the primary power supply to a backup power supply and how that time affects compliance with the allowable off-specification operation should be determined.

4.4.2.2 Power Conditioning Equipment

Power conditioning equipment may be necessary if the power quality analysis reveals frequent events (Section 3.4.6) that cause the UV facility not to meet disinfection objectives. A site-specific analysis should be completed to determine the most appropriate power conditioning approach (Cotton et al. 2005). Consideration should include off-specification compliance, quality of the power supply, the cost of power conditioning equipment, and site constraints (e.g., land availability).

- **Uninterruptible Power Supply (UPS)** systems provide continuous power in the event of voltage sag or power interruption. The battery capacity is large enough to supply power to all connected equipment until a generator starts. UPS systems can either be on-line or off-line:

  On-line UPS: The unit and batteries are installed in series between the incoming power feed and all critical equipment. The incoming power feed charges the UPS batteries, and the batteries supply the electrical load. In this situation, the power feed is completely separated from the electrical load. This alternative is the most costly and has the largest footprint.

  Off-line UPS: The unit is installed in parallel with the connection from the incoming power feed to the critical equipment. During normal operations, the electrical load receives power directly from the power feed. When the off-line UPS senses a voltage fluctuation greater than or less than 10 percent of the nominal voltage, the load transfers to the UPS until the electrical feed stabilizes or the generator starts. Off-line UPS systems are less costly and have a smaller footprint than on-line UPS systems.

- **Active Series Compensators** protect electrical equipment against momentary voltage sags and interruptions. These devices boost the voltage by injecting a voltage in series with the remaining voltage during a sag condition. The corrected response time is a fraction of a cycle, preventing the equipment from experiencing a voltage sag. Active series compensators are well suited for instantaneous sags and interruptions; however, they cannot correct sustained sags or interruptions. Active series compensators are the lowest cost and smallest power conditioning option.

4.4.3 Ground Fault Interrupt and Electrical Lockout

Proper grounding and insulation of electrical components are critical for protecting operators from electrical shock and protecting the equipment. When combined with effective lockout/tagout procedures, the risk of electrical shock is further minimized. Ground fault interrupt (GFI) is another important safety feature for any electrical system in contact with water, including UV reactors. All UV reactor suppliers should provide GFI circuits for their lamps, which should be included in the specifications developed for equipment procurement. For a GFI to function properly, the transformer in the UV reactor ballast must not be isolated from the ground. If the UV reactor ballast isolates the output from the ground, ground faults will not be properly detected, and safety can be compromised.

Provisions enabling the UV reactors to be isolated and locked out for maintenance, both hydraulically and electrically, should be included in the design. Control of all lockout systems should remain local; however, when appropriate, the status of local lockouts could be monitored remotely. In all cases, the design must comply with electrical code and policy requirements for equipment lockout.

4.5 UV Facility Layout

Site layout for a UV facility is generally similar to the layout for any treatment process. Access for construction, operation, and maintenance should be considered. Typically, a preliminary layout is developed during project planning (Section 3.8.2). This preliminary layout may be modified to address space constraints or special installation conditions that result from the final equipment selection or based on more extensive site information gathered during detailed design. In addition to those items identified in Section 3.8.2, this section describes the items to be considered in the more detailed layout developed in the design phase.

Components of the UV reactors are typically located inside a building for protection from the weather and to provide a clean, convenient area for maintenance. The UV reactors themselves, associated electrical components and controls, and electrical support equipment should be enclosed. In some installations, UV reactors and control panels are uncovered. Before designing an uncovered facility, however, the state and UV manufacturer should be consulted. Exposed equipment and control panels should be rated for the anticipated environment, and appropriate site security should be in place to restrict public access.

The piping, valve, and flow meter design developed in the hydraulic evaluation (Section 4.1) should be considered in the UV facility configuration. For example, the length of straight-run piping before and after each flow meter to achieve the proper hydraulic conditions for accurate and repeatable flow rate measurement should be considered in the piping layout, depending on the flow control and measurement technique used (Section 4.1.2).

The location of the power and control panels associated with UV reactors should allow adequate space for panel doors to be opened without interference, and to allow unhindered access to the UV reactors when the doors are open. In selecting the location of the power and control panels, UV manufacturer cable length limitations should not be exceeded. The maximum allowable cable length is UV manufacturer-specific and may be less than 30 feet. If power quality is a concern, room for power conditioning equipment should be provided. Such equipment may be located adjacent to the UV reactors or in a separate control room.

When allotting space for maintenance activities, adequate space to remove the lamps and the lamp wiper assembly should be provided. In some cases, access may be needed on both sides of the UV reactor. In addition, provisions should be included to collect and convey water that is discharged during maintenance activities.

Certain UV reactors need maintenance involving an OCC procedure in which a UV reactor is taken off-line, isolated, drained, filled with a cleaning solution, cleaned, flushed, and returned to service. The OCC equipment is typically self-contained and the cleaning chemical is recirculated. If applicable, sufficient space should be maintained around the UV reactors to provide access for the OCC procedure. Also, the OCC solution often has specific handling requirements. Appropriate drains, storage, and health and safety equipment (e.g., emergency eyewash station) should be provided as recommended by the chemical manufacturer.

Sample taps in the lateral pipe are recommended upstream and downstream of each UV reactor. The sample taps may be used for collecting water quality samples or during validation testing, if on-site validation is necessary. If on-site validation will be conducted, the number and location of sample and feed ports should be coordinated with the UV manufacturer or third-party oversight entity to comply with the recommendations of the selected validation protocol. Additional details on the locations of sample taps and other validation-related appurtenances are provided in Section 5.4.

Drain valves or plugs should be located on each lateral between the two isolation valves. In many cases, the UV manufacturer may have already incorporated a drain into the UV reactor design. Drain valves should also be provided at one or more low points in the UV facility to enable the UV reactor and entire lateral to be fully drained for maintenance activities. These drains should be large enough to drain the reactor and adjacent piping in a reasonable amount of time.

Additionally, the UVT analyzer installation (if necessary) should be considered in the layout. The specific size and operating characteristics of the UVT analyzer will vary depending on the UV manufacturer. If an on-line UVT analyzer is included in the design, adequate space and access to an electrical supply for monitor installation should be provided and appropriate sample taps and drains for withdrawing and discharging sample water should be included in the design. The sample line should be equipped with a valve to isolate the UVT analyzer. A sample pump (e.g., peristaltic) should be installed if insufficient pressure is available in the system. The UVT analyzer should be in a location that minimizes the likelihood of air bubbles (which can cause erroneous readings) passing through the monitor.

4.5.1 Additional Considerations for Unfiltered and Uncovered Reservoir UV Facility Layouts

Site issues that should be considered with unfiltered systems are generally consistent with those for filtered surface water systems. The most significant difference is the increased opportunity for debris to be present in the inflow to UV reactors in unfiltered applications. To address the increased potential for debris, UV facility designs for unfiltered applications should incorporate features that prevent potentially damaging objects from entering the UV reactor. The optimal approach is site-specific. Such features could include screens, baffles, or low-velocity collection areas. Another option is to install the UV reactors vertically with the inlet closest to the ground, following a low-velocity zone. This arrangement will decrease the momentum of larger debris and reduce the risk of lamp breakage. The effects of lamp breakage and methods for minimizing it are discussed in Appendix E.

4.5.2 Additional Considerations for Groundwater UV Facility Layouts

Site issues that should be considered with groundwater systems are generally consistent with those for post-filtration surface water systems; the most significant difference is access of the site and potential sand particles affecting the UV reactor. Because well sites can be located in remote areas and may be more accessible to the general public or unauthorized individuals, the UV reactor should be installed within a building to protect sensitive equipment. The need to enclose the UV facility will ultimately be based on the manufacturer's recommendations, local regulatory and code requirements, state requirements, environmental conditions, and site-specific constraints. Site security should be appropriate to prevent tampering with the equipment and water supply and to protect people from injury (e.g., electrocution).

In addition, sand or debris flowing through the UV reactor may scratch the lamp sleeves or cause the sleeve wiping mechanisms to jam. Larger sand and debris could break the lamp sleeves and lamps. (See Appendix E for lamp breakage issues.) Intermittently used wells may accumulate sand or other particles; this initial concentration of particles should be discharged before operation and should bypass the UV reactor to avoid scratching the quartz sleeves. A sand/debris trap or other removal equipment prior to UV disinfection may be necessary if evidence suggests that the well pump will pull any sand or particles through the screen during normal well operation.

4.6 Elements of UV Equipment Specifications

When procuring the UV reactors, the UV facility layout and UV reactor specification are typically provided to the UV manufacturer. This section describes the potential elements included in a UV reactor specification and outlines the information that could be requested from the UV manufacturer.

4.6.1 UV Equipment Specification Components

Table 4.3 summarizes the factors that should be considered when developing equipment specifications for the UV equipment. The information included in Table 4.3 is not exhaustive and should be modified to meet the specific needs of the PWS and the requirements for the UV facility.

Table 4.3. Possible Content for UV Equipment Specifications (Table Spans Pages 4-20 – 4-22)

Item	Specification Content
Flow rate	Maximum, minimum, and average flow rates should be clearly identified. The maximum flow rate must be within the validated range documented in the validation report [40 CFR 141.720 (d)(3)]. The minimum flow rate may be important to avoid overheating with MP reactors. One method for determining the maximum flow rate is described in Section 3.4.3.
Target Pathogen(s) and Log Inactivation	The log inactivation for the target pathogen(s)
Required UV Dose	The required UV dose for the target microorganism and log inactivation that must be verified by the validation process. Additional detail is provided in Chapter 5.
Water Quality and Environment	The following water quality criteria should be included: - Influent temperature - Turbidity - UV transmittance at 254 nm - UVT scan from 200 – 300 nm (MP reactors only) - Total hardness - pH - Iron - Calcium - Manganese - ORP For some parameters, a design range may be most appropriate.
Operating Flow and UVT Matrix	Appropriate matrix of paired flow and UVT values based on flow and UVT data (Section 3.4.4.1).
Operating Pressure	The expected operating pressures, including the maximum and minimum operating pressure to be withstood by the lamp sleeves and UV reactor housing.
UV Sensors	A germicidal spectral response should be specified (Section 5.4.8). A minimum of one UV sensor should be specified per UV reactor. The actual number should be identical to the UV reactor that was, or will be, validated. The uncertainty of the UV sensors used during **validation** should meet the criteria described in Section 5.5.4. The uncertainty of the duty UV sensors during **operation** should meet the criteria described in Section 6.4.1.1. Reference UV sensors should be calibrated against a traceable standard. For example, the following standards are currently being used by UV manufacturers: - National Physical Laboratory (NPL) - National Institute of Standards and Technology (NIST) - Deutsche Vereinigung des Gas- und Wasserfaches (DVGW) - Österreichisches Normungsinstitut (ONORM)
Redundancy	The reactor redundancy determined in Section 3.8.1.
Hydraulics	The following hydraulic information should be specified: - Maximum system pressure at the UV reactor - Maximum allowable head loss through the UV reactor - Special surge conditions that may be experienced - Hydraulic constraints based on site-specific conditions and validated conditions (e.g., upstream and downstream straight pipe lengths).

Table 4.3. Possible Content for UV Equipment Specifications (Table Spans Pages 4-20 – 4-22)

Item	Specification Content
Size/Location Constraints	Any size constraints or restrictions on the location of the UV reactor or control panels (e.g., space constraints with individual filter effluent installation).
Validation	The range of operating conditions (e.g., flow, UVT) that must be included in the validation testing, and submittal of a validation report (40 CFR 141.720) should be required. The validation testing should be completed in accordance to the procedures and data analysis described in detail in Chapter 5.
Dose-Monitoring Strategy	A description of the preferred dose-monitoring strategy for the UV reactors.
Operating Approach	A description of the intended operating approach for the UV reactors, as described in Section 4.2.
Economic and Non-Economic Factors	The necessary information to thoroughly evaluate the UV equipment based on the PWS's specific goals. As appropriate, this information may include both economic (e.g., energy use, chemical use) and non-economic (e.g., future expansion, manufacturer experience) factors.
Lamp Sleeves	Lamp sleeves should be annealed to minimize internal stress.
Safeguards	At a minimum, the following UV reactor alarms should be specified: - Lamp or ballast failure - Low UV intensity or low validated UV dose (depending on dose-monitoring strategy used) - High temperature - Operating conditions outside of validated range - Wiper failure (as applicable) - Other alarms discussed in Section 4.3.3, as appropriate.
Instrumentation and Control	At a minimum the following signals and indications should be specified: - UV lamp status - UV reactor status - UV intensity - Lamp cleaning cycle and history - Accumulated run time for individual lamps or banks of lamps - Influent flow rate. At a minimum the following UV reactor controls (**as applicable**) should be specified: - UV dose setpoints, UV intensity setpoints, or UVT setpoints (depending on dose-monitoring strategy used) - UV lamps on/off - UV reactor on/off control - UV reactor manual/auto control - UV reactor local/remote control - Manual lamp power level control - Manual lamp cleaning cycle control - Automatic lamp cleaning cycle setpoint control.

Table 4.3. Possible Content for UV Equipment Specifications (Table Spans Pages 4-20 – 4-22)

Item	Specification Content
Performance Guarantee	The equipment provided should meet the performance requirements stated in the specification for an identified period or during on-site performance testing (Section 6.1.5). The following specific performance criteria may be included: - Allowable head loss at each design flow rate - Estimated power consumption under the design operating conditions - Disinfection capacity of each reactor under the design water quality conditions - Sensitivity of equipment to variations in voltage or current - Reference UV sensor, duty UV sensor, and UVT analyzer (if provided) performance compared to specification
Warranties	A physical equipment guarantee and UV lamp guarantee should be specified. The specific requirements of these guarantees will be at the discretion of the PWS and engineer. Significant variation from common commercial standards should be discussed with the manufacturer. Lamps should be warranted to provide the lamp intensity under the design conditions for the fouling/aging factor and a minimum number of operating hours. To limit the UV manufacturer's liability, the guarantee could be prorated after a specified number of operating hours.
UVT Analyzer	During operation, the difference between the UVT analyzer measurement and the UVT measured by a calibrated spectrophotometer should be less than or equal to 2 % UVT.

4.6.2 Information Provided by Manufacturer in UV Reactor Bid

The UV manufacturers should provide adequate information when bidding to enable the designer to conduct a proper, timely review of the proposed equipment. Suggested information to be obtained from the UV manufacturer is presented in Table 4.4.

Table 4.4. Suggested Information to Be Provided by UV Manufacturer

Item	Description of Information
Design Parameters	Demonstration of an understanding of the design parameters for the UV equipment. All UV equipment design parameters from the contract documents should be repeated in the proposed UV equipment submittal information.
Summary of Design	A summary of the equipment proposed (number of UV reactors, lamp type) and specified equipment redundancies.
Reactor Technical Specifications	Ability of proposed UV reactors to meet technical specifications and an explanation of any exceptions taken.
UV Equipment Documentation and Specifications	Documentation that identifies and describes the UV equipment components that were validated, as described in Section 5.11.1.[1]
UV Manufacturer's Experience	Information on project experience, including previous facilities and references.
UV Lamps	Detailed description of the lamp dimensions and electrical requirements.

Table 4.4. Suggested Information to Be Provided by UV Manufacturer

Item	Description of Information
UV Sensor	Information on the UV sensor(s), including spectral response, acceptance angle, external dimensions, working range in mW/cm^2, measurement uncertainty, environmental requirements, linearity, and temperature stability. Data and calculations should be provided showing how the total measurement uncertainty of the UV sensor used during **validation** meets the criteria established in Section 5.5.4. Data that demonstrate duty UV sensors will meet the criteria described in Section 6.4.1.1 will be met during **operation**.
Lamp Sleeves	Calculations showing the maximum allowable pressure for the lamp sleeves and the maximum bending stress the lamp sleeves may experience under the maximum specified flow rate conditions.
UVT Analyzer (if applicable)	Data that prove the UVT analyzer used during validation meets the criterion in Section 6.4.1.2 during operation.
Validation Report	UV reactor validation should be provided that includes the elements described in Section 5.11.3. If on-site validation is proposed, validation data for the UV reactors from off-site validation (if completed) should be included to provide a baseline comparison to the proposed conditions.
Upstream and Downstream Hydraulic Requirements	A statement of the length of straight pipe and hydraulic conditions necessary upstream and downstream from the UV reactor to ensure the desired flow profile is maintained and the design conditions are met. If pre-validated equipment is specified, a description of the hydraulic configuration used during validation testing should be provided.
Power Requirements	The power needs of each UV reactor and which elements, including electrical cable and wiring, are included as part of the equipment.
Power Quality Tolerance	The power quality tolerance of the UV equipment for voltage sags, surges, and interruptions.
Cleaning Strategy	The strategy that will be used for cleaning the UV lamps in the UV reactor.
Dose-monitoring Strategy	The proposed UV reactor dose-monitoring strategy, including manual and automatic control schemes and a listing of inputs, outputs, and the types of signals that are available for remote monitoring and control.
Reactor Data	The materials of construction, dimensions of the UV reactors and ancillary equipment, a list of spare parts, and a sample operations and maintenance manual.
Safeguards	The safeguards built into the UV reactor and accompanying equipment, such as high temperature protection, wiper failure alarms, and lamp failure alarms.
Warranties	A statement of the proposed UV reactor guarantees, including the physical equipment, UV lamps, lamp sleeves, fouling/aging factor, and the system performance guarantee. Any exceptions should be indicated and explained.

[1] Key elements of this documentation are also listed in this table.

4.7 Final UV Facility Design

The UV reactors can be selected after all bids have been carefully reviewed. Once the UV reactors are selected, the designer can coordinate with the selected UV manufacturer to develop the final facility design based on the selected UV equipment. The hydraulic design, I&C design, electrical design, and facility layout should be modified based on the selected UV equipment.

Particular emphasis should be given to the integration of the overall dose-monitoring strategy with the alarms, signals, and interlocks that are integral to the UV reactor design. That the final design be coordinated with the validation testing results is critical. The validation results must be sufficient to implement the proposed operations approach and should meet the water supply's disinfection objectives under the specified operating conditions.

4.8 Reporting to the State during Design

Interaction with the state throughout the design phases is recommended and increases the likelihood that the objectives of both the PWS and the state are met. Currently many states have limited experience in the use of this technology; therefore, the appropriate level of state involvement during design should be greater than that for more traditional designs. Early agreement on the specific objectives and requirements of the project can significantly reduce the potential for conflict or costly design changes later in the project. The level of state involvement during design, as well as the specific submittal requirements, will vary by state and may vary by project. PWSs are urged to consult with their state early in their UV disinfection design process to understand what approvals and documentation will be required.

5. Validation of UV Reactors

The purpose of validation testing is to determine the operating conditions under which a UV reactor delivers the validated dose.[1] As noted elsewhere in this guidance document, the validated dose must be greater than or equal to the required dose (presented in Table 1.4) to receive log inactivation credit for a target pathogen. Validation testing also establishes the operational setpoints used during reactor operations to confirm delivery of the validated dose.

This chapter explains the key steps in EPA's recommended validation protocol for UV reactors. It includes recommendations for selecting test conditions, quality assurance/quality control (QA/QC) steps, and data analysis procedures. It provides the rationale for the recommended steps and cites relevant research studies where appropriate.

Chapter 5 covers:

Several appendices support this chapter:

- **Appendix A** provides recommendations for preparing stock solutions of and assaying challenge microorganisms.
- **Appendix B** presents validation testing examples for two hypothetical water systems.
- **Appendix C** provides the recommended procedure for conducting collimated beam tests, including test conditions, apparatus design, equipment accuracy, and QA/QC. Appendix C also provides guidelines for using collimated beam test data to develop a UV dose-response curve.

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[1] For the purposes of this guidance manual, the validated dose is defined as the UV dose in units of millijoule per centimeter squared (mJ/cm^2) delivered by the UV reactor as determined through validation testing. The required dose is defined as the UV dose needed to achieve log inactivation credit. All UV dose terms are included in the glossary at the beginning of this manual.

- **Appendix D** contains the background theory used to support the recommended validation protocol.

The material in this chapter is intended to help water systems and states understand how the validation testing process works. It should be considered as a resource when reviewing validation reports or overseeing validation testing activities. Some of the terms and acronyms used in this chapter are unique to UV reactor validation. EPA has included an extensive glossary and acronyms list at the beginning of this guidance manual to help the reader keep track of new terms.

5.1 Minimum Requirements for Validation Testing

Unlike chemical disinfection, UV light leaves no residual that can be monitored to determine the delivered dose. UV sensors can measure intensity of UV light, but they cannot measure the dose delivered to the microorganisms as they pass through the reactor at different trajectories. Therefore, to receive treatment credit for inactivating *Cryptosporidium*, *Giardia,* or viruses using UV light, the LT2ESWTR requires water systems to use UV reactors that have undergone validation testing.

Section 1.4 of this manual summarizes all LT2ESWTR requirements related to UV disinfection, including minimum dose, validation, monitoring, and reporting requirements. For easy reference Table 5.1 summarizes the regulatory requirements for validation.

Table 5.1. Summary of LT2ESWTR Validation Requirements

Requirement	Conditions	Citation
Validated operating conditions must include	• Flow rate • UV intensity as measured by a UV sensor • UV lamp status	40 CFR 141.720 (d)(2)
Validation testing must include [1]	• Full-scale testing of a reactor that conforms uniformly to the UV reactors used by the water system • Inactivation of a test microorganism whose dose-response characteristics have been quantified with a low-pressure mercury vapor lamp	40 CFR 141.720 (d)(2)(ii)
Validation testing must account for	• UV absorbance of the water • Lamp fouling and aging • Measurement uncertainty of on-line sensors • UV dose distributions arising from the velocity profiles through the reactor • Failure of UV lamps or other critical components • Inlet and outlet piping or channel configurations of the UV reactor	40 CFR 141.720 (d)(2)(i)

[1] The state may approve an alternative approach to validation testing.

The LT2ESWTR does not specifically address "re-validation" if the design of a validated UV reactor changes. If design modifications significantly impact UV dose delivery or monitoring, however, the UV reactor should be considered a different reactor (with unsubstantiated performance) than the one previously validated and as such, must be re-validated [40 CFR 141.720 (d)(2)]. Section 5.13 discusses some of the common types of UV reactor modifications and provides recommendations for which types of changes necessitate re-validation.

5.2 Overview of the Recommended Validation Protocol

EPA's recommended validation protocol uses ***biodosimetry***. Under this approach, the log inactivation of a challenge microorganism is measured during full-scale reactor testing for specific operating conditions of flow rate, UV transmittance (UVT),[2] and UV intensity. The dose-response equation for the challenge microorganism (relating UV dose to log inactivation) is determined using independent, bench-scale testing. Log-inactivation values from full-scale testing are input into the laboratory derived-UV dose-response relationship to estimate the Reduction Equivalent Dose (RED). The RED value is adjusted for uncertainties and biases to produce the validated dose of the reactor for the specific operating conditions tested. The validated dose is compared to the required dose for compliance purposes.

The protocol can be described in three main steps, as shown in Figure 5.1 and described in more detail in Section 5.2.1. Alternative approaches to validation are discussed in Section 5.2.2. Sections 5.2.3 and 5.2.4 present recommendations for third-party oversight and emerging validation approaches, respectively.

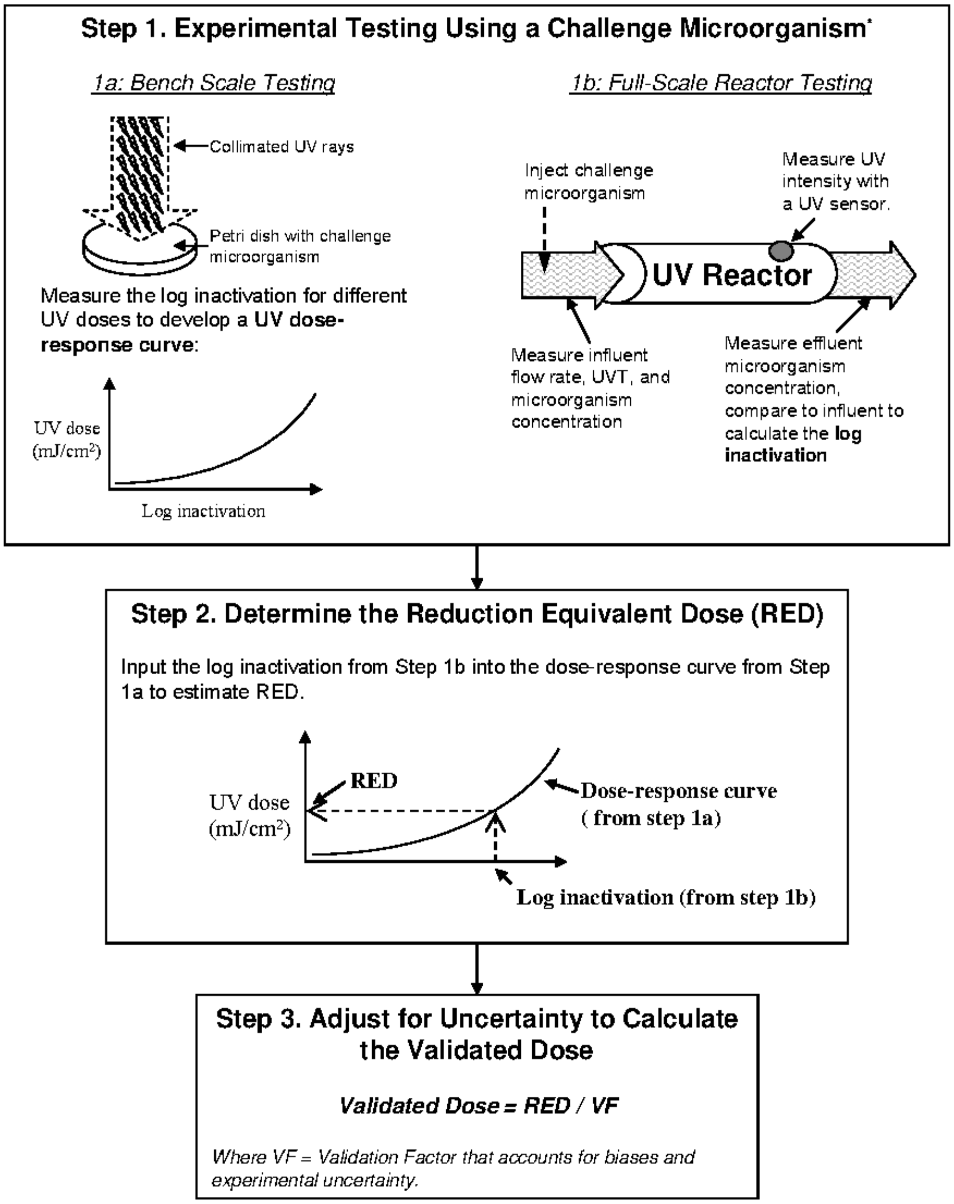
5.2.1 Key Steps in Recommended Validation Protocol

Consistent with other recommendations in this guidance manual, EPA developed the validation protocol working closely with industry representatives and experts in the field of UV disinfection. EPA believes that the approach produces reliable results and can be used to meet microbial treatment requirements of the LT2ESWTR and encourages water systems to use it where applicable. Water systems are not required, however, to follow the protocol as long as they meet the minimum regulatory requirements summarized in Section 5.1. EPA recommends that water systems contact their states early to discuss any additional state-specific requirements for reactor validation.

[2] In this Chapter, UVT implies UVT measurement specifically at 254 nanometers (nm) and 1 centimeter (cm) pathlength unless otherwise noted. UV absorbance at 254 nm (A_{254}) can be related to UVT using the following equation:

$$A_{254} = -\log\left(\frac{UVT(\%)}{100}\right)$$

Figure 5.1. Overview of Recommended Validation Protocol



** Simple representations of testing equipment shown. For more details, see Figures C.1 and 5.2.*

Step 1: Conduct Experimental Tests Using a Challenge Microorganism

Because handling of the target pathogen during validation testing is neither practical nor in the best interest of public health[3], a ***challenge microorganism*** whose sensitivity to UV light is similar to the target pathogen should be used in all experiments. Using a challenge microorganism instead of the target pathogen, however, introduces uncertainty into the testing results. This uncertainty is accounted for by applying a validation factor (see Step 3).

UV reactor validation includes two types of experimental tests, as described below. Importantly, the same stock solution of challenge microorganisms should be used for both tests because UV sensitivity for stock solutions can vary.

1a. Bench-scale testing using a collimated beam apparatus. Collimated beam testing characterizes the UV dose-response relationship of the challenge microorganism. In these experiments, UV light is directed down a collimating tube to dose a sample of challenge microorganisms of a known concentration. After a specified exposure time, the sample is analyzed to determine the log inactivation (where log inactivation in this situation equals the log concentration prior to UV light exposure minus the log concentration after UV light exposure) as a function of UV dose. The UV dose delivered to the microorganisms is calculated based on the UV intensity, exposure time, and other experimental factors. Figure C.1 in Appendix C illustrates a typical collimated beam apparatus.

Collimated beam tests are performed at a range of doses to generate ***a UV dose-response curve*** for the specific challenge microorganism. The functional forms of the equations for UV dose-response curves can vary depending on the results (guidance on developing UV dose-response curves is provided in Section C.3). A quadratic UV dose-response equation is provided below.

$$UV\ Dose = A \times (log\ \ inactivation) + B \times (log\ \ inactivation)^2 \qquad \text{Equation 5.1}$$

For this equation type, the coefficients "A" and "B" would be solved for using the collimated beam testing data.

1b. Full-scale reactor testing. In these experiments, the challenge microorganisms are injected upstream of the UV reactor. Samples are analyzed to determine the ***log inactivation*** (where log inactivation in this situation equals log influent concentration minus log effluent concentration) at the test conditions of flow rate, UVT, lamp status, and UV intensity as measured by UV sensors. Full-scale reactor testing can be performed on-site at a water treatment plant or off-site at a validation test center (see Figure 5.2 in Section 5.4 for a diagram of a typical biodosimetry test stand used for off-site validation).

[3] Culturing pathogenic microorganisms introduces additional risks in terms of handling, disposal, and cross connections. Therefore, the industry regularly uses challenge microorganisms as surrogates for pathogenic target microorganisms.

Step 2: Estimate the Reduction Equivalent Dose

Step 2 combines results from the two experimental tests in Step 1. The log inactivation of the challenge microorganism measured during the full-scale testing is entered into the UV dose-response equation (Equation 5.1 if the relationship is quadratic) to calculate the **RED** of the reactor. Another way to conceptualize this step is to consider the RED to be "back-calculated" using the field-measured log inactivation as the input variable. This approach is the opposite of most applications in which UV dose is the independent variable and log inactivation is the dependent variable.

RED values are always specific to the following:

- The challenge microorganism used during experimental testing,
- Validation test conditions during full-scale reactor tests (flow rate, UVT, lamp status, and UV intensity as measured by the UV sensor)

Step 3: Adjust for Uncertainty to Calculate the Validated Dose

In the last step shown in Figure 5.1, the RED is divided by a ***Validation Factor (VF)*** to produce the Validated Dose. The VF accounts for biases associated with using a challenge microorganism instead of the target pathogen and for experimental uncertainty (Section 5.9 provides a detailed description of how the VF is derived). The Validated Dose is associated with the validation test conditions of flow rate, lamp status, UV intensity as measured by a UV sensor, and in some cases, UVT. As noted previously, the validated dose is compared to the required dose to determine the inactivation credit for the target pathogen.

5.2.2 Alternative Validation Protocols

The Austrian Standards *ÖNORM M 5873-1* and *M 5873-2* (2001 and 2003, respectively) and the German Guideline DVGW W294 (2006) define measured flow rate, UV intensity, and lamp status for a *Bacillus subtilis* RED of 40 mJ/cm^2. Based on the recommended validation protocol presented in this guidance manual, UV reactors certified by ÖNORM and DVGW for a *B. subtilis* RED of 40 mJ/cm^2 should be granted 3-log *Cryptosporidium* and 3-log *Giardia* inactivation credit. Validation by *NWRI/AwwaRF Guidelines* and *NSF Standard 55* should be evaluated on a case-by-case basis (NWRI 2003, NSF 2004).

5.2.3 Third Party Oversight

EPA recommends that an independent third party provide oversight to ensure that validation testing and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV reactor manufacturer should oversee validation testing. Individuals qualified for such oversight include engineers experienced in testing and evaluating UV reactors and scientists experienced in the microbial aspects of biodosimetry. Appropriate individuals should have no real or apparent conflicts of interest regarding the ultimate use of the UV reactor being tested.

At a minimum, independent oversight should include observing validation testing to verify that the individuals performing the validation follow the documented protocol and reviewing the report for accurate data and results. The independent third party should review the validation report before its release. When appropriate, the third party should rely on additional outside experts to review various aspects of UV validation testing, such as lamp physics, optics, hydraulics, microbiology, and electronics.

5.2.4 Emerging Methods

In recent years, researchers have been working on alternative approaches to biodosimetry for UV reactor validation. Potential model-based approaches use computational fluid dynamics (CFD) to predict microorganism trajectories through a UV reactor, and hence the UV dose delivered to each microorganism. Section D.6 in Appendix D describes certain aspects of using CFD to predict UV dose delivery. A possible approach for verifying and validating hydraulic CFD models is outlined in the AIAA CFD guide (1998). Another emerging experimental approach uses microspheres that undergo a chemical reaction when exposed to UV light (Blatchley et al. 2005). The microspheres are injected upstream of the UV reactor and are collected downstream. The extent of the UV light-induced chemical reaction within each sphere is measured and used to calculate the UV dose delivered to that sphere as it traveled through the reactor.

Although model and experimental-based approaches clearly have potential for use in validating UV reactors, they are still subjects of current research. EPA anticipates that these methods will continue to develop and improve in the future.

5.3 Selecting the Challenge Microorganism

For the reasons stated in Section 5.2.1, the disinfection performance of the UV reactor is measured using a non-pathogenic “challenge” microorganism. Ideally, the challenge microorganism should have the same sensitivity to UV light (i.e., the same microbial dose-response) as the target pathogen.[4] If medium-pressure (MP) lamps are used, the organism should display a similar action spectrum, which is the relative sensitivity of the organism at other wavelengths compared to its sensitivity at 254 nm. In addition, the challenge microorganism should be:

- Easily cultured and enumerated, with repeatable results,
- Culturable to high concentrations, and
- Stable over long periods of time (to allow for shipment to and from the laboratory, on-site use, and enumeration without loss of viability or change in UV dose-response).

[4] In this guidance document, the UV sensitivity of the target microorganisms *Cryptosporidium*, *Giardia*, and viruses is defined by the required UV doses as presented in Table 1.4.

- If the challenge microorganism is a phage, the host bacteria used to assay the phage concentration should not be pathogenic to humans.

Male-specific-2 bacteriophage (MS2) phage and *B. subtilis* spores historically have been used for validation testing to receive treatment credit for *Cryptosporidium* and *Giardia*. Because their UV resistance is notably greater than that of *Cryptosporidium* and *Giardia*, other, more sensitive microorganisms such as T1 and T7 phage are gaining favor (Mackey et al. 2006).

To demonstrate 3- or 4-log inactivation for viruses, validation testing would need to demonstrate greater than 6-log inactivation of MS2 phage and *B. subtilis* spores. Such a demonstration requires an extremely high concentration in the reactor influent to allow for enumeration of the organisms in the effluent samples. Because of the need for serial dilutions, these high concentrations are difficult to measure and can introduce error into the experiment. Research to find an alternative challenge microorganism for demonstrating virus inactivation is ongoing.

Other challenge microorganisms that have been used for validation testing include non-pathogenic *Escherichia coli*, *Saccharomyces cerevisae*, and Qβ phage. Table 5.2 summarizes the UV sensitivity of some commonly used and some candidate bioassay microorganisms.

Table 5.2. UV Sensitivity of Challenge Microorganisms

Microorganism	Reported Delivered UV Dose (mJ/cm^2) to Achieve Indicated Log Inactivation				Reference
	1-log	2-log	3-log	4-log	
Bacillus subtilis	28	39	50	62	Sommer et al. 1998
MS2 phage	16	34	52	71	Wilson et al. 1992
Qß phage	10.9	22.5	34.6	47.6	Mackey et al. 2006
PRD-1 phage	9.9	17	24	30	Meng and Gerba 1996
B40-8 phage	12	18	23	28	Sommer et al. 1998
ϕx174 phage	2.2	5.3	7.3	11	Sommer et al. 1998
E. coli	3.0	4.8	6.7	8.4	Chang et al. 1985
T7	3.6	7.5	11.8	16.6	Mackey et al. 2006
T1	~5	~10	~15	~20	Wright 2006

Some microorganisms, such as *B. subtilis*, exhibit shoulders or tailing in their UV dose-response, meaning that the shape of the UV dose-response curve is flat at either low or high doses. Shoulders and tailing limit the range of UV doses that can be used to validate the reactor. See Section C.6 in Appendix C for an example of shoulders and tailing and limitations of using challenge microorganisms exhibiting this response in developing the UV dose-response curve.

As noted in Section 5.2.1, the validation test results are adjusted by a VF to account for bias and experimental uncertainties. A portion of the VF accounts for the difference in microbial response between the challenge microorganism and target pathogen. Using a challenge organism with significantly higher UV resistance than the pathogen of interest (e.g., using MS2 to earn *Cryptosporidium* inactivation credit) may result in a high VF. To provide a better estimate of the UV dose that a UV reactor can deliver to a target pathogen, a challenge microorganism with similar UV sensitivity to the target pathogen can be used. Alternatively, two challenge microorganisms whose UV sensitivities bracket that of the target pathogen (i.e., one challenge microorganism is less resistant and the other is more resistant than the target pathogen) can be selected. One advantage to this second approach is that the factor used to account for the difference between the microbial response of the challenge microorganism and target pathogen can be set to 1.0 (see Section 5.9 for discussion of the RED bias factor).

If the UV reactor being validated uses MP lamps and a challenge microorganism other than MS2 Phage or *B. subtilis*, a correction factor should be applied to the test results to account for differences in action spectra between the challenge microorganism and the target pathogen. Section D.4.1 explains how the correction factor is derived and how it should be applied to validation testing results.

5.4 Equipment Needs for Full-scale Reactor Testing

As noted in Section 3.6, full-scale reactor validation can occur on-site at the water treatment plant or off-site at a third-party validation test center or a UV manufacturer's facility. If full-scale reactor testing is performed off-site, tests are often conducted using a ***Biodosimetry Test Stand*** as shown in Figure 5.2. Regardless of the testing location, testing equipment should include (1) injection pumps and ports to introduce the challenge microorganism, the UV-absorbing compound, and, if needed, a disinfectant residual quenching agent into the feed water, (2) rate-of-flow control and a flow meter either upstream or downstream of the reactor, and (3) a strategy to ensure that the water is well mixed before sampling (e.g., static mixers or appropriate number of pipe lengths with good mixing confirmed, see Section 5.4.3 for details). There should also be a state-approved plan for wastewater disposal with any associated required permits.

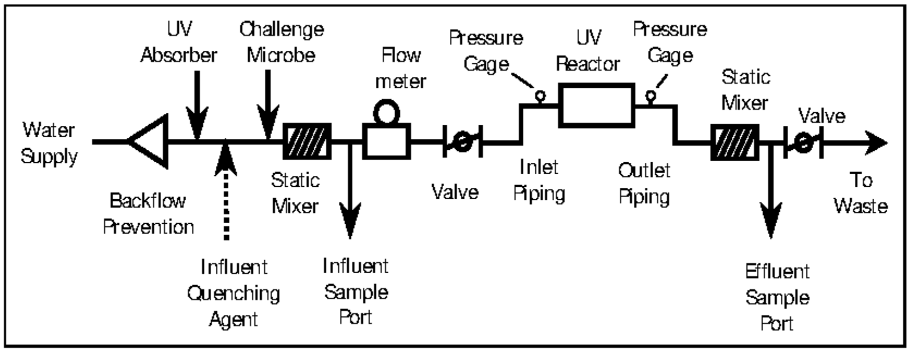
The next several sections provide detailed recommendations regarding water source, the UV-absorbing chemical to be used to simulate reduced UVT, mixing, sampling ports, configuration of inlet/outlet piping, accounting for non-uniform lamp aging, lamp positioning, UV sensors, and UV sensor port windows.

5.4.1 Water Source

When validation testing is conducted off-site, the source water for experiments is usually a potable water supply with a high UVT. To protect the potable water source, backflow prevention should be provided.

The water passing through the reactor should not contain disinfectant residuals that inactivate the challenge microorganism during testing. If this is a concern, a quenching agent can be injected into the water upstream of the microorganism injection port. When validating UV reactors using MP lamps, the quenching agent should have a minimal impact on the spectral UVT from 200 to 400 nm. Some common quenching agents like sodium thiosulfate can have a significant impact on the UV absorbance spectra if added in high enough concentrations. Testers should use a quenching agent, such as sodium bisulfite, that does not influence UVT.

Figure 5.2. Block Diagram of a Typical Biodosimetry Test Stand for Full-scale Reactor Testing



5.4.2 UV Absorbing Chemical

Typically during validation, a UV-absorbing chemical is injected into the flow to produce UVT values that span the required range. Common UV-absorbing compounds include the following:

- Coffee,
- Lignin sulfonic acid (LSA), and
- Humic acids, such as those derived from leonardite shales (Mackey et al. 2006, Bircher 2004).

5.4.3 Mixing

Additives passing through the reactor (e.g., UV-absorbing compound, the challenge microorganism) should be well mixed through the cross-section of the influent pipe prior to the reactor influent sampling port. The challenge microorganisms surviving UV disinfection should be well mixed through the effluent pipe cross-section prior to the reactor effluent sampling port.

Additives to the influent and effluent can be mixed by either using appropriately sized and designed static mixers or relying on the turbulent mixing in the lengths of pipe upstream of the sampling ports. If the water passing through the UV reactor is obtained from a large tank, the additives can be premixed in the tank to obtain a uniform concentration for testing. If pumps are used to inject the additives, the mechanism should provide a pulse-free flow rate or have a cycle time (i.e., time between pulses) an order of magnitude less than the residence time of the reactor. The flow rate generated by the pump should be stable over the time required to take samples.

Adequate mixing at the influent sampling port can be confirmed by comparing the UV absorbance at 254 nm (A_{254}) of water samples collected from various locations across the pipe cross-section. Samples can be collected across a pipe section using a perforated stab tube. The standard deviation of the A_{254} values measured at different locations should be less than 5 percent of the mean A_{254} value. Another approach is to compare the A_{254} of water samples collected at the influent and effluent sampling ports. The average A_{254} values of the influent and effluent samples should agree within 5 percent and the standard deviation of each should be less than 5 percent of their respective means.

The mixing at the effluent sampling port can be confirmed by injecting a UV-absorbing chemical into the flow at a location immediately downstream of the UV reactor and comparing the A_{254} of water samples collected from various locations across the pipe cross-section. Alternatively, the A_{254} of water samples collected at the effluent sampling port and a second effluent sampling port located five pipe diameters or more downstream of the first can be compared. The water samples should meet the criteria given above for the influent samples.

Mixing tests should be done at the minimum and maximum flow rates with the UVT adjusted to the minimum value that will be used during testing. If the water samples collected during the tests do not meet the above criteria for good mixing, the mixing should be increased and retested.

5.4.4 Sampling Ports

The sampling points for microorganisms should be located far enough from the UV reactor that the germicidal UV intensity at the point of sampling is < 0.1 percent of the germicidal intensity within the UV reactor. If the outlet sample port is located downstream of a 90° bend (or the inlet sample port is upstream of a 90° bend), incident light is not a concern.

To estimate intensity at a certain distance from the reactor, the following equation can be used:

$$I(r) = \frac{P_L}{2\pi r} e^{-\alpha_e r} \qquad \text{Equation 5.2}$$

where:

P_L = UV power emitted per unit arc length of the line source (mW/cm)
r = Radial distance from the line source (cm)
α_e = Naperian (base e) absorption coefficient of the media for water, (~0.015 cm^{-1})
$I(r)$ = UV intensity (mW/cm^2) at a distance r from the line source

For example, suppose the outlet sample port at a hypothetical UV test facility is located 10 feet downstream of the last UV lamp in a reactor. The lamp's maximum power per unit arc length is 100 watts per centimeter (W/cm). Using Equation 5.2, the intensity at a radial distance of 10 feet (305 cm) is calculated to be 5.4 x 10^{-4} mW/cm. Because this intensity is less than 0.1 percent of the intensity within the reactor, the sample port location is acceptable.

Sample taps may draw water from a single point or simultaneously from multiple points across the pipe diameter. Samples taken from multiple points within the flow should have the same concentration of additives and microorganisms (within the measurement error of the analytical method). If samples from different points in the flow have different concentrations, the flow at the sampling point is either insufficiently mixed or not at steady state. Sampling from multiple points at the same time should not be used to compensate for poor mixing.

5.4.5 Configuration of Inlet and Outlet Piping

Appendix D describes how flow conditions of the water can significantly impact dose delivery inside a UV reactor. Flow conditions are dependent on the velocity of the water and configuration of inlet and outlet piping. If the reactor is validated off-site, the inlet and outlet piping at the water treatment plant should result in a UV dose that is ***the same or greater than*** the dose delivered at the validation test facility. Section 3.6 provides suggestions for inlet and outlet piping design for water treatment plants and validation testing facilities.

Computational fluid dynamics (CFD) is a tool that can be used to assess whether the dose delivery at the treatment plant is the same or greater than the dose delivery at the validation testing facility. Section D.6 in Appendix D provides guidelines on using CFD for the purposes of modeling UV dose delivery.

5.4.6 Accounting for Non-uniform Lamp Aging

As will be discussed in Section 5.6, validation testing of full-scale reactors should account for decreased UV light transmittance caused by sleeve fouling, sleeve aging, lamp aging, and UV sensor window fouling. During design, the engineer and UV manufacturer will typically estimate a "fouling factor" and an "aging factor" for the reactor. The fouling factor is defined as the fraction of UV light passing through a fouled sleeve as compared to a new sleeve. The aging factor is the fraction of UV light emitted from aged lamps and sleeves at the end of the specified useful life compared to UV light emitted from new lamps and sleeves. The "fouling/aging factor" is equal to the fouling factor multiplied by the aging factor and typically ranges from 0.4 to 0.9 (NWRI 2003). See Section 3.4.5 for a more detailed discussion on determining these factors.

Traditionally, lamp power is turned down to simulate aging and fouling during validation testing. The magnitude of the power reduction (or power turn-down) is determined by calculating the *relative sensor intensity*, which is defined as follows:

$$\text{Relative sensor intensity} = S/S_o \qquad \text{Equation 5.3}$$

Where

S_o = UV intensity measured at 100 percent lamp power

S = UV intensity measured at reduced lamp power

For example, if the fouling/aging factor is 0.7, the lamp power would be reduced until the relative sensor intensity was 0.7, or 70 percent.

Recent studies have shown, however, that UV lamps and sleeves can exhibit significant non-uniform aging along their length and around their circumference (e.g., Mackey et al. 2005 and 2006). Turning down power during validation testing to simulate aging for lamps that experience non-uniform aging may result in under-dosing when the reactor is operated at the treatment plants, particularly at the end of useful lamp life. This guidance manual recommends that water systems use one of the following three alternatives to account for non-uniform lamp aging:

1. Request data from the manufacturer to verify that the lamps age uniformly. The manufacturer can provide such verification by simulating lamp aging in a test bed, then measuring lamp output at different locations along the length of the lamp and around the circumference. Results from a recently-completed AwwaRF study showed that output at the lamp ends is usually less than in the middle of the lamp when significant non-uniform aging is observed (Mackey et al. 2006). If the manufacturer can show that the lamp aging factor either already accounts for non-uniform aging or that it is not an issue, power turn-down can be used to simulate lamp aging during validation tests.

2. Use aged lamps (i.e., lamps that have been operated under similar conditions to the end of their specified lamp life) for validation testing. Power turn-down to simulate lamp aging during validation tests is not necessary in this approach (although power turn-down should still be considered to simulate lamp fouling).

3. Conduct experimental testing to determine if lamp aging can be simulated by power turn-down:

    a. Prepare a stock solution of the challenge microorganism.

    b. Fit the UV reactor with aged lamps and sleeves.

    c. Pass water through the reactor at a constant UVT, flow rate, and lamp power that will be used during challenge testing.

    d. Inject the challenge microorganism into the flow passing through the reactor (ensure they are well-mixed prior to entering the reactor).

    e. Collect at least five (5) microbiological samples spaced one (1) minute apart from the influent and effluent sampling ports for analysis.

    f. Record the UV sensor measurements.

    g. Fit the UV reactor with new lamps that have undergone 100-hour burn-in and new sleeves.

    h. Operate the UV reactor at the flow rate and UVT used in Step c. Lower the lamp power to produce a UV sensor reading equivalent to the reading obtained in Step f. Repeat steps e and f.

    If the mean log inactivation achieved with aged lamps is similar to the log inactivation achieved with new lamps with reduced lamp power, power turn-down can be used to simulate lamp aging. If results show significant differences, Alternative 2 (aged lamps and sleeves) should be used during validation testing.

5.4.7 Lamp Positioning to Address Lamp Variability

Due to manufacturing tolerances and differences in operation and aging, UV output typically varies from lamp to lamp. If a UV reactor has fewer UV sensors than lamps and the lamps are randomly distributed in the reactor, the UV sensors may monitor the lamps with the lowest outputs during validation. If this were to occur, the validation data collected would typically lead to under-dosing at the treatment plant.

To prevent underdosing, the lamps with the highest UV output should be placed closest to the UV sensors during validation testing. Other lamps should be randomly distributed in the lamp array throughout the reactor. This approach is unnecessary if the reactor uses one UV sensor per lamp.

The lamps with the highest UV output can be identified by measuring UV output using either a dedicated test stand or the UV reactor. One approach for determining the UV lamp output using the UV reactor is described below.

Procedure

1. Install a lamp within a lamp sleeve located at the position nearest to one of the reactor's UV sensors.
2. Pass water through the reactor at a constant flow rate and UVT.
3. With only the lamp under evaluation on, record the measured UV intensity.
4. Repeat the test for each lamp and rank the results.
5. For full-scale reactor testing, install the lamps with the highest output closest to the UV sensors. The rest of the lamps should be randomly distributed (with respect to lamp intensity).

5.4.8 UV Sensors

UV sensors are photosensitive detectors that measure UV intensity. UV sensors used in drinking water UV applications, particularly those with MP or other polychromatic lamps, should be ***germicidal***. Germicidal sensors are defined as having the following properties:

- A spectral response (i.e., UV intensity measured at various wavelengths) that peaks between 250 and 280 nanometers (nm).
- Less than 10 percent of its total measurement is due to light above 300 nm when mounted on the UV reactor and viewing the UV lamps through the water that will be treated.

Manufacturers should document the spectral response of the UV sensors. Tables 5.3 and 5.4 provide two examples of spectral response for a hypothetical germicidal sensor and a hypothetical non-germicidal sensor, respectively. Figure 5.3 graphically depicts the spectral response for the data in Tables 5.3 and 5.4, respectively.

Table 5.3 shows that nearly 100 percent of the area under the spectral response curve between 200 and 400 nm is at wavelengths below 300 nm - almost none of the sensor reading is due to wavelengths greater than 300 nm. Moreover, the peak spectral response is at 270 nm. Therefore, this UV sensor is classified as germicidal. Conversely, Table 5.4 reveals that only 74 percent of the area under the curve is below 300 nm, which means that 26 percent of the area is measured at wavelengths greater than 300 nm. Because 26 percent is greater than the maximum allowable 10 percent, this UV sensor is classified as non-germicidal.

EPA recognizes that, before the publication of this document, some UV reactors using MP lamps with non-germicidal sensors are in the final design phases, and some have been installed at water treatment plants. These water systems should apply a correction factor to validation test data to account for ***polychromatic bias***. Section D.4 in Appendix D explains how polychromatic bias impacts sensor reading and provides guidelines for deriving the correction factor. As noted in Chapter 4, facilities installing new UV treatment systems should use reactors that are equipped with germicidal sensors.

5.4.9 UV Sensor Port Windows

UV sensors often view the lamps through a UV sensor port window. These windows are typically made of quartz and have a UVT greater than 90 percent. The UVT of the sensor port windows should be checked before and after validation testing. If the sensor port windows are fouled or contaminated, UV sensor readings will be low. If this were to occur during validation testing, it could lead to under-dosing at the water treatment plant whenever the sensor port windows are clean. A collimated beam apparatus and a radiometer can be used to measure the sensor port window UVT either before the reactor is shipped to the test site or during validation testing.

5.5 Accuracy of Measurement Equipment

During validation testing, all equipment should be carefully selected and calibrated to minimize uncertainty. All measurements of flow rate, electrical power consumption, and head loss[5] should be traceable to an independent standard. Moreover, because they are key parameters that affect UV dose delivery, measurements of UVT and UV intensity should be NIST[6]-traceable or equivalent[7] with a known measurement uncertainty.

[5] Although not part of UV validation, headloss as a function of flow rate is often measured during validation testing as it offers an opportunity to gather such design data on the system

[6] National Institute of Science and Technology

[7] For example, the German national testing and standards agency, Physikalisch Technische Bundesanstalt (PTB), or the United Kingdom's National Weights and Measures Laboratory.

Table 5.3. Hypothetical Example of the Spectral Response of a Germicidal UV Sensor

Wavelength (nm)	Spectral Response[1] (mW/cm^2)	Area Under the Curve Between Readings	Cumulative Area Under the Curve	Cumulative Area as % of Total Area
200	0.11	–	–	–
210	0.21	1.600 [2]	1.6	3%
220	0.30	2.550 [3]	4.15	8%
225	0.35	1.625	5.775	11%
230	0.40	1.875	7.65	14%
235	0.48	2.200	9.85	18%
240	0.58	2.650	12.5	23%
245	0.72	3.250	15.75	29%
250	0.88	4.000	19.75	36%
255	1.03	4.775	24.525	45%
260	1.15	5.450	29.975	55%
265	1.23	5.950	35.925	66%
270	1.30	6.325	42.25	77%
275	1.21	6.275	48.525	89%
280	0.30	3.775	52.3	95%
285	0.19	1.225	53.525	98%
290	0.08	0.675	54.2	99%
295	0.03	0.275	54.475	99%
300	0.02	0.125	54.6	100%
310	0.01	0.150	54.75	100%
320	0.00	0.050	54.8	100%
330	0.00	0.000	54.8	100%
340	0.00	0.000	54.8	100%
350	0.00	0.000	54.8	100%
360	0.00	0.000	54.8	100%
370	0.00	0.000	54.8	100%
380	0.00	0.000	54.8	100%
390	0.00	0.000	54.8	100%
400	0.00	0.000	54.8	100%

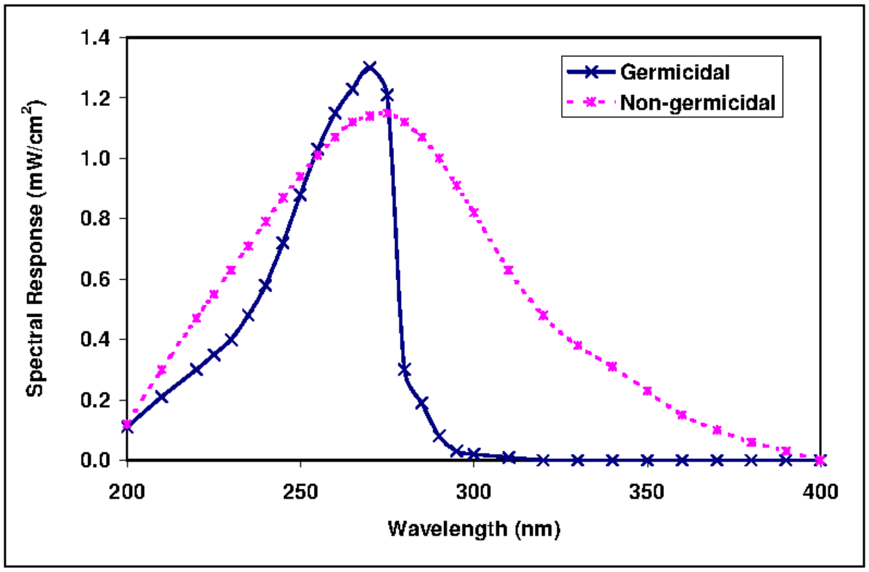
[1] UV intensity measured by the UV sensor.
[2] $(0.21 + 0.11) \times (210 - 200) / 2$
[3] $(0.30 + 0.21) \times (220 - 210) / 2$

Table 5.4. Hypothetical Example of the Spectral Response of a Non-germicidal UV Sensor

Wavelength (nm)	Spectral Response [1] (mW/cm²)	Area Under the Curve Between Readings	Cumulative Area Under the Curve	Cumulative Area as % of Total Area
200	0.12	–	–	–
210	0.30	2.100 [2]	2.1	2%
220	0.47	3.850 [3]	5.95	6%
225	0.55	2.550	8.5	8%
230	0.63	2.950	11.45	11%
235	0.71	3.350	14.8	14%
240	0.79	3.750	18.55	17%
245	0.87	4.150	22.7	21%
250	0.94	4.525	27.225	25%
255	1.01	4.875	32.1	30%
260	1.07	5.200	37.3	35%
265	1.12	5.475	42.775	40%
270	1.14	5.650	48.425	45%
275	1.15	5.725	54.15	50%
280	1.12	5.675	59.825	56%
285	1.07	5.475	65.3	61%
290	1.00	5.175	70.475	66%
295	0.91	4.775	75.25	70%
300	0.82	4.325	79.575	74%
310	0.63	7.250	86.825	81%
320	0.48	5.550	92.375	86%
330	0.38	4.300	96.675	90%
340	0.31	3.450	100.125	93%
350	0.23	2.700	102.825	96%
360	0.15	1.900	104.725	98%
370	0.10	1.250	105.975	99%
380	0.06	0.800	106.775	99%
390	0.03	0.450	107.225	100%
400	0.00	0.150	107.375	100%

[1] UV intensity measured by the UV sensor.
[2] (0.31 + 0.12) × (210 − 200) / 2
[3] (0.47 + 0.30) × (220 – 210 / 2

Figure 5.3. Hypothetical Examples of the Spectral Response of a Germicidal and a Non-germicidal UV Sensor



Source: Data from Tables 5.3 (germicidal sensor) and 5.4 (non-germicidal sensor).

The next three sections provide recommendations for verifying measurement uncertainty for flow meters, UV spectrophotometers, and power consumption. Section 5.5.4 provides the recommended approach for determining the measurement uncertainty of UV sensors, which the LT2ESWTR requires. Tests verifying equipment accuracy (particularly UV sensor checks as described in Section 5.5.4) should be documented in the Validation Report (See Section 5.11 for guidance).

5.5.1 Flow Meters

During validation testing, the uncertainty of flow rate measurements should be less than or equal to ***5 percent.*** The measurement uncertainty of the flow meter can be verified by comparing measured flow rate to a second, calibrated flow meter or a calibrated pitometer.

5.5.2 UV Spectrophotometers

Spectrophotometer measurements of A_{254} should be verified using NIST-traceable potassium dichromate UV absorbance standards and holmium oxide UV wavelength standards. Many UV spectrophotometers have their own internal QA/QC procedures to verify calibration. UV absorbance of solutions used to zero the spectrophotometer should be verified using reagent-grade organic-free water certified by the supplier to have zero UV absorbance.

The measurement uncertainty of the spectrophotometer should be ***10 percent or less***. A recommended approach for achieving this goal is as follows:

1. Verify that the spectrophotometer reads the wavelength to within the accuracy of a holmium oxide standard (typically ± 0.11 nm at a 95-percent confidence level),

2. Verify that the spectrophotometer reads A_{254} within the accuracy of a dichromate standard (e.g., 0.281 ± 0.004 cm^{-1} at 257 nm with a 20 mg/L standard), and

3. Verify that the water used to zero the instrument has an A_{254} value that is within 0.002 cm^{-1} of a certified zero absorbance solution.

When the UVT is greater than 90 percent, it is recommended that a 4-cm or greater pathlength cuvette be used (as opposed to the standard 1-cm cuvette). This greatly improves the accuracy of the UVT measurement at values above 90 percent. Measurements made with a 4-cm cuvette can be converted to 1-cm UVT measurements using the following equation:

$$UVT_{1-cm} = UVT_{4-cm}^{\ 1/4} \qquad \text{Equation 5.4}$$

When validation testing is performed using unfiltered water, the UV spectrophotometer should be equipped with an integrating sphere, which will provide more accurate UV absorbance readings if there are particles in the water.

If the spectrophotometer provides biased readings, the measurements should be corrected to account for that bias, or another instrument with measurement uncertainty of 10 percent or less should be used.

5.5.3 Power Measurements

Voltmeters, ammeters, and power meters used to measure (1) ballast and UV equipment input voltage, and (2) consumed current and power, should bear evidence of being in calibration (e.g., have a tag showing that it was calibrated). The accuracy of the measurements can be verified using a second instrument or a standard measurement. Power meters should provide a measure of true power as opposed to apparent power in units of kilovolt ampere (kVA).

5.5.4 UV Sensors

During validation testing, duty UV sensor measurements should be within ***10 percent*** of the average of two or more reference sensor measurements.[8] Duty sensors that do not meet this criterion should be replaced or the measurement uncertainty should be incorporated into the VF (see Section 5.9).

[8] Note that this error range is smaller than recommended for operations (in Section 6.4.1.1, EPA recommends that sensor readings be within 20 percent of the average of two or more reference sensors). EPA believes that a 10-percent error is easily attainable during validation testing and will help ensure good data quality for developing operational setpoints.

The following procedure can be used to check the uncertainty of the duty and reference UV sensors used during validation (this calculation is also illustrated in the examples in Appendix B).

1. Pass water through the reactor at the maximum UVT and the maximum lamp power setting to be used during validation testing.

2. Using two recently calibrated reference UV sensors (which should agree within the calibration certificate-specified measurement uncertainty[9]), install each sensor on the UV reactor at each port and record the measured UV intensity (S_{ref}). Repeat using each duty UV sensor (S_{duty}). If the UV sensors can be rotated, measure the minimum and maximum sensor readings across the complete range of rotation.

3. Repeat Steps 1 and 2 at either (a) maximum lamp power and UVT decreased to the minimum value expected during validation testing, or (b) maximum UVT and lamp power decreased to the minimum level expected to occur during validation testing. Duty UV sensors can be checked under both conditions, although this is not necessary.

4. For a given lamp output and UVT value, the difference between the reference and duty UV sensor measurements should follow Equation 5.5:

$$\left| \frac{S_{\text{duty}}}{S_{\text{Ref,avg}}} - 1 \right| \leq 10\% \qquad \text{Equation 5.5}$$

where:
S_{duty} = Intensity measured by a duty UV sensor
$S_{Avg\ Ref}$ = Average UV intensity measured by all the reference UV sensors in the same UV sensor port with the same UV lamp at the same UV lamp power.

5. Duty and reference UV sensors that do not meet this criterion should be replaced. Alternatively, measurement uncertainty can be re-stated at the maximum uncertainty observed during validation testing and incorporated into the VF (see Section 5.9).

Duty sensors should be checked prior to full-scale reactor testing to ensure that the data collected during testing will be useful. Sensors are also often spot-checked during and after full-scale testing to verify that they are still within the recommended uncertainty limit.

5.6 Identifying Test Conditions

Numerous combinations of experimental tests can be performed to validate a UV reactor. The number of tests could range from a few tests to a complex matrix spanning a range of UV

[9] If the reference sensors do not agree with the calibration certificate-specified measurement uncertainty, they should be sent back to the manufacturer.

dose, flow rate, UVT, ballast power, and lamp status combinations. The test design (i.e., number of tests and test conditions) depends on several factors, as summarized in Table 5.5.

Table 5.5. Factors to be Considered in Validation Test Design

Factor	Examples	Section of Manual with Additional Guidance
1. Purpose of validation testing	Validation of new reactor by water system vs. validation to confirm an existing validation equation	3.6 5.6
2. Dose-monitoring strategy of the UV reactor	UV Intensity Setpoint Approach vs. the Calculated Dose Approach[1]	3.5.2
3. Operational strategy (for the UV Intensity Setpoint Approach only)	Single-setpoint operations vs. variable-setpoint operations	3.5.2
4. Predicted lamp aging and fouling	Aging factor of 0.8 vs. using aged lamps used during validation testing (where the aging factor would equal 1.0)	3.4, 5.4.6
5. Target pathogen and target log inactivation	2.0 log inactivation of *Cryptosporidium* vs. 3.0 log inactivation of viruses	3.1
6. Full operating range of flow rate and UVT	Range of flow = 5 – 20 mgd, Range of UVT = 70 – 90 %	3.4

[1] As noted in Section 3.5.2, there are many dose-monitoring strategies for UV reactors. This guidance manual focuses on two common strategies, the UV Intensity Setpoint Approach and the Calculated Dose Approach.

Although all factors in Table 5.5 influence test design, the total number of experiments is highly dependent on the first three factors. For example, suppose a water system wants to validate a new UV reactor that uses the UV Intensity Setpoint Approach. The system decides to use single-setpoint operations, meaning that it will use one UV intensity setpoint for all operating conditions. Validation testing in this case would be fairly straightforward with a small number of tests. If another water system selects the same reactor but selects variable-setpoint operations to allow it to reduce lamp power at low flow rates, that system would conduct more validation tests to establish different setpoints for the different flow rate ranges. Another common scenario is when a manufacturer decides to validate a new UV reactor over a wide range of flow rates, UVT levels, and lamp status combinations to develop a dose-monitoring equation. This scenario likely would necessitate many tests.

As noted in Section 5.4.6, lamp fouling and aging are important factors that should be accounted for during validation testing. Power turn-down is typically used to simulate lamp aging and fouling at the end-of-lamp life. Instead of reducing power to simulate lamp aging, aged lamps can be used during validation testing (although power-turn down would still be needed to simulate lamp fouling). Section 3.4.5 provides information on how the fouling/aging factors are estimated, and Section 5.4.6 provides guidance on using new versus aged lamps during validation testing.

If a new, un-validated reactor is being tested for a specific water system, the last two items listed in Table 5.5 can help establish validation test conditions. The target pathogen and target log inactivation for the water system define the required dose that is the target for validation testing. The full range of operating conditions for flow rate and UVT dictate the flow rate and UVT conditions used during validation testing.

Sections 5.6.1 and 5.6.2 discuss the validation test design for the UV Intensity Setpoint Approach and the Calculated Dose Approach, respectively. Test designs for other dose-monitoring strategies that use setpoints should be similar to recommendations in Section 5.6.1 and should be developed using professional judgment. Section 5.6.3 provides considerations for water systems who are confirming an existing dose-monitoring equation (as developed for the Calculated Dose Approach). Section 5.6.4 lists the types of quality control samples that should be collected and analyzed during testing. Appendix C provides guidelines for identifying test conditions for collimated beam testing.

Experimental test conditions should be documented in a ***Validation Test Plan***. Section 5.11.2 provides recommendations on what a Validation Test Plan should contain. EPA recommends including the Test Plan into the final Validation Report (see Section 5.11.3).

5.6.1 Test Conditions for the UV Intensity Setpoint Approach

For the UV Intensity Setpoint Approach, the purpose of validation testing is to determine the validated dose corresponding to the UV intensity setpoint for a reactor at a particular flow rate. Typically, the manufacturer determines the UV intensity setpoint for their reactor. If this is the case, water systems should work with the manufacturer to ensure that ***the setpoint is defined conservatively low enough*** to account for combined conditions of minimum UVT and maximum fouling/aging (commonly represented by the fouling/aging factor). If the manufacturer does not establish the UV intensity setpoint for their reactor, the water system can select a setpoint using the following procedure:

1. Record the UV intensity measurement at conditions of maximum UVT and 100 percent power (S_o)[10].

2. Reduce the lamp power until the measured UV intensity results in the following ***relative sensor intensity*** (S/S_o per Equation 5.3):

    a. If aged lamps are used during validation testing, the relative sensor intensity should be equal to the ***fouling factor***.

    b. If new lamps are used during validation testing, the relative sensor intensity should be equal to the ***fouling/aging factor***, which is the fouling factor multiplied by the aging factor.

3. Reduce the UVT of the water to the minimum UVT (see Section 3.4 for guidance on determining the minimum UVT).

[10] The impacts of lamp power and UVT on UV sensor readings are not dependent on the specific rate of flow traveling through the reactor. Thus, any flow rate can be used for this procedure.

4. Record the UV Intensity at reduced power and reduced UVT conditions. This intensity is the ***UV intensity setpoint.***

The UV Intensity Setpoint approach uses ***two validation test conditions***, as specified in Table 5.6. The first involves reducing UVT until UV intensity measured by the UV sensor is equal to the UV intensity setpoint. The second involves testing at high UVT but reducing power until the UV intensity measured by the sensor is equal to the UV intensity setpoint. Additional test conditions should be evaluated if the water system will be using variable setpoint operations (i.e., each test condition in Table 5.6 should be repeated at different flow rates).

Table 5.6. Minimum Test Conditions for the UV Intensity Setpoint Approach[1]

Test ID[2]	Flow Rate	UVT	Lamp Power
1	Design (highest)	Lowered to give the UV intensity setpoint [3]	Maximum (100 %)
2	Design (highest)	Maximum	Lowered to give the UV intensity setpoint [3]

[1] Minimum test conditions shown are for single-setpoint operations. Additional tests should be conducted at different flow rates for variable setpoint operations.
[2] At least three replicate tests with the same stock solution of challenge microorganisms should be performed for each test condition.
[3] The UV intensity setpoint is typically established by the manufacturer. Alternatively, it can be established by the water system using the procedure in Section 5.6.1.

Water systems may decide to use two challenge microorganisms with different UV sensitivities for validation testing (see Section 5.3 for additional discussion). In many cases, challenge microorganisms can be tested at the same time if they have been proven not to interfere with each other.

The validation approach described herein produces a UV intensity setpoint and Validated Dose that are independent of UVT. Thus, UVT is not typically monitored during reactor operations.

5.6.2 Test Conditions for the Calculated Dose Approach

For the Calculated Dose Approach, the purpose of validation testing is to develop a dose-monitoring equation relating RED[11] to operating parameters such as flow rate, UVT, lamp power (quantified as relative sensor value), and in some cases lamp status. For each operating parameter used in the equation, ***at least three conditions*** should be evaluated during validation testing. Three data points are needed for interpolation of results because the relationship between RED and operating parameters such as flow rate and UVT is typically non-linear.

[11] As a reminder, RED is the reduction equivalent dose, which is determined by inputting the measured log inactivation (observed during full-scale reactor testing) into the UV dose-response curve (generated through collimated beam testing).

In many cases, three operating parameters (UVT, flow rate, and lamp power) are used in the dose-monitoring equation, resulting in a minimum of ***27 test conditions*** (3 × 3 × 3). Fewer test conditions are needed when the dose monitoring equation is based on fewer than three parameters, such as when a minimum UVT is assumed for all operating conditions. More than 27 test conditions may be needed when the water system plans to vary lamp status during operations (e.g., UVT, flow rate, and lamp power are used in the dose monitoring equation and individual banks of lamps will be turned off and on to conserve power).

If validation tests are being conducted for a specific water system, the system's operating range of flow rates, UVT, and the required UV dose for their target pathogen and log inactivation help establish test conditions. For flow rate, the water system's maximum and minimum flow rates, as well as one or more intermediate flow rates, should be selected as test conditions. To select intermediate flow rates, EPA recommends using a geometric progression (because the relationship between UV dose and flow is non-linear) using the following equation:

$$Q_n = Q_{Max}\beta^{1-n} \qquad \text{Equation 5.6}$$

where:

Q_n = n^{th} flow rate to be tested

Q_{Max} = Maximum flow rate to be tested

β = Constant with a recommended value between 1.5 and 2.0 to achieve good separation of flow measurements

n = Flow rate test # to be evaluated (must be ≥ 3, if interpolating results)

The value of β should be sufficient to obtain at least three measured data points for developing the dose-monitoring equation. The value of n should be selected to span the range of flow rates. An example using Equation 5.6 is provided below.

Example 5.1. **Determining Flow Conditions for Validation Testing.** A UV reactor using the Calculated Dose Approach and operating within the range of 5 – 20 mgd is to be validated. The test engineer selects a ß value of 1.6, resulting in the following test flow rates:

n	Q (mgd)
1	20
2	12.5
3	7.8
4	4.9

For UVT, test conditions should include the water system's minimum UVT, maximum UVT, and at least one intermediate value. If the dose-monitoring equation will account for specific lamps operating either on or off or other power manipulations, validation test design should include these conditions.

Table 5.7 summarizes the recommended minimum test conditions for the Calculated Dose Approach. Table B.9 in Appendix B presents an example test matrix for a hypothetical water system.

Table 5.7 Minimum Test Conditions for the Calculated Dose Approach[1]

Test ID[2]	UVT Flow rate[3]	Flow Rate[3]	Lamp Power [4]
1	Maximum	Design	Maximum
2	Maximum	Intermediate	Maximum
3	Maximum	Minimum	Maximum
4	Maximum	Design	Minimum expected to occur during operations
5	Maximum	Intermediate	Minimum expected to occur during operations
6	Maximum	Minimum	Minimum expected to occur during operations
7	Maximum	Design	Intermediate
8	Maximum	Intermediate	Intermediate
9	Maximum	Minimum	Intermediate
10	Intermediate	Design	Maximum
11	Intermediate	Intermediate	Maximum
12	Intermediate	Minimum	Maximum
13	Intermediate	Design	Minimum expected to occur during operations
14	Intermediate	Intermediate	Minimum expected to occur during operations
15	Intermediate	Minimum	Minimum expected to occur during operations
16	Intermediate	Design	Intermediate
17	Intermediate	Intermediate	Intermediate
18	Intermediate	Minimum	Intermediate
19	Minimum	Design	Maximum
20	Minimum	Intermediate	Maximum
21	Minimum	Minimum	Maximum
22	Minimum	Design	Minimum expected to occur during operations
23	Minimum	Intermediate	Minimum expected to occur during operations
24	Minimum	Minimum	Minimum expected to occur during operations
25	Minimum	Design	Intermediate
26	Minimum	Intermediate	Intermediate
27	Minimum	Minimum	Intermediate

1 Assuming validation on a non-validated UV reactor. Minimum test conditions shown are for all lamps turned on. Additional tests should be performed to evaluate other lamp on/off combinations or other power combinations.
2 At least three replicate tests with the same stock solution of challenge microorganisms should be performed for each test condition.
3 See Section 3.4 for guidelines on identifying design flow and minimum and maximum UVT.
4 Minimum power should include reduction in lamp output caused by fouling and aging.

5.6.3 Test Conditions for Confirming an Existing Validation Equation

Water systems may decide to perform on-site validation testing to show that the hydraulic conditions at the water treatment plant result in a UV dose that is the same or greater than the UV dose delivered at the off-site validation test facility. Test conditions should generally span the range of operating conditions expected at the treatment plant (e.g., minimum and maximum UVT, minimum and maximum flow rate). See Section 3.6.2 for additional discussion on validation testing scenarios.

EPA cautions water systems on combining on-site validation testing data with off-site validation data to develop a new dose-monitoring equation. On-site and off-site testing is often done under different hydraulic conditions and may produce different results. Combining the datasets may result in greater noise about the fit for the dose-monitoring equation and, thus, a higher uncertainty factor (see Section 5.9.2.2 for a discussion of the uncertainty in interpolation factor)

5.6.4 Quality-control Samples

Recommended quality-control samples for full-scale reactor testing are listed below.

- *Reactor controls* – influent and effluent water samples taken with the UV lamps (in the reactor) turned off. The change in log concentration from influent to effluent should correspond to a change in RED (from the UV dose-response curve) that is within the measurement error of the minimum RED measured during validation (typically 3 percent or less).

- *Reactor blanks* – influent and effluent water samples taken with no addition of challenge microorganism to the flow passing through the reactor. Blanks should be collected at least once on each day of testing and the concentration of challenge microorganisms should be negligible.

- *Trip controls* – one sample bottle of challenge microorganism stock solution should travel with the stock solution used for validation testing from the microbiological laboratory to the location of reactor testing and back to the laboratory. The change in the log concentration of the challenge microorganism in the trip control should be within the measurement error. (i.e., the change in concentration over the test run should be negligible. This is typically on the order of 3 to 5 percent.

- *Method blanks* – sample bottle of sterilized reagent grade water that undergoes the challenge microorganism assay procedure. The concentration of challenge microorganism with the method blank should be non-detectable, according to *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 1998).

- *Stability samples* – influent and effluent samples collected at low and high UVT that are used to assess the stability of the challenge microorganism concentration and its UV dose-response over the time period from sample collection to completion of challenge microorganism assay. The challenge microorganism concentrations in the stability samples should be within 5 percent of each other.

5.7 Guidelines for Conducting Experimental Tests

Section 5.7.1 provides general guidelines for preparing the challenge microorganism for testing. Sections 5.7.2 and 5.7.3 provide recommendations for conducting full-scale reactor testing and collimated beam testing, respectively. Appendix C contains more detail on the collimated beam testing methods. Importantly, the recommendations in this section and in Appendix C are not step-by-step procedures, but rather an identification of key steps in the process. Individuals performing full-scale reactor testing and collimated beam testing should work closely with the laboratory personnel and experts in the field of validation testing to ensure that appropriate procedures and QA/QC steps are followed.

5.7.1 Preparing the Challenge Microorganism

The challenge microorganism used to validate UV reactors should be cultured and analyzed by a laboratory staffed by professional microbiologists and equipped to perform microbiological examinations as specified in *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 1998). Protocols for culturing the challenge microorganism and measuring its concentration should be defined and based on published and peer-reviewed methods.

The challenge microorganism concentrations should be stable over the holding time between sampling and completion of the assays. If they are not stable, the data collected will be unusable because distinguishing the sources of inactivation—exposure to UV light and die-off in holding—will be impossible. Instability problems with MS2 phage are well documented in the literature (Petri et al. 2000, Swaim et al. 2003, Hargy et al. 2004). Factors that can impact MS2 phage stability in water include the presence of chlorine, coagulants, ionic strength, surfactants, and UV absorbers (Thompson and Yates 1999, Petri et al. 2000, Hargy et al. 2004). Laboratory methods can also impact the stability of MS2 phage in water (Thompson and Yates 1999). Microbial stability in the test water should be verified before experimental testing begins. Stability verification can help ensure that the bioassay and challenge microorganism samples will be viable and the data useable.

Appendix A provides recommended procedures for preparing stock solutions of MS2 phage and *B. subtilis* spores and assaying their concentrations in water samples. Alternative procedures and challenge microorganisms can be used if they are acceptable to the state.

5.7.2 Full-scale UV Reactor Testing

Three key steps comprise full-scale reactor testing: (1) verifying reactor properties, (2) installing the reactor, and (3) conducting the tests. These steps are summarized below. Note that key steps are based on UV reactor testing at an off-site validation test facility. Additional steps may be necessary for on-site validation.

Verifying UV Reactor Properties

For validation, the UV manufacturer should provide the following:

- A UV reactor that matches the provided specifications.
- Duty and reference UV sensors that match the provided specifications.
- UV lamps that have undergone appropriate burn-in. If new lamps are to be used, the recommended burn-in period is 100 hours. If aged lamps are to be used, the recommended burn-in period is that which will produce lamp output equivalent to the fouling/aging factor. More information on aged lamps is provided in Section 5.4.6.
- For UV reactors with more than one lamp per UV sensor, lamps with the highest output positioned closest to the sensor. (See Section 5.4.7 for additional guidance on sensor positioning to address lamp variability.)
- Provisions to reduce lamp output.
- Provisions to measure the electrical power delivered to the lamps.
- A temperature sensor and safety cut-off switch to prevent overheating if MP lamps are used.

Installing the UV Reactor

The UV reactor and the reactor inlet and outlet connections should be installed at the test facility in accordance with the manufacturer's installation and assembly instructions. If reactors are installed in series, the piping between the reactors should conform to the specifications provided by the UV reactor manufacturer. The piping should be inspected to ensure compliance with the manufacturer's specifications. The configuration of inlet and outlet piping to and from the reactor and its impact on validation testing is discussed in Sections 3.6 and 5.4.5. Good mixing should be confirmed.

The physical integrity of the UV reactor and the test train should be verified before testing. Personnel who operate the UV reactor during all tests should be familiar with its operation and maintenance manual and with any safety requirements.

Measuring UV Dose Delivery

During full-scale reactor testing, the reactor is operated at each of the test conditions for flow rate, UVT, and lamp power (in accordance with the Validation Test Plan) as described in Section 5.6. The following steps should be taken to ensure good results:

- Confirm steady-state conditions before injecting the challenge microorganism by monitoring the UV sensor measurements and the UVT.
- Inject the challenge microorganism, prepared according to Appendix A, into the flow upstream of the reactor.
- Collect at least three (3) influent and three (3) effluent samples for each test condition. Sample volumes should be sufficient for assessing the challenge microorganism concentrations in the influent and effluent (typically 10 – 15 mL).
- Measure and record the flow rate through the reactor, all UV sensor measurements, on-line UVT measurements, and any calculated UV dose values both before and after the samples are collected.
- Measure and record the UVT as measured by the UV spectrophotometer with each influent sample.
- Measure and record the electrical power consumed by the lamp ballasts.
- Repeat the test if the flow rate, UV intensity, lamp power, or UVT changes by more than the recommended error of the measurement over the course of sampling (see Section 5.5).

Sample taps should remain open over the duration of the test. Sample collection should meet standards of good practice as defined by *Standard Methods* Section 9060 (APHA et al. 1998). Samples should be collected in bottles that have been cleaned and sterilized and should be immediately stored on ice, within a cooler, in the dark until analyzed.

The concentrations of the challenge microorganisms before and after exposure to UV light should generally be measured within 24 hours of sample collection, unless stability studies indicate that the samples can reliably be considered stable over longer periods of time. Samples that are not assayed immediately should be stored in the dark at 4 °C. Exposure of samples to visible light should be avoided.

5.7.3 Collimated Beam Testing

Collimated beam tests are performed in microbiological laboratories under controlled conditions. Recommended test procedures are provided in Section C.2.3. Importantly, all collimated beam testing should be conducted using a water sample collected from the influent sampling port of the biodosimetry test stand. If the full-scale reactor testing lasts for more than one day, at least one collimated beam test should be conducted for each day of testing. A minimum of two collimated beam tests is always recommended, one each at the highest and lowest UVT values evaluated during full-scale reactor resting.

5.8 Analyzing Experimental Data

Validation testing of UV reactors produces the following types of data for each experimental test:

- Concentration of the challenge microorganism in the influent and effluent sample [e.g., plaque forming units per milliliter (pfu/mL) for MS2 phage, colony forming units per milliliter (cfu/mL) for *B. subtilis* spores]
- UVT of water (percent)
- Flow rate [gallon per minute (gpm) or mgd]
- UV intensity as measured by the UV sensor (mW/cm^2)
- Lamp power [watt (W) or kilowatt (kW)]
- Status (on/off) for each lamp

All experimental data should be documented, preferably in tabular format, and included in the Validation Report. (See Section 5.11.3 for additional guidance on the Validation Report and Appendix B for examples.)

Section 5.8.1 shows how RED is calculated for each experimental test using a combination of full-scale reactor testing data and collimated beam results. Additional analyses of RED data depend on the reactor's UV dose-monitoring strategy. For the UV Intensity Setpoint Approach, RED results are averaged for each test condition and evaluated to identify the minimum value. For the Calculated Dose Approach, all RED values and associated test conditions are used to create a dose-monitoring equation. Sections 5.8.2 and 5.8.3 summarize recommended next steps for evaluating RED data for the UV Intensity Setpoint Approach and Calculated Dose Approach, respectively.

5.8.1 Calculating the Reduction Equivalent Dose (RED)

The RED should be calculated for all full-scale reactor test conditions, individually for each replicate, using the following method:

1. For each test condition replicate (i.e., influent and effluent sample pairs), calculate the log inactivation (log I) using Equation 5.7:

$$\log\ I = \log\left(\frac{N_o}{N}\right) \qquad \text{Equation 5.7}$$

where:

N_o = Challenge microorganism concentration in influent sample (pfu/mL or cfu/mL)

N = Challenge microorganism concentration in corresponding effluent sample (pfu/mL or cfu/mL)

2. Determine the RED, in mJ/cm^2 for each test condition replicate pair using the measured log inactivation (log I) and the UV dose-response curve developed through collimated beam testing (see Appendix C). If individual UV dose-response curves cannot be combined, the curve for a given day of testing should be used to determine RED for full-scale reactor testing data collected that day. If individual dose-response curves developed on the same day of testing cannot be combined, the curve resulting in the most conservative (lowest) RED values should be used.

Note that for the UV Intensity Setpoint Approach, replicates for a given test condition are averaged. For the Calculated Dose Approach, replicates are evaluated separately to develop the UV dose-monitoring equation.

Appendix B shows RED calculations for two hypothetical water systems. Example 5.2 shows the key inputs and results for the hypothetical water system in Section B.1.

Example 5.2. Calculating RED Using Validation Test Data. Collimated beam testing using a challenge microorganism produces the following UV dose-response curve:

UV Dose (mJ/cm^2) = 2.18(log I)^2 + 15.30(log I) *(from Figure B.2)*

Full-scale reactor testing produces the following data for each test condition and replicate test:

Test Condition	Replicate	N_o (pfu/mL)	N (pfu/mL)	Log I	**RED (mJ/cm^2)**
1	1	5.94	4.57	1.37	**25.1**
1	2	6.00	4.54	1.46	**27.0**
1	3	5.84	4.56	1.28	**23.2**
2	1	6.01	4.10	1.91	**37.2**
2	2	5.99	4.09	1.9	**36.9**
2	3	6.04	4.06	1.98	**38.8**

The RED values for each test are shown in the last column.

If the UV reactor uses MP lamps and validation testing is performed using a challenge microorganism other than MS2 phage or *B. subtilis*, an action spectra correction factor (CF_{as}) may need to be applied to the RED values to account for differences in the action spectra of the target pathogen and challenge microorganism. Section D.4.1 in Appendix D describes this concept and presents the correction factors that should be used for the RED adjustment (i.e., divide RED by the correction factor).

If validation testing is done with two challenge microorganisms whose UV sensitivities bracket the UV sensitivity of the target pathogen (i.e., one microorganism is more resistant and one is less resistant), the following approach can be used to estimate the RED of the target pathogen for each test condition:

1. For each test condition, calculate the UV sensitivity (mJ/cm^2 per log I) of the challenge microorganism using the following equation:

$$UV\ sensitivity = RED / Log\ I \qquad \text{Equation 5.8}$$

where:
RED = The RED for the test replicate as derived by inputting Log I into the UV dose-response equation
Log I= log inactivation for the test replicate as calculated using Equation 5.7

2. Create a graph with UV sensitivity on the *x*-axis and RED (mJ/cm^2) on the *y*-axis for each test condition.

3. For each challenge microorganism, plot paired UV sensitivity and RED values on the graph (2 values).

4. Draw a straight line between the two points.

5. Determine the UV sensitivity for the target pathogen by selecting the UV dose from Table 1.4 for ***1 log inactivation*** (log I = 1)

6. Using the straight line in the graph created in Step 4, read the corresponding RED value for the UV sensitivity of the target pathogen (as determined in Step 5).

Example 5.3 shows this procedure using hypothetical validation test data. As noted in Section 5.3, the main advantage of testing two challenge microorganisms whose UV sensitivities bracket the sensitivity of the target pathogen is that the factor used to account for challenge microorganism bias (the RED Bias factor) can be set to **1.0**. (See Section 5.9 for discussion of the RED bias factor.)

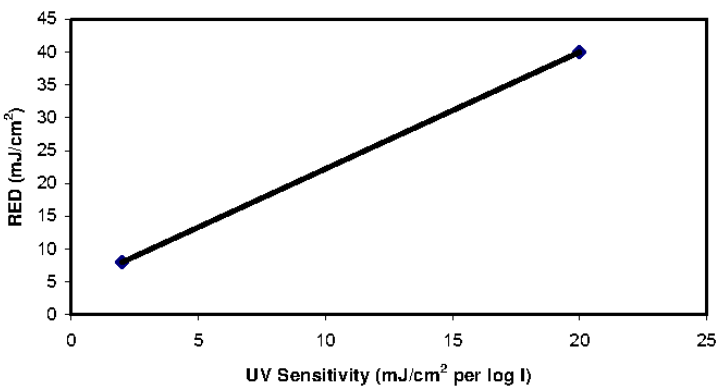
Example 5.3. Validation Testing Using Two Challenge Microorganisms

Validation testing is performed using MS2 and φx174. The table below summarizes average results for three replicates for one test condition (high UVT).

Challenge Microorganism	Influent Conc. (pfu/mL)	Effluent Conc. (pfu/mL)	UV Sensitivity (mJ/cm^2 per log I)[1]	Log I[2]	RED (mJ/cm^2)[3]
MS2	1×10^6	1×10^4	20	2.0	40
φx174	1×10^4	0	2	≥4.0	≥8.0

[1] As derived from collimated beam testing data for a log inactivation of 2.0 for MS2 and 4.0 for φx174 using Equation 5.9.
[2] Based on measured influent and effluent microorganism concentrations from validation testing.
[3] Determined by inputting log I into the UV dose-response equation.

Paired UV sensitivity and RED values for MS2 and φx174 were plotted on the graph below.



Straight-line interpolation between the two points yields the following equation:

$$RED = 1.78 \times UV\ Sensitivity + 4.44$$

The equation above predicts that the RED delivered to *Cryptosporidium*, defined with a UV sensitivity of 3.9 mJ/cm^2 per log inactivation (Table 1.4), is:

$$RED = 1.78 \times 3.9 + 4.44 = 11.4\ mJ/cm^2$$

Because the RED represents the dose delivered to *Cryptosporidium*, the RED Bias Factor is equal to 1.0.

5.8.2 Selecting the Minimum RED for the UV Intensity Setpoint Approach

Replicate RED values (typically 3 – 5 values) should be averaged to produce one RED for each test condition. From these average values, the ***minimum RED*** should be selected and used in the validated dose calculation. If variable-setpoint operations will be used at the water treatment plant (i.e., different UV intensity setpoints for different flow rate ranges), the minimum RED value should be identified for each flow rate range.

Table 5.6 in Section 5.6.1 presents the two test conditions that should be evaluated, at a minimum, for the UV Intensity Setpoint Approach. If the UV sensor is in the ideal location (i.e., a location that gives UV dose delivery proportional to the UV sensor reading), the two test conditions should yield the same RED. If the sensor is located farther from the lamp than the ideal location, the minimum RED will be produced under minimum UVT/maximum power conditions (Test 1). If the sensor is located closer to the lamp than the ideal position, the minimum RED will be produced under maximum UVT /minimum power conditions (Test 2). Selecting the minimum RED from these two test conditions accounts for UV reactor designs where the sensor is not in the ideal location. See Section D.2 in Appendix D for additional discussion on UV sensor positioning.

5.8.3 Developing the Dose-monitoring Equation for the Calculated Dose Approach

If the reactor uses the Calculated Dose Approach, validation testing results are used to develop a ***dose-monitoring equation*** for RED. The variables in the dose-monitoring equation are typically flow rate, UVT, UV intensity, or some subset thereof. The number of operating banks of lamps is also a possible variable for the equation for those water systems that use multiple banks.

EPA recommends using multivariate linear regression to fit an equation to the validation test data. Procedures for multivariate linear regression can be found in standard statistical textbooks such as Draper and Smith (1998). Software packages, such as Microsoft Excel, can also be used to perform the regression analysis and determine the goodness-of-fit. Recommended steps for the analysis are summarized below.

1. **Fit an equation for RED as a function of the operating parameters of interest (using all the replicate inlet-and-outlet pairs) using multivariate linear regression.** The equation used for interpolating validation data may have various forms depending on how it was derived. An empirical equation that can often provide a good fit to validation data has the following form (Wright et al. 2005):

$$RED = 10^{a} \times A_{254}{}^{b} \times \left(S/S_o \right)^{c} \times \left(1/Q \right)^{d} \times B^{e} \qquad \text{Equation 5.9}$$

   or in linear form,

$$\log(RED) = a + b \times \log(A_{254}) + c \times \log\left(\frac{S}{S_o}\right) + d \times \log\left(\frac{1}{Q}\right) + e \times B \qquad \text{Equation 5.10}$$

where:

RED	=	The RED calculated with the dose-monitoring equation, also referred to as the "calculated dose" in this guidance manual
A_{254}	=	UV absorbance at 254 nm
S	=	Measured UV sensor value
S_o	=	UV intensity at 100 percent lamp power, typically expressed as a function of UVT.
Q	=	Flow rate
B	=	Number of operating banks of lamps within the UV reactor
a, b, c, d, e	=	Model coefficients obtained by fitting the equation to the data

Either the full equation or part of the equation can be used for fitting validation data. For example, validation data collected at a constant UVT and lamp power setting can be fitted using:

$$RED = a \times \left(\frac{1}{Q}\right)^d \qquad \text{Equation 5.11}$$

or in linear form,

$$\log(RED) = \log(a) + d \log\left(\frac{1}{Q}\right) \qquad \text{Equation 5.12}$$

The exact form of the relationship will depend on the UV reactor and the functional relationships between RED and each variable.

The equation should pass through the origin (0,0) if the RED is calculated as a function of measured UV intensity or inverse flow rate. A zero measured dose should correspond to a zero calculated dose. A non-zero intercept would introduce a bias.

2. **Determine the goodness-of-fit.** This can be done using procedures found in standard statistics books or by reviewing variance tables produced by statistical programs. The analysis should determine the p-statistics for the model coefficients. For the fit to be acceptable, the p-statistic for each model coefficient should be ≤ 0.05.

   If the p-statistic for a given model coefficient is greater than 0.05, the coefficient is not statistically significant. The coefficients are calculated with all the variables included. If the p-statistic for any coefficient exceeds 0.05, then, working in reverse, the model coefficient with the highest p-statistic should be dropped from the equation and the multivariate regression repeated until all p-statistics are less than or equal to 0.05. Alternatively, the functional form of the equation could be revised to improve the relationship between RED and the parameters of interest (e.g., use Equation 5.12

instead of Equation 5.10).

3. **Verify that there is no significant bias in the fit.** One way to do this is to test for randomness in residual values (Draper and Smith 1998). The differences between the measured and calculated RED values should be randomly distributed around zero and not dependent on flow rate, UVT, or lamp status.

Because both UVT and UV intensity are part of the dose-monitoring equation, it is not important that the sensor be in the ideal location. If the UV sensor *is* in the ideal location, however, UVT could be removed from the dose-monitoring equation. See Section D.2 for additional discussion of UV sensor positioning.

5.9 Deriving the Validation Factor (VF)

Several uncertainties and biases are involved in using experimental testing to define a validated dose and validated operating conditions. For example, a challenge microorganism may have a different UV sensitivity than the target pathogen. To determine the validated dose, the RED (derived in Section 5.8) is divided by a ***VF*** to quantitatively account for key areas of uncertainty. The equation for the VF is shown below.

$$VF = B_{RED} \times \left(1 + {U_{Val}}/{100}\right) \qquad \text{Equation 5.13}$$

where:

VF = Validation Factor
B_{RED} = RED bias factor
U_{Val} = Uncertainty of validation expressed as a percentage

In addition to the RED bias factor, a bias factor to account for the influence of non-germicidal light on UV sensor readings (referred to as the "polychromatic bias factor") should be included in Equation 5.13 for MP reactors that meet either of the following criteria:

- The MP reactor is equipped with a non-germicidal sensor[12]
- The MP reactor is equipped with a germicidal sensor, but the sensor is mounted further than 10 cm from the lamp and the water to be treated has a low UVT (< 80%)

Derivation of the polychromatic bias factor and its inclusion in the VF calculation are addressed in Appendix D, Section D.4.3.

The next two sections provide recommendations for calculating the RED bias factor and uncertainty in validation and determining when each should be applied. Appendix D discusses in greater detail the basis for the uncertainty and bias terms and how they were derived.

[12] EPA recommends that MP reactors be equipped with ***germicidal sensors*** to more accurately measure UV light in the germicidal range. EPA recognizes, however that reactors with non-germicidal sensors have been installed or are about to be installed at water treatment plants prior to the publication of this document.

Appendix B uses two example case studies to illustrate the calculation of the VF using methods described in this section.

Some areas of experimental uncertainty are not included in the VF equation. Instead, EPA recommends that UV reactor monitoring components meet the performance criteria presented in Chapter 6 and validation test results meet the QA/QC criteria as presented throughout this chapter and summarized in Section 5.12. Section 5.9.2 includes a method for checking key areas of experimental uncertainty and determining when factors should be included in the U_{Val} calculation.

5.9.1 RED Bias Factor

The RED bias is a correction factor that accounts for the difference between the UV sensitivity of the target pathogen and the UV sensitivity of the challenge microorganism. If validation testing is performed using two challenge microorganisms whose UV sensitivities bracket those of the target pathogen (i.e., one challenge microorganism is less resistant than the target pathogen and the other is more resistant than the target pathogen), the RED bias is equal to 1.0 (i.e., it can be corrected for, see Section 5.8.1 for details).

If the UV sensitivities of the challenge microorganism and target pathogen are not the same, the RED delivered under the same reactor operating conditions will differ. The magnitude of this difference depends on the following factors:

- The dose distribution of the UV reactor
- The difference between the inactivation kinetics of the challenge microorganism and the target pathogen

If the challenge microorganism is more resistant to UV light than the target pathogen, the RED measured during validation will be *greater* than the RED that would be measured for the target pathogen. In this case, the RED bias would be greater than 1.0. If the challenge microorganism is less resistant (more sensitive) to UV light than the target pathogen, the RED measured during validation will be *less than* the RED that would be measured for the target pathogen. In this case, the RED bias should be assigned a value of 1.0.

The recommended procedure for determining the RED bias is as follows:

1. For the test condition with the lowest UVT, determine the observed ***UV sensitivity*** of the challenge microorganism for each test replicate using Equation 5.8.

2. Identify the ***maximum*** UV sensitivity for all test replicates.

3. Use Tables G.1 – G.17 (in Appendix G) to find the RED bias for the target pathogen and target log inactivation, the maximum UV sensitivity, and the lowest UVT. Note that Tables G.1 – G.17 are for discreet UVT values of 85 percent, 90 percent, and 95 percent. RED bias can be interpolated for intermediate values of UVT.

EPA recommends calculating one RED Bias for the UV facility, based on the site-specific application (i.e., minimum operating UVT and target pathogen log inactivation desired), which results in a constant VF for all conditions. As an alternative, the RED bias can be defined as a function of UVT. This alternative may be advantageous for the Calculated Dose Approach where UVT is continually monitored during operations, which means that the VF and the validated dose would vary along with UVT. The disadvantage of using a variable VF is that the UV reactor control system would need to be designed and programmed to do these calculations and that the VF reported to the state will vary (see Section 6.5 for reporting guidance), making operations and reporting more complex.

Values in Tables G.1 – G.17 are based on theoretical dose distributions (as determined by CFD modeling) for several UV reactor designs. Appendix D, Section D.5 provides additional information on the derivation of values in Tables G.1 – G.17. Example 5.4 shows how the RED bias is determined for hypothetical test conditions.

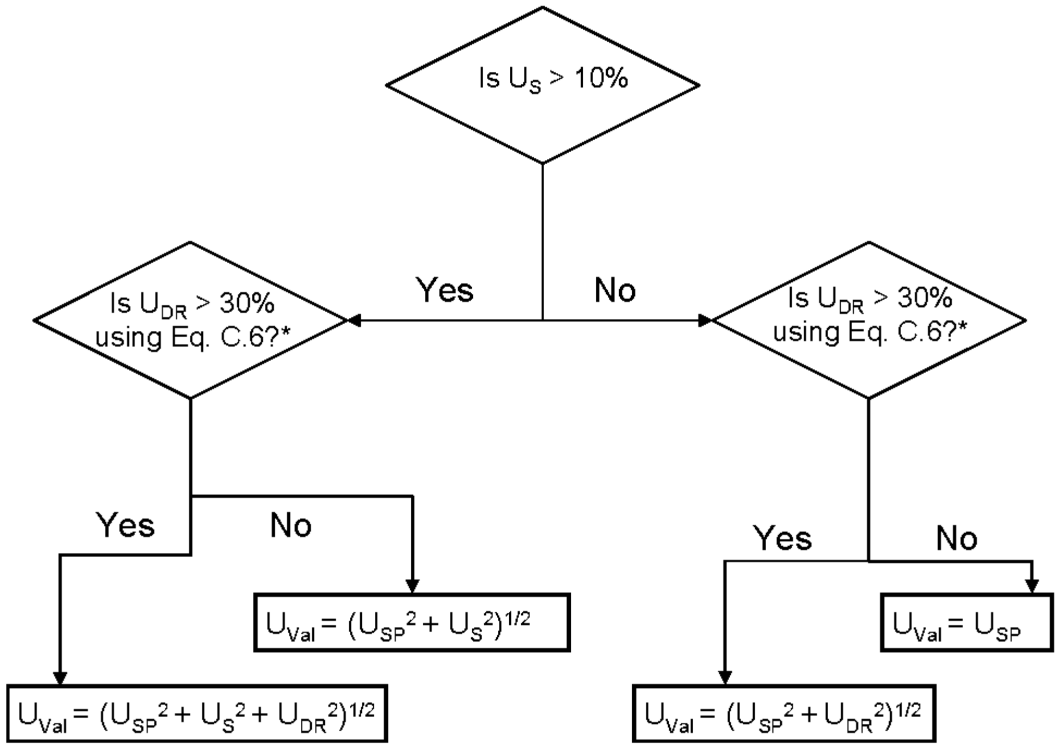
Example 5.4. Determining the RED Bias factor. A UV reactor is validated using MS2 phage for 3-log *Cryptosporidium* inactivation credit. The maximum MS2 phage UV sensitivity for the validation test condition of lowest UVT (86 percent) is 18.0 mJ/cm^2 per log inactivation. The RED bias from Table G.3 is **1.92**.

5.9.2 Uncertainty in Validation (U_{Val})

The Uncertainty in Validation (U_{Val}), also referred to as the experimental uncertainty, has between 1 and 3 input variables based on how well the validation testing adhered to recommended QA/QC limits in this guidance manual. At least one input variable, which depends on the dose-monitoring strategy of the UV reactor, should be used in all cases.

Figures 5.4 and 5.5 provide decision trees for selecting the appropriate equation for calculating U_{Val} and provide a description of the input variables used for the calculation. The next two sections provide guidance for deriving two of the input variables for U_{Val}, which are U_{SP} (the uncertainty in the setpoint value, which is always calculated for the UV Intensity Setpoint Approach) and U_{IN} (the uncertainty in interpolation, which is always calculated for the Calculated Dose Approach). U_S is the uncertainty in UV sensor measurements, expressed as a fraction (e.g., 15 percent, or 0.15) as described in Section 5.5.4. U_{DR} is the uncertainty of the dose-response fit at a 95-percent confidence level. Note that if individual UV dose-response curves cannot be combined and there is more than one U_{DR} value, the maximum value should be used in the decision tree. Additional guidelines for estimating U_{DR} are provided in Section C.4.

Figure 5.4. U_{VAL} Decision Tree for the UV Intensity Setpoint Approach



Where:

U_{Val} = Uncertainty of validation (representing experimental uncertainty)

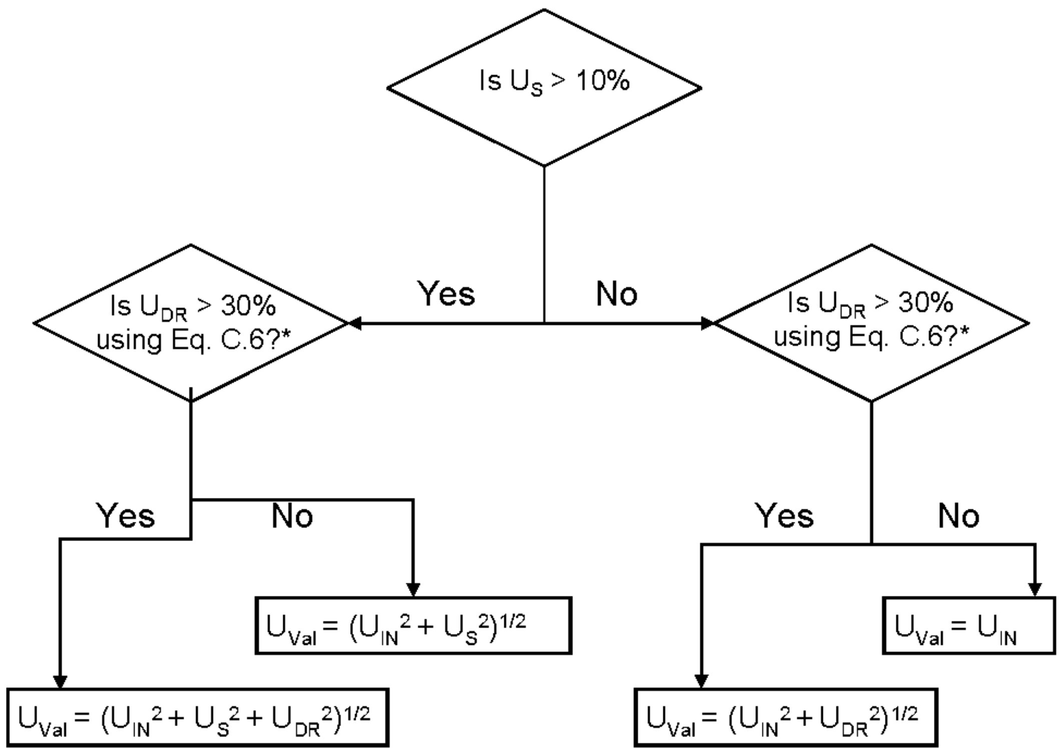
U_S = Uncertainty of sensor value, expressed as a fraction (i.e., if sensor uncertainty = 12%, U_S = 0.12. See Section 5.5.4 for guidance on determining sensor uncertainty.)

U_{DR} = Uncertainty of the fit of the dose-response curve, calculated using Equation C.6. If there is more than one U_{DR} value, use the maximum value

U_{SP} = Uncertainty of setpoint, calculated using Equation 5.14 (See Section 5.9.2.1 for additional guidance)

*If U_{DR} is calculated using standard statistical methods instead of using equation C.6, is it > 15%?

Figure 5.5. U_{VAL} Decision Tree for the Calculated Dose Approach



Where:

U_{Val} = Uncertainty of validation (representing experimental uncertainty)

U_S = Uncertainty of sensor value, expressed as a fraction (i.e., if sensor uncertainty = 12%, U_S = 0.12. See Section 5.5.4 for guidance on determining sensor uncertainty.)

U_{DR} = Uncertainty of the fit of the dose-response curve, calculated using Equation C.6 If there is more than one U_{DR} value, use the maximum value

U_{IN} = Uncertainty of interpolation, calculated using Equation 5.15 (See Section 5.9.2.2 for additional guidance)

*If U_{DR} is calculated using standard statistical methods instead of using equation C.6, is it > 15%?

5.9.2.1 Calculating U_{SP} for the UV Intensity Setpoint Approach

The uncertainty in the setpoint value is based on a prediction interval at a 95-percent confidence level using the following procedure:

1. Calculate the average and standard deviation of RED values for each test condition (typically at least 3 – 5 replicate pairs are generated for each test condition).

2. Calculate the uncertainty of the setpoint RED using:

$$U_{SP} = \frac{t \times SD_{RED}}{RED} \times 100\% \qquad \text{Equation 5.14}$$

where:

RED = Average RED value measured for each test condition

SD_{RED} = Standard deviation of the RED values measured for each test condition

t = t-statistic for a 95-percent confidence level defined as a function of the number of replicate samples using the following:

Number of Samples	t
3	3.18
4	2.78
5	2.57

3. Select the highest U_{SP} from all test conditions for calculating the VF.

5.9.2.2 Calculating U_{IN} for the Calculated Dose Approach

For reactors using the Calculated Dose Approach, the uncertainty of interpolation (U_{IN}) is calculated as the lower bound of the 95-percent prediction interval for the dose-monitoring equation. This prediction interval reflects the noise in the data about that fit. In non-statistical terms, the U_{IN} represents the difference between (1) the RED value as derived using measured log inactivation and the UV dose-response curve, and (2) the RED value as calculated using the dose-monitoring equation (also referred to as the "calculated dose" in this manual).

U_{IN} is calculated using the following equation:

$$U_{IN} = \frac{t \times SD}{RED} \times 100\% \qquad \text{Equation 5.15}$$

where:

SD = Standard deviation of the differences between the test RED (based on the observed log inactivation and UV dose-response curve), and the RED calculated using the dose-monitoring equation for each replicate

RED = The RED as calculated using the dose-monitoring equation

t = t-statistic at a 95-percent confidence level for a sample size equal to the number of test conditions used to define the interpolation:

Number of Data Points Used to Develop the Dose-Monitoring Equation	t		Number of Data Points Used to Develop the Dose-Monitoring Equation	t
3	3.18		14	2.14
4	2.78		15	2.13
5	2.57		16	2.12
6	2.45		17	2.11
7	2.36		18	2.10
8	2.31		19-20	2.09
9	2.26		21	2.08
10	2.23		22-23	2.07
11	2.20		24-26	2.06
12	2.18		27-29	2.05
13	2.16		≥30	2.04

The value of U_{IN} depends on the calculated RED (or calculated dose), increasing at low calculated RED values. EPA recommends that one U_{IN} be selected that represents the most conservative (largest) uncertainty value calculated for the validated dose operating range (for the lowest calculated RED). Alternatively, U_{IN} can be expressed as a function of the calculated RED.

5.10 Determining the Validated Dose and Validated Operating Conditions

As shown in Figure 5.1 in Section 5.2, the last step in the recommended validation protocol is to adjust the RED results by the VF to determine the Validated Dose for the UV reactor using the following equation:

$$Validated\ Dose = RED / VF \qquad \text{Equation 5.16}$$

Where:

RED = the Minimum RED for the UV Intensity Setpoint Approach; or the RED as calculated using the dose-monitoring equation (also referred to as the calculated dose) for the Calculated Dose Approach

VF = the Validation Factor, as calculated using Equation 5.13

Because the method and assumptions for this step depend on the dose-monitoring strategy of the UV reactor, they are discussed separately below.

5.10.1 Determining the Validated Dose and Operating Conditions for the UV Intensity Setpoint Approach

For the UV Intensity Setpoint Approach, Equation 5.16 produces ***one validated dose*** for a given UV intensity setpoint corresponding to the minimum RED. When the UV reactor is operating at a UV intensity level above the setpoint, the true UV dose delivered to microorganisms passing through the reactor is always equal to or greater than the validated dose.

The inactivation credit for the target pathogen is determined by comparing the validated dose to the required dose in Table 1.4.

Validated operating conditions are as follows:

- The UV intensity measured by UV sensors must be greater than the UV intensity setpoint.
- The flow rate must be equal to or less than the flow rate tested.
- The lamp status for each lamp (i.e., on/off setting) must be equivalent to the settings used during validation testing.

5.10.2 Determining the Validated Dose and Operating Conditions for the Calculated Dose Approach

For the Calculated Dose Approach, the validated dose varies based on operational parameters. Typically, measured values of UVT, UV intensity, and flow rate are entered into the dose-monitoring equation to calculate RED. RED is divided by the VF to produce the validated dose (Equation 5.16). Although EPA recommends using one VF, an equation may be used for the VF if the RED bias factor is expressed as a function of UVT or if U_{IN} is expressed as a function of RED.

As noted in Section 3.5.2, a key advantage of the Calculated Dose Approach is that water systems can reduce power when UVT is high and/or the flow rate is low as long as the Validated Dose is greater than or equal to the required dose for the target pathogen and log inactivation level. As a reminder, the validated dose must be greater than or equal to the required dose for the target pathogen and target log inactivation level to receive treatment credit.

Validated operating conditions for the Calculated Dose Approach are as follows:

- The operating UVT must be equal to or greater than the minimum UVT evaluated during validation testing.[13]
- The operating flow rate must not exceed the flow rate evaluated during validation testing (*see footnote 13*).

[13] If the operating UVT measures higher than the maximum UVT evaluated during validation testing, the maximum UVT evaluated during validation testing should be used as the default in the dose-monitoring equation. Similarly, if the operating flow rate measures less than the minimum flow rate evaluated during validation testing, the minimum flow rate evaluated during validation testing should be used as the default in the dose-monitoring equation. See Section 6.1.4 for guidance on setting operational controls.

5.11 Documentation

Prior to validation testing, the water system should work with the manufacturers, third party reviewers, and engineers assisting with or performing validation testing to prepare the following:

- Documentation for the UV reactor
- Validation Test Plan

Once validation testing and the associated data analyses are complete, the UV reactor documentation and Validation Test Plan, along with results of validation testing, should be incorporated into a ***Validation Report***.

The next several sections provide more detailed recommendations on validation testing documentation. Water systems purchasing a pre-validated reactor will not be preparing documentation; however, Sections 5.11.1 through 5.11.3 may be useful as they review validation documentation from manufacturers and consulting engineers. State personnel may also find these sections helpful when reviewing validation reports.

5.11.1 UV Reactor Documentation

Before validation testing, the UV manufacturer should provide the testing party with documentation identifying and describing the UV equipment. Documentation should include all reactor and component information that impacts UV dose delivery and monitoring, as described in Checklist 5.1.

Checklist 5.1 UV Reactor Documentation (Page 1 of 2)

Does UV reactor documentation contain the following elements?

Yes No

General

☐ ☐ Technical description of the reactor's UV dose-monitoring strategy, including the use of sensors, signal processing, and calculations (if applicable).

☐ ☐ Dimensions and placement of all wetted components (e.g., lamps, sleeves, UV sensors, baffles, and cleaning mechanisms) within the UV reactor.

☐ ☐ A technical description of lamp placement within the sleeve.

☐ ☐ Specifications for the UV sensor port indicating all dimensions and tolerances that impact the positioning of the sensor relative to the lamps. If the UV sensor port contains a monitoring window separate from the sensor, specifications giving the window material, thickness, and UV transmittance should be provided.

Lamp specifications

☐ ☐ Technical description
☐ ☐ Lamp manufacturer and product number
☐ ☐ Electrical power rating
☐ ☐ Electrode-to-electrode length
☐ ☐ Spectral output of new and aged lamps (specified for 5 nm intervals or less over a wavelength range that includes the germicidal range of 250 – 280 nm and the response range of the UV sensors)
☐ ☐ Mercury content
☐ ☐ Envelope diameter

Lamp sleeve specifications

☐ ☐ Technical description including sleeve dimensions
☐ ☐ Material
☐ ☐ UV transmittance (at 254 nm for LP and LPHO lamps, and at 200 – 300 nm for MP lamps with germicidal sensors)

Specifications for the reference and the duty UV sensors

☐ ☐ Manufacturer and product number
☐ ☐ Technical description including external dimensions
☐ ☐ Data and calculations showing how the total measurement uncertainty of the UV sensor is derived from the individual sensor properties. (See Table D.1 for an example of the calculation of UV sensor measurement uncertainty from the uncertainty that arises due to each UV sensor property.)

Checklist 5.1 UV Reactor Documentation (Page 2 of 2)

Does UV reactor documentation contain the following elements?

Yes No

Sensor measurement properties

☐ ☐ Working range
☐ ☐ Spectral and angular response
☐ ☐ Linearity
☐ ☐ Calibration factor
☐ ☐ Temperature stability
☐ ☐ Long-term stability

Installation and operation documentation:

☐ ☐ Flow rate, head loss, and pressure rating of the reactor
☐ ☐ Assembly and installation instructions
☐ ☐ Electrical requirements, including required line frequency, voltage, amperage, and power
☐ ☐ Operation and maintenance manuals that include cleaning procedures, required spare parts, and safety requirements. Safety requirements should include information on electrical lockouts, eye and skin protection from UV light, safe handling of lamps, and mercury cleanup recommendations in the event of lamp breakage.

5.11.2 Validation Test Plan

A validation test plan should document the key components of UV reactor testing. Recommended components of a validation test plan are provided in Checklist 5.2. This list is not meant to be all-inclusive; engineers should document any factors they believe are important for validation testing in their Validation Test Plan.

Checklist 5.2 Key Elements of the Validation Test Plan (Page 1 of 1)

Does the validation test plan contain the following elements?

Yes	No	
☐	☐	Purpose of Validation Testing. General description of why the tests are being done and how the data will be used.
☐	☐	Roles and Responsibilities. Key personnel overseeing and performing the full-scale reactor testing and collimated beam testing, including their qualifications. This section should include contact names and telephone numbers.
☐	☐	Locations and Schedule. Location for conducting full-scale reactor testing and collimated beam testing. Planned schedule for conducting the tests and performing the data analyses.
☐	☐	Challenge Microorganism Specifications. Specifications for the challenge microorganism to be used during validation that include the protocols required for growth and enumeration, the expected UV dose-response, and suitability for use in validation testing.
☐	☐	Plan for state review (if applicable).

Design of the Biodosimetry Test Stand/On-site Testing Facilities

☐	☐	Inlet/outlet piping design, including backflow prevention
☐	☐	Mixing
☐	☐	Sample ports
☐	☐	Pumps
☐	☐	Additives (Material Safety Data Sheets for UV-adsorbing chemical, quenching agent)

Collimated Beam Testing Apparatus

☐	☐	Lamp type
☐	☐	Collimating tube aperture
☐	☐	Distance from light source to sample surface
☐	☐	Radiometer make and model

Monitoring Equipment Specifications and Verification of Equipment Accuracy for the following:

☐	☐	Flow meters
☐	☐	UVT analyzers (if used)
☐	☐	UV Spectrophotometers
☐	☐	Power measurement
☐	☐	UV sensors
☐	☐	Radiometer make, model, and calibration certificates

Experimental Test Conditions including, but not limited to:

☐	☐	Number of tests, UVT, flow rate, lamp power, and lamp status for each test condition
☐	☐	Lamp fouling factor, use of new or aged lamps
☐	☐	Influent concentration of challenge microorganisms for each test condition
☐	☐	QA/QC Plan

5.11.3 Validation Report

The validation report should provide detailed documentation of all validation testing results. The report should also include all elements of the Validation Test Plan and a summary of the field-verified UV reactor properties.

EPA recommends that the report begin with an executive summary with key information that can be used by states and water systems to assess inactivation credit for the target pathogen(s). The executive summary should include, at a minimum,

- The validated dose or range of validated doses,
- The log credit achieved for the potential target pathogens by the UV reactor, and
- Validated operating conditions (i.e., flow rate, UVT if the Calculated Dose approach is used).

If the UV Intensity Setpoint approach is used, the executive summary should provide the UV intensity setpoint (or setpoints) for the validated dose. If the reactor uses the Calculated Dose Approach as its dose monitoring strategy, the dose-monitoring equation should be provided.

In addition to the items listed above, the executive summary should include the following:

- A brief description of the validated reactor,
- The assumed fouling/aging factors for the reactor and indication if new or aged lamps were used during validation testing,
- A summary of the validation test conditions, including but not limited to the flow rate, UVT, and lamp power for each test condition,
- Key validation test results used to derive the dose, including but not limited to the RED values for each test condition, the UV dose-monitoring equation from collimated beam testing, and the VF,
- A summary of QA/QC checks and results, including UV sensor and radiometer reference checks,
- A description of the validation facilities,
- The organizations conducting the validation test, and
- Names and credentials of the individuals/organizations providing third party oversight.

Recommended contents for the detailed validation report are listed in Checklist 5.3. Note that these recommendations are not intended to be all-inclusive. Engineers should document any test characteristics or outcomes they believe are important in the Validation Report.

Checklist 5.3 Key Elements of the Validation Report (Page 1 of 1)

Does your validation report contain the following elements?

Yes No
General

☐ ☐ Detailed reactor documentation (see Checklist 5.1), including drawings and serial numbers, and procedures used to verify reactor properties.
☐ ☐ Validation test plan (either a summary of key elements, or the test plan can be attached to the validation report along with documentation of any deviations to the original test plan)

Full-scale reactor testing results, with detailed results for each test condition evaluated. Data should include, but are not limited to:

☐ ☐ Flow rate
☐ ☐ Measured UV intensity
☐ ☐ UVT
☐ ☐ Lamp power
☐ ☐ Lamp statuses
☐ ☐ Inlet and outlet concentrations of the challenge microorganism

Collimated beam testing results, including detailed results for each collimated beam test used to create the UV dose-response equation:

☐ ☐ Volume and depth of microbial suspension
☐ ☐ UV Absorption of the microbial suspension
☐ ☐ Irradiance measurement before and after each irradiation
☐ ☐ Petri factor calculations and results
☐ ☐ Calculations for UV dose
☐ ☐ Derivation of the UV dose-response equation, including statistical methods and confidence intervals (i.e., calculation of U_{DR})

QA/QC Checks:

☐ ☐ Challenge microorganism QA/QC, including blanks, controls, and stability analyses
☐ ☐ Measurement uncertainty of the radiometer, date of most recent calibration, results of reference checks
☐ ☐ Measurement uncertainty of UV sensors and results of reference checks
☐ ☐ Measurement uncertainty of the flow meter, UV spectrophotometer, and any other measurement equipment used during full-scale testing

Calculation of the validated dose, log inactivation credit, and validated operating conditions:

☐ ☐ RED for each test condition
☐ ☐ Calculation of the VF
☐ ☐ Setpoints if the reactor uses the UV Intensity Setpoint Approach
☐ ☐ Dose-monitoring equation if the reactor uses the Calculated Dose Approach
☐ ☐ Log inactivation credit for target pathogens (e.g., *Cryptosporidium*, *Giardia*, and viruses)
☐ ☐ Validated operating conditions (e.g., flow rate, lamp status, UVT)

5.12 Guidelines for Reviewing Validation Reports

State engineers and water systems purchasing pre-validated reactors should review the validation report to confirm the following:

- Validation testing meets the minimum regulatory requirements as summarized in Table 5.1.
- EPA's recommended validation protocol was followed and any deviations from the protocol are adequately justified.
- Validated doses achieved by the UV equipment meet or exceed the target pathogen log inactivation desired.
- QA/QC criteria were met during validation testing.

Checklist 5.4 summarizes the QA/QC recommendations presented throughout this chapter and in Appendix C. If a QA/QC plan was prepared prior to validation, reviewers should request a copy of the plan and make sure it is consistent with industry standards.

Checklist 5.5 contains key elements that should be verified by state or water system personnel when reviewing validation reports. States and systems should keep documentation that these key validation criteria were met.

Checklist 5.4 Review for Quality Assurance/Quality Control (Page 1 of 1)

Yes No

Uncertainty in Measurement Equipment (See Section 5.5 and C.2.2 for more information)

☐ ☐ **Flow Meter:** Is the measurement uncertainty < 5 percent?

☐ ☐ **UV Spectrophotometer:** Is the measurement uncertainty ≤ 10 percent?

☐ ☐ **UV Sensors:** Did duty sensors operate within 10 percent of the average of two or more reference sensors? If not, was uncertainty in sensor measurement incorporated into the VF?

☐ ☐ **Radiometer:** (for collimated beam testing only). Do lamp output measurements vary by no more than 5 percent over exposure time? Was the accuracy of the radiometer verified with another radiometer?

QA/QC of Microbial Samples (See Section 5.6.4 for more information)

☐ ☐ **Reactor controls:** For influent/effluent samples taken with the UV reactor lamps turned off, does the change in log concentration correspond to a change in RED that is within the measurement error of the minimum RED measured during validation (typically ≤ 3 %)?

☐ ☐ **Reactor blanks:** For DAILY influent/effluent samples taken with NO challenge microorganisms injected, are the measured concentrations of the challenge microorganism negligible?

☐ ☐ **Trip Controls:** For an UNTESTED sample bottle of challenge microorganism stock solution that travels with tested samples between the laboratory and the reactor, is the change in the log concentration of the challenge microorganism within the measurement error. (I.e., the change in concentration over the test run should be negligible. This is typically on the order of 3 to 5%.)

☐ ☐ **Method Blanks:** For sterilized reagent grade put through the challenge microorganism assay procedure, is the challenge microorganism concentration non-detectable?

☐ ☐ **Stability Samples**: For influent/effluent samples at low and high UVT, are the challenge microorganism concentrations within 5 percent of each other?

Uncertainty in Collimated Beam Testing Data (See Appendix C for more information)

☐ ☐ Do the uncertainties in the terms in the UV dose calculation meet the following criteria:

- Depth of suspension (d) ≤ 10 percent
- Incidence irradiance (E_s) ≤ 8 percent
- Petri factor (P_f) ≤ 5 percent
- L/(d + L) ≤ 1 percent
- Time (t) ≤ 5 percent
- $(1 - 10^{-ad})/ad$ ≤ 5 percent

☐ ☐ Is the **uncertainty in dose-response** (U_{DR}), as calculated using equation C.6, less than or equal to 30 percent? If not, was U_{DR} incorporated into the VF?

Checklist 5.5 Review for Key Validation Report Elements (Page 1 of 2)

Yes	No	
☐	☐	Does the validation testing meet QA/QC criteria (see Checklist 5.4)?
☐	☐	For full-scale testing, does the mixing and location of sample ports follow recommendations provided in Sections 5.4.3 and 5.4.4, respectively?
☐	☐	If the reactor was validated off-site, do inlet/outlet piping conditions at the water treatment plant result in a UV dose-delivery that is **the same or greater than** the UV dose delivery at the off-site testing facility? (See Section 3.6 for recommended inlet/outlet piping configurations and Section D.6 for considerations for CFD modeling.)
☐	☐	Were collimated beam tests and full-scale reactor tests performed on the same day for a given test condition and using the same stock solution of challenge microorganisms? (See Section 5.7 for experimental testing guidelines.)
☐	☐	Is the UV sensitivity of the challenge microorganism and the overall shape of the UV dose-response curve consistent with the expected inactivation behavior for that challenge microorganism? See Appendix A of this manual for published UV dose-response curves for MS2 and *B. subtilis*.
☐	☐	Does the validation test design account for lamp fouling and aging, minimum UVT, and maximum flow rate expected to occur at the water treatment plant? (See Section 5.6 for recommended test design.)
For UV Reactors Using MP Lamps		
☐	☐	Is the UV reactor equipped with a germicidal sensor? New UV reactors should have germicidal sensors. If an installed reactor uses an MP lamp and a non-germicidal sensor, is a polychromatic bias factor incorporated into the derivation of the VF? (See Section D.4.3 for guidance on the polychromatic bias factor.)
☐	☐	Was validation testing conducted using a challenge microorganism other than MS2 or *B. Subtilis*? If yes, was the need for a correction factor assessed and was that factor applied based on the outcome? (See Sections 5.3 and D.4.1 for more information)
For UV Reactors Using the UV Intensity Setpoint Approach		
☐	☐	Were the minimum test conditions performed as specified in Section 5.6.1?
☐	☐	Is the UV intensity setpoint low enough to account for combined conditions of minimum UVT and maximum lamp fouling/aging at the water treatment plant (See Section 5.6.1 for guidance)
☐	☐	Was the **minimum RED** selected for calculating the validated dose? (See Section 5.8.1 for additional guidance.)
☐	☐	Does the VF calculation include both the B_{RED} and U_{SP}? (See Section 5.9 for additional guidance.)

Checklist 5.5 Review for Key Validation Report Elements (Page 2 of 2)

Yes	No	
		For UV Reactors Using the UV Intensity Setpoint Approach (continued)
☐	☐	If U_S and/or U_{DR} did not meet the QA/QC criteria, were they also included in the VF calculation?
☐	☐	Is the validated dose greater than or equal to the required dose for the water system's target pathogen and log inactivation level?
		For UV Reactors Using the Calculated Dose Approach
☐	☐	Was the minimum number of test conditions evaluated as specified in Section 5.6.2?
☐	☐	Was the empirical equation developed using standard statistical methods (e.g., multivariate linear regression)? (See Section 5.8.2 for additional guidance.)
☐	☐	Does the validation report include an analysis of goodness of fit and bias for the dose-monitoring equation? (See 5.8.2 for additional guidance.)
☐	☐	Does the VF calculation include both the B_{RED} and U_{IN}? (See 5.9.)
☐	☐	If U_S and/or U_{DR} did not meet the QA/QC criteria, were they also included in the VF calculation?
☐	☐	For the range of UVT values and flow rates expected to occur at the water system, is the validated dose greater than or equal to the required dose for the system's target pathogen and log inactivation?

5.13 Evaluating the Need for "Re-validation"

If a UV reactor is modified in a way that significantly impacts UV dose delivery or monitoring (e.g., the wetted geometry changes, the lamp technology changes, the UV sensor characteristics, and/or location change), validation testing should be conducted again (i.e., the UV reactor has been modified enough to be considered a different reactor with unsubstantiated performance). This section discusses some common types of UV reactor modifications and provides guidance on when UV reactors should be "re-validated."

Lamp Assembly

The relationship between UV dose delivery and monitoring may be impacted by any design change involving modifications to the following lamp components:

- Lamp arc length
- Any reflectors, connectors, and spacers used at the lamp ends
- Lamp envelope diameter
- Lamp envelope UV transmittance from 185 – 400 nm
- Mercury content of the lamp
- Argon content of the lamp

In many cases, UV dose delivery and UV sensor modeling can be used to assess the impacts of changing lamp material and justify the need, or lack of need, for re-validation.

Changes that will modify the UV output so that emitted intensity is uneven along the length of the lamp or around its circumference, however, can have a complex impact on UV dose delivery and would likely warrant re-validation.

Ballasts

Modifications to lamp ballasts include changing the operating voltage, current, frequency, and waveform. Modifications to LP lamps will not impact the relationship between UV dose delivery and UV intensity measurements. With MP lamps, changes in lamp operating temperature and mercury pressure caused by changes in ballast power will impact the spectral distribution of emitted light, resulting in a significant impact on UV reactors with non-germicidal sensors.

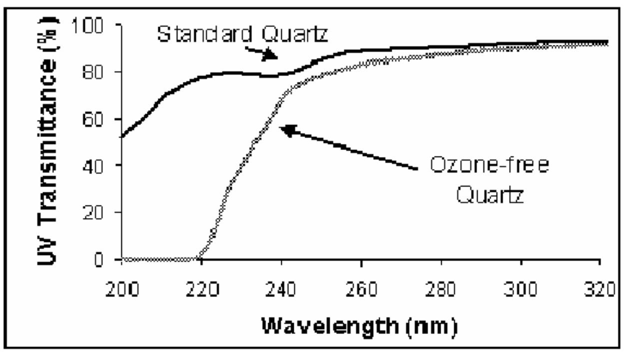
If a water system is using non-germicidal sensors, then EPA recommends that the reactor be re-validated if there are modifications to the lamp ballasts that change the operating voltage, current, frequency, and/or waveform.

Lamp Sleeves

Lamp sleeve design changes include changing the sleeve diameter, thickness, and material. Changing the sleeve diameter may significantly impact the hydraulics through the reactor, the measurement of UV intensity, and/or the ideal location of the UV sensors relative to the lamp. Changing the thickness and material of the lamp sleeve will impact its spectral UV transmittance, thereby impacting both UV dose delivery and UV intensity measurements.

UV dose delivery and UV sensor modeling may be used to assess the impact of lamp sleeve design changes. For example, a design change from a standard sleeve to the ozone-free sleeve described in Figure 5.6 would have a moderate impact on the relationship between UV dose delivery and UV sensor readings with a non-germicidal sensor and a negligible impact with a germicidal sensor. Modeling can also be used to show that the UV dose delivery at a given lamp output, water UVT, and flow rate would be approximately 10 percent greater with the standard sleeve than with the ozone-free sleeve. If the modeling indicates a change in dose delivery of greater than 10 percent as a result of lamp sleeve design changes, EPA recommends that the reactor be re-validated. If it is not possible to model the impact of lamps sleeve design changes, EPA also recommends the UV equipment be re-validated.

Figure 5.6 UVT of Standard and "Ozone-Free" Quartz Assuming Air-Quartz and Quartz-Water Interfaces



UV Reactor and Component Dimensions

Modifications to the wetted dimensions and positioning of the components within the UV reactor will impact the reactor hydraulics and UV dose delivery. Modifications could also impact the UV intensity field within the reactor and its measurement. Such changes include altering the dimensions of the UV reactor, inlet piping, exit piping, baffles, lamp sleeves, wipers, and/or UV sensors. The impact of such modifications on UV dose delivery and UV intensity measurements can be large or insignificant. Adding a baffle plate will likely have a large impact on UV dose delivery and a small impact on measured UV intensity. Changing the position of a UV sensor will likely have a small impact on UV dose delivery and a large impact on the measured UV intensity.

UV dose delivery and UV intensity modeling may be used to assess the impacts of these modifications. If the modeling indicates a change in dose delivery of greater than 10 percent as a result of changes to the wetted dimensions of the reactor and/or changes in the positioning of components, EPA recommends that the reactor be re-validated. If it is not possible to model the impact of modification to the wetted dimensions and positioning of components within the UV reactor, EPA recommends the UV equipment be re-validated.

UV Sensors

Modifications to the UV sensors include changes made by the sensor manufacturer to the sensor itself, its housing and its associated optical components, or installation within the reactor. Any modifications that affect the UV sensor response or the flow within the reactor affect should be evaluated to determine their impacts on dose delivery and dose monitoring. For example, if the measurement uncertainty of a new sensor is greater than 10 percent, it should be included in the VF calculations. If the angular response or spectral response of the UV sensor changes, measurements supported by calculations should be used to evaluate the impact of the change on UV dose delivery monitoring.

6. Start-up and Operation of UV Facilities

This chapter describes the start-up activities and routine operational issues associated with a UV disinfection facility. The start-up discussion focuses on the testing performed during the start-up process. The rest of the chapter describes requirements and recommendations for operation, maintenance, monitoring, recording, and reporting for UV facilities. Figure 6.1 illustrates the start-up and routine operation. A detailed description of each activity is provided in this chapter.

Chapter 6 covers:

The guidelines provided in this manual are based on industry experience and manufacturers' recommendations. Because of numerous differences among UV facilities and UV equipment, this document does not address all start-up and operation and maintenance (O&M) issues that may occur.

6.1 UV Facility Start-up

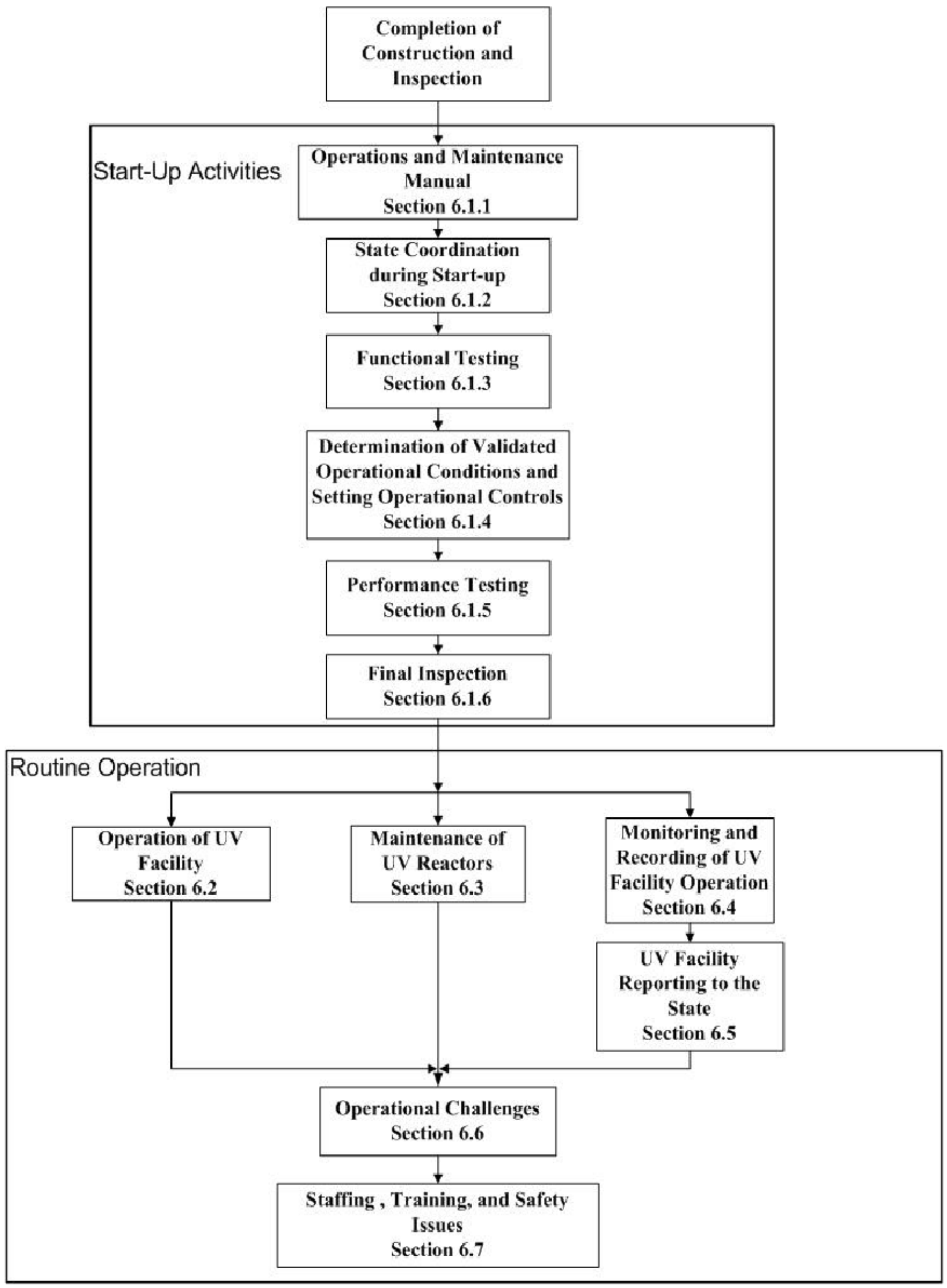
For the purposes of this manual, the start-up of the UV facility is considered as the transition from the construction phase to the operation phase. A start-up plan should be developed in collaboration with the UV facility designer, plant operations staff, and the UV manufacturer. The start-up plans should include O&M manual development, state coordination, functional testing, determination of validated operating parameters, performance testing, and final inspection.

6.1.1 O&M Manual

The O&M manual should be site-specific and based on as-built drawings, manufacturer's shop drawings, operating procedures, operational requirements, recommended maintenance tasks. If performance testing is completed before the O&M manual is finalized, testing results should be included in the manual. If possible, the O&M manual should be developed before performance testing and routine operations. At a minimum, O&M manuals should address the following items:

- Federal and state regulatory requirements and guidelines
- Treatment objectives

Figure 6.1. Start-up and Operation Flowchart[1]



[1] Start-up activities are not necessarily in chronological order.

- General description of UV facility
- Relationship to other unit treatment processes
- UV reactor design criteria
- Validated operational parameters
- Controls and monitoring
- Compliance monitoring, recording, and reporting
- Standard operating procedures
- Start-up procedures
- Shut-down procedures (manual and automatic)
- Safety issues
- Emergency procedures and contingency plan
- Alarm response plans
- Preventive maintenance needs and procedures
- Equipment calibration needs and procedures
- Troubleshooting guide
- Equipment component summary
- Spare parts inventory
- Contact information for equipment manufacturers and technical services

6.1.2 State Coordination during Start-up

States should be contacted during construction to determine the state-specific requirements and submittals. The states may request the record drawings, O&M manual, and an engineer's certificate of completion. In addition, the state may need to visit the site to approve the start-up of the UV facility.

6.1.3 Functional Testing

Functional testing verifies that each component's operation is in accordance with the specifications in the contract documents. It should include verification of UV equipment components, instrumentation and control (I&C) systems, and flow distribution and head loss. Items that are not unique to UV facilities (e.g., valves, flow meters, backup generators, or uninterruptible power supplies) are not described in this manual; however, their functionality should still be verified.

6.1.3.1 Verification of UV Equipment Components

Most functional testing is completed through simulations of specific operating conditions and monitoring UV reactor operation and response. Functional testing entails flooding and energizing UV reactors to confirm the operation of the lamps, ballasts, ballast cooling system, cleaning system, UV sensors, and UVT analyzers.

It is strongly recommended that the UV manufacturer inspect the UV facility before the UV reactors are energized and be present when the UV reactors are first energized. Manufacturers may require the presence of one of their representatives during these activities as a condition of their equipment warranty.

UV Sensor

UV sensors must be included in the UV reactor to verify that the reactor is operating within validated conditions [40 CFR 141.720(d)]. The calibration of the duty and reference UV sensors should be checked during functional testing using the procedure recommended in Section 6.4.1.1. UV sensors that are not in calibration should be returned to the manufacturer for replacement or recalibration.

Lamps, Ballasts, and Ballast Cooling System

The lamps, ballasts, and ballast cooling system operation are verified by energizing the UV lamps, then verifying lamp and ballast operation via the UV sensor measurements and visual verification of the ballast cooling fan operation. In addition, the power [kilowatt (kW)] delivered to the lamps should be verified as the same as documented in the validation report for at least three power settings.

On-line UVT Analyzer

If the dose-monitoring strategy of the UV reactor is the Calculated Dose Approach (see Section 3.5.2 for a description of dose-monitoring strategies), the UV reactor should be equipped with a UVT analyzer. Calibration of the on-line UVT analyzer should be verified. A recommended procedure for verifying calibration is described in Section 6.4.1.2.

Cleaning System

The necessary functional testing depends on the type of cleaning used, and the components to be verified for each cleaning system are summarized in Table 6.1. Cleaning systems are described in Section 2.4.5.

Table 6.1. Functional Testing of Cleaning Systems

Cleaning System	Items to be Verified
On-line mechanical cleaning (OMC)	• Smooth movement of the wiper with no jamming or binding of the wiper on the sleeve • Extension of wiper stroke to the full length of the sleeve with no impact at the end of travel that could damage or break the sleeve • Proper operation of the wiper drive mechanism and motor with no slipping or binding
On-line mechanical-chemical cleaning (OMCC)	• Same as on-line mechanical cleaning (above) • The chemical injection point is accessible • The seal that contains the chemical solution is intact
Off-line chemical cleaning (OCC)	• The chemical injection wand should be connected to the chemical pump to verify that a proper seal is achieved • Outside of the reactor, in a safe location, the chemical pump should be initiated to ensure that the wand is operating properly and an appropriate amount of pressure is achieved • The wand should then be connected to the reactor and turned on to make sure the seal is intact and the wand is functioning properly

6.1.3.2 Verification of Instrumentation and Control Systems

The amount of testing for the instrumentation and control systems depends on the complexity of the dose-monitoring strategy and operations approach used. Testing should include verifying control loops, checking operation functions, and verifying all control actions. As described below, the UV reactors should be run through a series of simulations that represent the possible operating scenarios to confirm that the UV reactor responses are appropriate. A manufacturer representative should be present during the simulations to assist in troubleshooting and addressing any issues that may result from the packaged UV reactor controls.

Typically, the packaged UV reactor control panel contains all the components needed to control and operate the UV reactor. The panel should provide the operating status, lamp status indicators, diagnostic information, and operator interface capability. The panel may also include programmable logic controllers (PLC), ballasts, and lamp starters.

Electronic signal simulations imitate the signals that will be sent to the control system during normal operation. The I&C logic programming should be monitored during simulations to verify the programming is correct. These "dummy" simulations should be used to confirm that UV reactors and all ancillary equipment and instrumentation, including valves, flow meters, and UVT analyzers will operate consistent with the I&C programming. The UV reactors should not operate during these simulations (i.e., water is not flowing and lamps are not energized). As applicable, the following specific operating conditions should be electronically simulated, as well as any other conditions the manufacturer recommends:

- Cold start of the UV reactors
- Cool down and restart of the UV reactor
- Sequencing of the UV reactors in multiple-reactor installations
- Adjustment of lamp intensity or number of lamps on in response to varying water quality and flow rate
- Shut-down of the UV reactors
- Operation of the UV reactors during line power failure (when back-up generators or UPS are available)
- Manual override, safety interlocks, and report generation
- Operation of the UV reactors through the plant SCADA system
- Incorporation of a sensor correction factor

In addition to simulating possible operating conditions, each alarm condition and monitoring function incorporated in the design should be verified. Possible monitoring functions and alarm conditions are discussed in Section 4.3.3 and may include the following conditions:

- Operation outside the validated conditions
  - Low validated dose or UV intensity
  - Low UVT
  - High flow rate
- Lamp age
- Lamp or ballast failure
- Low water level in the UV reactor
- High temperature
- OMC or OMCC system failure
- Loss of control signals

6.1.3.3 Verification of Flow Distribution and Head Loss

A minimum of three flow rates that span the range of operating conditions should be tested. If possible, one condition should be the maximum design flow rate through the UV facility with all duty reactors in operation; the other conditions should consist of combinations of the reactors operating at their design flow rates (e.g., two of five 10-mgd reactors operating at a total UV facility flow rate of 20 mgd). Clamp-on type flow meters can be used for field verification of the flow split.

The head loss should be measured at these same test conditions for each reactor and compared to the head loss specified in the contract documents (if applicable). Pressure transducers or pressure gauges can be used to measure the head loss.

6.1.4 Determining Validated Operational Conditions and Setting Operational Controls

For each UV reactor, the operating conditions associated with a given level of inactivation credit must be defined based on validation testing results [40 CFR 141.720(d)(2)].

Section 5.10.1 and 5.10.2 describe how the validated dose and validated operating conditions are established for two dose-monitoring strategies, the UV Intensity Setpoint Approach and the Calculated Dose Approach, respectively. Appendix B supports Sections 5.10.1 and 5.10.2 by providing examples of validation testing data analyses. Examples 6.1 and 6.2 expand on guidance in Section 5.10 and Appendix B by showing how the same hypothetical water systems in Appendix B established operational alarms to ensure that they operate within validated conditions.

Example 6.1. Setting Operational Controls for the UV Intensity Setpoint Approach – Single Setpoint Operation (Corresponds to the Validation Example in Section B.1)

Background: System X plans to add UV disinfection to its treatment plant to achieve 2.5-log *Cryptosporidium* inactivation credit. Based on LT2ESWTR UV dose requirements (summarized in Table 1.4 of this manual), the water system needs to meet a required UV dose of 8.5 mJ/cm^2 to achieve this level of inactivation. During UV facility planning, the water system establishes a design flow of 400 gpm and minimum UVT of 90 percent.

System X selects two low-pressure high-output (LPHO) reactors (one duty and one stand-by) with eight lamps each that use the UV Intensity Setpoint Approach. Because their flow rate and UVT do not vary much, System X decided to use the single setpoint approach that applies to all validated operating conditions.

Summary of Validation Test Results: Validation testing produced a UV intensity setpoint of 11.7 mW/cm^2 at a maximum flow rate of 394 gpm with a single reactor operating with all lamps turned on. The validated dose at the setpoint is 11.3 mJ/cm^2, which is greater than the required dose of 8.5 mJ/cm^2. As long as the UV intensity as measured by the UV sensor is greater than 11.7 mW/cm^2, the validated dose is greater than the required dose and the reactor is operating within the validated limits.

Operational Controls: As shown in the table below, System X set the UV intensity alarm at 12.5 mW/cm^2 to provide an operational cushion. System X also set a flow rate alarm at 375 gpm. Because the validation testing protocol for the UV Intensity Setpoint Approach (as described in Chapter 5) accounts for changes in UVT, UVT is not regularly monitored during operations.

Operating Parameter	Validated Operating Conditions	Major Alarm
UV Intensity as measured by the UV sensor	≥ 11.7 mW/cm^2	Sounds if < 12.5 mW/cm^2
Flow rate through the reactor	≤ 394 mgd	Sounds if > 375 gpm

Although this operating strategy is simple and straightforward, System X could have improved efficiency by reducing the UV intensity at lower flow rates, which can only be done if the validation data support UV intensity adjustment with flow. To further improve energy efficiency using the single setpoint approach, the flow could be maximized through one reactor before energizing another reactor for multiple reactor systems.

Example 6.2. Setting Operational Controls for the Calculated Dose Approach (Corresponds to the Validation Example in Section B.2)

Background: System Y plans to add UV disinfection to their treatment plant to achieve 2.0-log *Cryptosporidium* inactivation credit. Based on the LT2ESWTR UV dose requirements (summarized in Table 1.4 of this manual), the water system needs to meet a required UV dose of 5.8 mJ/cm^2 to achieve this level of inactivation. During UV facility planning, System Y establishes a design flow rate range of 3 to 10 mgd and a minimum operating UVT of 87 percent.

System Y selects three UV reactors (two duty and one stand-by) with six 8-kW medium-pressure (MP) lamps each with power settings ranging from 40 – 100 percent. The reactors have one germicidal UV sensor monitoring each lamp. The reactors were validated for flow ranges of 2.5 – 10 mgd and use the Calculated Dose Approach.

Summary of Validation Test Results: Validation testing as described in Appendix B produced the following dose-monitoring equation (Equation B.14):

$$\log(RED) = -0.829 - 2.519 \times \log(A254) + 0.166 \times \log\left(S/S_o\right) + 0.409 \times \log\left(1/Q\right)$$

where:
RED = Calculated dose

As noted in the validation report, the Validation Factor (VF) is 2.28. The validated dose is calculated by dividing the calculated dose by the VF. The validated dose must be greater than the required dose of 5.8 mJ/cm^2 for System Y to receive treatment credit for 2.0 log-inactivation of *Cryptosporidium*.

Operational Controls: The table below summarizes the major alarms that System Y programmed into their PLC to ensure that they operate within validated conditions

Operating Parameter	Validated Operating conditions	Major Alarm [3]
Validated Dose (equal to the Calculated Dose / 2.28)	≥ 5.8 mJ/cm^2	Sounds if < 6.3 mJ/cm^2
Flow rate through the reactor	≤ 10 mgd [1]	Sounds if > 9 mgd
UVT as measured by an on-line UVT analyzer	85 - 95% [2]	Sounds if <87%

[1] If the flow rate is less than 2.5 mgd, the PLC will default to 2.5 mgd in the dose-monitoring equation.
[2] If the UVT measured is higher than 95 percent, which is the highest validated UVT, the PLC will default the UVT to 95 percent in the dose-monitoring equation.
[3] Note the major alarms are set at a conservative level compared to the validation conditions to give the operators more time to respond to low validated dose, high flows, and low UVTs.

6.1.5 Performance Testing

Performance testing is intended to assess the operating performance of the UV facility as a whole and is generally accomplished through extensive monitoring during the early stages of continuous operation. Note that performance testing is not intended to validate disinfection performance, which is completed during validation testing (as described in Chapter 5). However, performance testing can be used to confirm that the actual operating conditions are within the constraints established during validation testing as described in Section 6.1.4.

Because performance testing should compare operating conditions to validated conditions, the lamps should be operated as they were during validation testing. Therefore, UV lamps should be burned-in before performance testing, which typically takes 100 hours of continuous operation (Section 5.7.2). The actual required burn-in time should be discussed with the manufacturer and confirmed through documented operating experience at other UV facilities.

The scope and duration of performance testing will be project-specific and should be established by the PWS and designer based on the objectives of the performance testing. The duration of performance testing should be adequate to demonstrate to the PWS and the state that the UV facility can continually perform according to specifications in uninterrupted operation. This could be as little as 48 hours, but may be longer, depending upon the nature of the installation, the variability of the source, and any specific state and PWS requirements. Similarly, the scope of the testing may range from an increased monitoring frequency that confirms operation within validated limits to an extensive testing protocol aimed at optimizing reactor performance and establishing long-term operating procedures. During performance testing, treated water may be sent to the distribution system if upstream treatment has not changed, meets existing regulations, and is approved by the state.

Performance testing may include the following items:

- Operation of each UV reactor in automatic mode to verify that the control system is identical to that established during validation testing
- Demonstration of UV reactor start-up and switchover sequences that result from water quality and/or flow rate changes
- Observation of operation, including periods of off-specification operation that arise from alarm conditions and any power quality problems
- Measurement of electrical service voltage, current, and power consumption with different flow and water quality combinations to optimize energy use within the constraints established during validation
- Assessment of the effectiveness of the cleaning system by inspecting sleeve clarity and condition at regular intervals throughout the test period

- Confirmation that the programmed cleaning frequency correlates with the actual frequency of cleaning
- Confirmation of duty UV sensor accuracy using reference UV sensors. (See Section 6.4.1.1.)
- Observation of ballast temperature and cooling system performance
- Verification of the calibration of the on-line UVT analyzer (if applicable). (See Section 6.4.1.2.)
- Confirmation of backup generator and/or UPS power transfer to the UV equipment

The performance testing should be tailored to the specific UV facility. An example monitoring program for a 4-week performance test is shown in Table 6.2.

Any off-specification time and flow volume should be recorded during all performance tests, and these results should be evaluated to verify that off-specification limitations are not exceeded. Off-specification volume during performance testing does not need to be reported to the state. Recording of the off-specification time and volume is meant to identify operational problems to be addressed. During performance testing, any component that is not operating properly should be corrected and retested to confirm satisfactory operation. This step may require manufacturer involvement, especially if specifications in the contract documents were not met. Following performance testing, ongoing monitoring and recording of reactor operation should continue at a reduced frequency as discussed in Section 6.4 and as required by the state.

Table 6.2. Example Monitoring During a Four Week Performance Test

Frequency	Task	Notes
Continuous	Confirm the validated setpoint(s)	Monitor reactor operation to confirm compliance with the setpoint(s) established during validation (Section 6.1.4).
	Develop energy efficient operation	Monitor the power consumption. Test the automatic operation and power consumption under the flow and water quality variations to determine if energy efficiency improvements can be made within the validation constraints.
	Log off-specification occurrences	Log alarms and indicate whether the reactor is off-specification according to validation criteria. Record off-specification time and volume.
Weekly	Monitor UV sensor calibration	Check the duty UV sensor against a reference UV sensor, using the recommended protocol (Section 6.4.1.1) to determine whether the duty UV sensor is in calibration.
	Monitor the on-line UVT analyzer calibration	Monitor calibration of the on-line UVT analyzer (Section 6.4.1.2).
Twice during testing period	Switch to standby reactor	Monitor the time necessary to switch to a standby reactor to determine if operation will be off-specification during switch-over.
	Switch to standby power or UPS	Monitor the time necessary to switch to the standby power supply to determine if operation will be off-specification because of power transfer. Test the backup power supply for a minimum of one hour.
After 4 weeks, 100 OMC or OMCC cycles, or one OCC event	Inspect lamp sleeves for fouling	Remove a sleeve from the reactor and inspect as recommended in Section 6.3.2.1.

OMC = on-line mechanical cleaning; OMCC = on-line mechanical chemical cleaning; and OCC = on-line chemical cleaning.

6.1.6 Final Inspection

As the last step in the start-up process, a detailed inspection of the UV facility should be completed. The inspection should include a visual assessment to verify that all components meet the technical specifications of the UV equipment specification and validation report and that the UV facility was completed in accordance with the construction documents. All UV facility components and associated valves and piping should be thoroughly cleaned and disinfected prior to service.

6.2 Operation of UV Facilities

The operation of UV facilities will vary based on the UV manufacturer, the UV reactor configuration, and the dose-monitoring strategy. This section discusses required and recommended operational and routine start-up and shut-down procedures common to most UV equipment and is general in nature. The site-specific operational procedures should be developed in coordination with the manufacturer, UV facility designer, and facility operators, and should be described in the O&M manual (Section 6.1.1). Small systems should consider discussing operations with the state to determine if simplified operations are possible.

6.2.1 Operational Requirements

To receive inactivation credit, the UV reactors must operate within the validated limits [40 CFR 141.720(d)]. When a UV reactor is operating outside of these limits, the UV reactor is operating off-specification as described in Section 3.4.1. Filtered and unfiltered systems that use UV disinfection to meet the *Cryptosporidium* treatment requirement of the LT2ESWTR must demonstrate that at least 95 percent of the water delivered to the public during each month is treated by UV reactors operating within validated limits [40 CFR 141.720(d)(3)]. Guidance on determining validated operating conditions is in Section 5.10. The specific monitoring requirements associated with off-specification operation are described in Section 6.4.1.

6.2.2 Recommended Operational Tasks

UV equipment typically uses automatic control systems and does not need significant manual attention for routine operation. Even when UV equipment is operated manually, the only parameter that typically can be controlled is lamp power, and some UV reactors can also vary the number of lamps energized. Therefore, even manual operation does not result in significant operator interaction. Table 6.3 summarizes recommended operational tasks. Recommended maintenance tasks are discussed in Section 6.3.

Table 6.3. Recommended Operational Tasks for the UV Reactor

Frequency	Recommended Tasks
Daily	• Perform overall visual inspection of the UV reactors. • Confirm that system control is on automatic mode (if applicable). • Check control panel display for status of system components and alarm status and history. • Verify that all on-line analyzers, flow meters, and data recording equipment are operating normally. • Review 24-hour monitoring data to confirm that the reactor has been operating within validated limits during that period. • Verify that ballast cooling fans are operational and that ballasts are not overheated.
Weekly	• Initiate manual operation of wipers (if provided) to verify proper operation.
Monthly	• Check lamp run time values. Consider changing lamps if operating hours exceed design life.
Semi-annually	• Check ballast cooling fans for unusual noise. • Check operation of automatic and manual valves.

6.2.3 Start-up and Shut-down of UV Reactors

This section describes start-up procedures, shut-down procedures, and winterization of the UV reactors.

6.2.3.1 Routine Start-up

The following routine start-up procedure serves as an example approach. The UV reactors should be operating within validated conditions once the start-up sequence is complete.

1. Initiate the UV reactors' start-up sequence. [Note: Some UV reactors may need reduced water flow to cool the lamps during start-up, which would normally be initiated automatically. The cooling water exiting the reactor is not disinfected and is considered off-specification unless it is diverted to waste.]

2. Check the SCADA panel or other display to verify that the necessary numbers of lamps are on and all of the monitoring parameters are being displayed.

3. Check and resolve any system alarms being displayed.

4. Confirm that all on-line analyzers (UV sensors and UVT analyzers, if applicable) and flow meters are operating within calibration.

5. After the lamp warm-up period, increase flow to the validated range (if flow is not automatically adjusted with UV reactor control sequence).

6. Verify correct flow split between parallel UV reactors using flow meters and/or differential pressure gauges if these devices are available.

7. Verify that the UV reactor is operating within validated limits (e.g., flow rate, UV intensity, lamp status, validated dose).

6.2.3.2 Start-up Following Maintenance

The following additional steps should be taken before completing Steps 1 – 7 described in the example routine start-up procedure (Section 6.2.3.1) when maintenance has been performed on the reactor:

1. Follow site-specific safety procedures for the power supply and control panel (e.g., removing lockouts and tagouts).

2. Confirm that all lamp and ground connections are properly made. Verify that all incoming power conductors, including ground conductors, are properly terminated.

3. Verify that the lamp ends and all other reactor ports are covered and/or sealed to eliminate the potential for operator exposure to UV light.

4. Confirm the breakers are turned on, and all electrical cabinets and equipment are clear and closed.
5. Perform Steps 1 – 5 of Section 6.2.3.1.
6. Verify that all air is purged from the reactors (i.e., the reactor is completely flooded). Check the top of the reactor for heat buildup, which indicates an air pocket.
7. Perform Steps 6 and 7 of Section 6.2.3.1.

6.2.3.3 Routine Shut-down

UV reactors are shut down periodically because of water quality or flow changes. The main steps involved in shutting reactors down are as follows:

1. Throttle the effluent valve (if not part of the control sequence) to close it.
2. De-energize the reactor immediately after the effluent valve is closed.

6.2.3.4 Shut-down Prior to Maintenance

UV reactors are also shut down periodically for maintenance (e.g., cleaning). The following steps should be taken following the routine shut-down steps (Section 6.2.3.3) to prepare a reactor for maintenance:

1. Follow lockout and tagout procedures for the facility.
2. Drain the reactor if necessary for the specific maintenance task.
3. Inspect and repair or replace any necessary equipment.

If extended shut-down time is planned, the reactor should be drained to avoid excessive fouling. After an extended shut-down period (more than 30 days), the operator should perform a cleaning and then inspect the lamp sleeves for fouling. Manual or more extensive cleaning may be necessary before start-up, as described in Section 6.3.2.1.

6.2.3.5 Winterization

In most drinking water applications, the UV reactors will be located within a building. However, in some instances, the reactors may be located in unheated concrete vaults or outside. When shutting down a UV reactor for an extended period of time is necessary and damage from freezing is possible, the UV reactors should be winterized according to the manufacturer's recommendations.

6.3 Maintenance of UV Reactors

No specific regulatory requirements exist for maintaining a UV reactor; however, the UV reactors should be maintained so that disinfection requirements are met. Poor maintenance may cause the UV reactors to operate off-specification for extended periods of time. As part of the maintenance tasks, UV reactor components will need to be replaced; therefore, an inventory of spare parts is necessary. These tasks are described in this section.

6.3.1 Summary of Recommended Maintenance Tasks

Table 6.4 summarizes the recommended maintenance tasks and refers to the general guidelines for those tasks that are discussed in Section 6.3.2. The frequency of performing the maintenance tasks in this section are recommendations and likely will be specific to the UV equipment installed. Therefore, the UV manufacturer should be contacted to determine the appropriate frequency. Items that are not unique to UV facilities (e.g., valves, flow meters, uninterruptible or backup power supplies) are not described; however, maintenance on such items should also be performed per the manufacturer's recommendation. Before maintenance is performed, the operator should wait at least 5 minutes (or as recommended by the UV manufacturer) for the lamps to cool and the energy to dissipate. Lockout and tagout protocol should be followed if the main electrical supply to the UV reactors needs to be disconnected for the maintenance task.

Table 6.4. Recommended Maintenance Tasks[1]

Frequency	Task General Guideline & *Section Reference*	Action
Monthly (no cleaning or OCC) Semi-annually (OMC or OMCC)	Check cleaning efficiency *Section 6.3.2.1*	• Record UV sensor reading. • Extract one sleeve per reactor (or one sleeve per bank of lamps) for inspection. • If fouling is observed on the first sleeve, check remaining sleeves and all UV sensor windows. • Manually clean sleeve(s) and UV sensor windows if fouling is observed. • Record UV sensor reading after cleaning and compare to original reading.
Monthly	Check reactor housing, sleeves, and wiper seals for leaks	Replace housing, sleeve, or wiper seals if damaged or leaking.
Bimonthly (MP lamps) Quarterly (LP and LPHO lamps)	Check intensity of UV lamps *Section 6.3.2.2*	If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-forth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.
Semi-annually	Check cleaning fluid	Replenish solution if the reservoir level is low. Drain and

Table 6.4. Recommended Maintenance Tasks[1]

Frequency	Task General Guideline & *Section Reference*	Action
(OMCC)	reservoir (if provided) *Section 6.3.2.1*	replace solution if the solution is discolored.
Annually	Calibrate reference UV sensor *Section 6.3.2.3*	Send the reference UV sensor to a qualified facility (e.g., manufacturer) for calibration. Calibration should use a traceable standard (e.g., National Institute of Standards and Technology (NIST), National Physical Laboratory (NPL), Österreichisches Normungsinstitut (ÖNORM), or Deutsche Vereinigung des Gas- und Wasserfaches (DVGW)).
Annually	Test-trip GFI *Section 6.3.2.4*	Maintain GFI breakers in accordance with manufacturer's recommendations.
When duty UV sensors fail calibration	Replace or recalibrate duty UV sensors *Section 6.4.1.1*	Send the duty UV sensors to a qualified facility (e.g., manufacturer) for calibration, or replace the duty UV sensors.
Manufacturer's recommended frequency	Check thermometer and/or water level indicator *Section 6.3.2.5*	Visually inspect thermometer and/or water level monitor and replace at the manufacturer's recommended frequency.
Lamp/ manufacturer specific	Replace lamp *Section 6.3.2.6*	Replace lamps when any one of the following conditions occurs: • Initiation of low UV intensity or low validated dose alarm (UV intensity or validated dose equal to or less than setpoint value) after verifying that this condition is caused by low lamp output. • Initiation of lamp failure alarm after verifying it is not a nuisance alarm.
When lamps are replaced	Properly dispose of lamps *Section 6.3.2.6*	Send spent lamps to a mercury recycling facility or back to the manufacturer.
Sleeve/ Manufacturer specific	Replace sleeve *Section 6.3.2.7*	Replace sleeve when damage, cracks, or irreversible fouling significantly decreases UV intensity of an otherwise acceptable lamp to the minimum validated intensity level. Adjust the replacement frequency based on operational experience.
Manufacturer's recommended frequency	Clean UVT analyzer and replace parts *Section 6.3.2.8*	Clean and replace parts according to manufacturer's recommended procedure.
Manufacturer's recommended frequency	Inspect OMC or OMCC drive mechanism	Inspect and maintain OMC or OMCC drive routinely as recommended by the manufacturer.
Manufacturer's recommended frequency	Inspect ballast cooling fan *Section 6.3.2.4*	Check the ballast cooling fans for dust buildup and damage. Replace if necessary. Replace air filters (if applicable).

OMC = on-line mechanical cleaning; OMCC = on-line mechanical chemical cleaning; and OCC = on-line chemical cleaning.

[1] Maintenance activities should be consistent with manufacturer's instructions.

6.3.2 General Guidelines for UV Reactor Maintenance

This section describes general guidelines for UV reactor components that relate to maintenance tasks summarized in Table 6.4.

6.3.2.1 Fouling

As discussed in Chapters 2 and 3, the lamp sleeves and UV sensors/windows will likely foul over time, depending on the water quality, lamp type, and cleaning regime. This section describes possible cleaning techniques and provides some specific recommendations for addressing fouling issues.

Sleeve and UV Sensor Surface/Window Fouling

Three types of sleeve cleaning techniques, as discussed in Section 2.4.5, are used: off-line chemical cleaning (OCC), on-line mechanical cleaning (OMC), and on-line mechanical-chemical cleaning (OMCC) methods. The frequency of cleaning is site-specific. An appropriate sleeve cleaning frequency (manual or automatic) can be determined based on the rate of fouling during the start-up period, which can be assessed by monitoring over time the UV sensor measurement or validated dose (Calculated Dose Approach). For routine operation, the cleaning frequency should be increased or decreased based on the amount of fouling left on the sleeves determined from the sleeve inspections and the loss of UV intensity before cleaning.

Sleeves should initially be inspected for fouling every six months if OMC or OMCC is used and every month if OCC or no cleaning is used. This frequency should be adjusted, if necessary, after operating data are available. A decrease in UV intensity or validated dose at a consistent UVT may indicate sleeve fouling, and sleeves should be inspected if fouling is the suspected cause of the UV intensity drop (Section 6.6.1). Additionally, the UV sensor windows (if applicable) should be inspected for fouling and supplemental cleaning should be conducted if necessary, according to the manufacturer's recommendation.

For sleeve inspection, one sleeve per reactor (or one sleeve per bank of lamps for reactors with multiple rows/banks of lamps) should be inspected. The sleeves should be handled as described in Section 6.3.2.7. If damage or fouling is observed, the remaining sleeves should be inspected. External sleeve fouling can be difficult to identify. Sleeve discoloration is more easily seen by placing the sleeve on a clean, white, lint-free cloth next to a new sleeve. The presence of streaks may indicate that the OMC or OMCC wiper material is worn, damaged, or misaligned; therefore, the wiper should also be inspected. If fouling is observed, the cleaning frequency should be increased, and supplemental manual cleaning should be conducted as necessary. The UV reactors need to be drained for sleeve inspection, and the inside of the UV reactor should also be inspected. Any algae that has grown on the surface or any other surface fouling that has occurred should be manually cleaned according to the UV manufacturer's recommended procedure.

Manual cleaning (i.e., beyond routine OCC, OMC, or OMCC cleaning) of lamp sleeves, if necessary, should be according to manufacturer recommendations and procedures. Abrasive cleaners or pads that might scratch the lamp sleeve should not be used. Also, the inside of the sleeve should be dry before re-installation because water or cleaning solutions could cause a coating to form during operation. One method of drying the sleeve is to use isopropyl alcohol and a lint-free cloth; however, no alcohol should remain inside the sleeve after this procedure. As noted earlier, when the sleeves are re-installed after inspection, the manufacturer's procedure should be closely followed to avoid over-tightening of the compression nuts.

If OMC or OMCC cleaning is used, the wipers should be checked for deformation or degradation at the same time the sleeves are checked. The cleaning solution reservoir in OMCC systems should be checked every six months to determine whether more solution should be added. The solution should be replaced if it is discolored or if the OMCC system is not effectively cleaning the sleeve.

Fouling While Out-of-service

When the UV reactors are out-of-service and full of water, the sleeves may foul (Toivanen 2000). The rate of fouling is site-specific and depends on the water quality. UV reactors equipped with OMC or OMCC should continue to clean the sleeves, potentially at a lower frequency, even though the UV reactor is off-line, which should prevent fouling of the sleeves. For UV reactors that do not include OMC or OMCC, the PWS should consider draining the UV reactor if it is off-line for more than one week. However, this period could be shorter or longer, depending on the water quality. After a shut-down period of more than 30 days, the operator should perform a cleaning (OCC, OMC, or OMCC) and then inspect the lamp sleeves for fouling. Extraction and manual cleaning of sleeves may be necessary before start-up after extended periods of standby.

6.3.2.2 Lamp Output Variability

UV lamp output differs for each lamp, depending on lamp age and lot. As discussed in Section 2.4.6, a UV sensor measures the changes in UV intensity at its location in the UV reactor. However, a UV sensor cannot measure lamp output variability unless each lamp has a UV sensor. PWSs that have UV reactors with a UV sensor monitoring more than one lamp should assess the UV lamp variability every 2 months for MP lamps or every 3 months for LP and LPHO lamps. If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor. The recommended procedure for evaluating the lamp output variability is to:

1. Identify the lamps that can be used to evaluate the lamp variability (one-fourth of the lamps in each row/bank or a minimum of 3 lamps, which ever is greater)

2. Place each evaluation lamp in the position nearest the UV sensor and record the intensity value

3. Repeat Steps 1 and 2 until one-fourth of the lamps (3 minimum) have been assessed

4. Place the lamp with the lowest UV intensity value in the position nearest the UV sensor for routine operation

6.3.2.3 Reference UV Sensors

Accurate UV sensors are necessary to verify adequate UV dose delivery during operation. Two types of UV sensors are available: duty and reference. Duty UV sensors are on-line sensors that continuously monitor UV intensity. Reference UV sensors are off-line sensors used to assess the duty UV sensor performance. Both types of UV sensors need to be maintained. Monitoring of duty UV sensor calibration is described in Section 6.4.1.1.

The reference UV sensor should be calibrated at least once per year at a qualified facility (e.g., manufacturer) to confirm that it is calibrated properly. The reference UV sensor should be calibrated against a traceable standard. For example, UV manufactures are currently using NIST, NPL, ÖNORM, and DVGW standards. The reference UV sensor should be exposed to UV light for a period no longer than necessary to perform the UV intensity measurement. When not in use, the reference UV sensor should be stored under conditions that will maintain its integrity and accuracy as recommended by the manufacturer. Some PWSs may choose to have multiple reference UV sensors to help determine if one reference UV sensor is out of calibration, as a replacement reference UV sensor, or to allow multiple duty UV sensors to be checked simultaneously. Having multiple reference sensors is helpful if the reference and duty sensor measurements do not match because the operator can easily determine which one is in error. If the reference UV sensor is found to be out of calibration, the period between calibrations should be decreased.

6.3.2.4 Electrical Concerns

Typically, power to the UV reactors is provided via a distribution transformer, a circuit breaker, a disconnect switch at the UV reactor, and related wires and conduits. If maintenance on the control panel is necessary, the main electrical supply should be disconnected and the PWS's safety procedures should be followed.

The power to the lamps is typically delivered through individual GFI circuit breakers and ballasts. The GFI breakers should be test-tripped at least once per year and should be maintained in accordance with the manufacturer's recommendations. Ballast output should be monitored through the UV reactor's control panel. Irregularities or instabilities in ballast output may indicate a problem with the electrical feed or the ballast itself.

A ballast cooling system is normally provided with LPHO and MP reactors to maintain the ballast temperature below the maximum specified limit. LP reactors typically do not need ballast cooling. This cooling system should be inspected and maintained as recommended by the manufacturer.

6.3.2.5 UV Reactor Temperature and Water Level

The water temperature or water level in the reactor should be monitored because UV lamps may break if they become overheated (Appendix E). The thermometer and/or water level monitor should be visually inspected and replaced at the manufacturer's recommended frequency. Reactor temperature monitoring and/or water level monitoring are typically included in the packaged control systems for MP reactors, although they may not be included in packaged control systems for LP and LPHO reactors (due to their much lower operating temperatures).

6.3.2.6 UV Lamp Replacement

UV lamp output decreases over time. UV lamps therefore should be replaced periodically to maintain sufficient UV dose delivery. Lamp manufacturers should provide documentation of lamp output decay characteristics and guaranteed life. This information will help the PWS determine the lamp replacement frequency.

The frequency of UV lamp replacement can be based on a PWS-determined schedule, lamp operating hours, or the UV intensity or validated dose reduction. During replacement, the lamps and sleeves should be handled in accordance with manufacturer recommendations, using clean cotton, powder-free latex, or vinyl gloves, because fingerprints can inhibit proper operation.

Because spent UV lamps contain mercury, they are usually considered hazardous waste under Subtitle C of the Resource Conservation and Recovery Act (RCRA) (40 CFR parts 260, 261, 264, and 273). Expended lamps should therefore be sent to a mercury recycling facility where the mercury is recovered and lamp components are recycled. Some UV reactor and lamp manufacturers will accept spent or broken lamps for recycling or proper disposal (Dinkloh 2001, Lienberger 2002, Gump 2002). PWSs should contact the UV manufacturer to determine if they accept spent lamps, or contact their state or local agencies for a list of local mercury recycling facilities.

Replacement lamps should be identical to those used during reactor validation with respect to arc length, internal and external diameter, spectral output, and placement within the quartz sleeve. If the supplied lamps are not equivalent to the lamps used during validation, the UV reactor is not operating as validated and will be considered off-specification. The manufacturer should provide independent data verifying the lamp aging curve over the entire lamp life to show that the new lamps are equal to or better than the validated lamps. However, if a PWS replaces the lamps with higher power lamps to receive higher log inactivation credit, validation testing should be completed to confirm performance.

6.3.2.7 Lamp Sleeves

Lamp sleeves degrade over time due to solarization (Section 2.4.4) and internal sleeve fouling, resulting in cloudiness and loss of UV transmittance. Abrasion of the sleeve surface during handling or mechanical cleaning may also contribute to the loss of UV transmittance. Reduced sleeve transmittance loss is reflected in the UV sensor reading and, therefore, does not have to be monitored. However, a low UV sensor reading may be due to reduced sleeve transmittance and should be considered when troubleshooting this problem (as discussed in Section 6.6.2).

Sleeves should be replaced when damage, cracks, or staining diminish UV intensity to the point where the minimum validated intensity level or validated dose cannot be met. Sleeves in MP equipment should typically be replaced every 3 to 5 years, although sleeves in LP or LPHO equipment may not need to be replaced as frequently. This replacement frequency should be increased or decreased based on operational experience. Replacement sleeves should be identical to the sleeves used during validation in terms of length, inside and outside diameter, and UV transmittance, and should meet the design and UV manufacturer's material and construction specifications. If the replacement sleeves differ from those used in validation, UV dose delivery and UV sensor modeling can be used to assess the impact of the changes as described in Section 5.13.

The sleeves should be handled in accordance with manufacturer recommendations, using clean cotton, powder-free latex, or vinyl gloves because fingerprints can damage the sleeves during operation. When sleeves are replaced, the manufacturer's procedure should be closely followed because the lamp sleeve can crack and break from over-tightening of the compression nuts that hold it in place.

6.3.2.8 On-line UVT Analyzer

On-line UVT analyzers should be cleaned and maintained according to the UV manufacturer recommendation. On-line UVT analyzer calibration is evaluated periodically as part of compliance monitoring (Section 6.4.1.2).

6.3.3 Spare Parts

The actual life of a component is a function of many variables, including operating conditions, maintenance practices, the quality of the construction materials, and fabrication practices. Consequently, estimating the actual life of every component is impossible. To overcome the operational impacts of this uncertainty, an adequate inventory of critical spare parts should be maintained to ensure reliable and consistent performance of the UV equipment and to avoid the delivery of off-specification water.

All UV equipment components have both a design life and a guaranteed life. The design life is the expected duration of operation. The guaranteed life incorporates the risk, assumed by the manufacturer, to account for the uncertainties associated with the quality of materials used, production, and operating conditions. Generally, guarantees are conditional and are valid under specified operating conditions. For example, guaranteed lamp life is normally linked to the lamp power setting or the number of on/off cycles per 24-hour period. If equipment failure occurs during the warranty period and if all of the warranty conditions are satisfied, the manufacturer will typically replace the component and charge the owner a prorated fee for the use of the replaced component.

Table 6.5 provides typical design and guaranteed lives for major UV reactor components. These represent current industry trends at the time of publication and are likely to change as more O&M information becomes available and technological advances occur. Manufacturers should be contacted directly for details specific to their equipment.

Table 6.5. Typical Design and Guaranteed Lives of Major UV Components (Based on Manufacturers' Input)

Component	Design Life[1]	Guaranteed Life [2]
Low-pressure Lamps (LP And LPHO)	12,000 hours	8,000 – 12,000 hours
MP Lamps	8,000 hours	4,000 – 8,000 hours
Sleeve	8 – 10 years	1 – 3 years
Duty And Reference UV Sensors	3 – 10 years	1 year
UVT Analyzer	3 – 5 years	1 year
Cleaning Systems	3 – 5 years	1 – 3 years
Ballasts	10 – 15 years	1 – 5 years

[1] Expected duration of operation
[2] Accounts for variability of material quality, production, and operating conditions

Following is a suggested minimum inventory of spare parts, expressed as a percentage of the installed number. The complete list of spare parts will vary depending on the specific equipment installed and should be coordinated with the UV manufacturer. The number of spare parts needed depends on the guaranteed life of the specific equipment. For example, a higher percentage of spare MP lamps may be appropriate compared to LP lamps because they need to be replaced more frequently.

- UV lamps – 10 percent with a minimum of two lamps
- Sleeves – 5 percent with a minimum of one sleeve
- O-ring seals – 5 percent with a minimum of two seals
- OMC or OMCC wipers – 5 percent with a minimum of two wipers
- OMC or OMCC wiper drive mechanisms – 2 percent with a minimum of one drive
- Ballasts – 5 percent with a minimum of one unit
- Ballast cooling fan – 1 unit
- Duty UV sensor – minimum of 2 units (adjust number based on operating experience)
- Reference UV sensor – 2 units (more may be needed if wet duty UV sensor are used as described in Section 6.4.1.1)
- On-line UVT analyzer – 1 unit (if used for dose-monitoring strategy)

6.4 Monitoring and Recording of UV Facility Operation

This section discusses the required and recommended monitoring and recording activities for UV facilities. PWSs should always contact their state to identify any state-specific monitoring and reporting requirements and determine when violations of these reporting requirements would occur.

6.4.1 Monitoring and Recording for Compliance Parameters

PWSs must monitor their UV reactors to determine if the reactors are operating within validated conditions. This monitoring must include UV intensity as measured by a UV sensor, flow rate, lamp status, and other parameters designated by the state [40 CFR 141.720 (d)(3)]. UV reactors should also be regularly monitored to diagnose operating problems, determine when maintenance is necessary, and maintain safe operation. In addition to monitoring operational parameters, PWSs must verify the calibration of UV sensors in accordance with a protocol that the state approves [40 CFR 141.720 (d)(3)]. This section describes the requirements for each of these items.

Because UVT is a critical parameter for the Calculated Dose Approach, EPA believes that calibration of UVT analyzers is necessary to determine if reactors are operating within validated conditions. Therefore, this section also includes a discussion of calibration of UVT analyzers.

6.4.1.1 Monitoring of Duty UV Sensor Calibration

Manufacturers will calibrate the UV sensors prior to installation. However, over time the UV sensors will drift out of calibration. Because UV sensors are vital to assessing disinfection performance, water systems ***must*** verify the calibration of UV sensors with a protocol that the state approves [40 CFR 141.720 (d)(3)]. If a UV reactor is turned on and the calibration of the UV sensors has not been verified, the UV reactor is operating off-specification.

EPA recommends that calibration of UV sensors be verified with a reference UV sensor ***at least monthly***. As noted in Section 6.3.2.3, reference UV sensors are off-line UV sensors that should be at least as accurate as the duty UV sensors and should be constructed identically (with any exceptions to the reference sensor to make it more accurate).

Water systems should designate in their protocol whether only the UV sensors in use will be monitored, or if all duty and standby sensors will be monitored to confirm calibration. Verifying calibration of all duty and stand-by UV reactors has the advantage of rendering all UV sensors ready for use at any time if they are needed.

This section describes the recommended procedure to verify UV sensor calibration and the options available if the duty UV sensor fails the recommended calibration criterion. Section 6.6 supports this section by presenting a flowchart of the calibration check procedure to facilitate decisions if the duty UV sensor fails the calibration criterion.

Duty UV Sensor Calibration Evaluation Procedure

To assess the calibration, the following protocol should be followed:

1. Because the calibration of the UV sensor is sensitive to the power level of the lamps (Swaim et al. 2002), set the lamp power to the level typically used during routine operation.

2. Measure the UV intensity with the duty UV sensor and record the measurement result.

3. Replace the duty UV sensor used in Step 2 with the reference UV sensor in the same location (i.e., port).

4. Measure and record the reference UV sensor measurement.

5. Calculate the UV sensor calibration ratio (Equation 6.1). If desired, Steps 2-5 can be repeated, and a mean calibration ratio can be calculated.

$$\text{Calibration Ratio} = \left(\frac{S_{\text{Duty}}}{S_{\text{Ref}}}\right) \qquad \text{Equation 6.1}$$

where:
S_{Duty} = Intensity measured with the duty UV sensor (mW/cm^2)
S_{Ref} = Intensity measured with the reference UV sensor (mW/cm^2)

6. Determine if the UV sensor calibration criterion (Equation 6.2) is met for the two UV sensor readings or the mean calibration ratio.

$$\text{Calibration Ratio} \le 1.2^{(\text{see footnote 2})} \qquad \text{Equation 6.2}$$

7. If the relationship in Equation 6.2 does not hold true, verify that the reference UV sensor is accurate with a different reference UV sensor (i.e., verify that the duty UV sensor truly failed the calibration check) by inserting a second reference UV sensor and repeating Steps 3 – 6. If a second reference UV sensor is unavailable, the sensor calibration can be checked against two duty sensors (as opposed to another reference sensor).

8. If Step 7 confirms the duty UV sensor is out of calibration, replace the duty UV sensor with a calibrated UV sensor or apply a UV sensor correction factor (described after Example 6.3).

[2] This calibration ratio is higher than the ratio recommended for validation testing (1.1, or 10%, as presented in Section 5.5.4). A recommended calibration ratio of 1.2 during operations is based on experience with existing UV equipment during routine operations.

9. If a duty UV sensor was replaced, check the replaced UV sensor one hour later by repeating steps 2-6 (or based on UV manufacturer's recommendation) to confirm that the replaced duty UV sensor is operating properly.

Issues to Consider when Monitoring UV Sensor Calibration

The above UV sensor criteria allow the UV facility to operate out of calibration if duty sensor reads conservatively low values compared to the reference sensor. Operating in this manner is not energy efficient, however, and the PWS would benefit from having the UV sensor recalibrated.

When re-inserting a duty UV sensor, the rotational alignment of the UV sensor within the UV sensor port can affect its sensitivity. This effect may be due to the UV sensor configuration (e.g., acceptance angle). The UV sensors should be rotated until the lowest UV intensity reading is obtained for routine monitoring purposes with the UV sensor completely inserted into the UV sensor port. This affect may not be an issue if the UV sensor is keyed in place or another method is used to prevent adjusting the alignment of the sensor.

Wet UV sensors are in direct contact with the water; therefore, the water in the UV reactor needs to be drained before the duty sensors are replaced with reference sensors (Step 3 above). To reduce the number of times the UV reactor needs to be drained, PWSs should own at least the same number of reference sensors as the duty UV sensors in one UV reactor. For example, a UV reactor has six duty wet sensors in each UV reactor; therefore, the PWS owns a minimum of 6 reference UV sensors to reduce the number of times the UV reactor has to be drained during the calibration check procedure.

Example 6.3. Duty UV Sensors are Verified using Reference Sensor (Corresponds to Example 6.1 in Section 6.1.4)

System X has one duty UV reactor and one standby reactor. Each reactor has two banks of four 200-W LPHO lamps with one germicidal UV sensor per bank (i.e., two UV sensors per reactor). The data from a monthly calibration check as presented below show that all of the UV sensors meet the UV sensor calibration criterion. Therefore, the duty UV sensors are in calibration, and no further action is necessary for the UV sensors this month.

Reactor Number	Bank Number for UV Sensor	Duty UV Sensor Reading (mW/cm^2)	Reference UV Sensor Reading (mW/cm^2)	Calibration Ratio $\left(\frac{S_{Duty}}{S_{Ref}}\right)$	Within UV Sensor Calibration Criterion? $\left(\frac{S_{Duty}}{S_{Ref}}\right) \leq 1.2$
1	1	13.4	14.6	0.9	Yes
1	2	12.6	11.8	1.1	Yes
2	1	11.9	12.5	1.0	Yes
2	2	15.2	13.7	1.1	Yes

Use of UV Sensor Correction Factor

A failed duty UV sensor should be replaced with a calibrated duty UV sensor or the UV reactor is off-specification (if operated). However, replacement may not be an option if multiple UV sensors fail and/or no additional UV sensors are immediately available. PWSs that cannot immediately replace a duty UV sensor that failed the UV sensor calibration criterion (Equation 6.2) should implement a UV sensor correction factor (CF). In this approach, a CF is selected and applied to either the intensity setpoint or required dose setpoint (depending on the dose-monitoring strategy) for the affected UV reactor(s). Operating with a CF is not energy efficient; however, this method enables the UV facility to remain in operation while the UV sensor problem is resolved. The selected CF should not be changed until the failed UV sensors are replaced with factory calibrated UV sensors. **This approach is not recommended for long-term operation, and the UV sensor problem should be resolved as quickly as possible.**

The specific steps for the UV sensor CF approach are summarized below:

1. Use the calibration data to determine the correction factor for each failed UV sensor (Equation 6.3). Note that twenty percent is subtracted from the calibration ratio to account for the acceptable UV sensor error of 20 percent (i.e., Equation 6.2 shows an allowable error of 20 percent). For example, if $S_{Duty} = 138$ W/m^2 and $S_{Ref} = 100$ W/m^2, the calibration factor is 1.18.

$$Sensor\ CF = \left(\frac{S_{Duty}}{S_{Ref}} - 0.2 \right) \qquad \text{Equation 6.3}$$

2. Determine the maximum Sensor CF for the failed UV sensors (Equation 6.3) (Example 6.4 below presents an example of how to select a Sensor CF).

3. Multiply the UV intensity setpoint or the required dose (depending on the dose-monitoring strategy) by the UV sensor CF to determine the corrected setpoint or required dose (Equations 6.4 and 6.5) that account for the UV sensor errors.

$$Corrected\ UV\ intensity\ setpoint = UV\ intensity\ setpoint \times Sensor\ CF \qquad \text{Equation 6.4}$$

$$Corrected\ required\ dose = D_{Req} \times \text{Sensor}\ CF \qquad \text{Equation 6.5}$$

4. The sensor CF and the corrected UV intensity setpoint or corrected D_{Req} setpoint should be included in the report to the state for the affected reactor(s). These corrected setpoints are now the basis for off-specification operation until the UV sensor calibration problem is resolved.

5. If the failed UV sensor(s) has not been replaced before the next monthly calibration check, the UV reactors with the corrected setpoints should use Equation 6.6 to evaluate whether any sensor exceeds the current Sensor CF. The Sensor CF should be increased if in any UV sensors fail the previous month's CF, as described in Equation 6.6.

$$\left(\frac{S_{Duty}}{S_{Ref}}\right) \leq UV\ Sensor\ CF + 0.2 \qquad \text{Equation 6.6}$$

Example 6.4 shows how a hypothetical water system addressed calibration checks that result in multiple UV sensors that are out of calibration.

Example 6.4. Duty UV Sensors that Do Not Meet Calibration Criteria (Corresponds to Example 6.2 in Section 6.1.4)

System Y has two duty reactors and one standby reactor. Each reactor has six germicidal UV sensors. System Y developed a sensor calibration protocol whereby on a monthly basis, system operators verify that sensors are calibrated using Equation 6.2 of this guidance manual. Their protocol was approved by the state.

Data from the UV sensor calibration check for the month of March are presented below:

Reactor Number	Duty UV Sensor Reading (mW/cm^2)	Reference UV Sensor Reading (mW/cm^2)	Calibration Ratio $\left(\frac{S_{Duty}}{S_{Ref}}\right)$	Within Calibration? $\left(\frac{S_{Duty}}{S_{Ref}}\right) \leq 1.20$	Correction Factor $\left(\frac{S_{Duty}}{S_{Ref}} - 0.2\right)$	Duty UV Sensor Replaced?
1	259.4	247.8	1.1	Yes	NA	No
1	303.8	268.5	1.1	Yes	NA	No
1	284.1	303.5	0.9	Yes	NA	No
1	400.5	387.1	1.0	Yes	NA	No
1	263.2	258.9	1.0	Yes	NA	No
1	258.2	266.6	1.0	Yes	NA	No
2	368.7	250.6	1.5	**No**	**1.3**	No
2	404.1	311.5	1.3	**No**	**1.1**	No
2	287.9	314.2	0.9	Yes	NA	No
2	299.8	214.9	1.4	**No**	**1.2**	No
2	321.3	287.4	1.1	Yes	NA	No
2	265.4	347.5	0.8	Yes	NA	No
3	379.6	284.6	1.3	**No**	**1.1**	No
3	357.3	303.9	1.2	Yes	NA	No
3	258.2	281.5	0.9	Yes	NA	No
3	565.5	321.3	1.8	**No**	**1.6**	**Yes**
3	244.4	147.7	1.7	**No**	**1.5**	**Yes**
3	238.9	268.1	0.9	Yes	NA	No

Example 6.4. Duty UV Sensors that Do Not Meet Calibration Criteria (continued)

Six sensors failed calibration with calibration ratios between 1.3 and 1.8; however, System Y has only three spare duty UV sensors. The two worst UV sensors were replaced (i.e., the UV sensors with a calibration ratio of 1.8 and 1.7), and one of the spare UV sensors was retained as a back-up, leaving four UV sensors that failed the calibration criterion. System Y applied the UV sensor CF approach to enable their facility to continue operating until the UV sensor problem could be resolved with the manufacturer.

System Y applied the CF to the individual reactors, not the entire UV facility. For Reactor 2 the highest calibration ratio was 1.5, resulting in a CF of 1.3 (using Equation 6.3). The highest calibration ratio for Reactor 3 (after the two sensors with the calibration ratios of 1.7 and 1.8 were replaced) was 1.3, giving a CF of 1.1.

System Y's required dose is 5.8 mJ/cm^2 for 2.0 log inactivation of *Cryptosporidium*. The corrected required doses for Reactors 2 and 3 are as follows:

- The corrected required dose for Reactor 2 is ***7.5 mJ/cm^2*** (5.8 mJ/cm^2 multiplied by a CF of 1.3).
- The corrected required dose for Reactor 3 is ***6.4 mJ/cm^2*** (5.8 mJ/cm^2 multiplied by a CF of 1.1).

System Y maintained a validated dose (i.e., the calculated dose from the dose-monitoring equation divided by the Validation Factor) of 7.5 mJ/cm^2 and 6.4 mJ/cm^2 for Reactors 2 and 3 respectively, until the four duty UV sensors were replaced the following week. If the validated dose had fallen below the corrected required dose, the reactors would have been off-specification. Any off-specification events and the volume of water treated during the event must be reported to the state as described in Section 6.5.

In this example, System Y applied a correction factor for two UV reactors with sensors that failed calibration. Another option for System Y would have been to move all of the UV sensors that require a CF to one UV reactor (i.e., switching out UV sensors between Reactors 2 and 3). In this case, the CF would have only been applied to one of the UV reactors instead of both Reactors 2 and 3.

6.4.1.2 Monitoring of UVT Analyzer Calibration

Compliance monitoring of UVT analyzer calibration is required only when UVT is an integral part of the dose-monitoring strategy, such as with the Calculated Dose Approach. If the UV Intensity Setpoint Approach is used, UVT analyzer calibration checks are not required because UVT is not used to verify UV dose delivery (Section 6.4.1.4).

EPA recommends that on-line UVT analyzers be evaluated ***at least weekly*** by comparing the on-line UVT measurements to UVT measurements using a bench-top spectrophotometer. The bench-top spectrophotometer should be maintained and calibrated at the frequency required by the manufacturer. The calibration monitoring frequency should be decreased or increased based on the performance demonstrated over a one-year period if approved by the state. For example, the frequency could be reduced to once per month if the UVT analyzer is consistently within the allowable calibration error for more than a month during the first year of monitoring.

To monitor the calibration, the following UVT calibration check protocol should be followed:

1. Record the reading of the on-line UVT analyzer ($UVT_{on\text{-}line}$).

2. Collect a grab sample from a location close to the on-line UVT analyzer sampling point.

3. Measure the UVT of the grab sample on a calibrated bench-top spectrophotometer (UVT_{bench}).

4. Compare the on-line UVT ($UVT_{on\text{-}line}$) reading to the bench-top spectrophotometer UVT reading using Equation 6.7.

$$\left| UVT_{on\text{-}line}(\%) - UVT_{bench}(\%) \right| \leq 2 \text{ percent UVT}^{3} \qquad \text{Equation 6.7}$$

5. Recalibrate the on-line UVT analyzer if Equation 6.7 is not met. If the UVT analyzer is not recalibrated, the UV facility is operating off-specification unless mitigation steps are taken.

If recalibration is necessary in four consecutive weeks, water system operators should check the calibration daily for 1 week to determine the rate of calibration decay (i.e., the amount the UVT analyzer drifts from the UVT_{bench} per day over the week period). Use these data to establish a more frequent recalibration frequency that will enable the on-line UVT analyzer to stay within the acceptable calibration error. If these data indicate that calibration cannot be maintained for at least 24 hours, water systems should consider one of the two options described below. The UV facility is off-specification until one of these options is followed or until the UVT analyzer meets the criterion shown in Equation 6.7.

Option 1 - Take manual UVT measurements with a calibrated bench-top spectrophotometer every 4 hours and enter the UVT into the PLC. The UVT_{bench} entered should be used for the following 4 hours in the monitoring strategy.

Option 2 - Enter the design UVT value into the PLC and verify daily that the design UVT does not exceed the actual UVT with a grab sample.

[3] The absolute value of the difference between the UVT analyzer and bench measurement should be used because both conservative and non-conservative UVT errors can cause inaccuracies with the dose monitoring strategy.

Although these options allow the UV facility to continue operating if the calibration error is exceeded while the on-line UVT analyzer is being repaired or replaced, these options are not intended for long-term operation. These options should not be employed for longer than six months.

Example 6.5 shows how a hypothetical water system confirmed that they met the calibration criteria listed above.

Example 6.5. UVT Analyzer Calibration Check
(Corresponds to Example 6.2 in Section 6.1.4)

System Y has a UVT analyzer that shows a $UVT_{on\text{-}line}$ of 93.5 percent. The PWS took a grab sample from the influent line to the UVT analyzer and brought it back to the laboratory. The sample was analyzed for UV absorbance at 254 nm (A_{254}) using a bench-top spectrophotometer that has been properly calibrated. The sample A_{254} is 0.032 cm^{-1}. The grab sample A_{254} was converted to UVT using Equation 2.2, which yields a UVT_{bench} value of 92.9 percent. The absolute difference between the on-line reading and bench spectrophotometer reading was 0.6 percent UVT. This difference was within the calibration error range of 2 percent UVT, and the UVT analyzer did not need to be recalibrated.

6.4.1.3 Off-specification Events

Off-specification operation occurs when the UV facility operates outside of the validated limits (Section 6.1.4), a UV sensor is not in calibration (Section 6.4.1.1), the UVT analyzer is not in calibration (Section 6.4.1.2) (and it is part of the dose-monitoring strategy), or UV equipment is not equivalent or better than the equipment validated.

Validated Parameters

PWSs must monitor each reactor to determine whether it is operating within validated conditions [40 CFR 141.720(d)(3)]. The validated parameters to monitor depend on the dose-monitoring strategy used and the validation results. Table 6.6 presents the monitoring parameters for the monitoring approaches and their off-specification triggers.

Calibration of UV Sensors

A UV reactor is producing off-specification water if all three of the following conditions occur:

1. Any of the duty UV sensors did not meet the calibration criteria in the state-approved protocol (Section 6.4.1.1) and
2. The duty UV sensors were **not** replaced with calibrated duty UV sensors and
3. UV sensor correction factor was **not** applied.

Table 6.6. Off-specification Examples for Each Monitoring Approach

Dose-monitoring strategy	Parameters Monitored	Off-specification Examples
UV Intensity Setpoint Approach	UV intensity, flow rate, lamp status	1. UV intensity below minimum value 2. Flow rate above validated limit
Calculated Dose Approach	calculated dose, VF, validated dose, flow rate, UVT, lamp status	1. Validated dose below D_{Req} 2. Flow rate above validated limit 3. UVT below minimum value

VF = Validation factor
D_{Req} = Required UV dose (Table 1.4)

$$Validated\ Dose = \frac{Calculated\ Dose}{VF}$$

Calibration of UVT Analyzers

Similarly, the UV facility is off-specification if the UVT analyzer is found to be out of calibration and the remedial actions described in Section 6.4.1.2 are not completed.

UV Equipment Components

The LT2ESWTR requires that water systems use reactors that have undergone validation testing [40 CFR 141.720 (d)(2)]. It follows, therefore, that installed and replaced components should be equal to or better than the components used during validation testing. If not, the UV facility is off-specification unless the UV equipment is re-validated. The need for re-validation and when the UV facility would be off-specification because of UV equipment components is described in Section 5.13.

6.4.1.4 Monitoring and Recording Frequency of Required Parameters

The required dose-monitoring parameters (flow rate, UV intensity, number of banks on, etc.) should be continuously monitored (i.e., at least every 5 minutes) for each UV reactor, and these values should be recorded at least once every 4 hours. Very small systems (e.g., systems serving fewer than 500 people) that cannot record reactor status every 4 hours (e.g., manual recording is practiced) could consider a reduced recording frequency; however, the frequency should not be less than once per day and should be discussed with the state.

All water systems should record off-specification alarms at a minimum of 5-minute intervals until the alarm condition has been corrected. The off-specification volume will start as soon as the flow is found to be outside of the validated range. The measurement of off-specification volume will stop as soon as the flow is shown to be within the validated limits.

The EPA recognizes that the off-specification event may begin before the off-specification alarm is monitored. The off-specification event may also end before the off-speciation alarm is cancelled and recorded. It is assumed that over time the underestimation of off-specification water before the alarm is activated and the overestimation of off-specification water before the alarm is cancelled will minimize any errors in the calculation of off-specification water. If a facility monitors more frequently than the minimum recommended 5-minute intervals, the off-specification volume will start as soon as the reactor is monitored as operating off-specification and the off-specification volume will stop as soon as the reactor is monitored as being on-specification. More frequent off-specification alarm monitoring may more accurately account for the off-specification volume.

These off-specification alarm records should be used to determine the percentage of flow volume that is off-specification. The compliance with the off-specification limits is based on the off-specification percentage for the UV facility, not for individual reactors. The monitoring guidelines are summarized in Table 6.7, and Example 6.6 illustrates the routine and off-specification recording recommendations.

Table 6.7. Recommended Recording Frequency for Required Monitoring Parameters

Parameter	Recommended Recording Frequency	Notes
Off-specification Alarm	Minimum of every 5 minutes	Recording should continue until the alarm condition has been corrected.
UV Intensity	Every 4 hours	The UV intensity must be greater than or equal to the validated setpoint.
UVT[1]	Every 4 hours	The UVT must be greater than or equal to the minimum UVT validated.
Validated Dose[1]	Every 4 hours	The validated dose must be greater than or equal to the D_{Req}.
Lamp Status	Every 4 hours	Lamps should be energized if water is flowing through the UV reactor.
Flow Rate	Every 4 hours	The flow rate should be less than or equal to the maximum flow tested in validation.
Production Volume	Off-specification events and monthly total	The production volume needs to be recorded so the off-specification compliance calculation can be completed.
Calibration of UV Sensors	Monthly	The calibration of the UV sensor should be monitored as described in Section 6.4.1.1.
Calibration of On-line UVT Analyzer[1]	Weekly[2]	The calibration of the UVT analyzer should be monitored as described in Section 6.4.1.2.[1]

[1] Required only if necessary for the dose-monitoring strategy (i.e., the Calculated Dose Approach).
[2] Frequency could be reduced as described in Section 6.4.1.2.

Example 6.6 Routine and Off-specification Recording
(Corresponds to Example 6.2 in Section 6.1.4)

This example illustrates System Y's daily monitoring and recording of UV equipment operation to verify that it is operating within validated limits. The System Y has two duty reactors and one standby. Reactor 1 is used only for part of the day; Reactor 2 is used 24 hours a day; and Reactor 3 is off-line in the 24-hour period. System Y monitors the off-specification alarms every 5 minutes, which is the minimum recommended.

At 1:08 PM the flow at System Y went above the validated range because an upstream filter was taken off-line for backwashing. At 1:10 PM, the flow through Reactor 2 **was recorded** as being above the validated limit of 10 mgd as an off-specification alarm. This resulted in the reactor operating off-specification while the flow split between the reactors was adjusted. The flow returned to within the validated range at 1:17 PM when the backwashed filter was placed back on-line. System Y recorded that the off-specification alarm was remedied at 1:20 PM

The off-specification recording started when the first off-specification alarm occurred (1:10 PM) and continued at 5-minute intervals until the reactor was monitored as being on-specification again (1:20 PM) when the data recording reverted back to every 4 hours. This event is illustrated in the table below. During this 24-hour period, no other off-specification events occurred. If System Y monitors the off-specification alarms at 1 minute intervals, the off-specification operation would have been more accurately recorded.

Example 6.6 Routine and Off-specification Recording (continued)

Monitoring	Reactor 1		Reactor 2		Reactor 3	
Time	Reactor Status	Data Recorded	Reactor Status	Data Recorded	Reactor Status	Data Recorded
12:00 AM	Off	Off-line	On-specification	On-specification	Off	Off-line
…	Off	None	On-specification	None	Off	None
4:00 AM	Off	Off-line	On-specification	On-specification	Off	Off-line
…	Off	None	On-specification	None	Off	None
8:00 AM	On-specification	On-specification	On-specification	On-specification	Off	Off-line
…	On-specification	None	On-specification	None	Off	None
12:00 PM	On-specification	On-specification	On-specification	On-specification	Off	Off-line
…	On-specification	None	On-specification	None	Off	None
1:05 PM	On-specification	None	On-specification	None	Off	None
1:10 PM	On-specification	None	*Off-specification*	*Off-specification*	Off	None
1:15 PM	On-specification	None	*Off-specification*	*Off-specification*	Off	None
1:20 PM	On-specification	None	On-specification	On-specification	Off	None
…	On-specification	None	On-specification	None	Off	None
4:00 PM	On-specification	On-specification	On-specification	On-specification	Off	Off-line
…	On-specification	None	On-specification	None	Off	None
8:00 PM	On-specification	On-specification	On-specification	On-specification	Off	Off-line
…	On-specification	None	On-specification	None	Off	None
12:00 AM	On-specification	On-specification	On-specification	On-specification	Off	Off-line
Daily total off-specification events		**0 events**		**1 event lasting 10 minutes**		**0 events**

Note shaded areas indicate data that were recorded.

Example 6.6 Routine and Off-specification Recording (continued)

The off-specification volume of water must be determined for compliance reporting (Section 6.5). The table below provides the flow and volume monitoring and recording for this example day. The volume was calculated using a flow totalizer in the PLC programming for each 5-minute off-specification period.

Monitoring Time	Reactor 1			Reactor 2		
	Flowrate[1] (mgd)	Volume[2] (gal)	Total Daily Volume (gal)	Flowrate[1] (mgd)	Volume[2] (gal)	Total Daily Volume (gal)
12:00 AM	0	-	-	9.2	1,526,782	9,144,269
…						
4:00 AM	0	-	-	9	1,358,972	1,358,972
…						
8:00 AM	7.2	1,120,254	1,120,254	9.3	1,534,682	2,893,654
…						
12:00 PM	7.4	1,225,897	2,346,151	9.5	1,510,036	4,403,690
…						
1:10 PM	NR[3]	NR[3]		12.2		4,870,357
1:15 PM	NR[3]	NR[3]		11.3	38,452	4,908,809
1:20 PM	NR[3]	NR[3]		9.7	37,522	4,946,331
…						
4:00 PM	7	1,102,564	3,448,715	9.4	1,551,123	5,954,813
…						
8:00 PM	7.2	1,025,951	4,474,666	9.2	1,520,321	7,475,134
…						
12:00 AM	7.3	1,159,951	5,634,617	9.3	1,536,987	9,012,121
Total Daily Off-specification volume (gal)		-			75,974	
Total Daily Volume (gal)		5,634,617			9,012,121	

Note shaded areas indicate data that were recorded.
[1] Maximum flow rate was recorded to show the flow was within validated limits.
[2] Volume was estimated in the PLC using the flow rate.
[3] NR indicates that data were not recorded

Example 6.6 is based on the flow rate's increasing beyond the validated range. Off-specification recording would follow the same procedure for any problem resulting in off-specification time (e.g., UV sensor failure or the UVT decreased beyond the validated range).

6.4.2 Monitoring and Recording for Operational Parameters Not Related to Compliance

To minimize operational problems, facilitate regulatory compliance, and evaluate UV reactor performance, parameters in addition to those required for regulatory compliance should be monitored. Table 6.8 presents these suggested parameters and the recommended recording frequency. These parameters and their monitoring frequency should be adjusted based on site-specific operating experience. For example, if sleeve fouling is a maintenance issue and supplemental cleaning is frequent (e.g., monthly), the fouling parameters should be monitored daily as shown in Table 6.7 rather than weekly.

Table 6.8. Recommended Monitoring Parameters and Recording Frequency

Parameter	Monitoring Frequency	Recording Frequency	Notes
Power Draw	Continuous	Every 4 hours	This information can be used to determine the most energy efficient operation strategies.
Water Temperature (Only Necessary for MP Reactors)	Continuous	Daily	Monitoring is important to verify that the high temperature limit is not exceeded (often part of packaged UV control system).
UV Lamp On/Off Cycles	Continuous	Weekly (Total cycles in a week)	The number of on/off cycles can help assess lamp aging.
Turbidity (In Addition to Monitoring Otherwise Required Under Subpart H)	Daily	Weekly	Recommended only if chemicals (e.g., lime) are added prior to UV disinfection. Monitoring may not be necessary for many UV facilities.
pH, Iron, Calcium, Alkalinity, Hardness, ORP	Weekly (reduce if fouling is not prevalent)	Weekly	These parameters will help assess fouling issues if necessary.
UVT Analyzer Calibration[1]	Weekly (reduce if appropriate based on operational experience)	Weekly	This information can assist in planning scheduled maintenance and the O&M budget.
Operational Age[2] of the Following Equipment: • Lamp • Ballast • Sleeve • UV Sensor	Monthly	Monthly	This information can assist in planning scheduled maintenance and the O&M budget.
Calibration of Flow Meter	Monthly	Monthly	This information can assist in planning scheduled maintenance and the O&M budget.

[1] Recommended if not being monitored as discussed in Section 6.4.1.2
[2] Operational age is the amount of time the equipment has been operated (e.g., lamp hours)

6.5 UV Facility Reporting to the State

Monthly reports must be prepared and submitted to the state (CFR 141.721). This section describes the required reporting and provides example reporting forms.

6.5.1 Required Reporting

The report must include the percentage of off-specification water for the UV facility and the UV sensor calibration monitoring [CFR 141.721(f)].

The percentage of off-specification water should be calculated on a volume basis. The percentage should be calculated by totaling the 5-minute off-specification alarm records and associated volume released during those periods for each reactor. The volume released during the off-specification event can be determined by:

- Using a flow totalizer that automatically records the volume when an off-specification event occurs.
- The PLC calculating the volume based on flow rate in one-minute (or shorter) intervals during the off-specification event.
- The PLC calculating the volume based on the maximum flow during the off-specification period multiplied by the length of time of the off-specification event.

Off-specification time can be used a surrogate for off-specification volume only if the flow is constant and this method is approved by the state.

The total off-specification volume for all UV reactors should be divided by the total volume produced by the UV facility that month and multiplied by 100 percent (See Example 6.7). PWSs with constant flows may use off-specification time as an indicator for off-specification volume (i.e., total off-specification divided by time in operation multiplied by 100 percent). SCADA and PLC interfaces can be designed to automatically calculate off-specification based on the required monitoring, recording, and reporting.

Example 6.7. Off-specification Computation
(Corresponds to Example 6.6 in Section 6.4.1.4)

This example illustrates the computation of monthly percent off-specification operation for System Y in Example 6.6. System Y had no other off-specification events this month; therefore, the table in Example 6.6 captures all off-specification volume for the month. To determine percent off-specification volume, monthly production volume totals were obtained from the SCADA system. The table below shows the data used for the computation. In this example, 0.02 percent (75,974 gal / 305,683,189 gal × 100%) of the volume of water System Y treated was off-specification, which is within the allowable regulatory limit of 5 percent.

Reactor No.	Monthly Total Off-specification for UV Facility		Monthly Total Production for UV Facility		Monthly Percent Off-specification[2]
	Time (hr)	Volume (gal)[1]	Time (hr)	Volume (gal)	
1	0.00	0	168	17,568,080	
2	0.17[3]	75,974	720	288,115,109	
3	0.00	0	0	0	
Totals	**0.17[3]**	**75,974**	**888**	**305,683,189**	**0.02%**

[1] Off-specification volumes are from Example 6.6.
[2] Total monthly off-specification volume divided by total volume produced in the month multiplied by 100 percent
[3] Total monthly off-specification time was shown in Example 6.6 to be 10 minutes (0.17 hr).

The percentage of UV sensors that were checked for calibration must be reported monthly. All UV sensors in operation that month should be checked. Additionally, the daily low validated dose or daily low UV intensity, depending on the dose-monitoring strategy, should be reported to the state monthly. The state may also have additional reporting requirements and should be contacted to determine the specific content of the monthly reports and to coordinate with other reporting requirements.

6.5.2 Example Reporting Forms and Calculation Worksheets

Example forms and calculation sheets are shown in Figures 6.2 through 6.8. The state should be contacted to determine whether these forms will be acceptable. The forms are described in greater detail below. Two calculation worksheets are also provided that can assist with completing the compliance forms; these forms need not be submitted to the state.

Figure 6.2 is an example of a summary report that would be completed by the PWS and submitted to the state on a monthly basis.

Figures 6.3 and 6.4 are example operating logs that would be completed on a daily basis for the calculated dose and UV Intensity Setpoint Approach, respectively. The forms would be used to record the operating status of the UV equipment and to record the volume of water discharged during off-specification operation each day. The state may request that this information is submitted on a monthly basis.

Figure 6.5 is an off-specification calculation worksheet that can assist PWSs with calculating the off-specification percentage for the daily logs (Figures 6.3 and 6.4); this form need not be submitted to the state.

Figure 6.6 is an example duty UV sensor calibration log. This log would be completed whenever UV sensor calibration checks are performed. The log would be used to record the results of the calibration testing and to track any UV sensor recalibration or repair work that was completed. The state may request this information to be submitted on a monthly basis.

Figure 6.7 is a UV sensor CF calculation worksheet that can help PWSs determine the appropriate UV sensor CF when the PWS needs to use this approach to stay in compliance. This form need not be submitted to the state.

Figure 6.8 is an example on-line UVT analyzer calibration log. This log would be completed only by those PWSs that have included on-line UVT analyzers as part of their dose-monitoring strategies. The log would be completed whenever UVT analyzer calibration checks are performed. The log would be used to record the results of the calibration testing and to track any recalibration or repair work that was completed. The state may request this information to be submitted on a monthly basis.

Figure 6.2. Example Summary Monthly Report

Reporting Period: ________________

System/Treatment Plant: ________________

PWSID: ________________

Signature of Principal Executive: ________________ Date: __________

Officer or Authorized Agent: ________________ Date: __________

			Off-Specification Data	
Unit Number	Total Run Time (hrs)	Total Production (MG)	Number of Off-Specification Events	Total Off-Specification Volume (MG)
Total				

Compliance Certification

Total Volume of Off-Specification Water Produced (MG) [A] __________

Total Volume of Water Produced (MG) [B] __________

Total Off-Specification Water Produced (% of Volume of Water Produced) ([A]/[B]*100) __________

Facility Meets Off-Specification Requirement (< 5% of Volume on a Monthly Basis) (Y/N) __________

Of the _____ sensors, _____ have been checked for calibration and _____ were within the acceptable range of tolerance.

The Following Reactors had a Sensor Correction Factor

Reactor Number	Sensor Correction Factor

Figure 6.3. Example Daily Operating Log for Calculated Dose Approach

Reporting Period: ____________
System/Treatment Plant: ____________
PWSID: ____________
UV Reactor: ____________
Process Train: ____________
Operator Signature: ____________
Date: ____________

Maximum Validated Flow Rate: ____________
Minimum Validated UVT: ____________
Target Log Inactivation: ____________
Target Pathogen: ____________
Dose Required ($D_{req'd}$): ____________
Validation Factor (VF): ____________

$$\text{Validated Dose} = \frac{\text{Calculated Dose}}{VF \times CF}$$

Calculated Dose =Dose that is calculated by validated PLC algorithm
VF = Validation factor
CF = UV intensity sensor correction factor.
The CF is only applied if sensors do not meet recommended criteria
(NOTE – a CF will not be needed in most cases)

Operational Data			Dose Requirements	Data at Daily Minimum Validated Dose					UV Dose Adequacy Determination	Total Off-Specification
Day	Run Time (hrs)	Total Production (MG)	$D_{req'd}$[1] (mJ/cm^2) [A]	Sensor Correction Factor[2] [B]	Calculated Dose[3] (mJ/cm^2) [C]	Daily Minimum Validated Dose[4] ([C]/[VF]/[B]) (mJ/cm^2) [D]	Flow Rate (MGD)	UVT (%)	Validated Dose > $D_{req'd}$ ([D] > [A]) (Y/N)	Total Off-Specification Volume (MG)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
Min										
Max										
Total										

[1] $D_{req'd}$ is the dose required for the target log inactivation without a VF or Sensor CF applied and can be found in the UVDGM Table 1.4.
[2] Sensor CF will be 1 is no CF is used
[3] Calculated dose is calculated using the dose algorithm in the PLC.
[4] The Validated Dose is the dose based on the calculated dose that is normalized on the Validation Factor and Correction Factor
[5] Off-specification worksheet (Figure 6.5) should be used to calculate daily off-specification volume. If UVT, flowrate, and/or Validated Dose off-specification occur simultaneously, the off-specification time should only be counted once

Figure 6.4. Example Daily Operating Log for UV Intensity Setpoint Approach

Reporting Period: ____________
System/Treatment Plant: ____________
PWSID: ____________
UV Reactor: ____________
Process Train: ____________
Operator Signature: ____________
Date: ____________

Maximum Validated Flow Rate: ____________
Minimum Validated UVT: ____________
Target Log Inactivation: ____________
Target Pathogen: ____________
Intensity Setpoint: ____________

Operational Data						Intensity Requirements			Daily Minimum Intensity		Total Flow Off-Specification
			Flow Rate								
Day	Run Time (hrs)	Total Production (MG)	Min (mgd)	Ave (mgd)	Max (mgd)	Intensity Setpoint (W/m^2) [A]	Sensor Correction Factor[1] [B]	Adjusted Intensity Setpoint (W/m^2) ([A] * [B]) [C]	Daily Minimum Intensity (W/m^2) [D]	Minimum Daily Intensity > Adjusted Intensity Setpoint ([D] > [C]) (Y/N)	Total Flow Off-Specification[3] (MG)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
Min											
Max											
Total											

[1] Sensor CF will be 1 is no CF is used.
[2] UVT measurements are not required but could be useful in addressing operational issues.
[3] Off-specification worksheet (Figure 6.5) should be used to calculate daily off-specification volume. If UV intensity or flowrate off-specification occur simultaneously, the off-specification time should only be counted once

Figure 6.5. Example Off-specification Calculation Worksheet

Reporting Period: ____________________ Operator Signature: ____________________
System/Treatment Plant: ____________________ Date: ____________________
PWSID: ____________________

Off-Specification Calculation Worksheet (Note - This sheet should only be used when an off-specification event occurs):

Date[1]	Reactor Number	Process Train Number	Off-Specification Event Description[2]	Flow Rate[3] (MGD) [A]	Time (days) [B]	Off-Specification Volume (MG) ([A]*[B])
					Total Off-Specification Flow for the Day[3]	

[1] This workseet should only be used for one date and one reactor.
[2] This worksheet assumes that the flowrate is constant during the off-specification event. Off-specification volume can also be obtained from a flow totalizer.
[3] Off-Specification event can be caused by UVT, flowrate, intensity, or validated dose being out of the validated range.
[4] The total off-specification flow should be transferred to Figure 6.3 or 6.4 if any off-specification events occurred.

Figure 6.6. Example Monthly UV Sensor Calibration Check Log

Reporting Period: ____________________
System/Treatment Plant: ____________________
PWSID: ____________________
CF used (if applicable): ____________________
Operator Signature: ____________________
Date: ____________________

$$\text{Calibration Ratio} = \left(\frac{S_{Duty}}{S_{Ref}}\right)$$

$$\text{Sensor Correction Factor} = \left(\frac{S_{Duty}}{S_{Ref}} - 0.2\right)$$

where S is the measured intensity

UV Sensor Calibration Report (Make Additional Copies of Form as Necessary)

Date	Reactor Number	Duty Sensor Number	UV Sensor Operating Time (hrs)	Reference Sensor Serial Number	Duty UV Sensor Reading[1] [A]	Reference UV Sensor Reading[1] [B]	Calibration Ratio ([A]/[B])	Calibration Ratio ≤ 1.2 (Y/N)	Sensor Correction Factor Used	If CF is used, Calibration Ratio - 0.2 ≤ CF (Y/N)

Certification:

Number of UV sensor calibrated ____________________

Number of UV sensors out of calibration ____________________

Number of UV sensor(s) sent to manufacturer to be recalibrated as documented below ____________________

UV Intensity sensors sent to manufacturer for calibration (Add additional rows as necessary):

Sensor Serial Number	Unit No.	Date Sent	Date Received

[1] If three duty UV sensor and reference UV sensor readings are taken, the mean of the reading can be used.

Figure 6.7. Example UV Sensor CF Calculation Worksheet

Reporting Period: ____________________
System/Treatment Plant: ____________________
PWSID: ____________________

CF used (if applicable): ____________
Operator Signature: ____________
Date: ____________

$$\text{Correction Factor} = \left(\frac{S_{Duty}}{S_{Ref}} - 0.2\right)$$

Where:
S_{Duty} is the duty UV sensor reading
S_{Ref} is the duty UV sensor reading

Optional Sensor Correction Factor Worksheet:

Date	Reactor Number	Duty Sensor Number[1]	UV Sensor Operating Time (hrs)	Reference Sensor Serial Number	Duty UV Sensor Reading[3] [A]	Reference UV Sensor Reading[3] [B]	Sensor Correction Factor (([A]/[B])-0.2)
						Selected UV Sensor CF[2]	

[1] Only failed sensors need to be input.
[2] UV Sensor CF should be based on the calibration ratios for the failed sensors and should use the maximum ratio. The CF is reactor specific.
[3] If three duty UV sensor and reference UV sensor readings are taken, the mean of the reading can be used.

Figure 6.8. Example Monthly UVT Analyzer Calibration Check Log

Reporting Period: ______

System/Treatment Plant: ______

PWSID: ______

UVT Analyzer Number: ______

Operator Signature: ______

Date: ______

$|UVT_{on\text{-}line}(\%) - UVT_{bench}(\%)| \leq 2\%$ UVT

UVT Analyzer Calibration Report (Make Additional Copies of Form as Necessary)

UVT Analyzer Number	Week Number	Dates	On-line Reading (%) [A]	Grab Sample Result (%) [B]	Difference (%) (|[A]-[B]|)	Difference ≤ 2% UVT? (Y/N)
	1					
	2					
	3					
	4					
	5					

Certification:

All calibration checks were within the acceptable tolerance during this month. ☐

Recalibration was required and is documented below. ☐

On-Site Calibration. ☐ Manufacturer Calibration. ☐

UVT Analyzer Calibration:

UVT Analyzer Number	On-site or manufacturer recalibration?	Date Recalibration Performed	Recalibration Successful? (Y/N)	Initials (On-site Calibration Only)

6.6 Operational Challenges

An excursion from validated operating limits can be caused by low UV intensity, low validated dose, low UVT, high flow rate, poor UV sensor calibration, poor UVT analyzer calibration, or a combination of these conditions. These conditions should be resolved quickly to verify regulatory compliance because they can result in prolonged off-specification operation. Additionally, the evaluations described in this section should be initiated before validated criteria are exceeded and off-specification occurs. This section discusses some of the potential operational challenges and suggests corrective measures.

6.6.1 Low UV Intensity or Validated Dose Below the Setpoint

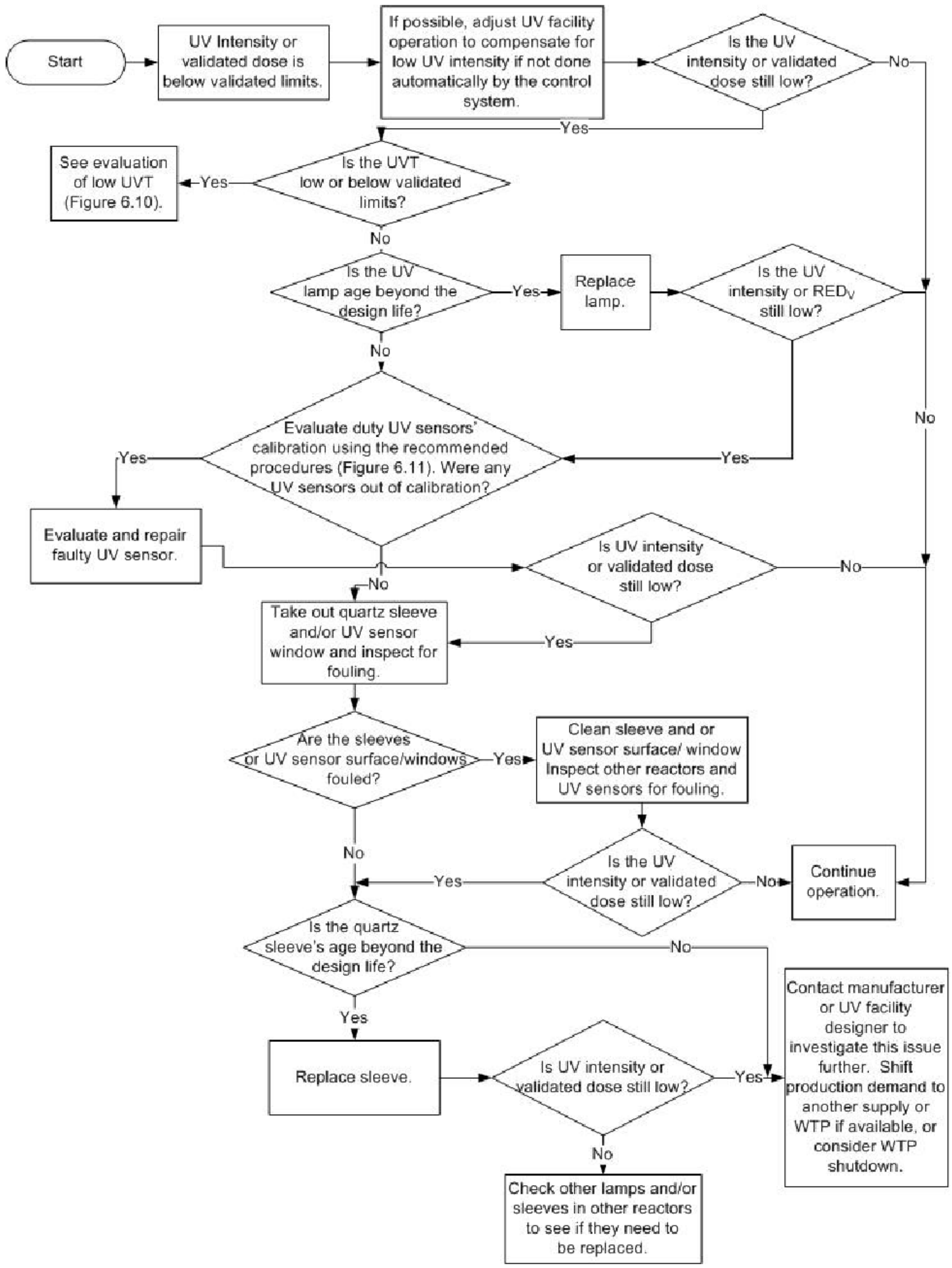
Low UV intensity or validated dose may cause a reactor to operate outside of validated limits. Although UV intensity limits are not explicitly set in the Calculated Dose Approach, a low UV intensity will reduce the validated dose that is delivered, along with low UVT or high flow rate. Therefore, approaches for addressing either a low UV intensity or low validated dose readings are often the same.

The output of the UV lamps, UV transmittance of the sleeves, status of the UV sensor, and fouling of both lamp sleeves and UV sensor windows affect UV sensor readings and validated dose. Figure 6.9 presents a decision tree for evaluating low UV intensity or low validated dose. If strategies in Figure 6.9 cannot be implemented or are not successful in getting the UV intensity or validated dose above the required setpoint, the UV manufacturer or UV facility designer should be contacted to investigate the problem further. The PWS should activate any backup disinfection, shift production to another WTP or source of supply, or consider shutting down the WTP until the UV intensity or validated dose is within the validated limits. Any time that the UV intensity or validated dose is lower than the validated limit, it should be recorded as off-specification (Section 6.4.1.3).

6.6.2 Low UV Transmittance

This evaluation of low UVT presumes that either the low intensity evaluation (Section 6.6.1) has been completed and either (1) the cause of the low UV intensity was low UVT or (2) the operational staff has observed low UVT. If the reactor uses the Calculated Dose Approach, it may be programmed to increase lamp output or number of lamps in service to accommodate a decrease in UVT if the UVT is still within the validated range. If the UV equipment does not sufficiently compensate, or if the UV reactor cannot adjust lamp output, the UV intensity or validated dose may fall below the validated limits.

Figure 6.9. Low UV Intensity or Low Validated Dose Decision Chart



The UVT analyzer or bench-top spectrophotometer equipment should be evaluated to determine if the instruments are operating properly as described in Section 6.4.1.2. If the low UVT is not due to faulty instruments and is below the validated UVT, the following WTP operational changes should be considered:

- Vary the source water blending ratio (if available) to increase UVT.
- Where applicable, evaluate whether the coagulation process has been optimized for natural organic matter (NOM) removal and whether the coagulant dose should be increased. Poor coagulation caused by coagulant under-dosing can lead to increased NOM concentration and an associated decrease in UVT.
- Increase the oxidant dose prior to the UV facility if possible. However, this strategy may increase DBP formation or increase fouling, which should be evaluated before this option is used.
- Investigate potential upstream chemical interferences from a process failure or upset. For example, if the ozone quenching system failed, the UVT would decrease.

A decision tree that summarizes the approach for troubleshooting low UVT is shown in Figure 6.10. If the strategies presented in Figure 6.10 and described above cannot be implemented or are not successful in correcting the low UVT, the UV manufacturer or UV facility designer should be contacted to investigate the problem further. The PWS may consider shutting down the WTP or activating a backup disinfection system, if available, until the UVT is within the validated limits. The low UVT condition must be recorded as off-specification (Section 6.4.1.3) when the UVT is lower than the validated limit **and** the Calculated Dose Approach is used.

6.6.3 Failure to Meet UV Sensor Calibration Criterion

Unreliable UV sensor readings can be due to UV sensor malfunction, condensation in the UV sensor or between the UV sensor and UV sensor window, lamp malfunction, poor grounding, degradation of UV sensor electronics, or electronic short-circuits. Monitoring the UV sensor calibration will identify poor performance.

The integrated procedure of monitoring multiple UV sensor calibrations and evaluating failures of the calibration criterion can be complex, especially if multiple UV sensors fail the calibration criterion. A decision tree (Figure 6.11) can assist with the monitoring of UV sensor calibration and determining whether UV sensors should be replaced or whether a UV sensor CF is needed.

6.7 Staffing, Training, and Safety Issues

To provide consistent and reliable operation of UV reactors, the PWS must have appropriate staffing, training, and safety measures in place. This section discusses these issues.

Figure 6.10. Low UV Transmittance Decision Chart

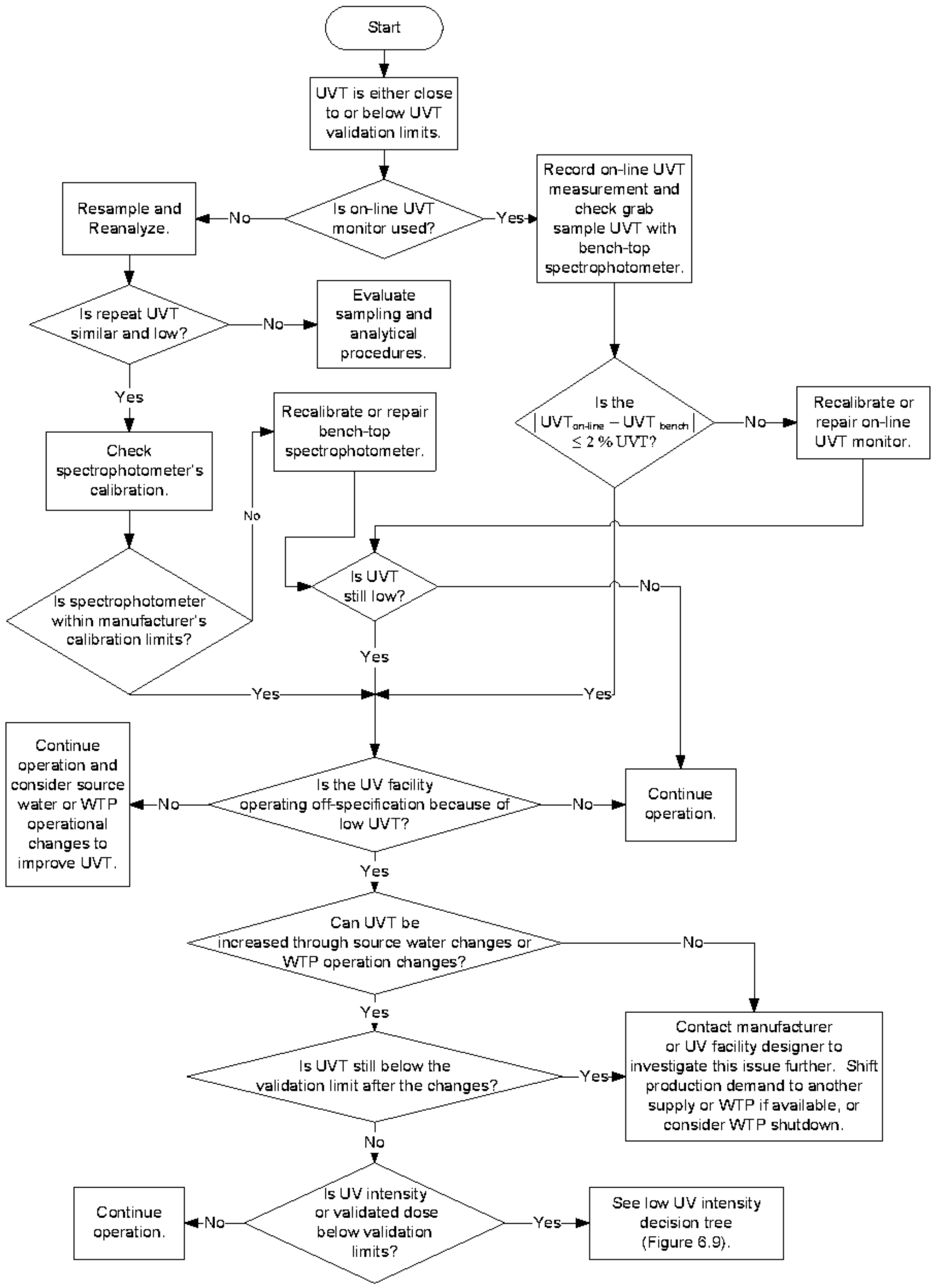
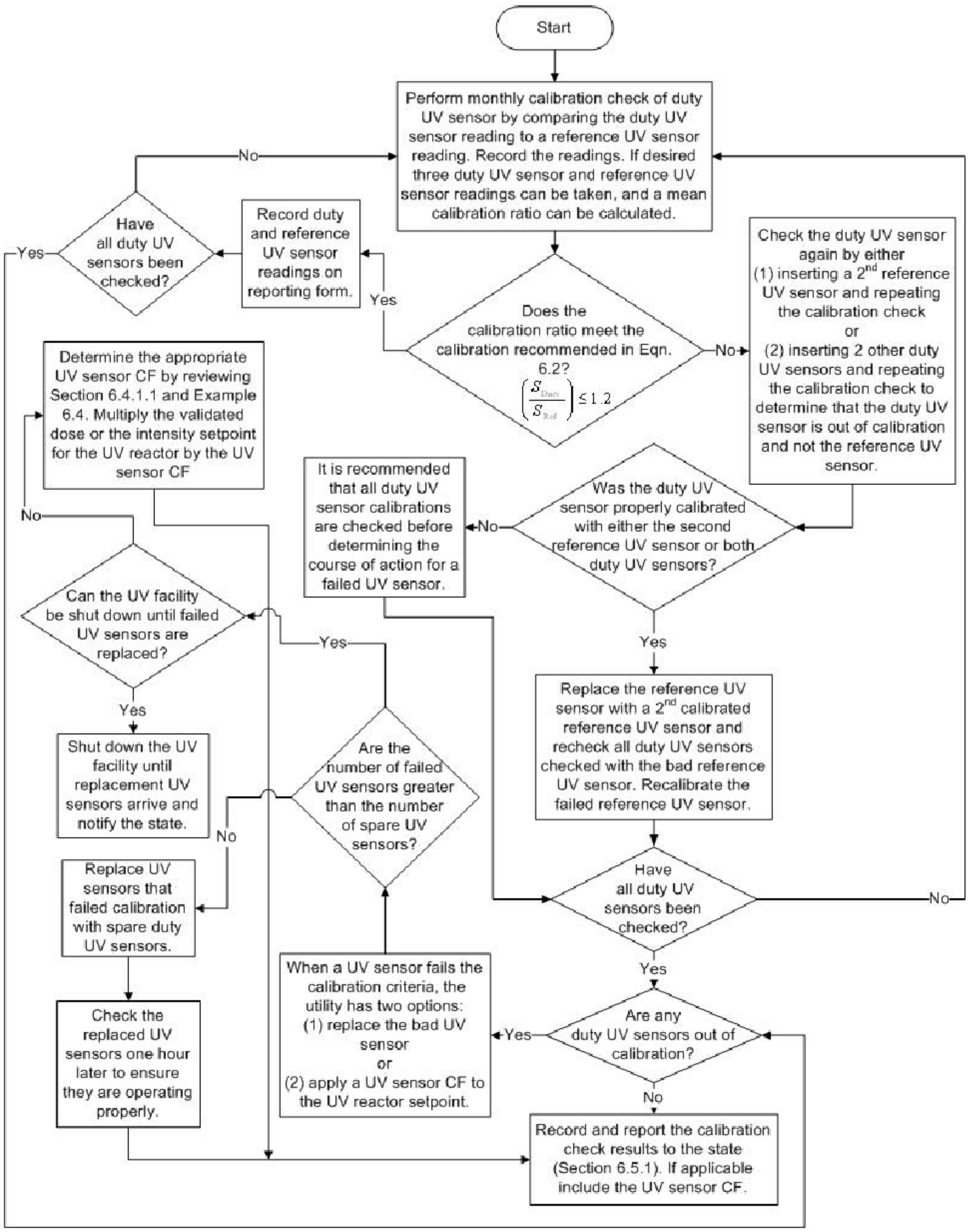


Figure 6.11. Monitoring of UV Sensor Calibration Flowchart



6.7.1 Staffing Levels

During initial start-up operation, more operator attention will be needed to assist with functional and performance testing and to establish site-specific O&M procedures (described in Section 6.1.1). However, depending on the level of automation, a typical UV facility requires minimal operator attention during normal operation. Generally, UV facilities use PLCs to monitor operating parameters, control the UV reactor, and generate alarms. Increased automation (e.g., remote monitoring capability) may be incorporated to further reduce operator requirements. Table 6.9 describes how various site-specific factors affect staffing needs for a UV facility.

Table 6.9. Factors Impacting Staffing Needs

Factor	Impact on Staffing
Type of UV Reactor	LP and LPHO reactors may require more maintenance than an MP reactor because they have more lamps and typically are cleaned off-line (i.e., OCC cleaning). However, MP lamps generally need to be replaced more often than LP lamps.
Instrumentation and Monitoring Strategy	More automated control strategies will result in lower staffing levels due to enhanced remote operation and monitoring capability.
Water Quality	Water quality and UV reactor design affect sleeve fouling and cleaning frequency. These factors, in turn, impact the staffing needs for manual cleaning for OCC systems and for maintaining the OMC or OMCC system.

6.7.2 Training

Training is necessary for all personnel who are associated with the UV facility, including operators, maintenance workers, instrumentation technicians, electricians, laboratory staff, custodial staff, engineers, and administrators. The training program should incorporate any state requirements and should emphasize both normal and emergency operating procedures, safety issues, process control and alarm conditions, validated operation, monitoring, instrumentation, and responses to operational issues.

The UV manufacturer and UV facility designer should provide training on the UV reactors, UV facility design, and O&M activities. Training should include both classroom instruction and field training. Additionally, actively involving the operators during start-up will provide another opportunity to reinforce classroom instructions. Continued training should be provided when new employees are hired or when a process or control is altered.

6.7.3 Safety Issues

This section provides some recommended safety precautions for UV reactor operations. The recommended precautions in this section should be considered in addition to manufacturer's recommended safety precautions and procedures, Occupational Safety and Health

Administration (OSHA) regulations, and state guidance and regulations for UV reactor operations.

In addition to the standards and procedures established for WTP operations, the following safety issues pertain specifically to UV reactors:

- UV light exposure
- Electrical safety
- Burns from hot lamps or equipment
- Abrasions or cuts from broken lamps or sleeves
- Potential exposure to mercury from broken lamps

Threshold limit values (TLVs) for UV light apply to occupational exposure to UV incident on the skin or eyes. The recommended TLVs depend on the lamp wavelengths emitted and the UV intensity (mW/cm^2). The PWS can determine the appropriate TLVs for their UV reactors, using *TLVs for Chemical Substances and Physical Agents and Biological Exposure Indices* (ACGIH 2006). These values are not enforceable standards, but should be considered when establishing operational procedures. To limit or prevent operator exposure to the UV light, UV reactors should have interlocks that deactivate the lamps when reactors are accessed. Viewing ports, if provided, should be fitted with UV filtering windows, or operators should wear a UV-resistant face shield when working in the UV reactor. To minimize the danger of exposure, warning signs also should be posted.

To reduce the risk of electrical shock, the main electrical supply to the UV reactors should be disconnected and the operator should wait at least 5 minutes for the lamps to cool and the energy to dissipate before maintenance is performed in areas where electric shock may be a risk. All safety and operational precautions required by the National Electric Code (NEC), OSHA, local electric codes, and the UV manufacturer should be followed and include the following precautions:

- Proper grounding
- Lockout, tagout procedures
- Use of proper electrical insulators
- Installation of safety cut-off switches

The ballasts and the reactor chamber can also become hot during operation. The temperatures of these components should be checked before touching them.

Broken lamps pose two potential safety hazards. The lamps and sleeves are constructed of quartz tubing, which can fracture and cause serious cuts or injury, and broken lamps may release mercury. Operators should be trained in proper mercury cleanup and disposal procedures to prevent mercury inhalation or absorption through the skin. Appendix E discusses lamp breakage and cleanup procedures.

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Appendix A

Preparing and Assaying Challenge Microorganisms

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Sections A.1 through A.4 describe procedures that can be used for preparing stock solutions of male-specific-2 bacteriophage (MS2 phage) and *Bacillus subtilis* spores and assaying the concentration of those microorganisms in water samples. Procedures for preparing stock solutions can be scaled to provide the volumes needed for UV reactor validation. Alternative procedures and challenge microorganisms can be used if they are acceptable to the state.

A.1 MS2 Phage Stock Preparation

MS2 phage (American Type Culture Collection [ATCC] 15597-B1) can be propagated using a variety of host bacteria, including *Escherichia coli* C3000 (ATCC 15597); *E. coli* Famp (ATCC 700891); and others (Meng and Gerba 1996, Oppenheimer et al. 1993, NWRI (2003). The following propagation method was adapted from NWRI (2003).

Procedure:

1. Inoculate sterile tryptic soy broth (TSB) (Difco, Detroit, Michigan) with host bacteria transferred from a single colony grown on a nutrient agar plate. Incubate the culture with constant stirring at 35 to 37 degrees Centigrade (°C) for 18 to 24 hours.

2. Transfer 0.5 milliliter (mL) of the host bacterial culture to 50 mL of fresh TSB and incubate at 35 to 37 °C for 4 to 6 hours with continuous shaking at 100 Hertz (Hz) to obtain a culture in its log growth phase (~3×10^8 cfu/mL, where cfu = colony forming unit).

3. Dilute stock MS2 phage using Tri-buffered saline (pH 7.3) to a concentration of ~100 pfu/mL (pfu = plaque forming unit).

4. Add 1 mL of diluted MS2 phage stock solution to the 50-mL volume of *E. coli* in TSB and incubate overnight at 35 to 37 °C.

5. Centrifuge the MS2-*E. coli* culture at 8,000 × G [G = 9.82 meter per second squared (m/s^2)] for 10 minutes at 4 °C to remove cellular debris.

6. Filter the supernatant by passing it through a 0.45-micrometer (µm) low protein-binding filter.

7. Assay the concentration of MS2 phage in the stock solution as described in Section A.2.

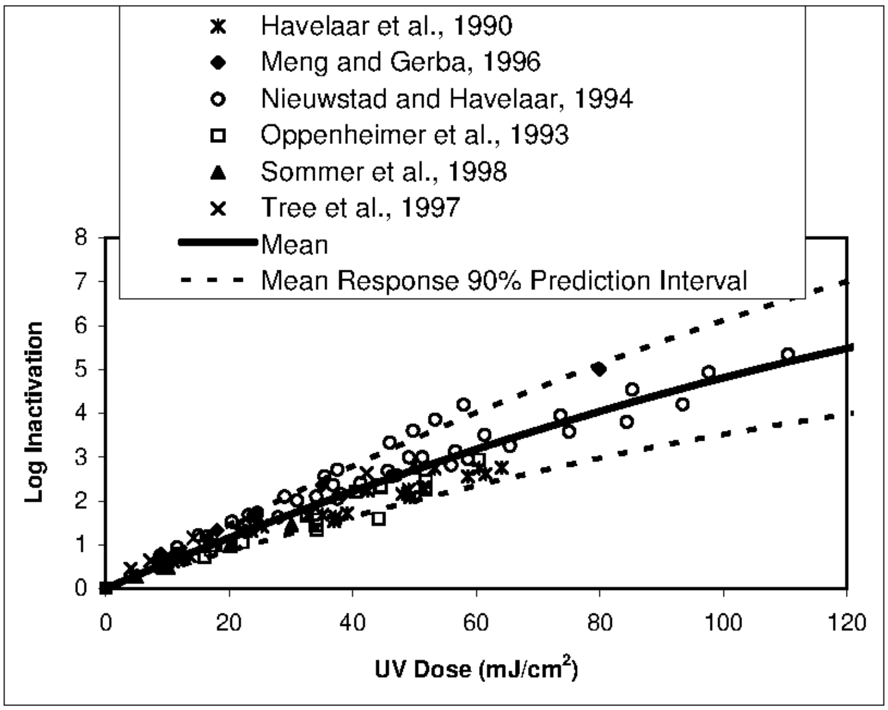
8. Collect and refrigerate the filtrate at 4 °C, and use within one month.

Propagation should result in a highly concentrated stock solution of essentially mono-dispersed phage whose UV dose-response follows second-order kinetics with minimal tailing. Figure A.1 presents the UV dose-response of MS2 phage as reported in the literature. Over the range of reduction equivalent dose (RED) values demonstrated during validation testing, the mean UV dose-response of the MS2 phage stock solution should lie within the 95-percent prediction interval of the mean response in Figure A.1. Over a UV dose range of 0 to 120 millijoule per centimeter squared (mJ/cm^2), the prediction intervals of the data shown in Figure A.1 may be defined using the following equations:

$$Upper\,Bound: \quad \log I = -1.4\times10^{-4}\times UV\ Dose^2 + 7.6\times10^{-2}\times UV\ Dose \qquad \text{Equation A.1}$$

$$Lower\,Bound: \quad \log I = -9.6\times10^{-5}\times UV\ Dose^2 + 4.5\times10^{-2}\times UV\ Dose \qquad \text{Equation A.2}$$

Figure A.1. UV Dose-response of MS2 Phage



A.2 MS2 Phage Assay

The concentration of MS2 phage (ATCC 15597-B1) in water samples can be assayed using agar overlay technique with *E. coli* (ATCC 15597) as a host bacterium [(Adams (1959), Yahya et al. (1992), Oppenheimer et al. (1993), and Meng and Gerba (1996)]. Each test sample should be assayed in triplicate and the sample concentration calculated as the arithmetic average of the three measured values. The following procedure can be used.

Procedure:

1. Inoculate sterile TSB (Difco, Detroit, Michigan) with the host bacterium and incubate at 35 to 37 °C for 18 to 24 hours to obtain an approximate concentration of 10^8 cfu/mL.

2. Transfer 1 mL of the host bacterial culture to 50 mL of fresh TSB and incubate at 35 to 37 °C for 4 to 6 hours with continuous shaking at 100 Hz to obtain a culture in its log growth phase.

3. Obtain serial dilutions of the MS2 phage sample using a 0.001-molar (M) phosphate-saline buffer or TSB.

4. Combine and gently stir 1 mL of host cell solution, 0.1 mL of diluted MS2 phage sample, and 2 to 3 mL of molten tryptic soy agar (TSA) (0.7 percent agar, 45 to 48 °C) (Difco).

5. Pour the mixture onto solidified TSA (1.5 percent agar) contained in petri dishes. The time between mixing the MS2 phage sample with the *E. coli* host and plating the top agar layer should not exceed 10 minutes. After plating, the agar should harden in less than 10 minutes.

6. After the top agar layer hardens, cover and invert the petri dishes, and incubate 16 to 24 hours at 35 to 37 °C.

7. Count the plaques with the aid of a colony counter. Plaques are identified as clear circular zones 1 to 5 millimeter (mm) in diameter in the lawn of host bacteria.

8. Record the number of plaques per dish and the MS2 phage sample volume and dilution. If individual plaques cannot be distinguished because of confluent growth, record the plate counts as “TNTC” (too numerous to count).

9. Calculate the MS2 phage concentration in the water samples:

$$Concentration = \sum 10^{F_D} \frac{n_{i,avg}}{V_i} \qquad \text{Equation A.3}$$

where:

F_D = Dilution factor
n_i = Number of counts on each plate (cfu or pfu)
V_i = Volume of diluted sample used with each plate (mL)

Example A.1. A water sample containing MS2 phage was diluted 10-, 100-, and 1,000-fold using a 0.1-mL aliquot dilution of the sample for each. Each dilution was assayed in triplicate and the average count from these three plate counts is the challenge microorganism corresponding to the applied UV dose. Plaque forming units observed on the plates were 2, 5, and 6 for the 1,000-fold diluted sample and 32, 40, and 47 for the 100-fold diluted sample. With the 10-fold dilution, plate counts were too numerous to count. The concentration in the original sample is calculated as:

$$Conc. = \frac{\left(10^3 \times \frac{(2+5+6)\ \text{pfu}/3}{0.1\ \text{mL}}\right) + \left(10^2 \times \frac{(32+40+47)\ \text{pfu}/3}{0.1\ \text{mL}}\right)}{2} = 4.15 \times 10^4\ \text{pfu/mL}$$

A.3 *Bacillus subtilis* Spore Preparation

B. subtilis spores (ATCC 6633) can be propagated using Schaeffer's medium [Munakata and Rupert (1972), Sommer et al. (1995), and DVGW (2006)]. The following propagation method was adapted from DVGW (2006).

Procedure:

1. Prepare 1 liter (L) of Columbia agar (Oxoid CM 331) using 23.0 grams (g) special peptone (Oxoid L 72), 1.0 g starch, 5.0 g NaCl, and 10.0 g agar (Oxoid L 11) in phosphate-buffered (to pH 7) water. Autoclave for 15 minutes at 121 °C.

2. Prepare 1 L of sporulation medium using 280 milligrams (mg) $MgSO_4 \cdot H_2O$, 1.11 g KCl, 3.1 mg $FeSO_4 \cdot 7H_2O$, and 8.9 g nutrient broth (Oxoid CM 67) in phosphate-buffered (to pH 7) water. Autoclave for 15 minutes at 121 °C.

3. Inoculate Columbia agar (Oxoid CM 331) plates with three smears of *B. subtilis* and incubate 24 hours at 37 °C.

4. Inoculate 300 mL of sporulation medium with three colonies collected from the agar plates that were prepared in Step 3.

5. Incubate the sporulation medium for 72 hours at 37 °C on a shaker operating at 2 Hz.

6. Sonicate the resulting culture for 10 minutes at 50,000 Hz and 10 °C.

7. Harvest the spores by centrifuging 80-mL aliquots at 5,000 × G and 10 °C for 10 minutes.

8. Wash the spores 3 times by re-suspending the pellet in 20 mL of distilled water and centrifuging at 5,000 × G for 10 minutes at 10 °C.

9. Re-suspend the washed spores in 100 mL of 0.001-M phosphate-saline buffer.

10. Inactivate the vegetative *B. subtilis* by heating at 80 °C for 10 minutes.

11. Sonicate the resulting culture for 10 minutes at 50,000 Hz and 10 °C.

12. Collect the resulting stock solution and assay the *B. subtilis* spore concentration as described in Section A.4.

13. Refrigerate at 4 °C and use within one month (unless stability over longer periods of time can be substantiated). Sonicate for 10 minutes at 50,000 Hz and 10 °C before use.

Propagation should result in a highly concentrated stock solution of mono-dispersed *B. subtilis* spores with a UV dose-response that follows the UV dose-response curves reported in the literature and presented in Figure A.2. Over the range of RED values demonstrated during validation testing, the mean UV dose-response of the *B. subtilis* stock solution should lie within the 90-percent prediction interval of the mean response provided in Figure A.2. Over a UV dose range of 0 to 70 mJ/cm^2, the prediction intervals of the data shown in Figure A.2 are defined using the following equations:

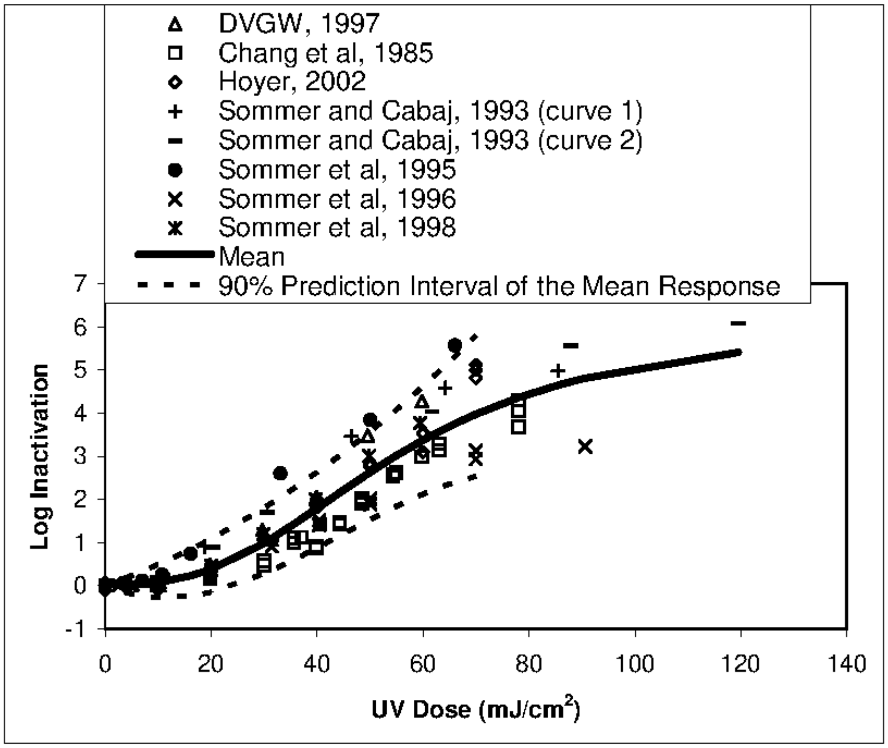
$$Upper\ Bound: \quad \log\ I = -2.0\times10^{-5}\times UV\ Dose^3 + 2.7\times10^{-3}\times UV\ Dose^2 - 5.3\times10^{-2}\times UV\ Dose$$

Equation A.4

$$Lower\ Bound: \quad \log\ I = 5.7\times10^{-4}\times UV\ Dose^2 + 4.3\times10^{-2}\times UV\ Dose$$

Equation A.5

Figure A.2. UV Dose-Response of *B. subtilis* Spores



A.4 *Bacillus subtilis* Spore Assay

The concentration of *B. subtilis* spores (ATCC 6633) in water samples can be assayed using plate count agar. As with MS2 phage, each test sample should be assayed in triplicate and the sample concentration calculated as the arithmetic average of the three measured values. The following procedure was adopted from DVGW (2006).

Procedure:

1. Prepare 1 L of plate-count agar (Oxoid CM 325) using 5.0 g casein peptone (Oxoid L 42), 2.5 g yeast extract (Oxoid L 21), 1.0 g glucose, and 9.0 g agar (Oxoid L 11) in distilled water. Adjust the pH to 6.8 ± 0.2 and autoclave for 15 minutes at 121 ° C.

2. Obtain serial dilutions of the *B. subtilis* spore sample using 0.001-M phosphate-saline buffer.

3. Vacuum filter 100 mL of diluted sample through a 47-mm 0.45-µm membrane filter.

4. Place filter on a petri dish containing hardened agar and cover plates.

5. Incubate plates 24 ± 2 hours at 37 ± 1 °C.

6. Count the number of colonies formed with the aid of a colony counter.

7. Record the number of colonies per dish, and the *B. subtilis* spore sample volume and dilution. If individual colonies cannot be distinguished because of confluent growth, record the plate counts as TNTC.

8. Calculate the *B. subtilis* spore concentration in the original samples in units of cfu/mL using Equation A.3.

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Appendix B

UV Reactor Testing Examples

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This appendix presents two validation data analysis examples. Section B.1 presents an example for the UV Intensity Setpoint Approach using single-setpoint operations. Section B.2 presents a more complex example for a UV reactor that uses the Calculated Dose Approach. These two examples bracket a wide range of complexities that UV reactor validation testing can encompass. All information and data are hypothetical but are representative of real validation data in terms of selection of test conditions and variability in measured values.

B.1 Example 1 – Validation for the UV Intensity Setpoint Approach (a Single Setpoint and a Single Disinfection Goal)

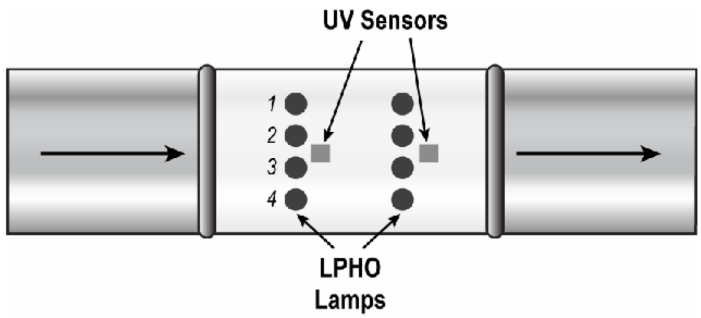
System X plans to add UV disinfection to their treatment process to earn 2.5-log *Cryptosporidium* inactivation credit. Based on the LT2ESWTR dose requirements as summarized in Table 1.4 of this manual, System X needs to deliver a minimum required dose of 8.5 mJ/cm^2 to receive this level of inactivation credit. The hypothetical proposed installation has the following design specifications:

Design flow rate	400 gpm
Minimum UVT	90 %
Lamp aging factor	80 %
Fouling factor	85 %
Fouling/aging factor	68 % (80 % × 85 %)
Disinfection goal	2.5-log *Cryptosporidium* inactivation credit

The water system's engineer selected a UV reactor (illustrated in Figure B.1) with the following characteristics:

UV Reactor	- 2 banks of lamps - 4 300-W LPHO lamps per bank - Rated for flow rates of 50 – 500 gpm - 1 UV sensor/bank positioned equidistant from Lamps 2 & 3
UV Dose-Monitoring Approach	UV Intensity Setpoint Approach with one alarm setpoint

Figure B.1 Schematic of Hypothetical UV Reactor for Example 1



B.1.1 Validation Test Plan

The validation test plan was developed using Checklist 5.2 in Chapter 5. Key elements defined in the validation test plan include:

- The UV manufacturer provided three reference UV sensors for calibrating the duty sensors during validation. These reference sensors had been calibrated by an independent, qualified sensor testing laboratory before validation and had a documented measurement uncertainty of 10 percent (Section 5.5.4)
- Because the number of UV sensors was less than the number of lamps, the highest-output lamps were identified prior to testing and were positioned closest to the sensors at lamp positions 2 and 3 (Section 5.4.7). New lamps were used during validation testing (after a 100 hour burn-in period).
- The validation testing was conducted over a one-day period. The UV dose-response of the challenge microorganism (measured via a laboratory collimated beam test) was evaluated with 1-L influent water samples collected at high and low UVT values (Section C.1).
- All recommended testing protocols as listed in Section 5.7 and Appendix C were followed.

The UV manufacturer had already identified a target setpoint (**11.7 mW/cm^2**) using numerical modeling. System X confirmed with the manufacturer that this setpoint is low enough to account for their combined conditions of minimum UVT and maximum lamp fouling and aging. The following two UVT–lamp power operating conditions were tested:

1. The UVT was lowered to produce the target UV sensor setpoint (in this case, the resultant UVT was 89.9%), while the lamp power was kept at 100%.

2. The UVT was raised back to its maximum value (no UV-absorbing chemical added), and the lamp power was reduced to produce the same UV sensor value (in this case, the resultant lamp power was 66%).

B.1.2 Test Data

The data collected during validation testing are presented in Tables B.1 through B.5 and are described below:

- Table B.1 presents the UV dose-response data measured on the influent water collected during field validation testing for the laboratory collimated beam test.
- Tables B.2 through B.4 present the data from full-scale reactor testing
  - Table B.2 presents the flow rate, UVT, lamp power, and UV sensor readings measured for each test condition.
  - Table B.3 presents the measured challenge microorganism concentrations for the influent and effluent samples collected (in triplicate) from the UV reactor for each test condition.
  - Table B.4 presents the UV output of the eight lamps used during validation testing measured at the same lamp location (Lamp #2 in Row #1) adjacent to the same UV sensor (#1), which was used to identify the highest output lamps.
- Table B.5 presents data comparing the three reference UV sensor measurements to the duty UV sensors used during validation.

Sections B.1.3 to B.1.8 show how the data will be used to determine whether QA/QC criteria are met, to calculate the necessary correction factors, and to determine the validated operating conditions for the target log inactivation.

Table B.1 Challenge Microorganism UV Dose-response Measured Using a Collimated Beam Apparatus

90% UVT					97% UVT				
UV Dose (mJ/cm^2)	Replicate #1		Replicate #2		UV Dose (mJ/cm^2)	Replicate #1		Replicate #2	
	N (pfu/mL)	Log N	N (pfu /mL)	Log N		N (v/mL)	Log N	N (pfu /mL)	Log N
0	882329	5.95	944980	5.98	0	1148154	6.06	1300460	6.11
10	180120	5.26	198394	5.30	10	316328	5.50	257749	5.41
20	64217	4.81	69438	4.84	20	113644	5.06	74396	4.87
30	20622	4.31	20100	4.30	30	34679	4.54	25189	4.40
40	7257	3.86	8145	3.91	40	12624	4.10	9226	3.97
60	1274	3.11	1399	3.15	60	1980	3.30	1722	3.24
80	188	2.27	261	2.42	80	387	2.59	211	2.32
100	80	1.90	90	1.95	100	80	1.90	100	2.00

Table B.2 Flow Rate, UVT, Lamp Power, and UV Sensor Data Measured during Validation Testing

Test ID	Banks On	Flow Rate (gpm)	UVT (%)	Relative Lamp Output (%)	$S_{duty, \#1}$ (mW/cm²)	$S_{duty, \#2}$ (mW/cm²)
1	1, 2	394	89.9	100%	11.7	11.7
2	1, 2	403	97.0	66%	11.6	11.7

Table B.3 Measured Influent and Effluent Challenge Microorganism Concentrations

Test ID	Influent Challenge Microorganism Log Concentration			Effluent Challenge Microorganism Log Concentration		
	Replicate #			Replicate #		
	1	2	3	1	2	3
1	5.94	6.00	5.84	4.57	4.54	4.56
2	6.01	5.99	6.04	4.10	4.09	4.06

Table B.4 Sensor #1 Measurements with Lamp #2 Operated at 100-percent Ballast Power

Lamp ID	$S_{duty \#1}$ (mW/cm²)	Lamp ID	$S_{duty \#1}$ (mW/cm²)
1	13.6	5	13.9
2	14.6	6	13.3
3	14.2	7	14.5
4	13.4	8	14.3

Table B.5 Reference UV Sensor Checks

Before/After Validation Testing	UVT (%)	Relative Lamp Power (%)	Sensor ID	S_{duty} (mW/cm²)	$S_{ref, \#1}$ (mW/cm²)	$S_{ref, \#2}$ (mW/cm²)	$S_{ref, \#3}$ (mW/cm²)
Before	97	100	1	11.3	11.7	12.1	11.4
Before	97	68	1	5.1	5.5	5.7	5.3
Before	90	100	2	3.7	4.0	4.1	3.8
Before	90	68	2	2.0	1.9	1.9	1.8
After	97	100	1	11.6	11.8	12.2	11.4
After	97	68	1	5.1	5.4	5.6	5.3
After	90	100	2	3.9	4.0	4.1	3.9
After	90	68	2	1.9	1.8	2.0	1.8

B.1.3 Develop the UV Dose-response Curve from the Collimated Beam Data

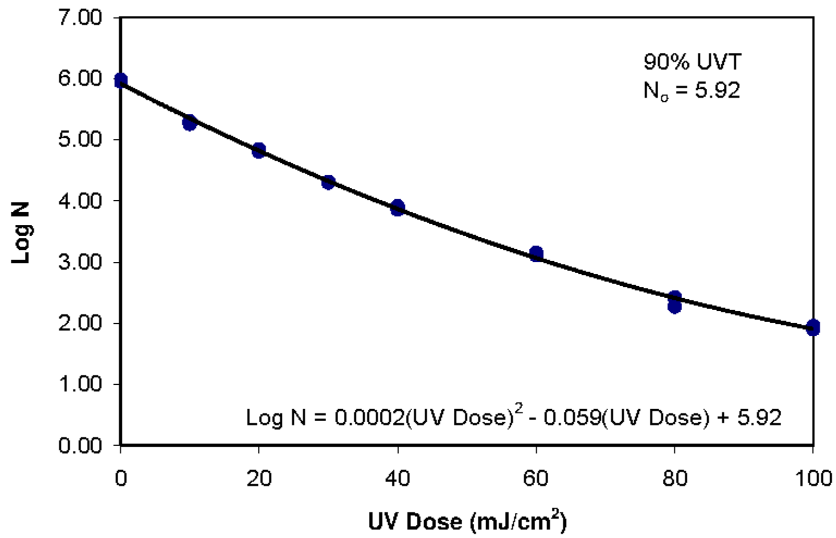
Figures B.1(a) and (b) present the UV dose-response data from Table B.1 at UVT values of 90 and 97 percent, respectively. The data have been fitted to quadratic equations that show log N as a function of UV dose. The fits were used to identify log N_o values of 5.91 and 6.05 (i.e., log N_o where the curves intersect the y-axes) from Figures B.1(a) and (b), respectively. Using these values, Table B.6 presents the UV dose-response data defined as UV dose versus log I, where log I = log(N_o/N).

The UV dose-response data described in Table B.6 were analyzed to determine if the two datasets could be combined using the method referred to in Section C.5 (Draper and Smith 1998).[1] A statistical analysis of the collimated beam data is recommended to determine which terms are significant, p-value ≤ 0.05, using a standard regression tool. The process is iterative, and each time the regression tool is used, one term is dropped until all of the coefficients are deemed significant (p-values ≤ 0.05). In this example, three iterations were needed.

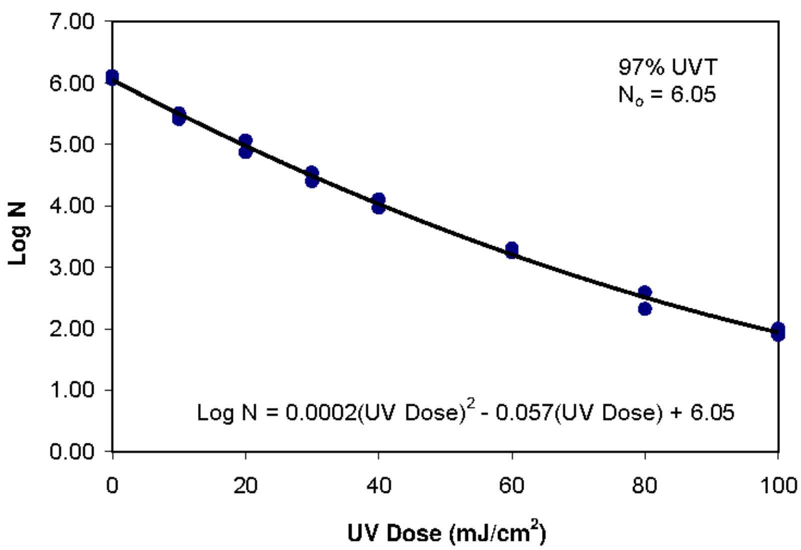
The regression analysis showed that the two measured UV dose-response curves were statistically similar ($p < 0.05$) and could be combined. Figure B.2 presents the plot of UV dose as a function of log inactivation for the combined dataset and the resultant UV dose-response equation.

[1] The datasets should be combined whenever possible to develop one UV dose-response equation for calculating all RED values. The inability to combine datasets indicates a problem may have occurred with either the calculation or the test. Details are provided in Section C.5.

Figure B.1 Log N Versus UV Dose Using the Data in Table B.1 at (a) 90 Percent UVT and (b) 97 Percent UVT



(a)

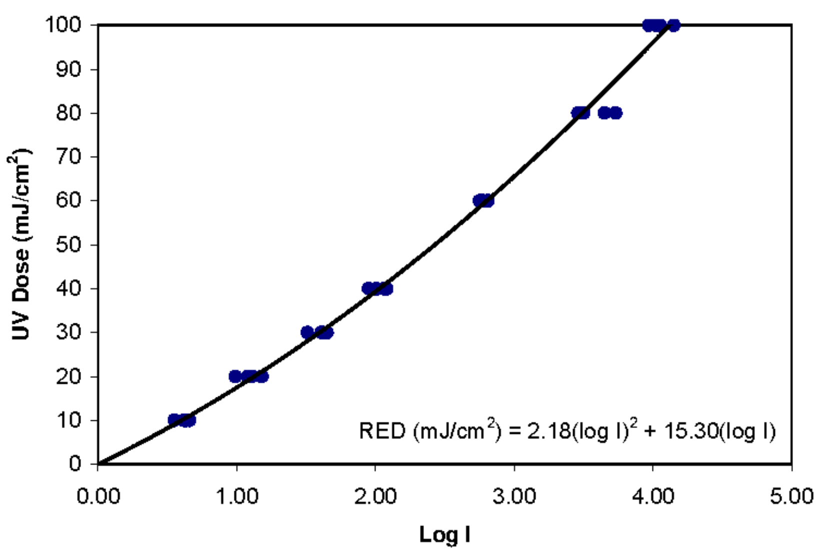


(b)

Table B.6 Challenge Microorganism UV Dose-response Defined as UV Dose Versus [Log (N_o/N)] (i.e., Log I)

90% UVT			97% UVT		
UV Dose (mJ/cm^2)	Replicate		UV Dose (mJ/cm^2)	Replicate	
	#1	#2		#1	#2
	5.92 - Log N			6.05 - Log N	
0	-0.03	-0.06	0	-0.01	-0.06
10	0.66	0.62	10	0.55	0.64
20	1.11	1.08	20	0.99	1.18
30	1.61	1.62	30	1.51	1.65
40	2.06	2.01	40	1.95	2.08
60	2.81	2.77	60	2.75	2.81
80	3.65	3.5	80	3.46	3.73
100	4.02	3.97	100	4.15	4.05

Figure B.2 Log I Versus UV Dose Using the Data in Table B.6



B.1.4 Verify That QA/QC Criteria Are Met

Checklist 5.4 was used to ensure that recommended QA/QC criteria were met. Calculations of key uncertainties are provided in the next two subsections.

B.1.4.1 Collimated Beam Data Uncertainty

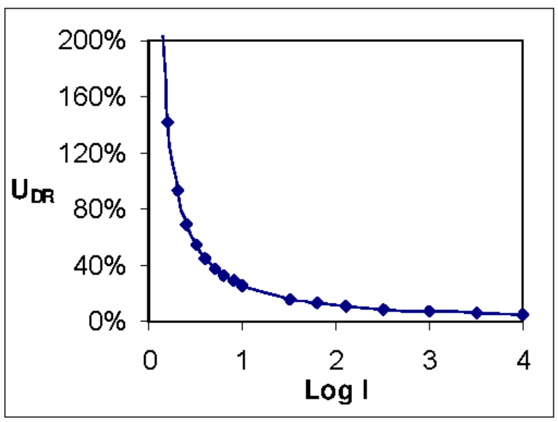
The uncertainty in the UV dose calculation using the collimated beam data is calculated according to Equation C.6, shown below as Equation B.1:

$$U_{DR} = t\frac{SD}{UV\ Dose_{CB}} \times 100\% \qquad \text{Equation B.1}$$

where

U_{DR}	=	Uncertainty of the UV dose-response fit at a 95-percent confidence level
UV $Dose_{CB}$	=	UV dose calculated from the UV dose-response curve in Figure B.2
SD	=	Standard deviation of the difference between the calculated UV dose-response and the measured values from Table B.1
t	=	t-statistic at a 95-percent confidence level for a sample size equal to the number of test condition replicates used to define the dose-response

In this case, SD = 2.2 at 1-log inactivation and t = 2.04 for 32 test condition replicates as shown in Table B.6. Equation B.1 can then be used to determine U_{DR} at various log inactivation values from Table B.1. The graph below shows the relationship between log inactivation and U_{DR}. The value of U_{DR} should not exceed 30 percent at the UV dose corresponding to 1-log inactivation of the challenge organism. In this case, **U_{DR} = 25 percent** at 1.0-log inactivation. This value is less than the recommended limit of 30 percent.



B.1.4.2 UV Sensor Uncertainty

Guidance in Section 5.5.4 recommends that the manufacturer's reported sensor uncertainty be confirmed as being less than 10 percent. Three reference sensors were used to confirm duty sensor measurements. Data analyses are shown in the table on the next page (using the data in Table B.5). The two duty UV sensors were within 10 percent of the average readings from three reference sensors.

Before/ After Validation Testing	UVT (%)	Lamp Power (kW)	Sensor ID	S_{duty} (W/m²)	$S_{Ref,\#1}$ (W/m²)	$S_{Ref,\#2}$ (W/m²)	$S_{Ref,\#3}$ (W/m²)	$S_{Ref,avg}$ (W/m²)	$\left\lvert \frac{S_{duty}}{S_{Ref,avg}} - 1 \right\rvert$
Before	97	100	1	11.3	11.7	12.1	11.4	11.7	4%
Before	97	68	1	5.1	5.5	5.7	5.3	5.5	7%
Before	90	100	2	3.7	4	4.1	3.8	4.0	7%
Before	90	68	2	2	1.9	1.9	1.8	1.9	7%
After	97	100	1	11.6	11.8	12.2	11.4	11.8	2%
After	97	68	1	5.1	5.4	5.6	5.3	5.4	6%
After	90	100	2	3.9	4	4.1	3.9	4.0	3%
After	90	68	2	1.9	1.8	2.0	1.8	1.9	2%

Source of sensor data: Table B.5

B.1.5 Calculate Log Inactivation and RED

Table B.7 shows the measured log inactivation through the UV reactor and the associated RED values for each validation test condition. The log inactivation values were determined from the field inactivation data in Table B.3. The RED values are determined by inputting the log inactivation into the UV dose-response equation. For example, for a log inactivation of 1.37 (Test No. 1, Replicate 1), the RED is equal to $[2.18 \times (1.37)^2] + [15.30 \times 1.37]$, or 25.1. Note that the average and standard deviations for each test condition are also calculated for later use in computing the Validation Factor (VF).

Table B.7 Measured Log I and RED Values for Each Test Condition in Table B.2

Test ID #	UVT	Log I			RED (mJ/cm²)				
		Replicate #			Replicate #			Avg.	SD_{RED}
		1	2	3	1	2	3		
1	89.9	1.37	1.46	1.28	25.1	27.0	23.2	25.1	1.9
2	97.0	1.91	1.9	1.98	37.2	36.9	38.8	37.6	1.0

B.1.6 Determine the Validation Factor

The VF is defined according to Equation 5.13[2], shown below as Equation B.2:

$$VF = B_{RED} \times \left(1 + {U_{Val}}/{100}\right)$$ Equation B.2

B.1.6.1 Calculate the RED Bias

2 If the UV reactor was equipped with MP lamps instead of LPHO lamps, the potential for polychromatic bias would need to be evaluated using the guidelines in Section 5.9.

Per guidance provided in Section 5.9.1, The UV sensitivity (RED / Log I) for each test replicate was calculated for the test with the lowest UVT value (in this case, Test 1). The RED bias for 2.5-log *Cryptosporidium* inactivation credit at the minimum UVT of 90 percent was determined to be 1.79 using Table G.4. Data for this analysis are summarized below.

Test #	RED (mJ/cm^2)	Log I	UVT[1]	Sensitivity (mJ/cm^2 per log I)	B_{RED}
1.1	25.1	1.37	89.9	18.3	1.79
1.2	27.0	1.46	89.9	18.5	
1.3	23.2	1.28	89.9	18.1	

[1] Note: rounding off to match the number of significant figures in Table G.4, to determine the value of B_{RED} the UVT value measured for Test #1 becomes 90 percent.

B.1.6.2 Calculate the Uncertainty of Validation

The decision tree in Figure 5.4 was used to identify the correct equation for U_{VAL}. As shown in Section B.1.4.1, U_{DR} is less than or equal to 30 percent. As noted in Section B.1.4.2, U_S is less than or equal to 10 percent. Therefore, the equation for U_{VAL} is as follows:

$$U_{Val} = U_{SP} \qquad \text{Equation B.3}$$

U_{SP} is defined by Equation 5.14

$$U_{SP} = \frac{t \times SD_{RED}}{RED} \times 100\% \qquad \text{Equation B.4}$$

where

t = t-statistic for the number of replicates

SD_{RED} = the standard deviation for the RED calculations (Table B.7)

RED = the RED at the specific test condition used for the SD_{RED}

The value for t is 3.18 for 3 test replicates. The highest SD_{RED} and associated RED should be used in this calculation. Using data from Table B.7, data from test condition #1 should be used as follows:

$$U_{SP} = \frac{3.18 \times 1.9}{25.1} \times 100\% = 24.1\%$$

Using Equation B.3, $U_{VAL} = 24.1\%$

B.1.6.3 Calculate the Validation Factor

The value of VF can now be calculated using Equation B.2:

$$VF = 1.79 \times (1 + 24.1/100) = 2.22$$

B.1.7 Calculate the Validated Dose

In the step, the minimum RED (in this case, the average RED from test condition #1, shown in Table B.7) is divided by the VF to calculate the validated dose using Equation 5.16:

$$D_{Val} = \frac{RED}{VF} \qquad \text{Equation B.5}$$

$$D_{Val} = \frac{25.1}{2.22} = 11.3\ mJ/cm^2$$

B.1.8 Assign Log Inactivation Credit Based for the Validated Dose

The validated dose must be greater than or equal to the required UV dose (D_{req}) to achieve a given level of pathogen inactivation credit:

$$D_{Val} \geq D_{req} \qquad \text{Equation B.6}$$

In this case, 11.3 mJ/cm^2 is greater than the required dose of 8.5 mJ/cm^{2}for 2.5-log inactivation of *Cryptosporidium*. The UV reactor can receive 2.5-log inactivation credit for an installation (with adequate inlet/outlet hydraulics, see Section 5.4.5) that operates under the following criteria (Table B.8):

Table B.8 Validated Dose and Operating Conditions for 2.5-log *Cryptosporidium* Inactivation Credit Using the Hypothetical UV Reactor Tested in Example 1

UV Sensor Setpoint	Lamp Status	Flow Rate Range	D_{Val}
11.7 mW/cm^2	All lamps should be turned on during reactor operations	Q ≤ 394 gpm	≥ 11.3 mJ/cm^2

B.2 Example 2 – Validation for the Calculated Dose Approach

System Y plans to add UV disinfection to their treatment plant to earn 2.0-log *Cryptosporidium* inactivation credit. Based on the LT2ESWTR UV dose requirements as summarized in Table 1.4 of this manual, System Y needs a minimum germicidal dose of 5.8

mJ/cm^2 to receive this level of inactivation credit. The hypothetical proposed installation has the following design specifications:

Design flow range	3 – 10 mgd
Design UVT range	87 – 93 %
Lamp aging factor	80 %
Fouling factor	85 %
Fouling/Aging factor	68 % (80 % × 85 %)
Disinfection goal	2.0-log *Cryptosporidium* inactivation credit

The water system's engineer selected a UV reactor with the following characteristics:

UV Reactor	- 1 bank of lamps - 6 8-kW MP lamps per bank - Ballast power settings range from 40 – 100 % - Rated for flow rates of 2.5 – 10 mgd - 1 germicidal UV sensor per lamp
UV Dose-Monitoring Approach	Calculated Dose Approach with dose pacing

B.2.1 Validation Test Plan

The test plan was developed using Checklist 5.2 in Chapter 5 to identify a range of target RED values at different flow rate-lamp output-UVT combinations for 1.0- to 3.0-log *Cryptosporidium* inactivation credit (depending on water quality and operating conditions). The UV manufacturer used modeled predictions of UV reactor performance to develop the desired validation test conditions. The UV manufacturer selected test conditions that target RED values ranging from approximately 4 – 43 mJ/cm^2 at UVT values of 85, 90, and 95 percent. Lamp power was to be adjusted during testing of the UV reactor to give RED values within the target range. Test flow rates of 2.5 – 10 mgd were selected in order to test the full design flow range of the UV reactor. This information is summarized in Table B.9 below.

Table B.9 Validation Test Conditions

Test ID	UVT (%)	Flow Rate (mgd)	Relative Lamp Output (%)	Predicted RED[3] (mJ/cm^2)
1	95	10	100	14.1
2	95	5	100	24.6
3	95	2.5	100	42.8
4	95	10	70	11.8
5	95	5	70	20.6
6	95	2.5	70	35.8
7	95	10	40	8.9
8	95	5	40	15.6
9	95	2.5	40	27.1
10	90	10	100	7.9
11	90	5	100	13.8
12	90	2.5	100	24.1
13	90	10	70	6.6
14	90	5	70	11.6
15	90	2.5	70	20.1
16	90	10	40	5.0
17	90	5	40	8.7
18	90	2.5	40	15.2
19	85	10	100	4.5
20	85	5	100	7.8
21	85	2.5	100	13.5
22	85	10	70	3.7
23	85	5	70	6.5
24	85	2.5	70	11.3
25	85	10	40	2.8
26	85	5	40	4.9
27	85	2.5	40	8.6

Other key test elements in the validation test plan include:

- The UV manufacturer provided three reference UV sensors for calibrating the duty UV sensors during validation. These reference UV sensors had been calibrated previously by an independent, qualified sensor testing laboratory and had a documented measurement uncertainty of 10 percent (Section 5.5.4).
- New lamps were used during validation testing (after a 100 hour burn-in period).
- The validation testing was conducted over a two-day period (Test Conditions 1 – 18 on Day 1 and Test Conditions 19 – 27 on Day 2). The UV dose-response of the challenge microorganism (measured via a collimated beam test) was evaluated with 1-L influent water samples at 95 percent UVT, collected on Day 1 of testing and at 85 percent UVT, collected on Day 2 of testing (Section C.1).

[3] From the numerical model predictions developed by the manufacturer.

- All recommended testing protocols as listed in Section 5.7 and Appendix C were followed.

B.2.2 Test Data

The data collected during validation testing are presented in Tables B.10 through B.13 and are described below:

- Table B.10 presents the UV dose-response data measured on the influent water collected during field validation testing for the laboratory collimated beam test.
- Tables B.11 presents the flow rate, UVT, lamp power, and UV sensor readings measured for Test Conditions 1 – 9 (95 percent UVT). Testing was also conducted at 90 and 85 percent UVT. For simplicity, only the results of testing at 95 percent UVT are reported here.
- Table B.12 presents measured challenge microorganism concentrations for the influent and effluent samples collected (in triplicate) from the reactor for several test conditions. A total of 27 tests (one for each condition described in Table B.9) were run. For simplicity, only the first tests at UVT measurements of 95, 90, and 85 percent, respectively, are shown.
- Table B.13 presents data comparing the three reference UV sensor measurements to UV Duty Sensor #1 used during validation. Comparisons were made to all six duty sensors, but for simplicity only the results for Sensor #1 are reported here.

Sections B.2.3 to B.2.8 show how the data will be manipulated to determine whether QA/QC criteria are met, to calculate the necessary correction factors, and to determine the validated operating conditions for the target log inactivation.

Table B.10 Challenge Microorganism UV Dose-response Measured Using a Collimated Beam Apparatus

95% UVT					85% UVT				
UV Dose (mJ/cm^2)	Replicate #1		Replicate #2		UV Dose (mJ/cm^2)	Replicate #1		Replicate #2	
	N (PFU/mL)	Log N	N (PFU/mL)	Log N		N (PFU/mL)	Log N	N (PFU/mL)	Log N
0	65560	4.82	67000	4.83	0	70440	4.85	70000	4.85
10	13270	4.12	15000	4.18	10	14400	4.16	16120	4.21
20	2790	3.45	2400	3.38	20	2590	3.41	2560	3.41
29	640	2.81	591	2.77	30	693	2.84	529	2.72
39	159	2.20	153	2.18	40	173	2.24	191	2.28
59	23	1.36	19	1.28	60	28	1.45	20	1.30

Table B.11 Flow Rate, UVT, Lamp Power, and UV Sensor Data Measured during Validation Testing (for UVT = 95% only)

Test ID	Banks On	Flow Rate (mgd)	UVT (%)	Lamp Power (kW)	Lowest Measured S_{duty} (W/m^2)
1	1	10	95	8.0	303.1
2	1	5	95	8.0	307.9
3	1	2.5	95	8.0	297.9
4	1	10	95	5.6	183.1
5	1	5	95	5.6	180.2
6	1	2.5	95	5.6	190.3
7	1	10	95	3.2	91.8
8	1	5	95	3.2	93.5
9	1	2.5	95	3.2	89.4

Table B.12 Measured Influent and Effluent Challenge Microorganism Conc. for Three Test Conditions (Three UVTs at 10 mgd and 100% Lamp Power)

Test ID	Influent Challenge Microorganism Log Concentration			Effluent Challenge Microorganism Log Concentration		
	Replicate			Replicate		
	#1	#2	#3	#1	#2	#3
1	4.92	4.8	4.87	3.79	3.69	3.70
10	4.88	4.89	4.83	3.94	4.01	3.94
19	4.93	4.90	4.91	4.24	4.28	4.29

Table B.13 Reference UV Sensor Checks for Duty Sensor #1

Before/After Validation Testing	UVT (%)	Lamp Power (kW)	Sensor ID	$S_{duty\ \#1}$ (W/m^2)	$S_{ref,\ \#1}$ (W/m^2)	$S_{ref,\ \#2}$ (W/m^2)	$S_{ref,\ \#3}$ (W/m^2)
Before	95	8	1	304.5	339.5	330.7	339.9
Before	95	3.2	1	80.2	90.9	86.2	82.7
Before	85	8	1	100.9	96.1	91.5	91.0
Before	85	3.2	1	23.2	20.9	21.3	20.9
After	95	8	1	320.2	301.1	315.0	330.4
After	95	3.2	1	69.6	76.5	76.3	78.3
After	85	8	1	99.4	99.4	93.2	91.3
After	85	3.2	1	19.3	20.4	20.4	20.0

B.2.3 Develop the UV Dose-response Curve from the Collimated Beam Data

Figures B.3(a) and (b) present the UV dose-response data from Table B.10 at UVT values of 85 and 95 percent, respectively. The data have been fitted to quadratic equations that show log N as a function of UV dose. The fits were used to identify log N_o values for the UV dose-response curves measured at 85 and 95 percent UVT (4.89 and 4.86, respectively). Table B.14 presents the UV dose-response data defined as UV dose versus log I (log [N_o/N]).

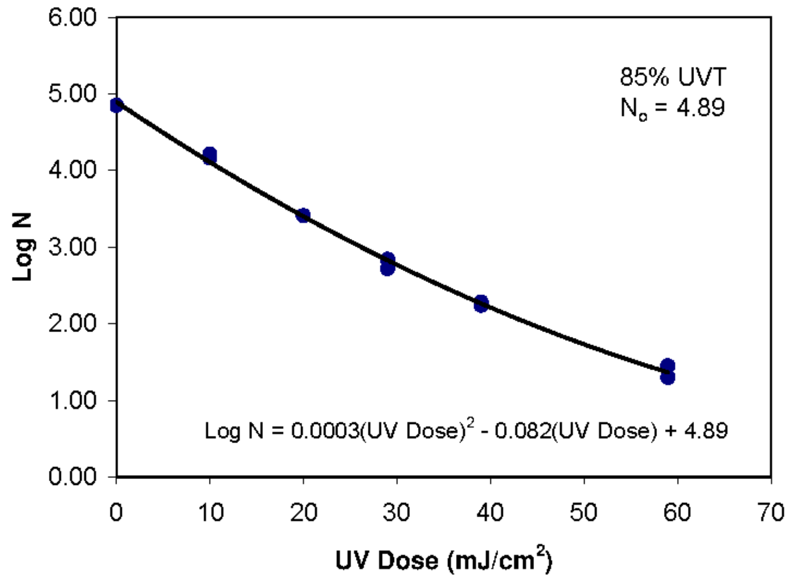
The UV dose-response data described in Table B.14 were analyzed to determine if the two datasets could be combined using the method referred to in Section C.5 (Draper and Smith 1998).[4] A statistical analysis of the collimated beam data is recommended to determine which terms are significant, p-value ≤ 0.05, using a standard regression tool. The process is iterative, and each time the regression tool is used, one term is dropped until all coefficients are deemed significant, p-value ≤ 0.05. In this example, three iterations were required.

The multiple regression analysis showed that the two measured UV dose-response curves were statistically similar and could be combined [i.e., they could each be expressed with only two variables, as A log I + B(log I)^2][5]. Figure B.4 presents the plot of UV dose as a function of log inactivation for the combined dataset and the resultant UV dose-response equation.

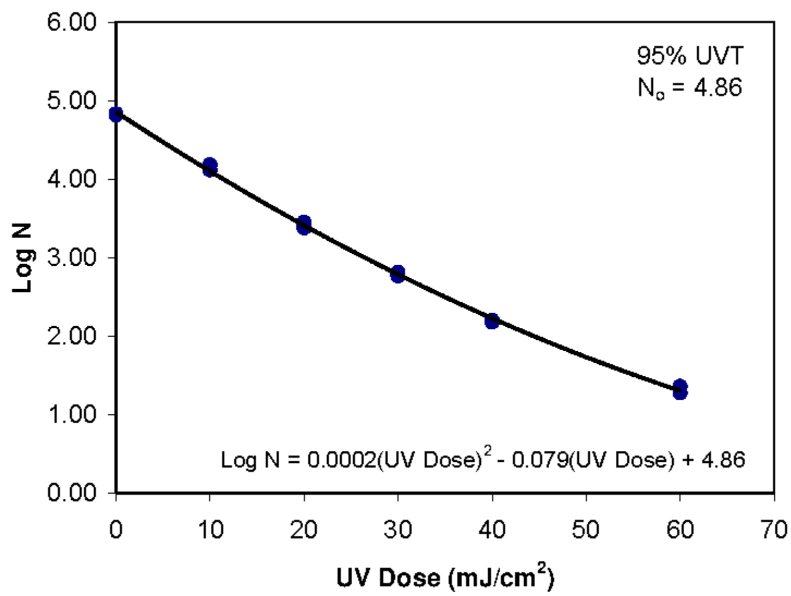
[4] The datasets should be combined whenever possible to develop one dose-response equation for calculating all RED values. The inability to combine datasets indicates a problem may have occurred with either the calculation or the test. Details are provided in Section C.5

5 If the regression analysis had shown that the UV dose-response curves *could not* be combined, separate curves would have been used to calculate RED values for data collected on each day of testing (i.e., the curve for 95% UVT would be used to calculate RED for full-scale reactor testing data collected on Day 1, and the curve for 85% UVT would be used to calculate RED for full-scale reactor testing data collected on Day 2)

Figure B.3 Log N Versus UV Dose Using the Data in Table B.10 at (a) 85 Percent UVT and (b) 95 Percent UVT



(a)

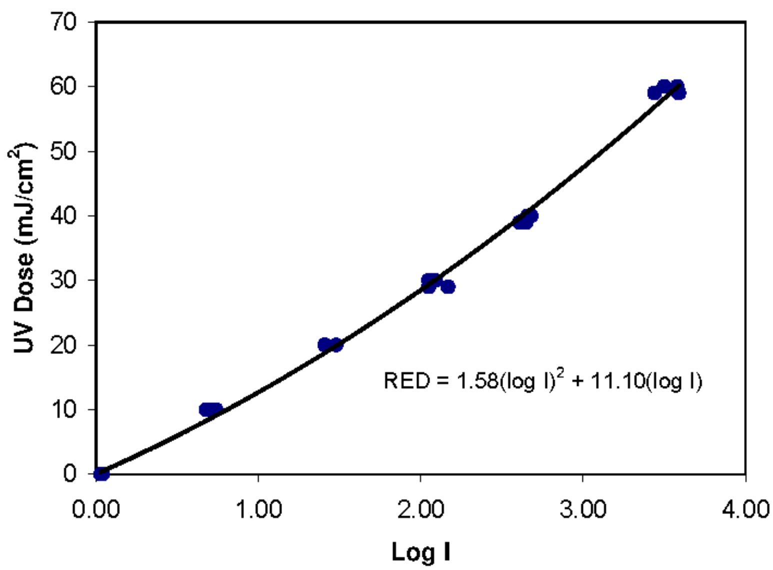


(b)

Table B.14 Challenge Microorganism UV Dose-Response Defined as UV Dose Versus Log(N/N_o) (i.e., Log I)

85% UVT			95% UVT		
UV Dose (mJ/cm^2)	Replicate		UV Dose (mJ/cm^2)	Replicate	
	#1	#2		#1	#2
	4.89 – Log N			4.86- Log N	
0	0.04	0.04	0	0.04	0.03
10	0.73	0.68	10	0.74	0.68
20	1.48	1.48	20	1.41	1.48
29	2.05	2.17	30	2.05	2.09
39	2.65	2.61	40	2.66	2.68
59	3.44	3.59	60	3.50	3.58

Figure B.4 Log I Versus UV Dose Using the Data in Table B.14



B.2.4 Verify That QA/QC Criteria Are Met

Checklist 5.4 was used to ensure that recommended QA/QC criteria were met. Calculations of key uncertainties are provided in the next two subsections.

B.2.4.1 Collimated Beam Data Uncertainty

The uncertainty in the UV dose calculation using the collimated beam data is calculated using Equation C.6, shown below as Equation B.7:

$$U_{DR} = t\frac{SD}{UV\ Dose_{CB}} \times 100\% \qquad \text{Equation B.7}$$

where

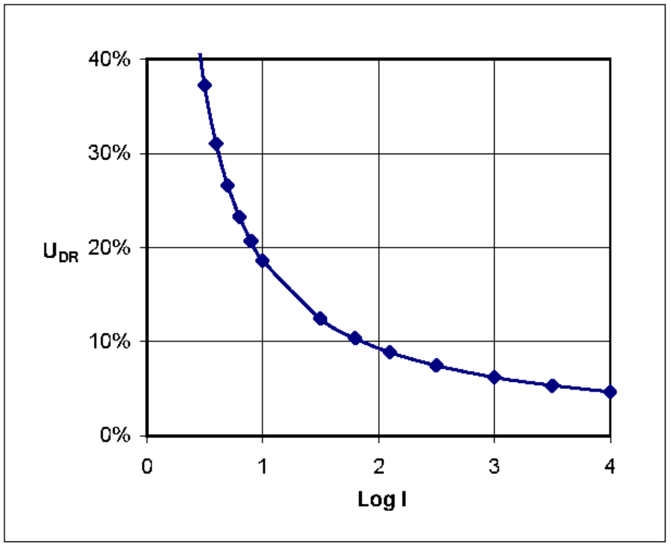
U_{DR} = Uncertainty of the UV dose-response fit at a 95-percent confidence level

$UV\ Dose_{CB}$ = UV dose calculated from the UV dose-response curve in Figure B.4

SD = Standard deviation of the difference between the calculated UV dose-response and the measured value from Table B.10

t = t-statistic at a 95-percent confidence level for a sample size equal to the number of test conditions replicates used to define the dose-response

In this case, SD = 1.2 at 1.0-log inactivation and t = 2.06 for 24 test conditions from Table B.14. Equation B.7 can then be used to determine U_{DR} at various log inactivation values from Table B.10. The graph below shows the relationship between log inactivation and U_{DR}. As shown in the figure below, **U_{DR} = 19percent** at 1.0-log inactivation. This value is less than the recommended limit of 30 percent.



B.2.4.2 UV Sensor Uncertainty

Guidance in Section 5.5.4 recommends that the manufacturer's reported sensor uncertainty be confirmed as being less than 10 percent. Three reference sensors were used to confirm duty sensor measurements. Data analyses are shown below. The two duty UV sensors were within 10 percent of the average readings from three reference sensors.

Before/ After Validation Testing	UVT (%)	Lamp Power (kW)	$S_{duty\ \#1}$ (W/m^2)	$S_{Ref,\#1}$ (W/m^2)	$S_{Ref,\#2}$ (W/m^2)	$S_{Ref,\#3}$ (W/m^2)	$S_{Ref,avg}$ (W/m^2)	$\left\lvert \frac{S_{duty}}{S_{Ref,avg}} - 1 \right\rvert$
Before	95	8.0	304.5	339.5	330.7	339.9	336.7	10%
Before	95	3.2	80.2	90.9	86.2	82.7	86.6	7%
Before	85	8.0	100.9	96.1	91.5	91.0	92.9	9%
Before	85	3.2	23.2	20.9	21.3	20.9	21.0	10%
After	95	8.0	320.2	301.1	315.0	330.4	315.5	1%
After	95	3.2	69.6	76.5	76.3	78.3	77.0	10%
After	85	8.0	99.4	99.4	93.2	91.3	94.6	5%
After	85	3.2	19.3	20.4	20.4	20.0	20.3	5%

Source of UV sensor data: Table B.13

B.2.5 Calculate Log Inactivation and RED

Table B.15 shows the measured log inactivation through the UV reactor and the associated RED values (determined from the UV dose-response equation) for each validation test condition. The log inactivation values were determined from the field inactivation data (excerpted in Table B.12).

Table B.15 Measured Log I and RED Values for Each Test Condition in Table B.11

Test ID	UVT	Log I			RED (mJ/cm^2)		
		Replicate #			Replicate #		
		1	2	3	1	2	3
1	95.1	1.13	1.11	1.17	15.7	15.4	16.3
2	94.8	1.36	1.35	1.34	19.2	19.0	19.0
3	94.8	1.66	1.63	1.67	23.9	23.5	24.1
4	95.4	1.03	1.09	1.12	14.2	15.2	15.6
5	94.6	1.28	1.27	1.35	18.0	17.8	19.1
6	94.8	1.55	1.56	1.59	22.2	22.4	22.9
7	94.7	0.91	0.92	0.90	12.5	12.6	12.4
8	94.5	1.16	1.17	1.20	16.2	16.3	16.8
9	95.5	1.39	1.39	1.44	19.7	19.7	20.4
10	90.0	0.94	0.88	0.89	12.8	12.0	12.1
11	89.9	1.13	1.11	1.14	15.7	15.3	15.9
12	90.1	1.35	1.42	1.39	19.1	20.1	19.6

Table B.15 Measured Log I and RED Values for Each Test Condition in Table B.11 (cont.)

Test ID	UVT	Log I Replicate #			RED (mJ/cm²) Replicate #		
		1	2	3	1	2	3
13	90.1	0.85	0.81	0.86	10.6	10.0	10.7
14	90.1	1.05	1.03	1.07	13.4	13.1	13.7
15	89.8	1.30	1.29	1.34	17.1	17.0	17.7
16	89.6	0.67	0.73	0.74	8.2	8.9	9.0
17	89.6	0.91	0.94	0.95	11.5	11.8	12.0
18	90.0	1.21	1.17	1.22	15.7	15.2	15.9
19	84.6	0.68	0.62	0.62	8.3	7.5	7.5
20	84.7	0.87	0.91	0.87	10.9	11.4	10.9
21	84.6	1.17	1.17	1.18	15.1	15.1	15.3
22	84.7	0.56	0.55	0.54	6.7	6.6	6.4
23	85.4	0.84	0.76	0.77	10.4	9.4	9.5
24	85.3	1.07	1.03	1.07	13.7	13.1	13.7
25	85.1	0.42	0.47	0.44	4.9	5.6	5.1
26	85.4	0.64	0.67	0.67	7.8	8.1	8.1
27	85.5	0.93	0.94	0.95	11.7	11.8	11.9

B.2.6 Develop an Equation to Calculate RED as a Function of the Control Variables

To define an equation to calculate RED as a function of the operating conditions, the validation data were fitted for a 1-bank configuration using Equations 5.8 and 5.10, shown below as Equations B.8 and B.9 (there is only one bank of lamps, so it is not included as a variable here):

$$RED = 10^{a} \times A254^{b} \times \left(S / S_o \right)^{c} \times \left(1 / Q \right)^{d} \qquad \text{Equation B.8}$$

Or in linear form,

$$\log(RED) = a + b \times \log(A254) + c \times \log\left(S / S_o \right) + d \times \log\left(1 / Q \right) \qquad \text{Equation B.9}$$

where

RED = The RED calculated with the UV dose-monitoring equation, also referred to as the “calculated dose” in this guidance manual

A_{254} = UV absorbance at 254 nm

S = Measured UV sensor value

S_o = UV intensity measured at 100 percent lamp power.

Q = Flow rate

a, b, c, d = Model coefficients obtained by fitting the equations to the data

Remember that the validation goal pursued in Example 2 is somewhat different from that in Example 1. In Example 1, the simplest possible method (Single Intensity Setpoint Approach) was desired. In Example 2, UV dose delivery will be paced to the operating conditions, so the goal is to develop an equation that provides the **best fit** of the data. In some validations, the user may try several different equation forms in an effort to find the best fit. The equation forms presented here were selected because they have been used successfully at full-scale for numerous UV reactors and operating conditions (Wright et al. 2005).

To develop a best-fit equation for RED in the form shown in Equation B.8 (or B.9 in linear form), a theoretical equation for S_o should first be developed using validation test data to capture the variation in S_o as a function of UVT. A strong goodness-of-fit as determined through statistical analysis allows the equation for S_o to be used in development of the best-fit equation for RED.

1. Develop an expression for S_o.

The term S_o is the UV sensor measurement made with a new lamp operating at 100 percent power in a new, unfouled sleeve being monitored by a calibrated UV sensor through a new, unfouled UV sensor port window. S_o varies with UVT. This relationship can be measured during validation or determined from the validation test conditions. In this example, S_o is determined by fitting the validation data using the following relationship. As with Equations B.8 and B.9, this approach has proven successful for several validation tests (Wright 2005):

$$S = e^{f} e^{g \times UVT} P^{h} \qquad \text{Equation B.10}$$

Equation B.10 can be expressed as:

$$\ln(S) = f + g \times UVT + h \times \ln(P) \qquad \text{Equation B.11}$$

where P is the lamp power in units of kW and *f*, *g*, and *h* are model coefficients to be determined in the subsequent analysis. Fitting this equation to the data in Table B.11 at a 95-percent confidence level (UVT and P) using the regression tool within spreadsheet software gives the following values:

Term	Value	p-Statistic
f	-8.402	2.15×10^{-11}
g	0.115	1.61×10^{-13}
h	1.578	6.97×10^{-16}

Inputting these calculated values into Equation B.10 results in the following relationship (8 kW is the UV reactor's maximum power setting, so S = S_o when P is equal to 8 kW):

$$S = e^{-8.402} e^{0.115 \times UVT} P^{1.578} \qquad \text{Equation B.12}$$

and

$$S_o = e^{-8.402} e^{0.115 \times UVT} 8^{1.578}$$ Equation B.13

The goodness of fit was evaluated by determining the p-statistic for the model coefficients in Equation B.13 (see Draper and Smith 1998 or similar for procedure). The p-statistic of each model coefficient was determined and found to be ≤ 0.05.

2. Calculate log (S/S_o).

By defining S as the measured UV sensor readings in Table B.11, Equation B.13 is then used to predict S_o and to produce the data that will be fit to Equation B.9. The UVT (measured as A_{254} values and converted to UVT units), S_{duty} and Q values are from the measured data (Tables B.9 and B.15).

3. Calculate an expression for RED.

As with the UV dose-response equations (shown in Figure B.4) and the sensor equations (Equations B.12 and B.13), the interpolation equation (Equation B.9) is fitted to the data in Table B.15 using a regression tool in spreadsheet software (at a 95-percent confidence level). The goodness-of-fit was again evaluated by determining the p-statistic for the model coefficients in Equation B.14 (Draper and Smith, 1998). The p-statistic of each model coefficient was determined to be ≤ 0.05 (i.e., all were significant). The results of this analysis are shown below with the following results:

Term	Value	p-Statistic	Term	Value	p-Statistic
a	-0.829	7.76×10^{-16}	c	0.166	1.21×10^{-19}
b	-2.519	3.71×10^{-42}	d	0.409	9.35×10^{-42}

Inputting these calculated values into Equation B.9 results in the following:

$$\log(RED) = -0.829 - 2.519 \times \log(A254) + 0.166 \times \log\left(S/S_o\right) + 0.409 \times \log\left(1/Q\right)$$

Equation B.14

Equation B.14 can be used to calculate RED values as a function of the operating conditions (measured UVT, flow rate, and UV intensity) provided S_o is calculated using Equation B.13.

This equation can be programmed within the UV reactor's program logic controller (PLC) to calculate the delivered RED as a function of the current operating conditions for UV dose-monitoring. The equation can be used for interpolation over the validated range of flow rates (2.5 – 10 mgd), UVT values (85 – 95 percent), and RED values (8.5 – 24.1 mJ/cm^2). If the flow rate falls below 2.5 mgd, the PLC should default to 2.5 mgd in the dose-monitoring equation. If the UVT reads above 85 percent, the PLC should default to 95 percent in the dose-monitoring equation.

B.2.7 Determine the Validation Factor

The Validation Factor (VF) is defined according to Equation 5.13, shown below as Equation B.15:

$$VF = B_{RED} \times \left(1 + U_{Val} / 100\right) \qquad \text{Equation B.15}$$

B.2.7.1 Calculate the RED Bias

Per guidance provided in Section 5.9.1, the UV sensitivity for the test condition with the lowest UVT (85 percent) was calculated to range from13 – 14 mJ/cm^2 per log inactivation. From Table G.5 (for a 2.0-log *Cryptosporidium* inactivation credit), the RED bias for the maximum UV sensitivity of 14 mJ/cm^2 is 2.01.

B.2.7.2 Calculate the Uncertainty of Validation

The decision tree in Figure 5.5 was used to determine the correct equation for U_{VAL}. As shown in B.2.4.1, U_{DR} is less than or equal to 30 percent. As noted in B.2.4.2, U_S is less than or equal to 10 percent. Therefore, the equation for U_{VAL} is as follows:

$$U_{Val} = U_{IN} \qquad \text{Equation B.16}$$

U_{IN} is defined by Equation 5.15:

$$U_{IN} = \frac{t \times SD}{RED} \times 100\% \qquad \text{Equation B.17}$$

where

SD = Standard deviation of the differences between the test RED (based on the observed log inactivation and UV dose-response curve), and the RED calculated using the dose-monitoring equation for each replicate

RED = The RED as calculated using the dose-monitoring equation

The value of U_{val} (i.e., U_{IN}) can be expressed in one of two ways:

1. As a single value, the most conservative (largest) uncertainty value calculated for the validated range. This is typically based on the lowest calculated RED value.

2. As a function of the calculated RED, that is, as a variable number.

In this example, more than 30 test measurements were made for RED, so the t-statistic is 2.04. The standard deviation was determined from the RED values recorded during testing and the RED values calculated using the dose-monitoring equation (equation B.14). The value of SD was determined to be 0.97.

The water system does not plan to operate below a calculated RED value of 15 mJ/cm^2, so a single value of U_{IN} can be calculated as (2.04 x 1.0) / 15 = 0.136. The following equation can be used if U_{IN} is calculated as a function of RED at another location (of the same UV reactor):

$$U_{IN} = \frac{t \times \sigma}{RED} \times 100\% = \frac{2.04 \times 0.97}{RED} = \frac{1.98}{RED} \qquad \text{Equation B.18}$$

where
RED = the RED calculated from the dose-monitoring equation (equation B.14)

B.2.7.3 Calculate the Validation Factor

If the user prefers to use one U_{IN} value, a single VF is determined using the following equation:

$$VF = 2.01 \times \left(1 + \frac{1.98}{15}\right) = 2.28 \qquad \text{Equation B.19}$$

If a user at another water system preferred to use U_{IN} as a function of the calculated RED, the following equation would be used for calculating the VF:

$$VF = 2.01 \times \left(1 + \frac{U_{Val}}{100}\right) = 2.01 \times \left(1 + \frac{1.98}{RED}\right) = 2.01 + \frac{3.98}{RED} \qquad \text{Equation B.20}$$

B.2.8 Calculate the Validated Dose

In the last step, the calculated RED associated with the operating conditions is divided by the VF to produce the validated dose:

$$D_{Val} = \frac{RED}{VF} \qquad \text{Equation B.21}$$

where
RED = RED calculated from the dose-monitoring equation (Equation B.14)
VF = Validation Factor (either Equation B.19 or Equation B.20)

To calculate D_{VAL} using a point estimate for the VF, use Equation B.22:

$$D_{Val} = \frac{RED}{2.28}$$ Equation B.22

To calculate a general expression with VF as a function of RED, to determine D_{Val}, Equation B.20 would be substituted into Equation B.21:

$$D_{Val} = \frac{RED}{2.01 + \frac{3.98}{RED}}$$ Equation B.23

B.2.9 Assign Log Inactivation Credit for the Validated Dose(s)

The validated dose must be greater than or equal to the required UV dose in Table 1.4 (D_{req}) to achieve a given level of pathogen inactivation credit:

$$D_{Val} \geq D_{req}$$ Equation B.24

or

$$D_{Val} \geq 5.8 \text{ mJ/cm}^2$$ Equation B.25

System Y is in the validated range when the calculated RED from the dose monitoring equation is greater than or equal to 5.8 mJ/cm^2 × 2.28 or 13.4 mJ/cm^2. (A similar calculation would follow if a different water system preferred VF to vary with RED.)

The UV reactor can receive 2.0-log *Cryptosporidium* inactivation credit for an installation (with adequate inlet/outlet hydraulics, see Section 5.4.5) that operates under the criteria outlined in Table B.18:

Table B.18 Validated Dose and Operating Conditions for 2.0-log *Cryptosporidium* Inactivation Credit Using the Hypothetical Reactor Tested in Example 2

Validated Conditions			
Flow Rate Range[1]	UVT Range[2]	Lamp Power Range	RED[3]
≤10 mgd	≥ 85%	3.2 – 8 kW	≥ 13.4 mJ/cm^2

[1] At flow rates below 2.5 mgd, this value (2.5 mgd) should be used as the default value in the RED calculation.
[2] At UVT values above 95 %, this value (95% UVT) should be used as the default value in the RED calculation.
[3] Calculated using equations B.13 and B.14.

Appendix C

Collimated Beam Testing to Develop a UV Dose-response Curve

SW10241-G1General Comment

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Mod_10241_G1_General_EPA UV Disinfection Guidance Manual 2006.pdf Page: 306

The LT2ESWTR requires that validation testing be conducted using "a test microorganism whose dose-response characteristics have been identified with a low pressure mercury vapor lamp" [40 CFR 141.720 (d)(2)(ii)]. To accomplish this, EPA recommends using a collimated beam study of the test (or challenge) microorganism, as described in this appendix. The procedure involves placing sample water with the challenge microorganism in an open cylindrical container (e.g., a petri dish) and exposing the sample to collimated UV light for a predetermined amount of time. The UV dose is calculated using the measured intensity of the UV light, UV absorbance of the water, and exposure time. The measured concentration of microorganisms before and after exposure provides the "response," or log inactivation of the microorganisms from exposure to UV light. Regression analysis of measured log inactivation for a range of UV doses produces the dose-response curve (sometimes expressed as a "dose-response equation").

This appendix describes the recommended collimated beam testing procedure and recommended data analyses for developing the UV dose-response curve. Section C.1 provides guidelines for identifying test conditions. Section C.2 discusses all aspects of experimental testing for the collimated beam study. Data analyses are discussed in Section C.3, followed by a discussion of data uncertainty in Section C.4. Specific recommendations for combining dose-response curves and limitations on applying results when the challenge microorganism exhibits a shoulder or tailing are presented in Sections C.5 and C.6, respectively. Documentation of test conditions and all results should be included in the Validation Report (see Section 5.11 for guidance).

C.1. Identifying Test Conditions

At least two water quality conditions should be tested by collimated beam analysis:

1. The highest UV transmittance (UVT) used in the full-scale reactor test

2. The lowest UVT used in the full-scale test

Because UVT is accounted for in the UV dose calculation, the test conditions should produce similar results that can be combined to produce one UV dose-response curve. (Performing two tests instead of one test verifies that the UV dose is independent of UVT.)

UV doses should be selected to cover the range of targeted values, using a minimum of five data points plus a control [zero (0) UV dose]. The selected UV doses should result in challenge microorganism inactivation ranging from 0.5 – 1 log unit higher than the highest log inactivation to be demonstrated by the UV reactor. Table C.1 shows a sample test matrix.

At least one collimated beam test should be conducted on each day of full-scale reactor testing.

Table C.1. Sample Collimated Beam Test Matrix for Target of 2.0-Logs Inactivation of *Cryptosporidium* and MS2 Phage as the Challenge Microorganism

Sample [1]	Test Condition[2]	Log Inactivation	Target UV Doses (mJ/cm^2) [3]
Lowest UVT	1	0 (control)	0
	2	0.5	10
	3	1.5	30
	4	2.0	40
	5	2.5	50
	6	3.0	60
Highest UVT	7	0 (control)	0
	8	0.5	10
	9	1.5	30
	10	2.0	40
	11	2.5	50
	12	3.0	60

[1] The sample should represent the influent water used in full-scale reactor tests. One sample should reflect the lowest UVT tested, and one should reflect the highest UVT tested. Dose-response curves should be developed separately for each water quality condition tested and compared to determine if they can be combined (see Section C.5).

[2] Each test condition should be repeated at least twice (resulting in a minimum of two test condition replicates), and three test condition replicates will likely improve the quality of the fit for the dose-response curve.

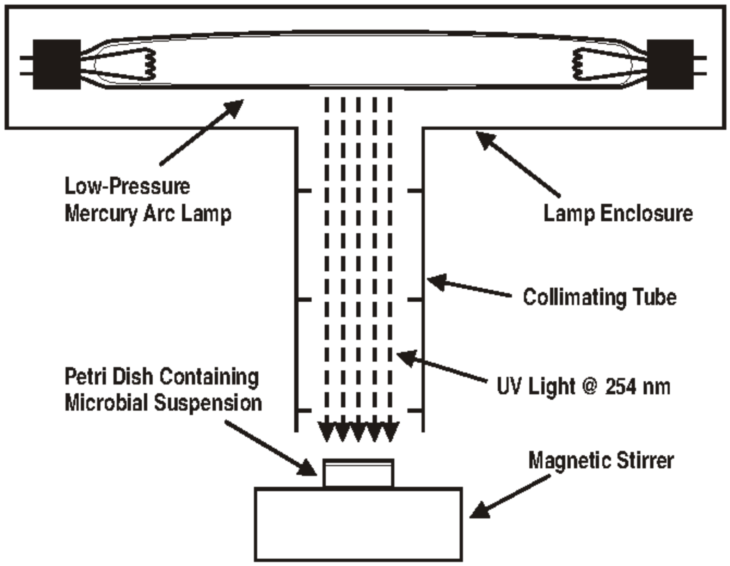
[3] Based on UV sensitivity of MS2 Phage

C.2 Measuring the UV Dose-response of the Challenge Microorganism

The challenge microorganism's UV dose-response should be measured using a low-pressure (LP) collimated beam apparatus (Figure C.1). This apparatus comprises an enclosed UV lamp and a tube with a non-reflective inner surface. The UV light enters the suspension with a near zero-degree angle of incidence and is relatively homogenous across the surface area. The UV dose delivered to the suspension is calculated using measurements of incident UV intensity, exposure time, suspension depth, and the absorption coefficient of the suspension.

Section C.2.1 provides a physical description of the collimated beam apparatus and recommendations for operational controls. Accuracy of monitoring equipment is addressed in Section C.2.2. Section C.2.3 provides the recommended test procedure, followed by equations for UV dose calculations in C.2.4.

Figure C.1. Collimated Beam Apparatus



Note: To measure intensity of UV light, a calibrated radiometer is positioned below the column in place of the petri dish.

C.2.1 Apparatus Design and Operation

Because UV dose requirements are based on the pathogen inactivation achieved using 254-nm light, the collimated beam apparatus should use a lamp that emits germicidal UV light only at 254 nm (i.e., a LP lamp). To prevent ozone formation, lamps that emit 185-nm light should not be used. The output from the lamp measured using a radiometer should vary by no more than 5 percent over the exposure time. A stable lamp output can be obtained by driving the lamp with a constant power source and maintaining the lamp at a constant operating temperature. If the line voltage is not sufficiently stable, a voltage regulator may be used to obtain a stable power supply. A stable temperature can be obtained by controlling the airflow around the lamp.

The UV lamp should be located far enough above the surface of the microbial suspension so that uniform irradiance is obtained across the sample's surface and UV light enters the suspension with a near zero-degree angle of incidence (Blatchley 1997). A recommended minimum distance from the lamp to the suspension is six times the longest distance across the suspension's surface. In order to vary the UV intensity incident on the suspension, the distance between the suspension and the lamp can be adjusted.

The uniformity of the intensity field across the sample's surface should be assessed by measuring the "Petri Factor," defined as the ratio of the average irradiance across the suspension surface to the irradiance measured at the center (Bolton and Linden 2003). The average irradiance is determined by averaging radiometer measurements taken at each point in a 5-mm spaced grid across an area defined by the suspension's surface. If the radiometer's sensing window is wider than 5 mm, it should be reduced using a cover slip with a small hole. The collimated beam apparatus should have a Petri Factor greater than 0.9.

The lamp and the light path from the lamp to the suspension should be enclosed to protect the user from exposure to UV light. A box-like enclosure made of aluminum is often used. A length of pipe is often used to enclose the light path from the lamp to the microbial suspension. The inside surface of the pipe should have a low UV reflectance and incorporate apertures to improve UV light collimation (Blatchley 1997). A shutter mechanism is sometimes used to control the exposure of the suspension to UV light. The exposure times should be measured with an uncertainty of 5 percent or less. Exposure times less than 20 seconds are not recommended.

The microbial suspension should be irradiated in an open cylindrical container (e.g., petri dish). The diameter of the container should be smaller than the diameter of the light beam incident on the container. Sample depth should be 0.5 – 2 cm. The material of the container should not adsorb the challenge microorganism enough to impact its measured UV dose-response.

Sample volumes irradiated in the container should be sufficient for measuring the challenge microorganism's concentration after irradiation. The microbial suspension should be mixed using a stir bar and a magnetic stirrer at a rate that does not induce vortices. The volume and diameter of the stir bar should be small relative to the volume and depth of the sample.

The irradiance at the center of the suspension's surface before and after exposure to UV light should be measured using a UV radiometer calibrated at 254 nm. During measurement, the radiometer's calibration plane should match the height of the suspension's surface and be perpendicular to the incident UV. The calibration plane of the radiometer should be specified in the radiometer's calibration certificate.

C.2.2 Accuracy of Monitoring Equipment

Similar to the recommended procedures for full-scale reactor testing in Chapter 5, spectrophotometer measurements of A_{254} should be verified using NIST[1]-traceable potassium dichromate UV absorbance standards and holmium oxide UV wavelength standards. The measurement uncertainty of the spectrophotometer should be ***10 percent or less***. See Section 5.5.2 for additional guidance on spectrophotometer use and the recommended procedure for verifying spectrophotometer measurements.

Radiometers should be calibrated according to the following procedure to ensure that the UV intensity is measured with an uncertainty of ***8 percent or less*** at a 95-percent confidence level:

1. The radiometers used in the collimated beam tests should come from the manufacturer with a certified uncertainty of 8 percent or less at a 95-percent confidence level at the intervals suggested by the manufacturer.

[1] National Institute of Standards and Technology

2. At minimum, the accuracy of the radiometer used to measure the UV intensity should be verified at least at the beginning and the end of each collimated beam test session using a second radiometer.

3. The two radiometers should read within 5 percent of each other. If the two radiometers do not read within 5 percent of each other, a third radiometer should be used to identify which radiometer is out of specification. The two radiometers with readings within 5 percent of each other should be used. If none of the radiometer readings match, at least two of them are likely out of calibration.

If the above criteria are met, the average radiometer measurement can be used in calculations. Alternatively, the radiometer that provides the lowest reading could be used. If these criteria are not met, the radiometers should be recalibrated. The radiometers should also be checked to be sure that the irradiance measurement does not differ by more than 5 percent before and after UV exposure.

C.2.3 Recommended Collimated Beam Test Procedure

Researchers should collect a sample from the influent sampling port of the biodosimetry test stand (or the influent sample for on-site reactor testing to be used for collimated beam testing) for collimated beam testing. Typically, a 1 liter sample is sufficient. If the testing extends over more than one day, at least one collimated beam test should be conducted for each day of testing. If different batches of challenge microorganisms are used, a UV dose-response curve should be generated for each batch.

Personnel who perform collimated beam tests should be experienced with the use and safety requirements of the equipment. Safety goggles and latex gloves should be worn. Skin should be shielded from exposure to UV light. Personnel should follow recommended procedures for challenge microorganism preparation and analysis as presented in Appendix A of this guidance manual or use an alternative peer-reviewed method.

The following procedure is recommended for collimated beam testing of a water sample containing challenge microorganisms:

1. Measure the A_{254} of the sample using a spectrophotometer that has a measurement uncertainty of 10 percent of less (see guidance on spectrophotometer measurements in Sections C.2.2 and 5.5.2).

2. Place a known volume from the water sample into a petri dish and add a stir bar. Measure the water depth in the petri dish.

3. Measure the UV intensity delivered by the collimated beam with no sample present using a calibrated radiometer (see Section C.2.2 for guidance on calibrating monitoring equipment).

4. Calculate the required exposure time to deliver the target UV dose using Equation C.2 (described in the next section).

5. Block the light from the collimating tube using a shutter or equivalent.
6. Center the petri dish with the water sample under the collimating tube.
7. Unblock the light from the collimating tube and start the timer.
8. When the target exposure time has elapsed, block the light from the collimating tube.
9. Remove the petri dish and collect the sample for measurement of the challenge microorganism concentration. If the sample is not assayed immediately, store in the dark at 4 °C. Each sample should be plated in triplicate and the average microbial value for the sample calculated from the three plate replicates.
10. Re-measure the UV intensity and calculate the average of this measurement and the measurement taken in Step 3. The value should be within 5 percent of the value measured in Step 3.
11. Using Equation C.1 (described in the next section), calculate the UV dose applied to the sample based on experimental conditions (this should be similar to the target dose).
12. Repeat steps 1 through 11 for each replicate and target UV dose value (see Table C.1). Repeat all steps for each water test condition replicate

C.2.4 UV Dose Calculation

The UV dose delivered to the sample is calculated using:

$$D_{CB} = E_s P_f (1-R) \frac{L}{(d+L)} \frac{\left(1-10^{-A_{254} d}\right)}{A_{254}\, d \ln(10)} t \qquad \text{Equation C.1}$$

where:

D_{CB} = UV dose (mJ/cm^2)
E_s = Average UV intensity (measured before and after irradiating the sample) (mW/cm^2)
P_f = Petri Factor (unitless)
R = Reflectance at the air-water interface at 254 nm (unitless)
L = Distance from lamp centerline to suspension surface (cm)
d = Depth of the suspension (cm)
A_{254} = UV absorbance at 254 nm (unitless)
t = Exposure time (s)

Alternatively, given a target UV dose, the required exposure time may be calculated by re-arranging Equation C.1.

$$t = D \frac{1}{E_s P_f (1-R)} \frac{d+L}{L} \frac{A_{254} d \ln(10)}{\left(1-10^{-A_{254} d}\right)}$$ Equation C.2

The term L/(d + L) accounts for the divergence of the UV light from the collimated beam as it passes through the suspension. The reflectance at the air-water interface (R) can be estimated using Fresnel's Law as 1.000/1.372, or 0.025 (the index of refraction of air divided by the index of refraction for water).

To control for error in the UV dose measurement, the uncertainties of the terms in the UV dose calculation should meet the following criteria:

Depth of suspension (d)	≤ 10%
Average incident irradiance (E_S)	≤ 8%
Petri Factor (P_f)	≤ 5%
L/(d + L)	≤ 1%
Time (t)	≤ 5 %
$(1 - 10^{-ad})/ad$	≤ 5%

The uncertainty in incident irradiance can be determined by the procedure for evaluating uncertainty of radiometer measurements as presented in Section C.2.2. The remaining uncertainties listed above should be estimated by laboratory personnel and documented in the Validation Report (See Section 5.11 for guidance).

C.3 Developing the UV Dose-response Curve

Collimated beam tests produce the following types of experimental data:

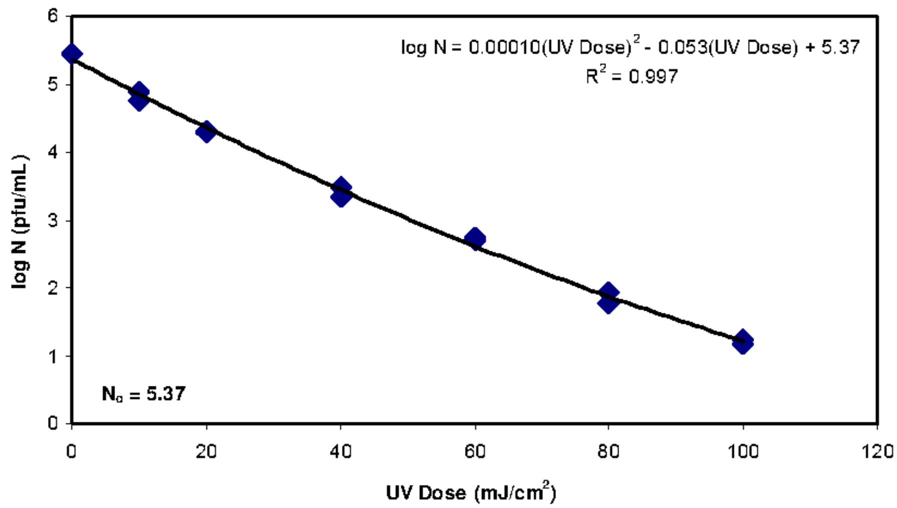
- UV Dose in units of mJ/cm^2,
- Concentration of microorganisms in the petri dish prior to UV exposure (N_o) in units of pfu/mL, and
- Concentration of microorganisms in the petri dish after UV exposure (N) in units of pfu/mL.

One UV dose-response curve should be developed for each UVT condition tested (typically high and low). If full-scale reactor testing spans more than one day, at least one UV dose-response curve should be developed for each day of testing.

EPA recommends using ***regression analysis*** to develop each UV dose-response curve using the following steps:

1. For each test condition and replicate, plot log N vs. UV dose to identify a common N_o as the intercept of the curve at UV dose = 0 (an example is illustrated in Figure C.2).[2]

Figure C.2. Fitting Effluent Concentration vs. UV Dose to Determine a Common Influent Concentration Value



2. Calculate log I for each measured value of N (including zero-dose) and the common N_o identified in Step 1 using the following equation:

$$\log I = \log\left(\frac{N_o}{N}\right) \qquad \text{Equation C.3}$$

where:

N_o = The common N_o identified in Step 1 (pfu/mL)
N = Concentration of challenge microorganisms in the petri dish after exposure to UV light (pfu/mL)

The log inactivation for each replicate should be averaged to produce one value of log I per test condition.

3. Plot UV dose as a function of log I for each test condition.

4. Use regression analysis to derive an equation that best fits the data, forcing the fit through the origin. The equation will have different forms depending on the data. For challenge microorganisms exhibiting first-order kinetics, a linear equation should be used:

[2] If the measured value of N_o is used for this calculation, any experimental or analytical error in the measured value is carried to all the data points, adding an unrelated bias to each measurement. Therefore, using the y-intercept of the curve is recommended.

$$UV\ \ Dose = A \times \log\ \ I \qquad \text{Equation C.4}$$

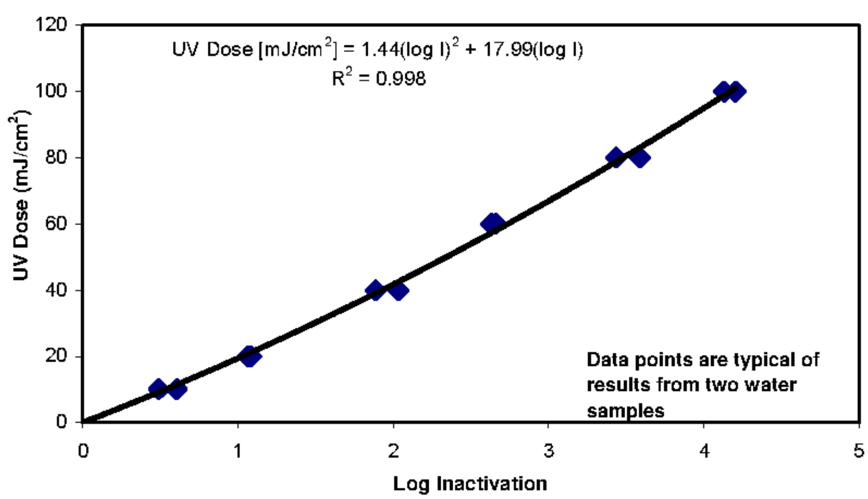
See Figure C.3 for an example of a linear UV dose-response curve.

Figure C.3. Typical *E. coli* UV Dose-response Curve

A quadratic equation can also be used, as illustrated in the example in Figure C.4:

$$UV\ \ Dose = A \times \log\ \ I + B \times \left(\log\ \ I\right)^2 \qquad \text{Equation C.5}$$

Figure C.4. Typical MS2 UV Dose-response Curve



5. Evaluate the equation's goodness-of-fit—the differences between the measured UV dose values and those predicted by the equation should be randomly distributed around zero and not be dependent on UV dose. The goodness of the fit can be examined by standard statistical tests, such as examining the p-statistics for the regression coefficients.

Note that the resulting equation should not be used for extrapolation outside of the measured range of UV dose.

C.4 Collimated Beam Data Uncertainty

As noted in Section C.3, collimated beam data will often be fit to a linear or a polynomial regression. The 95-percent confidence interval (U_{DR}) can be calculated using standard statistical methods, such as those described in Draper and Smith 1998, or can be conservatively estimated using Equation C.6.

$$U_{DR} = t \frac{SD}{UV\ Dose_{CB}} \times 100\% \quad \text{Equation C.6}$$

where:

U_{DR} = Uncertainty of the UV dose-response fit at a 95-percent confidence level

UV $Dose_{CB}$ = UV dose calculated from the UV dose-response curve for the challenge microorganism

SD = Standard deviation of the difference between the calculated UV dose-response and the measured value

t = t-statistic at a 95-percent confidence level for a sample size equal to the number of test condition replicates used to define the dose-response[3]

Number of Data Points Used to Develop the Dose-Response Equation	t	Number of Data Points Used to Develop the Dose-Response Equation	t
10	2.23	17	2.11
11	2.20	18	2.10
12	2.18	19-20	2.09
13	2.16	21	2.08
14	2.14	22-23	2.07
15	2.13	24-26	2.06
16	2.12	27-29	2.05
		≥30	2.04

If UV dose-response curves can be combined (as described in the next Section, C.5), the combined dataset should be used to calculate U_{DR}. If individual dose-response curves cannot be combined, U_{DR} should be calculated separately for each curve.

[3] For example, one test condition evaluated twice (two test condition replicates) with five UV dose points each would have a total of ten points.

EPA recommends that the value of U_{DR} (calculated by Equation C.6) not exceed ***30 percent*** at the UV dose corresponding to 1-log inactivation of the challenge organism (e.g., 18 mJ/cm^2 for MS2). If the 95-percent *confidence interval* is calculated using standard statistical methods, U_{DR} should not exceed ***15 percent*** at the UV dose corresponding to 1-log inactivation of the challenge organism.[4] If there is more than one estimate of U_{DR} (i.e., UV dose-response curves cannot be combined), the maximum U_{DR} should be used to determine if it meets this criterion.

If the U_{DR} value calculated by Equation C.6 is greater than 30 percent (15 percent if the standard statistical method is used), it should be added to the total uncertainty of validation [e.g., $U_{Val} = (U_{IN}^2 + U_{DR}^2)^{1/2}$, see Section 5.9.2].This allows for a validation plan that is sufficiently flexible to continue using the dose-response curve at low values, but will increase the U_{Val} accordingly. Similarly, if UV dose-response curves cannot be combined and one or more of the individual curves exhibits a U_{DR} value greater than 30%, the maximum value should be used in calculating the total uncertainty of validation [$U_{Val} = (U_{IN}^2 + U_{DR}^2)^{1/2}$].

C.5 Combining UV Dose-response Curves

Analysis of regression coefficients indicates whether or not UV dose-response curves developed using different water samples can be combined. In order for the UV dose-response curves to be combined, differences between the regression coefficients should not be statistically significant at a 95-percent confidence level.[5] If differences in the coefficients are statistically significant, the reason for this difference should be documented in the Validation Report. Differences between measured UV dose-response curves for different water samples could indicate one or more of the following:

1. The UV dose-responses of different batches of the challenge microorganism differ. In this case, the UV dose-response curve specific to each cultured batch of the challenge microorganism should be used to assess UV dose delivery for the validation test conditions using that batch.

2. Interferences due to water quality, such as coagulation or inactivation of the challenge microorganism. In this case, mitigate the cause of the interference or account for the interference when assessing UV dose delivery for the validation test conditions.

3. Errors calculating the UV dose delivered by the collimated beam apparatus. Mis-measuring the incident UV intensity or the UV absorbance of the water sample could introduce such errors.

If differences between UV dose-response curves cannot be resolved, a single curve corresponding to one day's worth of full scale reactor testing can be used to calculate RED values for that day (i.e., there will be one UV dose-response curve per day of full-scale reactor validation testing). If two or more UV doe-response curves from the same day of testing cannot be combined, the curve resulting in the most conservative (lowest) UV dose should be used for

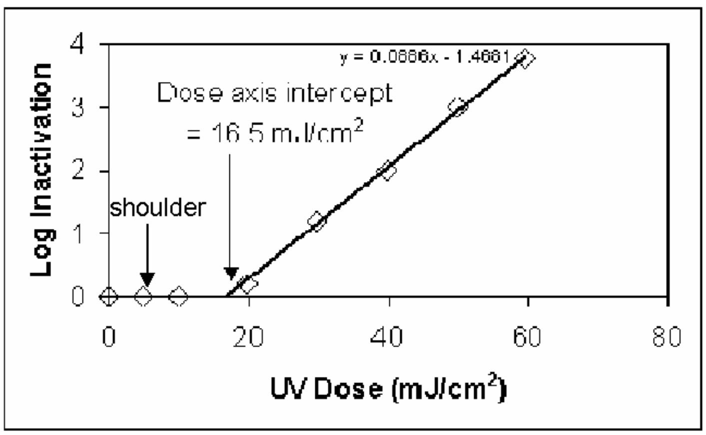
[4] This criterion (15 percent) differs from the criterion of 30 percent applied to Equation C.6 due to simplifications incorporated into Equation C.6.
[5] A good description for performing this test is provided in Draper and Smith, 1998.

calculating RED values. If different curves are used for RED calculations, the UV sensitivity of the challenge microorganism and shape of each UV dose-response curve should be consistent with expected inactivation behavior for that challenge microorganism.

C.6 Using Challenge Microorganisms with Shoulders or Tailing

In the case of a challenge microorganism with a shoulder or tailing in the UV dose-response, the UV sensitivity should be defined as the sensitivity over the region of linear log inactivation that occurs between the shoulder and the onset of tailing. The shoulder of the UV dose-response is defined as the point of intersection of the exponential region with the UV dose axis (see Figure C.5). The UV dose-response of the challenge microorganism should not demonstrate a shoulder at a UV dose beyond 50 percent of the demonstrated (measured) RED range, and should not demonstrate tailing until at least one log inactivation beyond the demonstrated (measured) inactivation range.

Figure C.5. UV Dose-response of *B. subtilis* Spores



(Adapted from Sommer et al. 1998)

Example C.1. The UV dose-response of *B. subtilis* spores has a shoulder at low UV dose values (Figure C.5). Because the measured UV dose-response has a shoulder of 16.5 mJ/cm^2, the *B. subtilis* spores should only be used to demonstrate RED values greater than or equal to 2 × 16.5 mJ/cm^2 = 33 mJ/cm^2.

Appendix D

Background to the UV Reactor Validation Protocol

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This appendix provides background material for the validation protocol given in Chapter 5. The background material is organized into the following six sections.

- **UV dose delivery by UV reactors.** Section D.1 describes why a correction factor (termed the "RED bias") should be applied in the Validation Factor calculation to account for systematic errors that arise if the challenge microorganism is more resistant to UV light than the target pathogen.
- **UV dose monitoring.** Section D.2 provides background information on the impact of UV sensor placement on UV dose monitoring (whether it is at, closer to, or farther from the lamp than the ideal position). It provides a rationale for defining test conditions to validate UV reactors using a given UV dose-monitoring approach and explains why sensor position is important.
- **UV sensors.** Section D.3 provides the basis for the UV sensor calibration criterion recommended in Chapter 5. It describes the properties of UV sensors, how those properties impact the sensor's measurement uncertainty, and how that measurement uncertainty can be determined.
- **Polychromatic considerations.** Section D.4 describes systematic errors that can occur with the validation of UV reactors that use medium-pressure (MP) UV lamps (1) equipped with non-germicidal UV sensors and/or (2) validated with a challenge microorganism that has a UV action spectrum significantly different from that of the target pathogen. This section provides a rationale for assessing those errors.
- **Uncertainty of validation.** Section D.5 provides a rationale for defining a validation factor that accounts for the random uncertainty associated with UV reactor validation and monitoring.
- **CFD modeling.** Section D.6 provides guidance on using Computational Fluid Dynamics (CFD) to model UV dose delivery.

D.1 UV Dose Delivery by UV Reactors

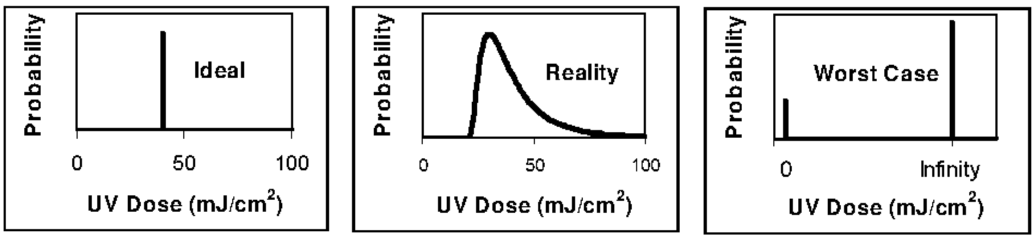
UV dose delivery by UV reactors to be used at water treatment plants (WTPs) is currently measured using biodosimetry (Qualls and Johnson 1983). With biodosimetry, inactivation of a challenge microorganism passed through the UV reactor is measured and related to a single dose value based on the known UV dose-response of that microorganism. This dose is termed the "reduction equivalent dose," or RED.

D.1.1 Using RED to Demonstrate Target Pathogen Inactivation

If the UV dose-response of the challenge microorganism does not match the target pathogen's, and the UV dose distribution of the UV reactor is not known, biodosimetry can only be used to estimate the target pathogen inactivation within a range bounded by the inactivation expected assuming "ideal" and "worst-case" hydraulics. Figure D.1 provides a comparison of the

UV dose distributions of reactors with ideal and worst-case hydraulics to a UV dose distribution that might be seen with a real reactor.

Figure D.1. UV Dose Distributions of Ideal, Realistic, and Worst-case UV Reactors



D.1.1.1 Ideal Reactor Hydraulics

A UV reactor with ideal hydraulics delivers the same UV dose to all the microorganisms passing through the reactor. Its UV dose distribution is represented by a single value. Examples of a UV reactor with ideal hydraulics include the stirred suspension irradiated during the measurement of UV dose-response with a collimated beam device and an ideal plug-flow reactor. In both cases, the delivered dose is the product of the average UV intensity within the reactor and the residence time. Accordingly, with an ideal reactor, the RED measured with a challenge microorganism is a measure of the RED delivered to all microorganisms that pass through the reactor because all the microorganisms receive the same dose.

D.1.1.2 Worst-case Hydraulics

For a reactor with worst-case hydraulics and a measurable RED, an infinite UV dose is delivered to one fraction of the flow rate, and zero UV dose is delivered to the other fraction (i.e., one of two UV dose values is delivered to each respective microorganism). The net inactivation achieved is constant, equal to the fraction receiving the infinite UV dose, and hence independent of the microorganism's inactivation kinetics. With a worst-case UV reactor, the measured inactivation is that which would occur with any microorganism regardless of its UV sensitivity.

D.1.1.3 Real-world Hydraulics

Using the above definitions of an ideal and a worst-case UV reactor, the log inactivation of a pathogen estimated from biodosimetry results will have a value between $\log(N_{o,c}/N_c)$ and $[RED/D_p]$,[1] that is, a "real" UV reactor will have a UV dose distribution that falls somewhere between ideal and worst-case (Wright and Lawryshyn 2000).

[1] $N_{o,c}$ is the influent challenge organism (c) concentration and N_c is the effluent challenge microorganism concentration. D_p is the UV sensitivity of the pathogen (p) in units of mJ/cm^2 per log inactivation.

If the inactivation of the pathogen must be known with absolute confidence, the lower bound of that range should be used (assume worst-case hydraulics). When the challenge microorganism is more resistant to UV light than the target pathogen, the lower bound is the log inactivation of that challenge organism, log [$N_{o,c}/N_c$]. In other words, if a UV reactor is validated with a challenge microorganism that is less sensitive to UV light than the target microorganism, one cannot know with certainty that the reactor achieved more than the log inactivation demonstrated during validation. For example, if 2-log MS2 inactivation is measured, one can conclude only that the water system attained ≥ 2-log inactivation for any organism less resistant to UV light.

If the challenge microorganism is less resistant to UV light than the target pathogen, the lower bound is the RED measured with the *challenge* organism divided by the sensitivity of the *target* pathogen, [RED/D_p]. For example, if one measures a φx-174 RED of 12 mJ/cm^2, corresponding to 4-log inactivation, one cannot assume that the reactor achieved 4.0-log inactivation of *Cryptosporidium*; one can assume only that the water system attained [12 mJ/cm^2] / [4.0 mJ/cm^2 per log I] = 3.0-log inactivation.

But both of these assumptions are extreme. For this reason, the "RED Bias" correction factor used in the VF is based on the UV dose distribution of a defined "real-world worst-case" UV reactor. The RED delivered to a pathogen by a given UV reactor can be estimated from the measured RED of the challenge microorganism using Equation D.1:

$$RED_p = RED_c \times \frac{RED_{p,wc}}{RED_{c,wc}} = \frac{RED_c}{B_{RED}} \qquad \text{Equation D.1}$$

where:

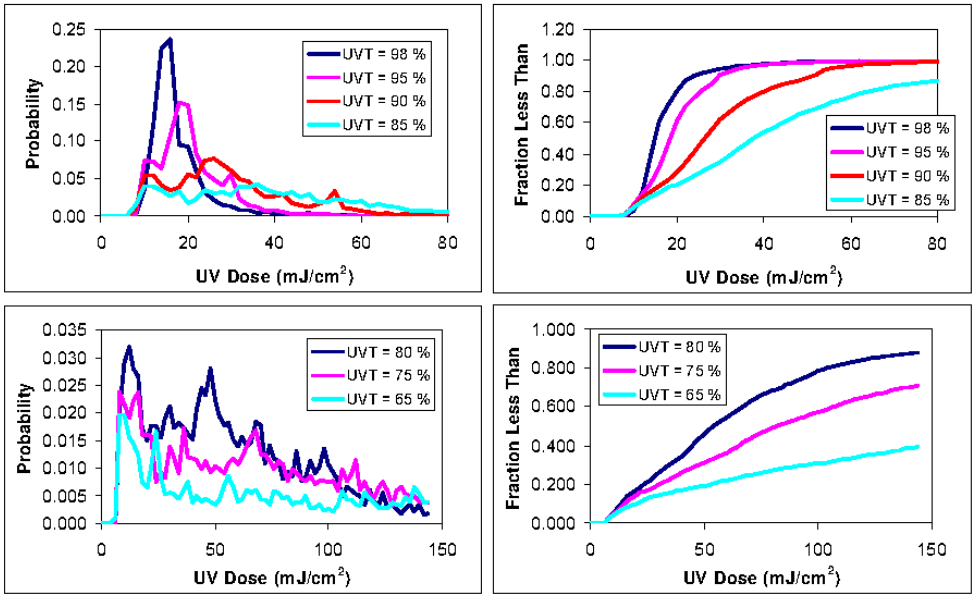
RED_p	=	Pathogen RED estimated for the UV reactor of interest (mJ/cm^2)
RED_c	=	Challenge microorganism RED measured during biodosimetry (mJ/cm^2)
$RED_{p,\,wc}$	=	Pathogen RED estimated from Figure D.2, the "worst-case" UV reactor (mJ/cm^2)
$RED_{c,\,wc}$	=	Challenge microorganism RED estimated from Figure D.2, the "worst-case" UV reactor (mJ/cm^2)
B_{RED}	=	RED Bias, the ratio of the RED of the pathogen to the RED of the challenge microorganism for a given set of operating conditions

The development of this factor (RED Bias, or B_{RED}) is discussed below.

Defining a Realistic Conservative UV Dose Distribution

Because UV manufacturers strive to optimize the hydraulic design of their UV reactors, using the worst-case UV dose distribution represented in Figure D.1 to define the lower bound of pathogen inactivation is overly conservative. An alternative approach is to use the UV dose distribution of a commercial UV reactor that is representative of plausibly poor UV reactor hydraulics.

Figure D.2. The UV Dose Distributions Used to Determine RED Bias Values Tabulated in Appendix G



UV dose modeling based on CFD was used to predict dose distributions for commercial low-pressure high-output (LPHO) and medium-pressure (MP) UV reactors. Details on the approach are provided in Wright and Reddy (2003) and Dzurny et al. (2003). CFD was used to predict the trajectories of approximately 3,000 microbes through the UV reactors. UV intensity fields within the reactor were modeled using the methods described by Bolton (2000). The UV dose delivered to each microbe was predicted by integrating the total UV dose delivered over its trajectory through the reactor. The REDs delivered to the target pathogens were calculated assuming first-order kinetics with a UV sensitivity defined as the required dose in Table 1.4 divided by the associated log inactivation credit. The dose distributions were scaled to give pathogen REDs equal to the required dose for a given level of log inactivation credit plus an uncertainty factor of 25 percent (i.e., for 3-log *Cryptosporidium* inactivation credit, dose distribution was scaled to give a *Cryptosporidium* RED = 12+ [0.25 × 12] = 15 mJ/cm^2). This approach assumes that the UV reactor uses dose pacing[2] to deliver the required RED without overdosing. REDs were estimated for test microbes of various UV sensitivities assuming first-order kinetics. The RED bias was calculated as the ratio of the test microbe RED to the pathogen RED ($B_{RED} = RED_{test\ microbe}/RED_{pathogen}$).

The commercial reactor that resulted in the most conservative RED bias values was used to develop the RED Bias values in Appendix G. Figure D.2 shows the scaled UV dose

[2] The UV reactor maintains the delivered dose at or near the target value by adjusting the lamp power or turning "on" or "off" banks of UV lamps or whole UV reactors to respond to changes in UV absorbance, lamp intensity, and/or flow rate.

distributions used to estimate the RED bias for 3-log inactivation credit with *Cryptosporidium*. Figure D.3 shows predictions of RED and log inactivation for those dose distributions as a function of the test microbe's UV sensitivity. Figure D.4 shows the RED bias for 3-log *Cryptosporidium* credit as a function of the test microbe's UV sensitivity obtained using the data in Figure D.2.

Figure D.3. RED as a Function of Microorganism UV Sensitivity for the UV Reactor Represented in Figure D.2

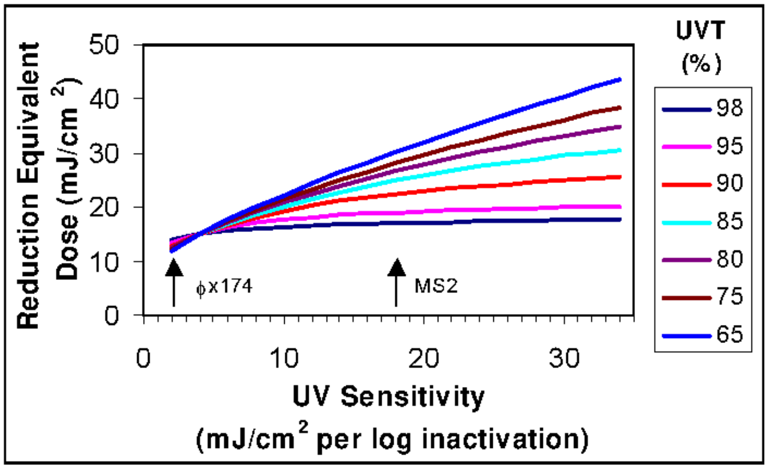
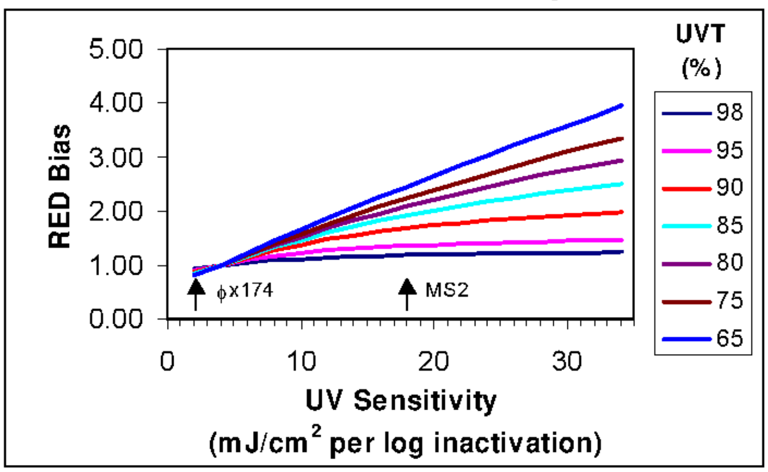


Figure D.4. RED Bias for 3-log *Cryptosporidium* Credit as a Function of Test Microbe UV Sensitivity



Example D.1. A UV reactor is challenged using MS2 with a UV sensitivity of 18 mJ/cm^2 per log inactivation. The UVT of the water is 85 percent. Two-log inactivation is measured, corresponding to an MS2 RED of 2-log × 18 mJ/cm^2-log I = 36 mJ/cm^2. These results are used to estimate the log inactivation of two pathogens, one with a UV sensitivity of 10 mJ/cm^2 per log inactivation and the other with a UV sensitivity of 25 mJ/cm^2 per log inactivation.

In Figure D.3, the RED delivered to the microorganisms with a UV sensitivity of 10, 18, and 25 mJ/cm^2 per log inactivation would be 20, 25, and 28 mJ/cm^2, respectively. The RED Bias values for MS2 relative to the first pathogen is 25/20 = 1.25 while the RED Bias for MS2 relative to the second pathogen is 25/28 = 0.89. Assuming the reactor has a UV dose distribution that is better than the dose distribution used to develop Figure D.2, the RED of the first pathogen has a value between 36 and 36/1.25 = 29 mJ/cm^2 and the RED of the second pathogen has a value between 36 and 36/0.89 = 40 mJ/cm^2.

D.2 The Impact of UV Sensor Positioning on UV Dose Monitoring

This guidance manual focuses on two commonly used UV dose-monitoring strategies, the UV Intensity Setpoint Approach and the Calculated Dose Approach, which are summarized below. Sections D.2.1 and D.2.2 discuss the impact of UV sensor positioning for the UV Intensity Setpoint Approach and Calculated Dose Approach, respectively.

1. **UV Intensity Setpoint Approach.** UV dose delivery is indicated by the measured flow rate and UV intensity. Minimum UV dose delivery is verified when the measured UV intensity is above an alarm (minimum) setpoint value defined as a function of the flow rate through the reactor. In a variation of this method, the minimum UV dose can be verified when the measured relative UV intensity (calculated as a function of UVT) is above an alarm (minimum) setpoint value defined as a function of the flow rate through the reactor.

2. **Calculate Dose Approach.** Minimum UV dose delivery is verified when the calculated UV dose (using an equation dependent on flow rate, relative UV intensity, UVT, and sometimes other parameters such as lamp status) is above an alarm (minimum) setpoint value.

D.2.1 UV Intensity Setpoint Approach

With the UV Intensity Setpoint Approach, dose monitoring is impacted by UV sensor positioning (Wright et al. 2002). To illustrate this impact, Figure D.5 presents the relationship between UV dose and measured UV intensity for a simple annular reactor containing a single low-pressure (LP) lamp. UV intensity was calculated using a radial UV intensity model and UV dose was calculated assuming ideal hydraulics (Haas and Sakellaropoulos 1979). UV intensity and dose were calculated for a fixed flow rate of 140 gpm. Simulated UVT values ranged from 70 to 98 percent, and simulated relative lamp outputs (characterized by relative sensor values) ranged from 20 to 100 percent. In each figure, the data are presented as plots of UV dose as a function of the UV sensor reading for a range of UVT values. Each point at a given UVT represents, in order of increasing UV dose, operation at 20, 40, 60, 80, and 100 percent relative lamp power. The differences between these figures are due to differences in sensor-to-lamp distance (i.e., UV sensor placement).

1. The UV Sensor Is Located at the "Ideal Position"

Figure D.5a presents the relationship between delivered UV dose and sensor reading obtained when the UV sensor is located at the sensor-to-lamp distance where the relationships between UV dose and measured UV intensity at different UVTs overlap. Because these relationships overlap, **a given UV intensity can be related to a specific level of dose delivery**.

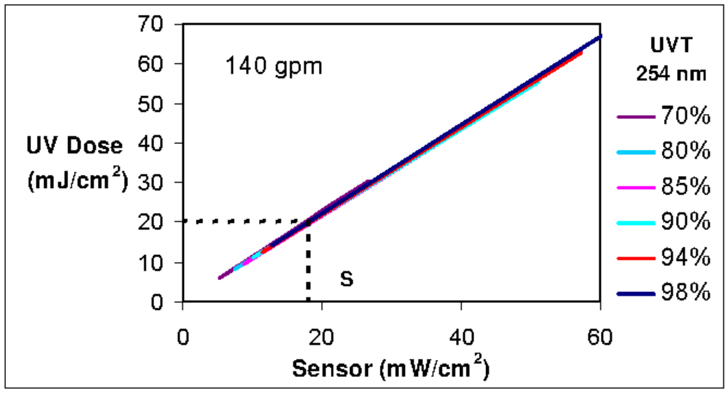
Example D.2. The UV reactor characterized in Figure D.5a is used in a disinfection application where the target dose is 20 mJ/cm^2. A UV sensor value *S* of 18 mW/cm^2 is used as an alarm setpoint to indicate the UV reactor delivers a dose of 20 mJ/cm^2 across the entire operating range—the ideal placement of the sensor ensures that an alarm setpoint value of 18 mW/cm^2 will indicate a dose of 20 mJ/cm^2.

2. The UV Sensor Is Located Closer to the Lamp Than the "Ideal Position"

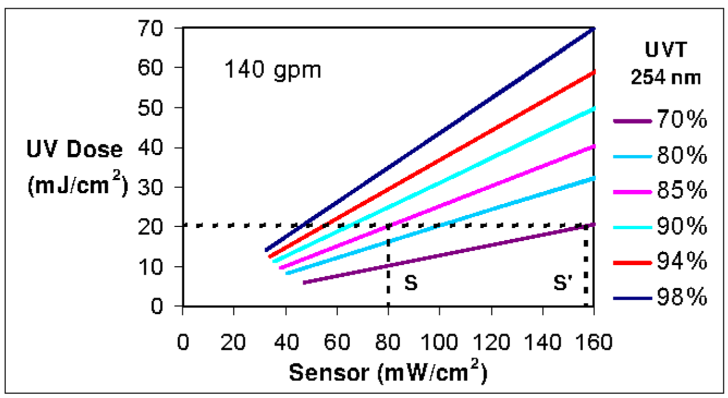
Figure D.5b presents the relationship between delivered UV dose and sensor reading when the UV sensor is placed closer to the lamp than the ideal position (i.e., a smaller sensor-to-lamp distance than in Figure D.5a). Because the sensor views the lamp through a relatively thin water layer, its response to changing UVT is small compared to that in Figure D.5a. Accordingly, the relationship between dose delivery and measured UV intensity cannot be described by a single relationship for all values of UVT. Unlike the situation depicted in Figure D.5a, the delivered dose will decrease at lower UVTs for a given UV sensor reading. Accordingly, the **measured UV intensity should only be used to indicate dose delivery at the lower end of that range, which occurs under conditions of maximum lamp power and reduced UVT**.

Example D.3 The UV reactor characterized in Figure D.5.b is used in an application where the target dose is 20 mJ/cm^2. The UV manufacturer states that a UV sensor value *S* of 80 mW/cm^2 will indicate a dose of 20 mJ/cm^2 under design conditions of 85% UVT and 60% relative lamp output. However, as shown in Figure D.5.b, a UV intensity of 80 mW/cm^2 corresponds to a dose ranging from 10 mJ/cm^2 (for 70% UVT) to 37 mJ/cm^2 (for 98% UVT). For a UV intensity alarm setpoint to ensure a delivered dose of 20 mJ/cm^2 under *all* possible conditions of water UVT and lamp output, a sensor setpoint value *S'* of 157 mW/cm^2 would need to be used.

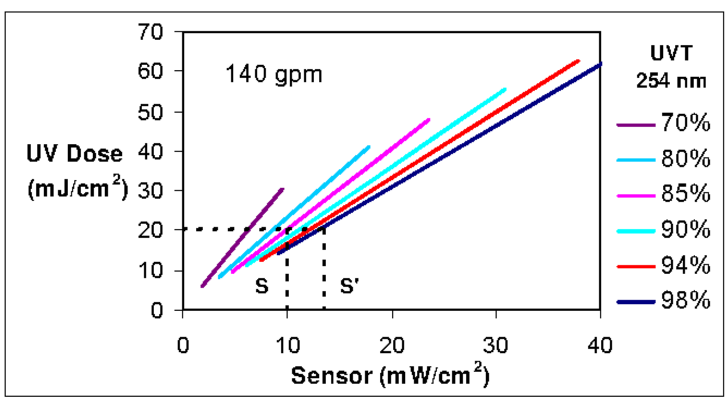
Figure D.5. Relationship between UV Dose and Intensity for a UV Sensor Located (a) at the "Ideal Position," (b) Close to the Lamp, and (c) Far from the Lamp



(a)



(b)



(c)

3. The UV Sensor Is Located Farther from the Lamp Than the "Ideal Position"

Figure D.5c presents the relationship between delivered UV dose and sensor reading when the UV sensor is located farther from the lamp than the ideal position (i.e., a greater sensor-to-lamp distance than in Figure D.5a). Because the sensor views the lamp through a relatively thick water layer, its response to changing water transmittance is greater at this position than at either the ideal or closer-than-ideal positions. Again, the relationship between UV dose delivery and measured UV intensity cannot be described by a single relationship for different values of UVT. However, unlike Figure D.5b, the UV dose delivered at a given measured UV intensity increases as UVT decreases. Thus, **the measured UV intensity should only be used to indicate UV dose delivery at the lower end of that range, which occurs under conditions of reduced lamp power and maximum UVT** (the opposite of what is observed with the closer-than-ideal UV sensor position).

Example D.4. The UV reactor characterized in Figure D.5c is used in an application where the target dose is 20 mJ/cm^2. A UV intensity alarm setpoint value *S* of 10 mW/cm^2 is proposed based on the UV intensity measured under design conditions of 85 percent UVT and 60 percent relative lamp output. However, a sensor value of 10 mW/cm^2 indicates a UV dose ranging from 15 to 32 mJ/cm^2. To ensure a delivered dose of 20 mJ/cm^2 under *all* possible conditions of water UVT and lamp output, a setpoint value *S'* of 14 mW/cm^2 would need to be used.

The manufacturer of the UV reactor selects the location of the UV sensor within a UV reactor. If the UV reactor uses the UV Intensity Setpoint Approach for UV dose monitoring, it is to the manufacturer's advantage to optimize the UV sensor's location to obtain overlapping relationships between UV dose delivery and measured UV intensity for different UVT values, similar to the example given in Figure D.5a.

If the UV manufacturer does not optimize the UV sensor's location, a given UV intensity will correspond to a range of UV dose values as opposed to a single value. While this does not prevent the UV reactor from using the UV Intensity Setpoint Approach, the monitoring approach will be significantly less efficient than with an ideally located UV sensor because the UV reactor will be overdosing at many UVT-lamp power combinations that give rise to operation at the setpoint. When this occurs, the manufacturer may opt to supplement measurements of UV intensity with measurements of UVT to enable more efficient UV dose monitoring (this is sometimes referred to in the literature as the "UV Intensity-UVT Setpoint Approach"). The UV reactor is verified to be delivering the required UV dose when both the measured UV intensity and UVT are above the minimum validated setpoint values ($S/S_{o,\ UVT\ setpoint}$, and $UVT_{setpoint}$), both defined for a specified range of flow rates. With this approach, there are no requirements for UV sensor positioning.

D.2.2 Calculated Dose Approach

Measurements of flow rate, UV intensity, and UVT can be incorporated into theoretical, empirical, or semi-empirical calculations of UV dose delivery. For example, the relationships represented in Figure D.5a – c could be defined experimentally and used in an empirical manner to calculate UV dose (e.g., Equation 5.8). Relationships could also be defined using advanced numerical modeling approaches to relate measured intensity to UV dose delivery as a function of flow rate and UVT.

In theory, the UV dose calculation does not necessitate that the UV sensor be placed at any one location within the reactor. However, if the UV sensor were placed at the ideal position (a location that gives UV dose delivery proportional to the UV sensor reading), the UV dose calculation would not require UVT as an input parameter.

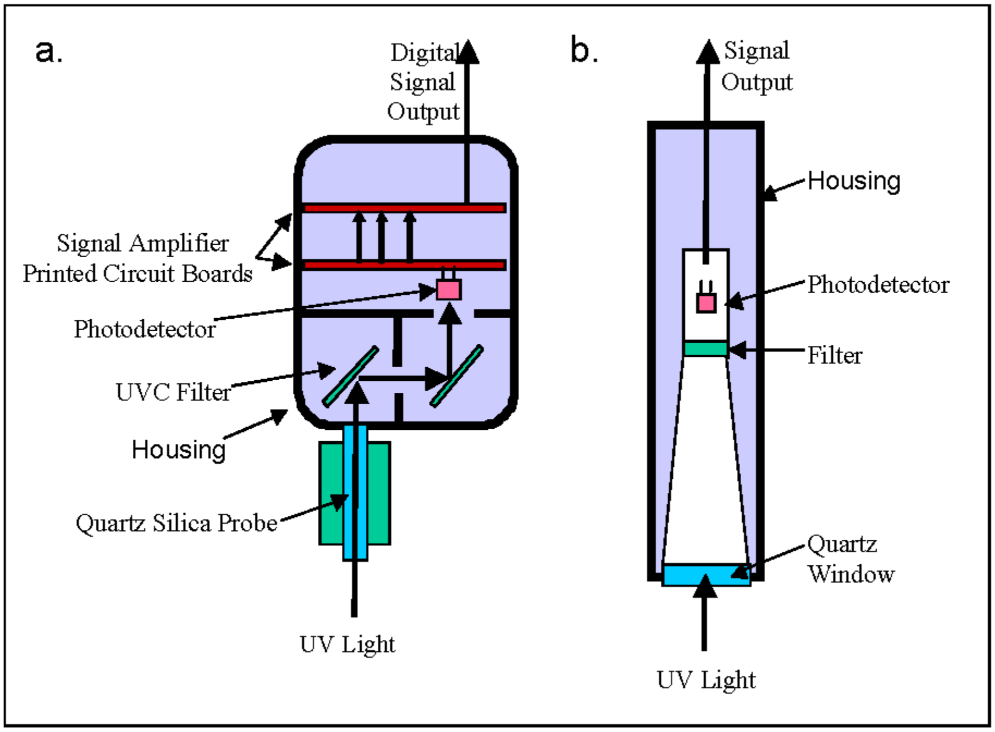
D.3 UV Sensors

UV sensors are photosensitive detectors that are used to indicate UV dose delivery by providing information related to UV intensity at different points in the UV reactor. Reference UV sensors are used to check that the measurements made by the on-line, or "duty" sensors are valid.

UV sensors include the following components, arranged as shown in Figure D.6:

- **Monitoring windows** and **light pipes** deliver light to the photodetector. Monitoring windows are typically quartz discs and light pipes are cylindrical probes made of quartz (quartz silica probe).
- **Diffusers** and **apertures** reduce the UV light incident on the photodetector to slow UV sensor degradation. Diffusers also modify the UV sensor's angular response.
- **Diffusers** and **apertures** reduce the UV light incident on the photodetector to slow UV sensor degradation. Diffusers also modify the UV sensor's angular response.
- **Filters** limit the light delivered to the photodiode, typically restricting it to germicidal UV wavelengths (~200 – 300 nm).
- **Photodetectors** are solid-state devices that produce a current proportional to the irradiance on the detector's active surface. The responsiveness of a typical photodetector to UV light is on the order of 0.1 – 0.4 mA/mW.
- **Amplifiers** convert the output of the photodetector from a low-level current to a standardized output proportional to the incident UV intensity.
- The **housing** of the UV sensor protects the components from the external environment. The housing should be electrically grounded to shield the photodetector and amplifier, thereby reducing electrical noise and bias.

Figure D.6. Interior UV Sensor Schematics[3]



D.3.1 UV Sensor Properties

The UV sensor should detect germicidal UV radiation and produce a standardized output signal proportional to the incident UV irradiance (e.g., 4 – 20 mA). A UV sensor may or may not measure the UV light through a monitoring window that is separate from the sensor body. Monitoring windows should have a high UVT over the sensor's spectral response range.

UV sensor properties that impact the measurement of UV intensity and dose delivery monitoring include angular response, acceptance angle, spectral response, working range, detection limit and resolution, linearity, temperature response, long term drift, calibration factor, and measurement uncertainty. An ideal UV sensor would have the following properties:

- A linear response to incident UV light, independent of water temperature and stable over time.
- A fixed angular response and a wavelength response that mimics the germicidal response of the target microorganism(s).

[3] Figure courtesy of (a) Aquionics and (b) WEDECO UV Technologies; UVC light is 200 – 280 nm (the germicidal range).

- Has zero measurement noise and bias.
- Responds only to germicidal UV light.
- Has zero measurement uncertainty.

The properties of an ideal UV sensor are presented here to illustrate the benchmark UV sensor manufacturers strive to approximate as closely as possible, that is, zero measurement error.

Angular response is a plot of the UV sensor measurement as a function of the incident angle of light on the sensor's window. Angular response is affected by the UV sensor's aperture size, the size of the photodetector's active surface, the distance between the aperture and the active surface, and the impact of any diffusers and reflecting surfaces within the sensor. An ideal UV sensor has a "cosine response" (Equation D.2), which results in an accurate measure of the light incident on the surface of the photodetector. In practice, UV sensors deviate from the cosine response; some potential responses are shown in Figure D.7.

$$S_m = S_i \cos\theta \quad \text{Equation D.2}$$

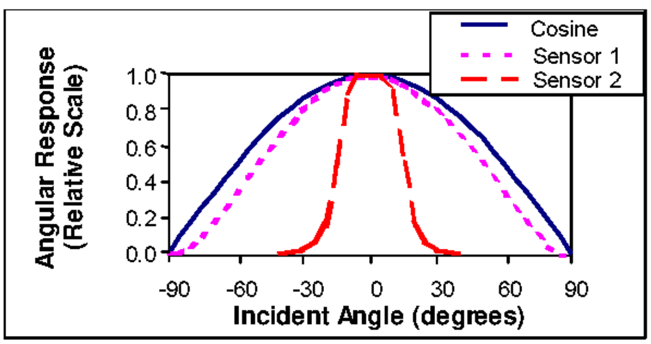
where:

S_m = Intensity measured by the UV sensor's photodetector [watt per centimeter squared (W/cm^2)]

S_i = Intensity incident on the UV sensor's photodetector's surface (W/cm^2)

θ = Incident angle at the UV sensor's photodetector surface (°)

Figure D.7. Angular Response of Two UV Sensors Relative to the Ideal Cosine Response



The opening or **acceptance angle** of the UV sensor is the angle over which the sensor detects UV light. The opening angle is typically measured by either the threshold detection of UV light or detection at some percentage of the maximum value (e.g., 50 percent). The acceptance angle is a characteristic of the sensor but does not affect its performance.

The **spectral response** is a measure of the output of the UV sensor as a function of wavelength. It depends on the response of the photodetector and filters and the UV transmittance of the monitoring windows, light pipes, and filters.

The **working range** of the UV sensor is the intensity range that the sensor is able to measure. The low end of the working range is defined by the detection limit of the measurement. The high end of the working range is limited by the saturation of the photodetector and the amplifier. Saturation is the point at which the UV sensor can no longer respond to an increase in intensity.

The **detection limit** of the UV sensor is the lowest UV intensity that can be detected and quantified at a known confidence level. The detection limit is calculated based on repeated measurements of low intensity UV light, usually at a specific percentage confidence interval.

The **measurement resolution** is the smallest difference in UV intensity that can be differentiated at a given confidence level. The detection limit and the resolution depend on the measurement noise and on any digitalization of the analog output from the UV sensor by the system's electronics. Measurement bias and noise of a photodetector are increased by electromagnetic fields within the UV reactor if the sensor is not properly shielded and grounded.

An ideal UV sensor (a sensor with an ideal cosine response) responds proportionally to the intensity incident on the sensor (Figure D.7). The **linearity** of the UV sensor is a measure of the adherence of the sensor response to that proportional relationship. It is reported as the ratio of the measured response to the known incident intensity, usually at a specific confidence level. Linearity is affected by bias and saturation.

D.3.1.1 Calibration and Quantification of UV Sensor Properties

UV sensors used to monitor monochromatic lamps are often calibrated using the substitution method of Larason et al. (1998). With this approach, the intensity of a collimated beam of UV light at 254 nm is measured using the UV sensor; the measured value is then compared to that made using a standard measurement, such as a NIST[4]-traceable UV sensor or chemical actinometer. The ratio of the standard measurement to the UV sensor output is the calibration factor. With UV sensors designed to measure the output of MP lamps, the sensor can be calibrated at 254 nm, calibrated as a function of wavelength, or calibrated using polychromatic light from an MP lamp with a known spectral output.

UV sensor **linearity** is determined by comparing the sensor output as a function of incident irradiance to standard measurements of that irradiance. UV sensor **temperature response** is determined by measuring the dependence of sensor output on the sensor's operating temperature with the sensor measuring a constant irradiance. The **angular response** of a UV sensor is determined by measuring the dependence of the UV sensor reading on the incident angle of a beam of fixed-intensity, collimated UV light.

[4] National Institute of Science and Technology, Boulder, Colorado.

The **spectral response** of a UV sensor is determined by measuring the dependence of the sensor output on the wavelength of monochromatic light of known irradiance incident on the sensor. Spectral response is typically presented as a plot of the ratio of sensor output to incident irradiance as a function of the wavelength of light.

The **measurement accuracy** of UV sensors changes over time due to mechanical wear and environmental exposure. Temperature cycling, exposure to UV light, mechanical vibration, and other factors will impact the linear, spectral, angular, and temperature response of a sensor. Long-term sensor stability is best determined using field data, but may be estimated using accelerated life-cycle testing.

D.3.1.2 Recommendations for Calibration and Quantification of UV Sensor Properties

UV sensors provided by the manufacturer should be individually calibrated. The manufacturer should determine linearity and temperature-response over the expected operation range of lamp intensity and water temperature expected during operation at WTPs. Because it may be affected by infrared transmission of glass filters and fluorescence of diffusers that are part of the UV sensor (Larason and Cromer 2001), the sensor spectral response should be evaluated from 200 to 1,000 nm. The sensor response should be "germicidal" (see Section 5.4.8 for the definition of a "germicidal" UV sensor response).

UV sensor manufacturers should conduct regular testing on their UV sensors to develop a database on the effect of long-term use on sensor properties. While some UV sensor properties may be measured with each sensor (e.g., calibration), other properties, such as long-term stability and angular and spectral response, can practically be measured only on a representative sample from a lot. The UV sensor manufacturer should have available for inspection the following information:

- A description of the measured UV sensor properties.
- A description of the system used to measure each property.
- A description of the measurement standards used.
- The documented uncertainty associated with each measurement.
- A description of the QA/QC procedures used to ensure that the measurements were traceable to a standard.
- Data that demonstrates that the properties of the manufactured UV sensors are within specifications over time.

D.3.2 UV Sensor Measurement Uncertainty

UV sensor measurement uncertainty quantifies how the UV intensity value measured with a duty UV sensor (mounted on the UV reactor) compares to the true value. For the purposes of this manual, UV sensor uncertainty should be determined by summing the uncertainties that arise from calibration, linearity, angular and spectral response, temperature response, and long-term stability (see Table D.1 for an example of this calculation):

- Uncertainty in the UV sensor calibration arises from the uncertainties associated with the standards and instrumentation used to calibrate the sensor (e.g., voltmeters and amplifiers).

- Uncertainty in the UV sensor's linearity and temperature response arises because sensor calibration factors, determined at one temperature and UV irradiance, are used over a range of temperatures and irradiances during operations at a WTP.

- Uncertainty in angular response arises because UV sensors are used in UV reactors to measure UV light impacting from different directions but are calibrated with collimated light (i.e., light is incident to the surface from only one angle).

- Variability in spectral and angular response from UV sensor-to-UV sensor results in an additional measurement uncertainty not accounted for in calibration. The impact of spectral and angular response variability on UV sensor measurement uncertainty can be determined either by calculation or by measurement.

  In the calculation approach, UV sensor spectral and angular response, measured on a representative sample from a lot, is used as an input to a numerical model that predicts sensor readings in a reactor. The variability in the readings predicted by the model is used to define an uncertainty term that is included in the calculation of the total sensor uncertainty. In the measurement approach, the variability in measurements made by a representative number of UV sensors mounted on the reactor is used to define the uncertainty.

- Uncertainty in spectral response arises in MP systems because sensors, calibrated at a fixed wavelength, are used in UV reactors equipped with polychromatic lamps.

- Additional uncertainty arises from long-term UV sensor drift.

The information described above should be provided by the manufacturer for each duty sensor as part of the UV reactor documentation. The purpose of this information is to indicate the ability of the manufacturer to quantify the uncertainty for important sensor properties and to demonstrate whether the sensor can meet sensor specifications prepared by the system purchaser. This information should *not* be used to verify sensor performance during validation testing or operations. Instead, sensor uncertainty should be field-verified by comparing duty sensor measurements to calibrated reference sensors, as described in Sections 5.5.4 and 6.4.1.1.

Table D.1. Example of a UV Sensor Uncertainty Calculation Datasheet

Property	Uncertainty (%)
Spectral response	4
Angular response	3
Linearity	3
Calibration	5
Temperature response	3
Long term drift	12
Total Uncertainty[1]	**15**

[1] Total uncertainty is calculated as: $(1^2+3^2+3^2+5^2+3^2+10^2)^{1/2} - 15\%$.

Example D.7. A UV sensor manufacturer calibrates each UV sensor at 20°C with an uncertainty of ±1 percent. Linearity, temperature response, angular response, and spectral response are evaluated on every tenth sensor manufactured. Linearity ranges from 1 – 5 percent over the measurement range of the sensor. Temperature response ranges from 0.1 – 0.2 percent per °C—an uncertainty of 5 percent over the temperature range 0 – 40 °C. Models predict that the variability in angular and spectral response from sensor-to-sensor will cause uncertainties of 8 percent and 3 percent, respectively. A laboratory evaluation of UV sensors returned from the field indicates that the long-term drift over a one-year period is 11 percent. The measurement uncertainty of the UV sensors is calculated as the square root of the sum of the squares of the individual percent uncertainties:

$$\textbf{Measurement uncertainty} = \sqrt{1^2 + 5^2 + 5^2 + 8^2 + 3^2 + 11^2} = 16\%$$

D.3.3 Number of UV Sensors

Lamp-to-lamp variability in UV output impacts both UV dose delivery and monitoring (Wright et al. 2004). If a lamp has a lower output than the other lamps in a UV reactor, it will deliver lower UV doses to microorganisms passing in its vicinity, thereby shifting the UV dose distribution to lower values and reducing the net performance (UV dose delivery) of the reactor. The shift in the UV dose distribution will be more pronounced in a reactor with fewer lamps.

If the number of UV sensors is less than the number of lamps and the sensors do not monitor the lamps with the lowest output, the monitoring system will overestimate UV dose delivery. Sections 6.3.2.2 and 5.4.7 provide guidance on dealing with this issue in operations and validation, respectively.

D.4 Polychromatic Light Considerations

LP and LPHO lamps are monochromatic, with UV output at a single wavelength, 254 nm. MP lamps are polychromatic, with UV output at multiple wavelengths. UV dose delivery and monitoring in MP reactors involves UV light from 200 to 320 nm. The output from the UV sensor is an integrated response to UV light over wavelengths spanning the sensor's spectral response. If the spectral properties of the UV reactor that influence UV dose delivery and monitoring during operation at a WTP are the same as during validation, then the characterized UV dose delivery will occur at the WTP. However, if the spectral properties are significantly different, UV dose delivery at the WTP can differ substantially from UV dose delivery measured during validation for the same measured operating values. The following spectral properties may differ:

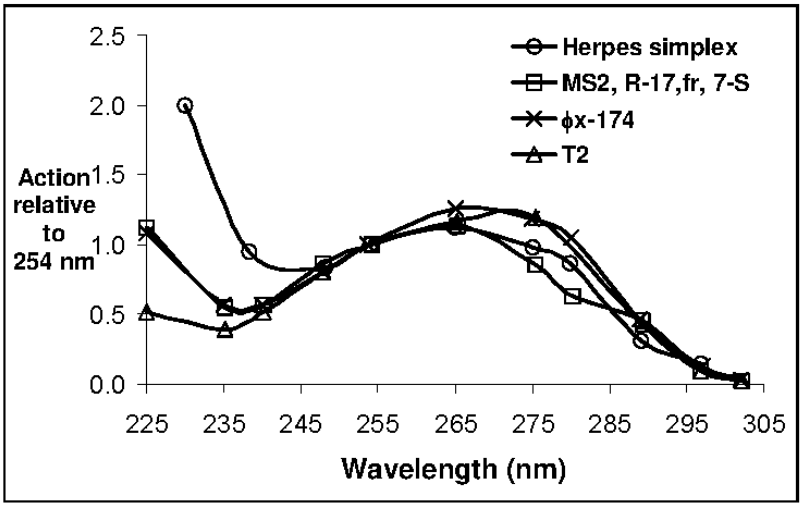
- Action spectra of the challenge microorganism and of the target pathogen.
- Spectral UV absorbance of the water used during validation and at the WTP.
- UV output of the lamps during validation and at the WTP (see 5.4.6 for details).
- UVT of the lamp sleeves during validation and at the WTP (see 5.4.6 for details).

Section D.4.1 describes approaches for assessing the impact of differences in microbial action spectrum properties. Section D.4.2 describes an approach for developing a correction factor for polychromatic bias for MP reactors when the challenge microorganism is something other than MS2 or *Bacillus subtilis*. Derivation of the polychromatic bias factor for MP UV reactors with non-germicidal sensors is presented in Section D.4.3.

D.4.1 Impact of Microorganism UV Action Spectra Differences

The dependence of microorganism inactivation kinetics on wavelength can be described using an action spectrum – the UV inactivation sensitivity of a microorganism as a function of wavelength (Figure D.8). Ideally, the action spectrum of the challenge microorganism used to validate a polychromatic UV reactor would either match that of the target microorganism or provide a conservative estimate of inactivation.

Figure D.8. Action Spectra for Various Microorganisms



(Adapted by H. Wright from Rauth 1965.)

The impact of various action spectra on UV dose delivery may be estimated by calculating the germicidal lamp output using Equation D.3:

$$P_G = \sum_{\lambda=200}^{320} P(\lambda)G(\lambda)\Delta\lambda \qquad \text{Equation D.3}$$

where:

P_G	=	Germicidal output of the MP lamp (W/cm)
λ	=	Wavelength (nm)
$P(\lambda)$	=	Lamp output at wavelength λ, measured over 1-nm increments [watt per nanometer (W/nm)]
$G(\lambda)$	=	Relative UV sensitivity of the microorganism at wavelength λ (cm^{-1})
$\Delta\lambda$	=	1-nm wavelength increment (nm)

Using the published action spectra of fourteen microorganisms (Cabaj et al. 2002, Linden et al. 2001, Rauth 1965), Table D.2 presents the germicidal lamp output calculated for a commercial MP lamp and the ratio of that output to that of *Cryptosporidium*. A ratio greater than one (1) indicates that the microorganism receives more germicidal output compared to *Cryptosporidium*. If a challenge microorganism with a ratio greater than 1.05 is used to validate a MP reactor for *Cryptosporidium* inactivation, the ratio should be used as a correction factor (called the "action spectra correction factor," or CF_{as}) to account for the greater proportional inactivation of the challenge microorganism that arises from the differences in the two action spectra. In the case of MS2 and *B. subtilis*, the ratio is close to one (1) and the correction is small (< 0.06). However, based on the data in Table D.2, if φx174 was used to show *Cryptosporidium* inactivation, an action spectra correction factor of 1.16 would be needed with MP reactors. In other words, the φx174 RED would be divided by 1.16 to determine the RED used to calculate the validated dose (see Section 5.8).

Table D.2. Germicidal Output Delivered to 14 Microorganisms by an MP Lamp

Microorganism	Type / Nucleic acid (SS = single strand, DS = double strand)	Germicidal Output (W/cm)	Germicidal Output Relative to *Cryptosporidium* (Action Spectra Correction Factor)
Cryptosporidium oocysts	Protozoa / DS DNA	5.64	1.00
Vaccinia	Animal virus / DS DNA	5.46	0.98
B. subtilis spores	Aerobic spore / DS DNA	5.58	0.99
VSV	Animal virus / RNA	5.53	0.99
MS-2, R-17, fr, 7-S	Bacteriophage / SS RNA	5.78	1.04
T2	Phage / DS DNA	6.05	1.07
EMC	Animal virus / SS RNA	5.98	1.07
φx-174	Bacteriophage / DS DNA	6.53	1.16
Polyoma	Animal virus / DS DNA	6.74	1.18
Herpes simplex	Human virus / DS DNA	7.00	1.26
Reovirus-3	Animal virus / DS RNA	7.46	1.32

The germicidal output of the MP lamp calculated using the action spectra of *B. subtilis* spores and MS2 is equal to or less than that of most of the 14 microorganisms listed in Table D.2. Thus, it is reasonable to assume that these microorganisms are acceptable as challenge microorganisms for many pathogens whose action spectra are not known, like adenovirus and *Giardia*. However, if an alternative challenge microorganism is to be used, its action spectra should be assessed for suitability.

As an alternate approach to measuring the action spectrum, the correction factor can also be estimated by comparing the UV dose-response of the challenge microorganism to that of MS2 measured with a LP and a MP lamp. The correction factor would be defined as:

$$CF_{as} = 1.04\left(\left(\frac{k_{MP}}{k_{LP}}\right)_{challenge} \Big/ \left(\frac{k_{MP}}{k_{LP}}\right)_{MS2} \right) \qquad \text{Equation D.4}$$

Where:

CF_{as} = Correction factor for the difference in action spectra between the challenge microorganism and MS2 (unitless)

k_{MP} = Slope of the UV dose-response measured with a MP collimated beam (cm^2/mJ)

k_{LP} = Slope of the UV dose-response measured with a LP collimated beam (cm^2/mJ)

1.04 = Germicidal output of MS2 relative to *Cryptosporidium,* from Table D.2 (unitless)

Example D.8. A UV reactor is validated with the virus φx-174 (germicidal output relative to *Cryptosporidium* is 1.14). The reactor uses the UV Intensity Setpoint Approach and measures an RED of 25 mJ/cm² at the setpoint. In calculating the validated dose for *Cryptosporidium* or *Giardia* inactivation credit, the measured RED used to calculate the Validated Dose (discussed in Section 5.8.2) would have to be adjusted to 25 $mJ/cm^2/1.14 = 22\ mJ/cm^2$.

NOTE: The correction factor described in this section is applicable ***only to MP reactors***. It should be used if $CF_{as} \geq 1.06$. The correction factor that accounts for differences in the action spectra is not the same correction factor that accounts for differences in the microorganism UV sensitivities described in Section D.1 (UV dose-distribution impacts). The correction factor described in Section D.1, the "RED Bias," applies to all UV reactors regardless of lamp type.

D.4.2 Water Absorption of UV Light

During UV reactor validation, a UV-absorbing chemical is added to the bulk flow passing through the reactor in order to simulate high-UV absorbance (low-UVT) events that could occur at a WTP. Common UV-absorbing chemicals currently in use for validation testing include lignin sulfonate, sodium thiosulfate, fluorescein, coffee, concentrated humic acids, tea, and parahydroxybenzoic acid. Ideally, the spectral absorption of the water used to validate UV reactors equipped with MP lamps should match the spectral absorption of the water at the WTP over the wavelength range associated with UV dose delivery and monitoring. Figure D.9 illustrates UV spectra measured in waters at several different WTPs.

Figure D.10 compares the UV absorbance spectra of coffee and lignin sulfonate to those of two drinking water sources ("Water A" and "Water B"). For a given UVT, the UV absorption at wavelengths above and below 254 nm is greater with coffee and lignin sulfonate than with the drinking water sources. If those chemicals are used during validation of a MP reactor, the RED and UV intensity values measured at a given flow rate, lamp output, and water UVT will be lower during validation than at the WTP (Wright et al. 2002).

Figure D.9. Spectral UV Absorption of Water at Various WTPs

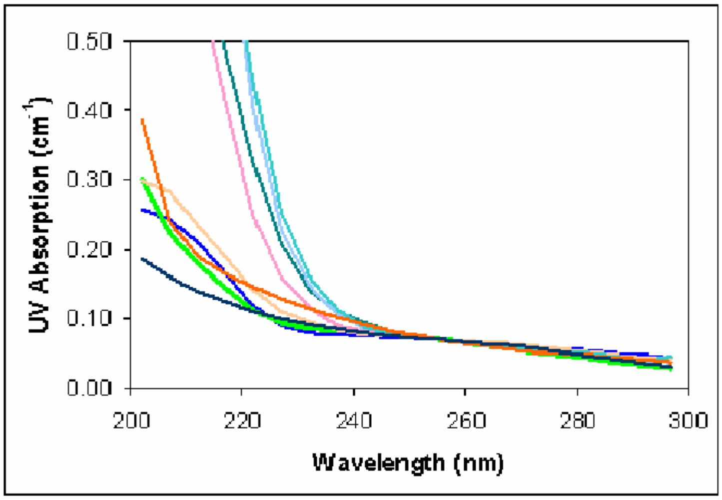
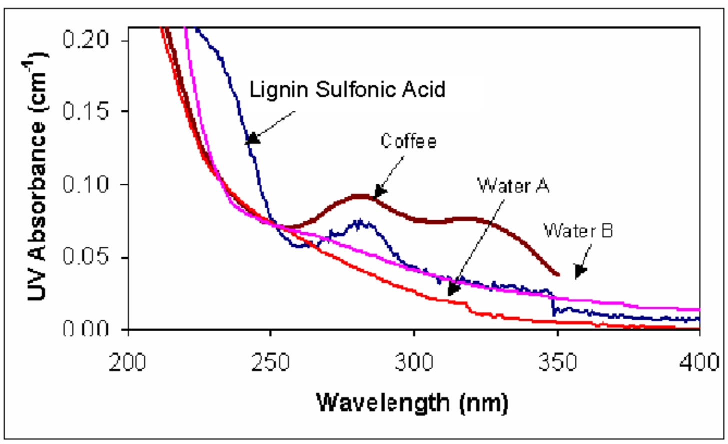


Figure D.10. Comparison of the UV Absorbance Spectra of Additives Used during UV Reactor Validation to the UV Absorbance of Two Finished Waters



The magnitude of the impact of this difference in the UV absorbance spectra on the measured UV intensity will depend on the location of the UV sensors relative to the lamps (Wright et al. 2002). Any new or alternative chemical used to alter UVT in the validation test should have its UV absorbance spectra evaluated and compared to natural waters. Significant differences will result in a proportionally large impact on RED and intensity readings during validation.

D.4.3 Determining the Polychromatic Bias Factor (B_{Poly})

The term "polychromatic bias" refers to polychromatic differences between validation and operation of a UV reactor. UV reactors with MP lamps that were installed prior to the publication of this document may use ***non-germicidal sensors*** and, thus, may exhibit polychromatic bias. To account for polychromatic bias during validation testing, a polychromatic bias factor (B_{poly}) should be incorporated into the Validation Factor:

$$VF = B_{RED} \times B_{Poly} \times \left(1 + {}^{U_{Val}}\!/_{100}\right) \qquad \text{Equation D.5}$$

See Section 5.9 for a complete discussion of the Validation Factor.

Tables D.2 and D.3 should be used to estimate B_{Poly} using the following validation testing information:

- The UV-absorbing compound (coffee or LSA)
- The minimum UVT tested (for all validation tests)
- The lamp sleeve-to-sensor distance (i.e., water layer)

Note that Tables D.2 and D.3 are for discreet values of UVT and lamp sleeve-to-sensor distance. The Polychromatic Bias Factor can be interpolated for intermediate values.

Example D.9. An MP UV reactor with a non-germicidal sensor located 5 cm from the lamp sleeve is validated using coffee as a UV-absorbing chemical. The UV reactor is validated at a minimum UVT value of 85%. Using Table D.4, the polychromatic bias values at 85% UVT values is **1.12**.

Table D.3. Polychromatic Bias Values for an MP UV Reactor Using a Non-germicidal UV Sensor and Validated with LSA

Water Layer (cm)	Polychromatic Bias Values for a UVT of:					
	70%	80%	85%	90%	95%	98%
2	1.00	1.00	1.00	1.00	1.00	1.00
5	1.22	1.08	1.04	1.00	1.00	1.00
10	1.74	1.38	1.25	1.13	1.05	1.02
15	2.28	1.71	1.48	1.27	1.12	1.05
20	2.76	2.07	1.74	1.42	1.18	1.07
25	3.19	2.41	1.99	1.58	1.25	1.10

Note: water layer = sensor to lamp distance

Table D.4. Polychromatic Bias Values for an MP UV Reactor Using a Non-Germicidal UV Sensor and Validated with Coffee

Water Layer (cm)	Polychromatic Bias Values for a UVT of:					
	70%	80%	85%	90%	95%	98%
2	1.01	1.00	1.00	1.00	1.00	1.00
5	1.57	1.22	1.12	1.05	1.01	1.00
10	3.70	1.99	1.56	1.29	1.11	1.04
15	9.42	3.42	2.25	1.61	1.22	1.08
20	24.6	6.11	3.34	2.04	1.35	1.12
25	64.3	11.0	5.11	2.61	1.50	1.16

Note: water layer = sensor to lamp distance

In addition to the polychromatic bias that can occur from the use of non-germicidal sensors, polychromatic bias can occur when a germicidal sensor in an MP UV reactor is farther away from the lamp than the ideal location. In this case, the water layer can act as an optical filter, preferentially absorbing lower wavelength light and introducing polychromatic bias. The polychromatic bias exhibited by germicidal UV sensors that are further away from the lamp than the ideal location is not expected to be significant as long as the sensor is 10 cm or closer to the lamp (or further if the water being tested exhibits a UVT greater than 90%). This criterion is met for most MP reactors on the market at the time of manual publication and thus is not addressed in this manual.

D.5 Analytical Foundation for UV Dose Monitoring and Defining Uncertainty

UV installations should be sized and operated in a manner that accounts for the measurement uncertainty associated with UV dose delivery monitoring. The objective of UV dose delivery monitoring is to indicate the level of inactivation of the target pathogen. This section derives a measurement equation for UV dose monitoring (Wright and Mackey 2003). This equation is used in this manual as the analytical foundation for defining the uncertainty of UV dose monitoring.

Consider a UV installation operating at a WTP. Assuming first-order kinetics, the log inactivation of a target pathogen achieved by the UV reactor at some point in time can be expressed using Equation D.6:

$$\log I_p = \frac{RED_p}{D_{10p}} \qquad \text{Equation D.6}$$

where:

$log\ I_p$ = Log inactivation of the pathogen

RED_p = RED of the pathogen (mJ/cm^2)

D_{10p} = UV sensitivity of the pathogen (mJ/cm^2 per log I)

If the UV reactor delivers a UV dose distribution, the log inactivation of the pathogen is related to the inactivation of a challenge microorganism by substituting Equation D.1 into Equation D.6:

$$\log I_p = \frac{1}{B_{RED}} \frac{RED_c}{D_{10p}} \qquad \text{Equation D.7}$$

where:
RED_c = RED of the challenge microorganism (mJ/cm^2)

Assuming the challenge microorganism RED is proportional to the measured UV intensity ($RED_c \propto S$), the log inactivation of the pathogen can be expressed according to Equation D.8:

$$\log I_p = \frac{1}{B_{RED}} \frac{\alpha S}{D_{10p}} \qquad \text{Equation D.8}$$

where:
S = UV intensity measured at the WTP with a duty UV sensor (mW/cm^2)
α = Constant relating challenge microorganism inactivation to measured intensity (mJ/mW)

The constant α is determined during validation as the ratio of the measured RED of the challenge microorganism to the measured UV intensity (RED_c/S). Assuming that inactivation is proportional to flow rate ($\log N_p \propto Q$), Equation D.9 can be used:

$$\log I_p = \frac{1}{B_{RED}} \frac{RED_c}{D_{10p}} \frac{S}{S_v} \frac{Q_v}{Q} \qquad \text{Equation D.9}$$

where:
S_v = UV intensity measured during validation (W/cm^2)
Q_v = Flow rate measured during validation (mgd)
Q = Flow rate measured at the WTP (mgd)

Assuming the UV dose-response of the challenge microorganism follows first-order kinetics, the challenge microorganism RED during validation is calculated using the log inactivation of the challenge microorganism measured through the reactor:

$$RED_c = D_{10c} \log\left(N_{\propto} / N_c \right) \qquad \text{Equation D.10}$$

where:
D_{10c} = UV sensitivity of the challenge microorganism (mJ/cm^2 per log inactivation)
$N_{o,c}$ = Challenge microorganism concentration measured at the reactor influent (organisms/mL)

N_c = Challenge microorganism concentration measured at the reactor effluent (organisms/mL)

The UV sensitivity of the challenge microorganism (D_{10c}) can be calculated according to Equation D.11 from the UV dose-response measured using the collimated beam apparatus:

$$D_{10c} = \frac{D_{CB}}{\log\ I_C} \qquad \text{Equation D.11}$$

where:

D_{CB} = UV dose delivered by the collimated beam apparatus (mJ/cm^2)

$\log I_C$ = Log inactivation of the challenge microorganism observed with a UV dose of D_{CB}

Substitution of Equations D.10 and D.11 into equation D.9 gives the equation for dose monitoring using the UV Intensity Setpoint Approach:

$$\log\ I_p = \frac{1}{B_{RED}} \frac{D_{CB}}{D_{10p}} \frac{S}{S_v} \frac{Q_v}{Q} \frac{\log\left(N_{0,C} / N_C\right)}{\log I_C} \qquad \text{Equation D.12}$$

The uncertainty of dose monitoring arises from the uncertainties associated with each term in the measurement equation (Wright and Mackey 2003, Taylor 1982) and is accounted for by application of the validation factor (VF) in Section 5.9 and the application of quality assurance/quality control during operation of the reactor at the WTP.

D.6 Considerations for CFD Modeling

CFD UV dose modeling of the impact of UV reactor inlet and outlet conditions on RED could be used in conjunction with one of the approaches outlined in Section 3.6. to assess whether UV dose delivery at the WTP installation is equal to or better than UV dose delivery achieved during validation. However, several issues with a CFD-based approach should be considered:

- There is little agreement on appropriate procedures for assessing the credibility of CFD models.
- CFD models for prediction of UV dose delivered by a reactor comprise coupled sub-models for turbulent flow, microbial transport, UV intensity, and microbial inactivation. Many options and approaches are available for each sub-model. Currently, no consensus has been reached for which approaches are most suitable for predicting UV dose delivery in a full-scale reactor.
- CFD modeling of UV dose delivery requires a multi-disciplinary approach. Knowledge of fluid mechanics, light physics, microbial inactivation, numerical modeling, and UV process engineering is essential for credible CFD modeling of UV

dose delivery. The pool of this type of integrated expertise is currently limited, which presents a challenge for states tasked to review CFD modeling reports.

A generalized modeling approach for predicting UV dose delivery involves the following:

1. Construct a 3-D computational model of the UV system, including all major components that influence the flow patterns in the reactor. This includes resolution of all wetted surfaces in the reactor and the upstream/downstream piping systems.

2. Perform a steady-state CFD simulation by solving governing flow equations (i.e., Navier-Stokes and turbulence equations). This results in a prediction of point velocities across the interior of the UV system for the specified inlet flow rate.

3. Perform a UV intensity simulation for the UV system using a UV light intensity model. This results in a prediction of point UV intensity values across the interior of the UV system for specified values of UV lamp intensity and UVT.

4. Perform a particle tracking simulation using the combined numerical flow/UV intensity field. A random walk or particle physics model may be employed. Hundreds of numerical particles are randomly "injected" at the model inlet, and their x,y,z-coordinates are predicted as a function of time. The result is a predicted path line for each injected particle, which represents a random microbial path through the reactor.

5. Calculate the estimated UV dose for each injected particle by summing the cumulative UV dose at a series of points along the predicted particle path. The result is a UV dose distribution.

6. Determine the log inactivation and RED for a microorganism with known UV inactivation kinetics based on the UV dose distribution calculated in Step 5.

If CFD is applied for simulation of UV dose delivery, it should adhere to the following guidelines:

1. Only a qualified party with appropriate expertise should develop a CFD-based hydraulic or full UV reactor performance model. Such parties could include a professional engineer with extensive modeling experience, a CFD consulting firm, or a manufacturer with review by an independent CFD consultant.

2. The same overall modeling approach and sub-models should be used for both the validation site model and the WTP model. At a minimum, the following QA/QC procedures should be used during CFD model development and execution:

   - The density of the numerical grid and size of the time step used in simulations affect CFD results. In general, results become more accurate as the grid becomes finer and the time step becomes smaller. Grid and time-step convergence analysis should be performed to verify that grid and time-step sizes are sufficiently resolved such that smaller grid and time step sizes do not change predicted results.

Procedures for this analysis are presented in the *Guide for the Verification and Validation of Computational Fluid Dynamics Simulations* (AIAA 1998).

- Numerical convergence and consistency of the CFD models should be verified and documented. Procedures for this analysis are presented in the above-referenced AIAA guide.
- A sensitivity analysis of the major parameters that affect UV-dose prediction should be conducted. Examples include (but are not limited to) boundary conditions for lamp UV output and reactor wall reflection, number of particles used in a microbial transport simulation, and UV dose-response inactivation constants.

3. CFD models should not be calibrated with experimental RED data for the purposes of obtaining agreement between model predictions and field measured values. Calibration to RED data for a limited set of conditions does not necessarily improve the accuracy of future predictions, particularly because hydraulic conditions can greatly differ between the validation site and the WTP installation.

4. Error estimates and confidence intervals for the CFD model predictions should be developed for both the validation site and the WTP installation. This could be performed by comparing CFD model predictions and experimental data for the validation site, then assuming the same level of error for the CFD model prediction for the WTP installation.

Following the above guidelines, CFD can be used to predict the relative difference in RED between a validation site and a WTP installation. If analysis indicates that UV dose delivery is better at the WTP, RED credit should only be granted for the experimentally measured RED from the validation site.

CFD-based UV dose modeling should not be used in lieu of validation for prediction of the actual RED magnitude as a means of granting pathogen inactivation credit. As discussed previously, CFD is still an emerging technology, and CFD models for UV dose delivery are complex. Uncertainty and error ranges for these models are not known. CFD-based UV dose delivery models would need to undergo a formal industry-wide verification and validation process before they could be considered suitable for extrapolation of data for establishing inactivation credit. A possible approach for verification and validation of hydraulic CFD models is outlined in the AIAA CFD guide (1998).

It is anticipated that CFD models for UV dose prediction will develop and improve in the future. This manual is not intended to be the final word on CFD modeling for UV disinfection. Engineers, regulators, and manufacturers should also consult with the AIAA manual and future CFD guidance that may arise in the water industry.

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Appendix E

UV Lamp Break Issues

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The lamps in most UV reactors designed for water disinfection contain mercury or an amalgam of mercury and another element, such as indium or gallium. Mercury has properties that allow for cost-effective generation of UV light. These properties include a sufficient vapor pressure at ambient temperatures to provide for efficient production of resonance radiation and a low ionization energy to facilitate starting a lamp (Phillips 1983). Lamp manufacturers are continuing to reduce the mercury content of UV lamps (USEPA 1997b; Walitsky 2001). However, mercury-free lamps, such as pulsed UV lamps containing xenon, are not widely used for water disinfection at present.

The mercury contained within a UV lamp is isolated from exposure to water by the lamp envelope (referred to as the "lamp" in this appendix for simplification) and a surrounding lamp sleeve (Figure 2.13). However, breakage of a UV lamp creates the risk of exposure to mercury, which can cause adverse health effects (USEPA 2006).

Although UV disinfection utilizes UV lamps with mercury, UV disinfection is an important disinfection technology that provides additional public health protection. To date, there have been few lamp breaks at existing UV facilities. The risk to human health and the environment from the mercury in UV lamps used in the treatment of drinking water is very small. It can be addressed through engineering and administrative methods used to prevent UV lamp breaks and exposure to mercury if breaks do occur, as described in this appendix.

This appendix discusses the issues associated with breaks of UV lamps used for drinking water disinfection. Lamp breaks are divided into off-line and on-line breaks. Off-line breaks occur when the lamps are not installed in the reactor or when the reactor is not in operation. On-line lamp breaks occur when the lamp and lamp sleeve break during reactor operation.

Sections E.1.1, E.2.1, and E.2.2 address potential causes of lamp breaks (including known occurrences) and corresponding preventive measures. Sections E.2.3 and E.2.4 address containment of mercury after a break and suggest components of a lamp-break response plan. Regulatory issues associated with lamp breaks, including lamp disposal, are discussed in Section E.3. Mercury in UV disinfection facilities and documented mercury reactions in PWS, is discussed in Sections E.4 and E.5. A summary of the information presented in this appendix is located in Section E.6. References for this appendix are presented in Chapter 7.

E.1 Off-line Lamp Breaks

Off-line breaks occur when a lamp breaks during shipping, handling, storage, or maintenance. Off-line breaks also can occur when the lamp and the lamp sleeve break in a UV reactor that is **not** in operation. Because water is not flowing through the reactor, off-line breaks do not pose a hazard to the water consumer but may be a hazard to operators or employees in the vicinity of the break.

E.1.1 Potential Causes of Off-line Lamp Breaks and Corresponding Prevention Measures

Off-line lamp breaks are caused by improper handling. The UV manufacturer should train operators in proper handling and maintenance of UV lamps. In addition, lamps should be stored horizontally in individual packaging to reduce the potential for lamp breaks. Lamps should not be stacked unpackaged or propped vertically in corners (Dinkloh 2001).

E.1.2 Off-line Mercury Release Cleanup Procedures

Water systems should have a lamp break response plan for containing and cleaning the off-line spills. The local poison control center, fire department, or public health board can assist in determining appropriate responses for different spill sizes and in developing a plan.

Small spills can be contained and collected with commercially available mercury spill kits. Small spills are defined as the amount of mercury in a broken thermometer, or less than 2.25 grams (g) (USEPA 1992, USEPA 1997a). Given that the mercury content in a single UV lamp typically ranges from 0.005 – 0.4 g (discussed in Section E.4.2), a single lamp break and multiple lamp breaks that result in release of less than 2.25 g are categorized as small spills.

Mercury and materials used during the cleanup procedure are regulated as hazardous wastes and should be disposed of properly as described in Section E.3.3. EPA's Office of Superfund Remediation and Technology Innovation (formerly the Office of Emergency and Remedial Response) recommends that "…[in] the event of a large mercury spill (more than a broken thermometer's worth), immediately evacuate everyone from the area, seal off the area as well as possible, and call your local authorities for assistance…" (USEPA 1997a).

E.2 On-line Lamp Breaks

On-line lamp breaks occur when a lamp and lamp sleeve break while water is flowing through the reactor. These breaks may have the potential to pose a hazard to the water consumer, as well as to operators or employees in the vicinity of the break. This section discusses potential causes of on-line lamp breaks, prevention measures, and documented occurrences of on-line lamp breaks and mercury release.

E.2.1 Potential Causes of On-line Lamp Breaks and Corresponding Prevention Measures

Lamp breaks can be caused by debris in the water, improper UV reactor orientation, water temperature variations, exceeding positive or negative pressure limits (water hammer), electrical surges, or improper maintenance. Lamps may also break as a result of manufacturing defects in the lamp or improper selection of the lamp or sleeve material.

E.2.1.1 Debris

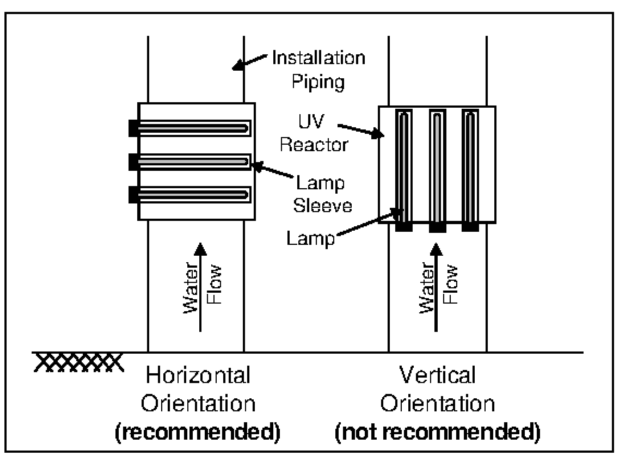
Debris may originate from the raw water or from treatment process equipment. Although most UV reactors will be installed after the filters in the treatment train, upstream equipment may release parts or fragments such as nuts or bolts that can break the lamp sleeves or UV lamps. Unfiltered systems may be more prone to debris because there is minimal upstream treatment to UV disinfection, which should be considered in the UV facility design. Groundwater systems have the potential to pull stones or gravel from wells that can enter UV reactors and break lamps (Malley 2001, Roberts 2000).

The consideration of prevention measures may be beneficial if debris historically has occurred prior to installation of the UV facility. Placement of screens, baffles, or low velocity collection areas upstream of UV reactors or vertical orientation (i.e., vertical flow of water through the UV reactor) may reduce the risk of debris entering the reactor (Cairns 2000, Malley 2001, McClean 2001b). Note that the lamps should be oriented horizontally relative to the ground even if the UV reactor is installed with water flowing vertically as discussed in Section E.2.1.2. The extent of containment these safety measures provide is unknown. Water systems and designers should determine the applicability of these techniques on a site-specific basis.

E.2.1.2 Improper UV Lamp Orientation

The orientation of UV lamps within a UV reactor can also increase the potential for lamp breaks. Orienting lamps perpendicular to the ground can result in differential heating of the lamp and the sleeve, which can lead to eventual cracking of the lamp and sleeve. As such, regardless of the direction of water flow relative to the ground, UV lamps should be oriented parallel and not perpendicular to the ground (Figure E.1).

Figure E.1. Example of Proper Horizontal and Improper Vertical UV Lamp Orientation in Reactors Relative to the Ground



E.2.1.3 Loss of Water Flow and Temperature Increases

UV lamps are designed to operate within a specific temperature range to maximize UV light output. Without flowing water to cool the lamp, the lamp temperature can rise above the maximum operating temperature and break (Dinkloh 2001, Malley 2001, Srikanth 2001a, Srikanth 2001b). There are two conditions that may cause overheating of lamps:

- Operating UV lamps while there is no water in the UV reactor (i.e., the lamp is in air)
- Operating UV lamps while water is not flowing through the UV reactor (i.e., the water in the UV reactor is stagnant)

Overheating occurs much faster in air than in stagnant water and is more likely to occur with medium-pressure (MP) than low-pressure (LP) lamps (due to lamp operating temperatures). If UV lamps are energized in air, the lower temperature water entering the reactor may cause the lamp sleeve and the lamp to break due to temperature differentials (Dinkloh 2001, Malley 2001), even if upper temperature levels are not exceeded. Lamp overheating and temperature differentials could, therefore, break all the lamps within the affected reactor.

Operating a UV lamp in stagnant water can also cause lamps to overheat and break. Water flow during UV start-up (i.e., cooling water) cools the lamps and prevents lamps from overheating and breaking. However, cooling water may not be necessary with low-pressure high-output (LPHO) lamps (Haubner 2005). Whether cooling water is needed depends on the specific MP reactor manufacturer, and the manufacturer should be contacted to determine this (Leinberger 2005, Larner 2005, Bircher 2005).

To prevent lamp breaks, operating procedures should ensure that the following conditions are met:

- The lamps are not operating while the reactor is not full (i.e., while air is in the reactor).
- If recommended by the UV manufacturer, water should be flowing through the UV reactor if the UV lamps are operating.

Hydraulics should be designed so that lamps are submerged at all times during reactor operation. UV facility designs should also incorporate low flow alarms, air relief valves, or other devices to ensure that lamps are operating only when the reactor is completely flooded and water is flowing. UV equipment should and typically does include temperature sensors and alarms that automatically shut down the reactor before critical temperatures are exceeded (Leinberger 2005, Larner 2005, Bircher 2005, Dinkloh 2001, Malley 2001, Srikanth 2001b).

E.2.1.4 Pressure-related Events

Hydraulic pressures that exceed the operating limits of the lamp sleeves may break them. Although breaking the lamp sleeve does not automatically break the lamp, the lamp is more vulnerable when the sleeve has been damaged, potentially allowing the hot lamp to come into direct contact with colder surrounding water.

Most lamp sleeves are designed to withstand continuous positive pressures of at least 120 pounds-force per square inch gauge (psig) (Roberts 2000, Aquafine 2001, Dinkloh 2001, Srikanth 2001a, Srikanth 2001b). However, negative gauge pressures below −1.5 psig have been shown to adversely affect lamp sleeve integrity (Dinkloh 2001). The pressure tolerance of the quartz lamp sleeve varies and depends on the quality, thickness, and length of the sleeve. Positive and negative pressures that exceed these levels, such as those associated with water hammer, may cause the lamp sleeve to crack or break.

Thus, water hammer can potentially break all lamps within an affected reactor. The water system should perform a surge analysis to determine if water hammer is a potential problem, and the UV facility designer should specify the pressure and flow ranges expected. The manufacturer should provide lamp sleeves with the appropriate material, thickness, geometry, and seals for the specified pressure and should provide the water system with the lamp sleeve pressure tolerances.

E.2.1.5 Handling and Maintenance Errors

A lamp or lamp sleeve damaged by improper off-line handling or maintenance may break when the UV reactor is returned to service. For example, over-tightening compression nuts when securing the lamp sleeve can cause a fracture of the lamp sleeve or a leak around the sleeve or compression nut cavity (Aquafine 2001, Dinkloh 2001, Srikanth 2001a, Srikanth 2001b, Swaim et al. 2002). This problem may not become apparent until after start-up of the UV reactor and may cause a lamp break. Operation and maintenance training can help prevent these types of lamp breaks.

E.2.1.6 UV Reactor Manufacturing Problems

The UV reactor manufacturer should design the UV reactor to reduce the possibility of lamp breaks. This section describes UV manufacturing problems that may cause lamp breaks if not properly addressed. Addressing these UV reactor manufacturing issues is typically the responsibility of the manufacturer. However, some causes of lamp breaks can be mitigated during the design of the UV facility.

Electrical Considerations

If the UV facility electrical support system is improperly designed (e.g., inadequate circuit breakers and ground fault indicator circuits), electrical surges can cause short-circuiting and lamp socket damage (Srikanth 2001a, Srikanth 2001b). In addition, system electronics that can produce voltages exceeding lamp ratings (overdriving lamps) may also cause the lamp to break (Malley 2001).

To reduce the likelihood of these problems, the UV facility designer should specify circuit/ground fault interrupters (GFI) in the UV facility electrical design. In addition, replacement UV lamps should be electrically compatible with the UV equipment.

Cleaning Mechanism Considerations

The cleaning mechanism may break the lamp sleeve and lamp if the mechanism is not aligned properly. Although the cleaning mechanism closely surrounds the lamp sleeve for cleaning, manufacturers should ensure that the mechanism is flexible and able to adjust to minor misalignment of the lamp sleeves.

At high lamp temperatures, the cleaning mechanism in some UV reactors may fuse to the lamp sleeve when not in use. As a result, during the next cleaning event, the lamp sleeve may crack when the cleaning mechanism is activated or when the cleaning mechanism passes back over the residual left on the lamp sleeve (Dinkloh 2001). Some UV reactors are not subject to this problem because the wipers rest away from the lamp sleeve when not in use and an alarm sounds when the wiper stops along the lamp sleeve.

Once the UV facility is in operation, the operators should perform routine inspections of the inside of the UV reactors to ensure that the cleaning mechanism is not fused to the sleeve.

Thermal Expansion and Contraction

Other potential causes of lamp breaks include improper matching of lamp materials with respect to thermal expansion characteristics. Manufacturers should use compatible materials within the lamp to avoid stress and damage from thermal expansion and contraction differences between materials that can occur under various operating, shipping, or handling conditions (Cairns 2000). In addition, improper seal design or lamp swelling can cause water leaks around the seals that can result in electrical shorts and cracking of lamps (Cairns 2000).

The UV facility designer should specify the temperature ranges likely to be encountered during shipping, storage, and lamp operation in the UV equipment procurement documents so the manufacturer can select the appropriate materials.

E.2.1.7 Summary of Potential Causes and Methods of Prevention of On-line UV Lamp Breaks

Table E.1 summarizes the potential causes of on-line lamp breaks and briefly describes the preventive measures that UV facility designers and operators can implement to reduce each risk. Documented cases of on-line lamp breaks are discussed in Section E.2.2.

E.2.2 On-line Lamp Break Incidents

Relatively few incidents of on-line lamp breaks with mercury release have been documented. A literature review was conducted to compile information on UV lamp breaks in operating UV facilities. Several facilities were contacted for more information about the incidents. Although all documented lamp breaks involved MP lamps, some of the causes reported for the lamp breaks are independent of the lamp type (Malley 2001). The documented lamp break incidents, categorized according to the cause of the incident, are summarized in Table E.2.

Table E.1. Summary of Potential Causes and Methods of Prevention of On-line UV Lamp Breaks

Potential Cause	Description	Preventive Measure
Debris	• Physical impact of debris on lamp sleeves may cause lamp breaks.	• Installation of screens, baffles, or low velocity collection areas upstream of UV reactors or vertical installation of UV reactors will help prevent debris from entering the reactor.
Lamp Orientation	• Vertical installation relative to the ground may cause overheating and lamp breaks.	• Install reactors with lamps oriented parallel to the ground to reduce differential heating.
Loss of Water Flow and Temperature Increases	• Lamps may overheat and break. • The temperature differential between stagnant water or air and flowing water (upon resumption of flow) may cause lamp breaks.	• Reactors should always be completely flooded and flowing during lamp operation. Temperature and flow sensors that are linked to an alarm and automatic shutoff system can be used to indicate irregular temperature or flow conditions.
Pressure-related Events	• Excessive positive or negative pressures may exceed lamp sleeve tolerances and break the lamp sleeve.	• A surge analysis should be completed during design to determine the occurrence of water hammer. • Pressure relief valves or other measures can be used to reduce pressure surges. • Applicable pressure ranges should be specified for lamp sleeves.
Maintenance and Handling Errors	• Improper handling or maintenance may compromise the integrity of the lamp sleeve and/or lamp.	• Operators and maintenance staff should be trained by the manufacturer.
UV Reactor Manufacturing Problems	• Electrical surges can cause short-circuiting and lamp socket damage.	• Adequate circuit breakers/GFI should be specified to prevent damage to the reactor.
	• Applying power that exceeds design rating of lamps can cause lamps to burst from within.	• Replacement lamps should be electrically compatible with reactor design.
	• Misaligned or heat-fused cleaning mechanism may break or damage the lamp sleeve and lamp.	• Operators and maintenance staff should perform routine inspection and maintenance according to manufacturers' recommendations.
	• Thermally incompatible materials do not allow for expansion and contraction of lamp components under required temperature range.	• Designers should specify temperature ranges likely to be encountered during shipping, storage, and operation of lamps to aid the manufacturer in the selection of thermally compatible materials.

Table E.2. Mercury Release Incidents Involving UV Lamp Breaks

Identified Cause	Number of Incidents	Description of Incident
Debris	5	(4) Stones entered the reactors and struck the lamps.[1] (1) Gravel entered the reactor through the booster pump and struck the lamp.[2]
Loss of Water Flow and Temperature	2	(2) Lamps were left on and allowed to reach high temperatures [600 degrees Centigrade (°C)] in empty non-operating reactors.[1] Restoration of flow caused cooler water (20 °C) to break the lamps.
Operator Error	1	(1) Forklift collided with on-line reactor.[3]
Manufacturer Design	7	(1) Applied power exceeded the tolerances of the lamp, causing the lamp to burst from within.[1] (2) Vertical orientation of lamps in the reactor resulted in differential heating and eventual cracking of the lamp and sleeve because heat accumulated at the tops of the lamp and sleeve.[1] (1) High operating temperatures resulted in deformation of the lamp sleeve. The lamp sleeve sagged and on contact with the lamp, both the lamp and lamp sleeve broke.[4] (1) Manufacturing defect. Lamps exploded after approximately 300 hours of operation.[5] (2) Contaminated quartz material used by lamp manufacturer.[6]

[1] Survey of European water and domestic wastewater and hazardous waste treatment systems (Malley 2001)
[2] European drinking water systems (Roberts 2000)
[3] European brewery (Roberts 2000)
[4] UV-peroxide groundwater remediation reactor (Moss 2002a)
[5] Drinking water system (Region of Waterloo 2004)
[6] Drinking water system (Wright 2005)

Impacts from debris caused five of the documented lamp breaks. In four of the five incidents reported, UV lamps were oriented perpendicular to the flow of water, indicating that lamps in this orientation may be more vulnerable to lamp breaks. However, the lamps in one instance were parallel to the flow of water, so orientation alone will not prevent lamp breaks.

An additional incident involving debris occurred when a bolt from the filter underdrain broke a lamp sleeve. The lamp was not broken by the bolt, and mercury was not released because the UV equipment was immediately shut down to respond to the sleeve break (McClean 2001a). Because no mercury was released, the incident is not included in Table E.2; however, this incident indicates that equipment debris can also be hazardous.

Loss of water flow and the resulting increase in lamp temperature caused two of the documented lamp breaks. In these cases, the operating lamps reached extremely high temperatures (> 600 °C) in air. When water flow resumed, the cooler water (20 °C) caused the lamps to break (Malley 2001). These incidents can be prevented if UV equipment has a safety mechanism that will shut down the UV lamps if flow decreases or lamp temperature significantly increases (Malley 2001).

Operator error caused one of the documented lamp breaks. A forklift was driven into an operating reactor and physically damaged the UV reactor. The event activated an alarm and pneumatic valve closure, which contained the mercury release (Roberts 2000).

The seven remaining lamp breaks are attributed to improper manufacturer design. In one of the lamp breaks, 30-kilowatt (kW) power was specified for the application. However, a manufacturing error resulted in a higher power being applied and caused the lamp to burst from within (Malley 2001).

Another manufacturer design problem that resulted in two breaks was vertical orientation of the lamps within the UV reactor. The vertical orientation allowed heat to accumulate at the tops of the lamp and sleeve, which caused them to break (Malley 2001). It is worth noting that modern UV reactors do not mount lamps vertically, even in vertically oriented reactors such as those discussed in Section E.2.1.2.

Another lamp break attributed to a manufacturer design flaw resulted from deformation of the lamp sleeve at operating temperatures. The incident occurred in a UV-peroxide reactor designed for well-head treatment of tetrachloroethene-contaminated groundwater (Moss 2002a). The UV reactor was positioned between the groundwater extraction pump and the distribution system booster pumps. The 7-foot long MP lamp sleeve sagged and came into contact with the lamp. The lamp and lamp sleeve broke, releasing mercury. The lamp failure triggered an alarm, shutting down both the groundwater extraction and distribution system booster pumps. Liquid mercury was found on the bottom of the reactor. Water samples taken at a nearby fire hydrant were positive for mercury but were below the maximum contaminant level (MCL) of 2 micrograms per liter (μg/L) (Moss 2002a, Moss 2002b).

Similar to the prior incident, a manufacturing defect in an MP lamp caused several lamps at a WTP to explode after approximately 300 hours of operation, releasing mercury into the water (Tramposch 2004). The break occurred in a large 47-inch diameter horizontal reactor. The lamp failure alarm triggered closure of the reactor isolation valves within 90 seconds and initiated automatic flushing of the clearwell. The quartz fragments and 64 percent of the mercury were recovered in the bottom of the reactor. The baffles within the reactor appear to have prevented the mercury and quartz from leaving the reactor after the break. The flushed clearwell water was sent to an on-site holding tank where it was tested for mercury, which was not detected. Mercury was also not detected in the piping between the UV reactors and the clearwell and in the UV reactor drain water. The water system believes that the remainder of the mercury was fused to the reactor walls because mercury was not discovered downstream, and mercury vapor was detected in the UV reactor when the hazardous materials (HazMat) contractor was cleaning the UV reactor.

Twenty four hours after the reactor was drained in response to the lamp break, mercury vapor concentrations within the reactor exceeded health and safety limits (Section E.3.2), although mercury vapor concentrations in the ambient air surrounding the UV reactor were not above these safety limits. During all stages of the cleanup operation, the HazMat contractor ensured that the area was well-ventilated and monitored for mercury vapor. As a result of this incident, the water system observed that cleaning the reactor quickly is imperative because mercury vapor can accumulate in the reactor (Region of Waterloo 2004).

The two final documented lamp breaks occurred because of the use of contaminated quartz material by the lamp manufacturer. The contamination weakened the protective quartz sleeve and the lamp, resulting in breaks at two water treatment plants (WTP).

E.2.3 Design Considerations for Containment after a Lamp and Sleeve Break

This section briefly describes potential methods to contain mercury from a lamp break. However, the extent of containment provided by these measures is unknown. Water systems and designers should determine the applicability of these isolation techniques on a site-specific basis and include the specific steps to be taken in the water system's response plan.

To isolate the mercury in the reactor or downstream, water systems may install spring-return actuated valves with a short closure time on the reactor inlet and outlet piping (McClean 2001b). Given the short residence time of many MP reactors, the outlet-side valve should be located far enough downstream so that the valve has time to close and isolate the mercury upstream. UV facility designers should evaluate valve closure times with respect to the potential for water hammer.

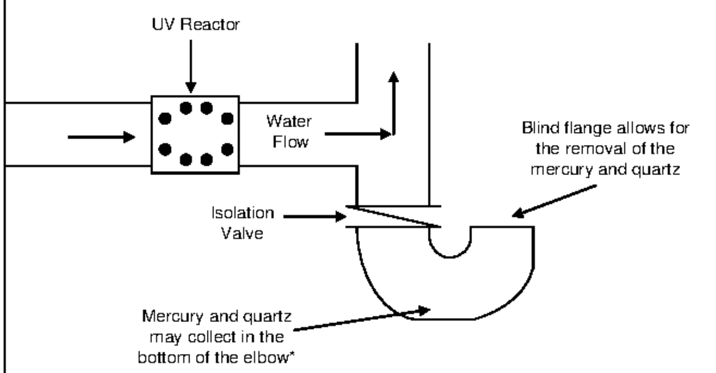
Condensed mercury and quartz fragments may be contained and collected in areas of low water velocity such as the bottom of a shut-down reactor, sumps, or a clearwell. To prevent quartz fragments from entering the water system, a strainer can be installed on the reactor outlet piping (McClean 2001b, Srikanth 2001a, Srikanth 2001b). Another option is to include a mercury trap in the design (Figure E.2). A mercury trap could include a tee fitting after the UV reactor. Flow will enter the tee and flow upward. The tee may also include an elbow that is sealed but accessible. If the water velocity in the tee fitting and following pipe is low enough, some of the mercury and quartz fragments may settle out in bottom of the elbow (Mutti 2004). The head loss associated with such measures should be considered in the hydraulic profile. Designers should also consider installation of drains and piping to allow disposal of potentially contaminated water from the reactor or trap to a waste container or truck. **The effectiveness of a strainer and mercury trap has not been evaluated and is unknown.**

E.2.4 On-line Lamp Break Response Plan

On-line lamp breaks should be preventable with appropriate design and operation of UV reactors. However, water systems should develop a written lamp break response plan in case an on-line UV lamp break occurs. Water systems should coordinate with their state when developing the following plan components:

- Identification of a lamp break
- Site-specific containment measures
- Mercury sampling and compliance monitoring
- Site-specific cleanup procedures
- Reporting requirements
- Public notification requirements

Figure E.2. Example of a Potential Mercury Trap*



*The effectiveness of the mercury trap has not been evaluated and is unknown.

Identification of a Lamp Break

UV reactors should be equipped with alarms that are activated when a lamp fails. A lamp failure alarm may be due to a lamp break or to another problem. Because alarms associated with lamp failure and GFIs may be due to lamp and sleeve breaks, the UV equipment should be shut down, isolated in response to these alarms, and inspected to determine whether a lamp break occurred.

Site-specific Containment Measures

In the event of a lamp failure alarm, the UV reactor should be immediately shut down, and operators should assume a lamp break has occurred and implement the procedures to contain the mercury while determining the cause of the alarm. The containment procedures should be outlined in detail in the water system's response plan based on the specific UV facility and any containment measures included in the design.

Mercury Sampling

Mercury sampling should be implemented after an on-line UV lamp break. Sampling procedures should specify sample locations, frequencies, and analysis methods. Sampling frequencies should consider flow rate, detention time, and travel time to the first potential consumer. Sample locations should be chosen based on where the mercury may settle (e.g., low velocity areas) and where mercury vapor may accumulate (e.g., a drained UV reactor). Table E.3 lists some possible sample locations (Region of Waterloo 2004, Stantec 2004).

Table E.3. Mercury Sampling Locations

Media	Location	Purpose
Water	• Reactor drain • Piping downstream of the UV reactor, including the distribution system entry point at a minimum • Low velocity areas, such as clearwells	• Assess the extent of mercury contamination and identify areas requiring cleanup.
Air[1]	• Reactor or other locations where mercury vapor may collect • Ambient air	• Assess whether it is safe to access mercury-contaminated equipment and piping for cleanup. The UV reactor interior may be accessible through an air vent. • Assess whether adequate ventilation is provided to safely proceed with mercury cleanup.

[1] Methods for air sampling are available from the Occupational Safety and Health Administration (OSHA) at http://www.osha.gov/dts/sltc/methods/inorganic/id140/id140.html.

Site-specific Cleanup Procedures

Site-specific cleanup procedures should be incorporated into the water system's response plan. Issues to consider are assessment of mercury contamination in the air, water, or on surfaces, disposal of any isolated or condensed mercury, potential disposal or treatment of contaminated water, cleanup responsibilities (by water system staff or contracted hazardous materials team), and Federal or state cleanup or disposal requirements.

An example of a currently operating UV facility's site-specific clean-up procedures is summarized below. The procedure includes the following major steps (Stantec 2004):

1. Hydraulically isolate the UV reactor.
2. Ventilate the area and shut down ventilation equipment that circulates air to other parts of the building.
3. Wear personal protective equipment, including gloves, eye protection, suits, shoe covers, and breathing protection.
4. Drain water from the reactor through a mesh filter into a tank for disposal.
5. Measure the mercury vapor concentration within the reactor and ensure that it is at an acceptable level (limits shown in Section E.3.2).
6. Open the reactor and remove quartz and mercury from the reactor using a mercury spill kit.
7. Perform a mass balance to assess how much mercury has been recovered.

Reporting and Public Notification Requirements

The water system should determine any reporting and public notification requirements by coordinating with the state. If reporting or public notification is required, the response plan should include the information that must be reported to the state and the notification procedures. Reporting requirements may include a description of the release, estimated quantity of the release, shut-down or containment procedures, cleanup or disposal methods, and sampling procedures (including sampling locations, frequencies, and results).

E.3 Regulatory Review

This section presents a review of regulations that may apply if UV lamp breaks occur at a WTP.

E.3.1 Safe Drinking Water Act

Under the Safe Drinking Water Act (SDWA), EPA established a primary MCL of 2 μg/L for inorganic mercury [40 CFR 141.62(b)] and the associated monitoring requirements. The limit was designed to protect against mercury contamination in the source water and not a transient event like lamp breaks. Consequently, the water system should contact the state to determine whether additional mercury monitoring will be required in response to lamp breaks.

E.3.2 Operator Health and Safety – Exposure Limits

Mercury exposure to employees in WTPs falls under the regulatory authority of OSHA. The exposure limits set by OSHA focus on exposure through inhalation. OSHA regulations have established permissible exposure limits (PELs) for mercury compounds and organo alkyls containing mercury. A PEL is a time-weighted average concentration that is not to be exceeded for an 8-hour workday during a 40-hour workweek. When a PEL is designated as a ceiling level (cPEL), the concentration cannot be exceeded during any part of the workday. PELs and cPELs are enforceable standards. The National Institute for Occupational Safety and Health (NIOSH) also publishes Immediately Dangerous to Life or Health (IDLH) concentrations for a variety of compounds. IDLH concentrations represent the maximum concentrations that one could escape within 30 minutes without symptoms of impairment or irreversible health effects. These values are not enforceable, but can be used as guidance for safety procedures. Table E.4 lists the PELs, cPELs, and IDLHs for mercury compounds and organo alkyls containing mercury.

In the event of a spill, the volatilization and the resultant mercury vapor concentration depends on air currents, temperature, surface area/dispersion of mercury droplets, and time. If a mercury spill is not cleaned up promptly, the levels in Table E.4 may be exceeded where mercury vapor collects (e.g., drained UV reactor). For example, in the lamp break described in Section E.2.2, these limits were exceeded within the reactor 24 hours after the reactor was drained. However, prompt response and proper cleanup procedures (e.g., ventilation and other measures described in Section E.2.4) should prevent exposure levels over these standards.

Table E.4. Health and Safety Standards for Mercury Compounds in Air

Compound	OSHA PEL (mg-Hg/m^3)[1]	OSHA cPEL (mg-Hg/m^3)	NIOSH IDLH (mg-Hg/m^3)
Mercury compounds	NR	0.1	10
Organo alkyls containing mercury	0.01	0.04	2

NR – not reported
[1] milligrams mercury per meter cubed

E.3.3 UV Lamp Disposal Regulations

UV lamps must be disposed of properly, as described in Section 6.3.2.6 and should be recycled. Some UV reactor and lamp manufacturers will accept spent or broken lamps for recycling or proper disposal (Dinkloh 2001, Leinberger 2002, Gump 2002). Alternatively, water systems should contact their state primacy agency or other local or state resource agencies for a list of local mercury recycling facilities.

E.3.4 Clean Water Act

Mercury discharges to water bodies in the United States are regulated under the Clean Water Act. Mercury-contaminated water from a lamp break should not be discharged to the environment through storm sewers or other means; discharges should be coordinated with the state and the local wastewater authority for proper treatment and disposal.

E.4 Mercury in UV Disinfection Facilities

Understanding the type of mercury and amount of mercury present in UV disinfection facilities can help determine the potential dispersion and transport of mercury through a WTP. However, the fate and transport of mercury after a lamp break has not been assessed by the drinking water industry.

E.4.1 Type of Mercury in UV Disinfection Facilities

Characterizing the form of mercury in an operating lamp is important because this form represents the starting point for mercury dispersion, speciation, and reaction chemistry in the water following a lamp break. Mercury in an LP or MP UV lamp is pure elemental mercury while LPHO lamps use a mercury amalgam, which typically is an alloy with indium.

Elemental mercury is usually a liquid at ambient temperature and pressure. However, given its vapor pressure (Table E.5), elemental mercury can vaporize at ambient temperatures. Other physical and chemical properties of elemental mercury that affect its fate and transport are given in Table E.5.

Table E.5. Physical and Chemical Properties of Elemental Mercury (Merck & Co., Inc. 1983)

Property[1]	Value
Density (g/mL[1] at 25 °C)	13.534
Solubility (g/L[2] at 25 °C)	0.06[2]
Vapor pressure (mm Hg at 25 °C)	0.002

[1] grams per milliliter; grams per liter
[2] Further information regarding mercury solubility in water can be found in Glew and Hames (1971).

In operating lamps, elemental mercury (from pure or amalgamated mercury) is vaporized in the presence of an inert gas. The concentration of mercury in the vapor phase is controlled predominantly by temperature. At typical LP and LPHO lamp operating temperatures, only a small portion of the liquid (pure) or solid (amalgam) mercury is vaporized. However, at typical MP lamp temperatures (600 to 900 °C; Table 2.1), mercury is present primarily in the vapor phase due to the high operating temperatures (Phillips 1983).

The relative proportion of mercury in the liquid/amalgam phase and in the vapor phase in an operating lamp may affect the fate of the mercury. (See Section E.5.) Liquid-phase elemental mercury is considerably denser than water (density = 13.5 g/mL; Table E.5).

As the UV lamp is operating, mercury-containing compounds can be formed on the internal lamp surface (Altena et al. 2001). After a break, these deposits may dissolve in water, releasing mercury into the water (Merck & Co. 1983).

Figure E.3 illustrates the expected forms of mercury in an operating lamp. Note that much of the elemental mercury will volatilize in an operating MP lamp and that amalgams are only used in LPHO lamps.

E.4.2 Amount of Mercury in UV Disinfection Facilities

The amount of mercury in a UV disinfection facility is site-specific and can be calculated using the amount of mercury per lamp, the number of lamps per reactor, and the number of reactors in the facility. This section contains information on the amount of mercury in UV lamps and uses this information in example calculations showing the amount of mercury contained in hypothetical UV facilities. This information is provided as an order of magnitude range of mercury levels that could be present in UV facilities.

Mercury content within lamps depends on type (LP, LPHO, or MP), length, and power rating. Although mercury content data are specific to manufacturer and lamp, longer lamps and lamps with higher pressures and power ratings typically contain more mercury. Table E.6 summarizes the quantities of elemental mercury added to lamps during manufacturing based on information provided by manufacturers and published literature values.

Figure E.3. Mercury Speciation in Operating UV Lamps

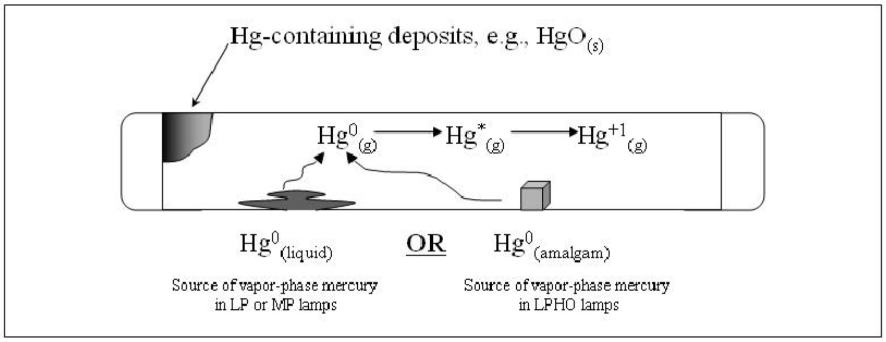


Table E.6. Elemental Mercury Content in UV Lamps

Lamp Type	Electrical Power Rating [Watt (W)]	Mercury Content (mg per lamp)		
		Phillips (1983)	Clear and Berman (1994)	Manufacturer Survey
LP	15 – 70	"a single drop"(1)	20(2)	5 – 50
LPHO	120 – 260	NR	26,(3) 36(4)	150
	400	NR	75.5	NR
MP	1000	NR	250	NR
	1 – 25 kW	1.4 – 14.5 mg/cm(5)	NR	200 – 400, 0.3 – 7.9 mg/cm length

1 Phillips (1983)
2 75 – W mercury vapor lamp
3 175 – W mercury vapor lamp
4 250 – W mercury vapor lamp
5 milligram per centimeter (mg per cm) of lamp length, reported lamp lengths are 6 – 300 cm (Primarc Limited 2001)
NR – Not Reported

The amount of mercury in a UV facility can be estimated using the values in Table E.6 as a guide. In order to develop these estimates, two UV reactor manufacturers established design parameters for three treatment flowrates [0.18, 3.5, and 210 million gallons per day (mgd)] with a specified water quality and required UV dose and validation reduction equivalent dose (RED) target (Table E.7). Design parameters included the number of lamps needed to obtain an MS2 phage RED of 40 millijoule per centimeter squared (mJ/cm^2)[1] during validation testing and the total number of reactors for each of the three design flows. Calculations assume 50, 150, and 400 milligrams (mg) of mercury per LP, LPHO, and MP lamp, respectively. When determining the amount of mercury at a specific UV facility, water systems should contact the lamp manufacturer for updated information because mercury content varies with lamp type and manufacturer.

[1] Corresponds approximately to a 3 log *Cryptosporidium* inactivation (depending on validation testing and associated Validation Factor)

Table E.7. Mercury Quantity in Example UV Facilities[1, 2]

Design Flow (mgd)	Average Flow (mgd)	Lamp Type	Average Number of Reactors	Average Number of Lamps (per reactor)	Total Hg in UV Facility[3] (g)
0.18	0.054	LP	1	2	0.1
		LPHO	1	1	0.2
		MP	1	1	0.4
3.5	1.4	LPHO	1	30	4.5
		MP	1	4	1.6
210	120	LPHO	6	72	64.8
		MP	6	7	16.8

[1] Target MS2 phage RED of 40 mJ/cm^2 , which corresponds approximately to a 3 log *Cryptosporidium* inactivation (depending on validation testing and associated Validation Factor)
[2] Water quality criteria: Ultraviolet transmittance (UVT) = 89% (A_{254} = 0.05 cm^{-1}), Turbidity = 0.1 nephelometric turbidity units (NTU), Alkalinity = 60 mg/L as $CaCO_3$, Hardness = 100 mg/L as $CaCO_3$
[3] Values given represent the amount of elemental mercury added to lamps during manufacturing.

E.5 Documented Mercury Reactions in PWSs

Currently the fate of mercury following a lamp break has not been experimentally determined. This section describes documented mercury reactions in water systems.

Liquid elemental mercury and solid mercury amalgams have high densities (Table E.5) and will probably settle in areas of low water velocity, providing an opportunity for containment and removal. In prior cases when liquid mercury was released from water treatment equipment, such as manometers, flow instrumentation, or pump seals, mercury was found to have settled in the clearwell, but whether all of the released mercury was recovered is not known (Cotton 2002). Smaller particles from the vapor phase mercury may be transported farther or be more readily dissolved in water than liquid elemental mercury and solid mercury amalgams. However, in sampling following a recent on-line MP lamp break (described in Section E.2.2), mercury was not detected in any of the downstream sample locations, which could indicate that the mercury was contained by the UV reactor. The water system theorized that the remaining mercury was potentially attached to the UV reactor walls.

Liquid-phase elemental mercury does not readily dissolve in water. Kolch (2001) monitored the mercury concentrations in a 50-L batch reactor following the destruction of one LPHO lamp (containing approximately 150 mg Hg). Mercury concentrations reached approximately 2.5 µg/L in the batch reactor water, and amalgamated mercury was found settled on the bottom of the reactor (Dinkloh 2001). The low concentration of dissolved mercury in the water is likely an indication that little, if any, of the mercury amalgam dissolved into the water.

E.6 Summary and Conclusions

UV disinfection is an important disinfection technology that provides additional public health protection. To date, there have been few lamp breaks at existing UV facilities. The risk to human health and the environment from the mercury in UV lamps used in the treatment of drinking water is very small. Procedures and actions can be taken to reduce the chances of a lamp break and mitigate mercury release that UV lamp breaks cause. In addition, monitoring of mercury after known lamp breaks indicates that most of the mercury is contained, and concentrations in the water downstream of the UV reactor do not exceed the SDWA MCL. However, more research is needed to understand the fate of mercury in a drinking water environment following a UV lamp break and to evaluate the dispersion and transport of mercury through a WTP and distribution system.

Lamp breaks are divided into off-line and on-line breaks. Off-line lamp breaks typically occur during storage, handling, or maintenance and cause small spills. Small spills should be contained, cleaned up, and disposed of properly. Monitoring of mercury vapor concentration in the ambient air is important to protect personnel during the clean-up procedures.

On-line breaks occur when the lamp sleeve and lamp break while the UV reactor is in operation. Incidents have been reported of on-line UV lamp breaks associated with impact from debris, improper UV reactor orientation, loss of water flow, temperature differentials, faulty UV equipment design, procedural errors, and manufacturing defects. However, on-line lamp breaks are largely preventable with appropriate design, operation, maintenance, and operator care. The following engineering and administrative methods may help prevent UV lamp breaks:

- Screens, baffles, or low-velocity collection areas prior to the reactor influent to prevent entrance of debris
- UV reactor installation with lamps oriented parallel to the ground to reduce differential heating
- Temperature and flow sensors and alarms to detect critical conditions and to shut down the UV reactors and water flow
- Surge analysis to determine if water hammer may be a potential problem or whether pressure relief values need to be installed
- Comprehensive operator training and UV equipment maintenance program
- Adequate circuit breakers/GFIs should be specified to prevent damage to the reactor.
- Operators and maintenance staff should perform routine inspection and maintenance according to manufacturers' recommendations.
- Designers should specify temperature ranges likely to be encountered during shipping, storage, and operation of lamps to aid the manufacturer in the selection of thermally compatible materials.

In the event of a mercury release, the following engineering controls are additional precautions that may aid in the containment and collection of mercury:

- Strainers and low velocity collection areas downstream of the reactor
- Isolation valves activated by an alarm to attempt to isolate potentially contaminated water

The extent of containment and prevention these measures provide is unknown. Water systems and designers should consider the applicability of these isolation techniques on a site-specific basis. Water systems should prepare a lamp break response plan in preparation for a potential UV lamp break and mercury release. This plan should address sampling and cleanup procedures as well as compliance with the SDWA, OSHA health and safety standards, and Clean Water Act. Water systems are encouraged to recycle or return all mercury-containing lamps to mercury re-generating facilities or the lamp manufacturer.

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Appendix F

Case Studies

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This appendix provides examples of how various utilities have implemented UV disinfection in their water systems. The UV facilities described in the following case studies were selected because they represent a broad range of UV facility conditions. They represent medium-pressure (MP) and low-pressure high-output (LPHO) reactor installations; on-site and off-site validation testing; installation on filtered water, unfiltered water, and an uncovered reservoir; and other varying goals and design issues.

The purpose of this appendix is to provide an overview of the manner in which UV disinfection has recently been implemented for drinking water disinfection in North America. The case studies describe issues and approaches used to implement UV disinfection technology. Specific step-by-step procedures for selecting design criteria and validation are not described. Rather, each case study provides a summary of the reasons for implementing UV disinfection, the design issues that were considered, and how implementation was approached. They are meant to be instructive as examples of how UV disinfection can be applied across a range of source waters, equipment types, and retrofit locations. It is important to follow the specific step-by-step guidance and examples provided in the previous sections of this manual to ensure that the final guidance is appropriately applied to any new installations.

The organization of each case study generally follows the organization of this manual. Each study provides introductory information about the water system and a discussion of the planning, design, validation, and operation and maintenance steps completed by each public water system (PWS). The first two case studies (Albany, New York and Weber Basin Water Conservancy District, Utah) feature in-depth descriptions, and the remaining three case studies contain briefer summaries of similar information.

When reading these case studies, it is important to recognize that these facilities were implemented before the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and the guidance provided in this manual were finalized. Although drafts of this manual were available, some of the guidance has changed over time. In particular, the validation approaches and testing programs have changed since these projects were implemented.

Following are some of the highlights from each case study:

- Section F.1 – Albany, New York. MP reactors installed on an uncovered finished water reservoir that experiences bi-directional flow.
- Section F.2 – Weber Basin Water Conservancy District, Utah. LPHO reactors validated off-site at the Portland Validation Facility.
- Section F.3 – Clayton County Water Authority, Georgia. LPHO reactors in which challenge microorganism die-off problems were resolved to allow for on-site validation to proceed.
- Section F.4 – Newark, Ohio. MP reactors installed at a lime-softening facility on individual filter effluent pipes.
- Section F.5 – Winnipeg, Manitoba. MP reactors installed on an unfiltered source.

F.1 Albany, New York – MP Facility on a Finished Water Reservoir with On-site Validation

The City of Albany (City) owns and operates a 32-million gallons per day (mgd) conventional surface water treatment plant (WTP), serving over 100,000 people. The Feura Bush WTP operates at a relatively constant treatment rate (typically about 20 mgd). The Loudonville Reservoir, a finished water reservoir on the opposite side of the City, floats on the distribution system, filling and emptying throughout the day as distribution system demand fluctuates.

Loudonville Reservoir has two functions—distribution storage and emergency/backup supply. The reservoir is a 200-million gallon, uncovered, finished water storage facility, consisting of three basins. The reservoir has two inlets/outlets to the distribution system, and reservoir effluent water is automatically rechlorinated before delivery to the distribution system. In addition to rechlorinating the water as it re-enters the City's distribution system, the City periodically batch chlorinates the reservoir to maintain water quality.

The City expanded its water quality enhancement program at the Loudonville Reservoir, which consisted of a series of water system improvements, including UV disinfection, being made under the direction of Albany's Mayor Gerald Jennings to ensure that customers receive the best possible water quality at all times.

Early in the project planning phase, the City and its consultant determined that UV disinfection offers the most flexible and holistic solution for improving the reservoir water quality. UV disinfection provides the City with an additional disinfection barrier that is compact, relatively simple to operate, free from regulated disinfection byproducts (DBP), and effective against chlorine-resistant pathogens.

Few data were available on the water quality at the reservoir. Therefore, the reservoir water quality was assumed to be similar to the Feura Bush WTP finished water quality, which is summarized in Table F.1.

F.1.1 Planning

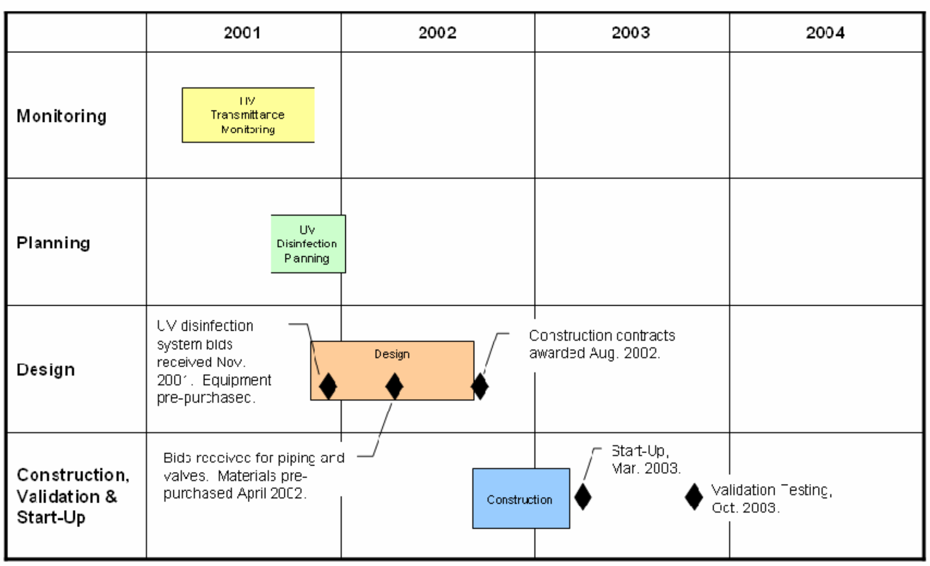
This section discusses key planning decisions made for Albany's UV facility. Figure F.1 is a timeline of the process the City used to implement UV disinfection.

Table F.1. Summary of Feura Bush WTP Finished Water Quality (2000)

Parameter	Units	Average	Minimum	Maximum
UV Absorbance[(1)]	cm^{-1}	0.03	0.011	0.054
UV Transmittance[(1)]	percent	93	88	98
Turbidity	NTU[(2)]	0.23	0.12	0.54
pH	–	8.40	7.80	9.20
Alkalinity	mg/L[(3)]-$CaCO_3$	40.9	35.7	48.3
Temperature	°C	10.4	1.1	20.0
Total Hardness	mg/L-$CaCO_3$	54.2	50.0	58.0
Iron	mg/L	<0.03	<0.03	0.03
Manganese	mg/L	<0.03	<0.03	<0.03
Aluminum	mg/L	0.07	0.07	0.07
Specific Conductance	m-mhos/cm[(4)]	176	148	211

[1] Data collected January 2001 – September 2001.
[2] nephelometric turbidity units
[3] milligrams per liter
[4] millimhos per centimeter

Figure F.1. Albany UV Implementation Timeline



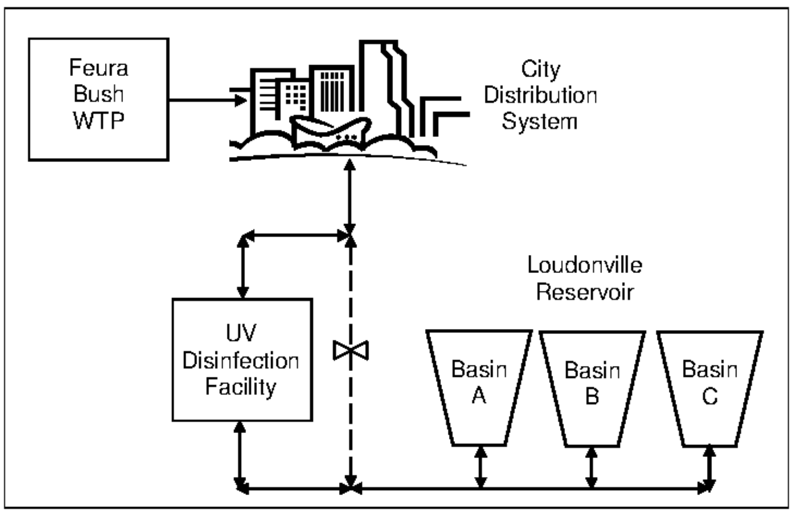
F.1.1.1 UV Disinfection Goals

The City chose a multiple-barrier approach for disinfection at the reservoir, incorporating both UV disinfection and chlorination, to provide a greater level of protection. The City's UV light and chlorine disinfection systems provide more effective inactivation of viruses and chlorine-resistant pathogens than the former chlorine-only system, while minimizing DBP formation. Additionally, the UV facility provides an additional level of protection to facilitate the City's compliance with the LT2ESWTR inactivation requirements for uncovered storage (Section 1.3.3).

F.1.1.2 UV Retrofit Location

The UV facility is located at the reservoir rather than at the WTP. Flow from each of the three reservoir basins is routed through the UV disinfection facility (Figure F.2) before it enters the City's distribution system.

Figure F.2. UV Retrofit Location at Loudonville Reservoir



F.1.1.3 Key Design Parameters

Water quality, the fouling/aging factor, and flow rate are key parameters to be considered during the planning phase. Table F.2 summarizes key preliminary design parameters for the UV facility design.

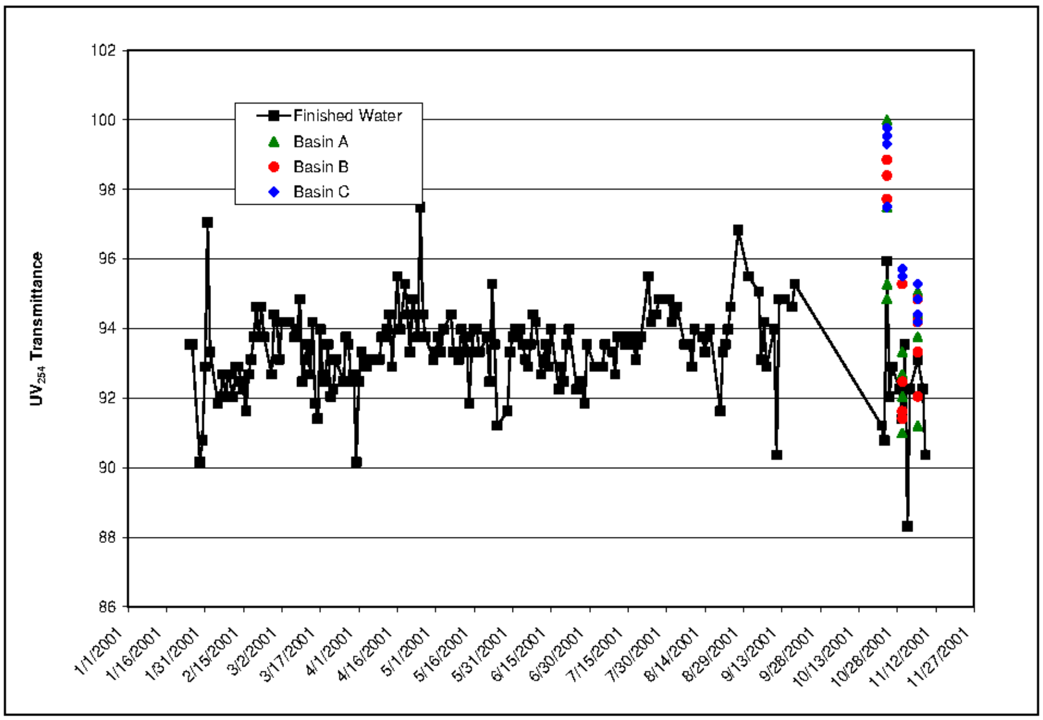
Table F.2. UV Facility Preliminary Design Parameters

Criterion	Unit	Value
UV Transmittance	percent	88
Fouling/Aging Factor	percent	60
Peak Flow Rate	mgd	40

Water Quality

Several water quality parameters affect UV dose delivery and, therefore, UV equipment design (Table F.1). The most important is ultraviolet transmittance (UVT), which is calculated from A_{254} as described in Section 3.4.4.1. Reservoir UVT data were collected for approximately 3 months prior to design, but long-term UVT data were not available for the reservoir. The minimum UVT of 88 percent (A_{254} of 0.054) measured in the WTP finished water, therefore, was used to conservatively estimate UVT at the reservoir (Figures F.3 and F.4).

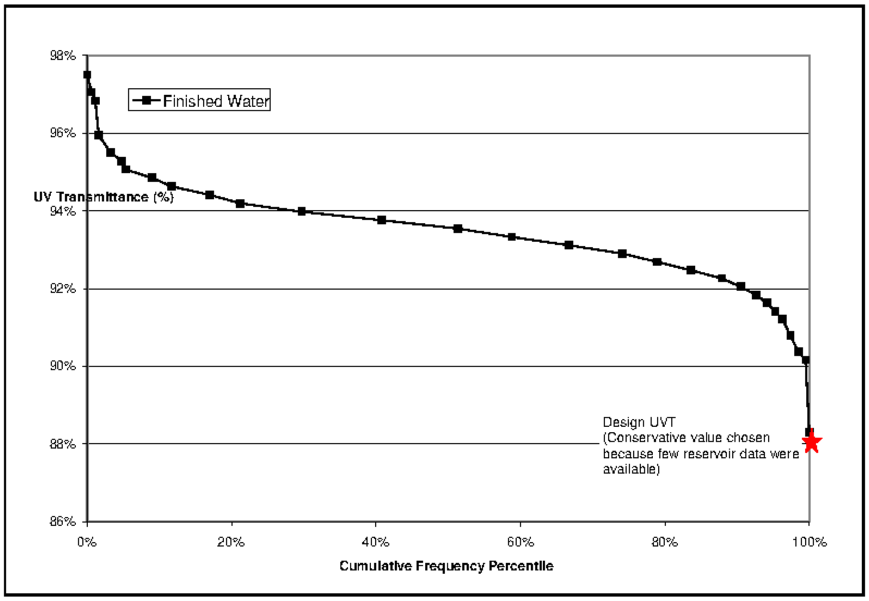
Figure F.3. UVT Data for Feura Bush WTP Finished Water



Fouling/Aging Factor

A fouling/aging factor of 0.6 was selected for Albany's UV equipment to be conservative. Because of the low hardness, iron, and manganese concentrations, fouling was not considered a significant issue. Nevertheless, the selected fouling/aging factor does reduce the necessary frequency of lamp replacement.

Figure F.4. Cumulative UVT Data for Feura Bush WTP Finished Water



[1] Note: 190 samples collected between January 2001 and November 2001.

Flow Rate

The UV facility was sized for 40 mgd (10 mgd per unit) for emergency or backup conditions when the reservoir and UV facility must be able to satisfy the entire system demand (30 mgd maximum). Under normal operating conditions, the UV facility maximum flow is 10 mgd.

Power Quality

The electric service provider for the proposed location of the UV facility was contacted regarding the availability and quality of power at the site. It was determined that high quality power was available, and power conditioning equipment was therefore unnecessary.

F.1.1.4 Equipment and Monitoring Strategy

Both MP and LPHO UV equipment were considered during the planning phase. MP UV equipment was selected for the design because of the smaller footprint and because, at that time, there was more experience with MP equipment in the United States. Another benefit of MP equipment was the use of the calculated dose-monitoring strategy, which allowed the City to address the anticipated variability in flow rate and direction.

F.1.1.5 UV Equipment Validation Options

The City of Albany chose on-site validation testing because no UV validation centers were operating in the United States at that time and because on-site testing would allow for:

- Testing under the exact piping configuration of the UV facility.
- Optimizing UV facility operations throughout the life of the facility.

Space requirements, injection and sample ports, and other elements required for on-site validation were coordinated with the UV equipment supplier and included in the UV facility design.

F.1.1.6 Hydraulics

No modifications to existing hydraulics were required for the UV facility at the reservoir. Installation of the UV facility did slightly reduce the full operating capacity of the reservoir. However, during an extended emergency condition, the UV facility can be bypassed to allow use of the entire reservoir volume.

F.1.1.7 Selected Configuration

The selected configuration of the UV equipment is summarized in Table F.3. The target male-specific-2 bacteriophage (MS2) reduction equivalent dose (RED) to be verified during validation was 40 millijoules per centimeter squared (mJ/cm^2) and was chosen to target high-level inactivation of various pathogens during emergency operation. The MS2 RED was based on best practices in North America and Europe at the time.

Table F.3. UV Equipment Configuration

Criterion	Unit	Value
UV Lamp Type	–	MP
Target MS2 RED	mJ/cm^2	40[1]
Number of UV Units (Duty + Standby)	number	4 + 0[2]
Design Flow Rate per Unit	mgd	10
Number of Lamps per Unit	number	8
Lamp Power (Each)	kW[3]	10

1 40 mJ/cm^2 is the target MS2 RED to be proven during validation testing and to be used when the reservoir is operating in its emergency mode. The target MS2 RED used during the normal distribution function of the reservoir is 240 mJ/cm^2 for virus inactivation.
2 40 mgd is needed for emergency and not normal operation; therefore, a standby unit was not provided.
3 kilowatt (kW)

F.1.2 Design

Given the wide range of UV equipment available, pre-purchase of the UV equipment by the owner was selected as the best way to proceed. Pre-purchase documents were issued in November 2001. Two suppliers bid on the UV equipment, and the contract was awarded to the low bidder, Trojan Technologies, Inc., in December 2001. By selecting the equipment early in the project, the project team was able to work closely with the manufacturer during the design of the system and support facilities (e.g., instrumentation and control) for the 24-inch UVSwift™ units. The following sections describe Albany's UV facility design.

F.1.2.1 Facility Hydraulics

Four parallel treatment trains of equal capacity (10 mgd) comprise the UV facility (Figure F.5). Water enters and exits the UV facility via 48-inch diameter influent and effluent manifolds. Each parallel treatment train consists of a 24-inch diameter lateral, influent and effluent modulating isolation valves, strap-on ultrasonic flow meter, and an MP UV unit. The UV units are installed in vertical piping to minimize the footprint of the UV facility and to promote settling of debris, if any, in the inlet piping to protect the lamps.

Figure F.5. UV Disinfection Facility at the Loudonville Reservoir

Although water hammer and surge conditions were determined to be minimal, a combination air/vacuum release valve was incorporated into each UV treatment train. The valves provide protection from adverse pressure conditions and facilitate the release of trapped air during start-up.

The UV facility was designed to handle large flow variations. The facility can treat typical daily flows with one or two 10-mgd units in service. With all four units in service, the facility can also treat the City's full system demand during WTP or transmission main shut-downs or during an emergency condition.

The UV facility was also designed to handle bi-directional flow through the UV equipment because water passes through the UV units during both the reservoir fill and the draw cycles. The bi-directional flow design (described below) enables the City to maintain the UV facility in a constant state of readiness to deliver disinfected water to the distribution system whenever the reservoir switches to a draw cycle (i.e., when treated water is sent to customers).

Operation in Fill Mode

When WTP production exceeds distribution system demand, the reservoir fills (fill mode). All flow passes through the UV facility to the reservoir, and the UV equipment operates at minimum intensity because disinfection of the influent water is not needed. The primary objective of operating the UV facility during the fill mode is to ensure that the UV equipment is on and ready to provide adequate disinfection when the reservoir switches to draw mode.

Operation in Draw Mode

When distribution system demand is greater than WTP production, water drains from the reservoir to the distribution system (draw mode). Because a UV unit is always on, there is no time delay for disinfection of outgoing water when the flow direction changes.

F.1.2.2 Operational Strategy, Instrumentation and Control

The UV equipment was designed so that at least one UV train is in service at all times to ensure that a UV unit is ready to disinfect the reservoir water whenever flow into the distribution system occurs. When system demand matches the WTP production rate, however, very little flow into or out of the reservoir occurs. To prevent high lamp temperature (and automatic shut-down), a cooling water bypass line was installed downstream of the UV equipment and upstream of each isolation valve to allow a nominal flow through the unit [approximately 80 gallons per minute (gpm)]. The cooling water line is equipped with a motor-actuated valve for automatic opening when the water temperature exceeds a set value [90 degrees Fahrenheit (°F)] or when a start-up or shut-down signal is received. During start-up of a UV unit, the cooling water flow is discharged to waste. Following start-up, all flow enters the distribution system.

The UV equipment is controlled by a central programmable logic controller (PLC) using the calculated dose-monitoring strategy. The central PLC uses flow rate and direction data from each of the four treatment trains to control the overall operation of the UV equipment and to sequence the operation of individual UV units. Input for controlling the UV equipment is provided by a strap-on flow meter on each UV treatment train, two on-line UVT analyzers in the piping header, and eight UV sensors in each UV unit. The individual control panel for each UV unit adjusts the lamp power and calculated dose of each UV unit in response to the flow rate, UVT, and UV intensity, to ensure an appropriate level of disinfection.

As the distribution system demand increases, the central PLC initiates start-up of the next UV unit once the flow rate through the first unit reaches a manually entered percentage of its rated capacity. After the second unit has warmed up (approximately 5 minutes), the central PLC opens the modulating valve for that train and brings the unit on-line. Flow is then split between the two active UV trains. This scenario continues with the other two UV units as necessary based upon distribution system demand.

F.1.2.3 Electrical Power Configuration

Power quality was not expected to be an issue at the reservoir. Therefore, power conditioning equipment for the UV equipment was not necessary. An uninterruptible power supply (UPS) was included for the UV control panel to convey alarms and other critical UV facility information. A backup diesel generator, capable of providing backup power for all elements of the UV facility, and an automatic transfer switch were also included in the design. Because the UV equipment is not on a UPS, a brief interruption of the UV disinfection occurs when the UV facility switches to the backup generator. Disinfection is reinitiated once backup power is active and the UV lamps have restarted. To minimize the number of power transfers and resulting UV lamp power interruptions, retransfer of the facility back to grid power is done manually to allow an operator to determine when conditions are appropriate for a transfer back to grid power (e.g., when the reservoir is inflowing).

F.1.2.4 Capital Costs

Bids were received upon completion of the final design, and the construction contract was awarded. The approximate cost of the UV facility at the time of construction was $3,125,000, which, when adjusted to 2006 dollars (ENR BCI = 4356), equates to approximately $3,805,000. Major cost components (in 2006 dollars) included:

- $680,000 for the UV equipment
- $2,410,000 for a new UV building and yard piping
- $360,000 for ancillary piping, valves, and controls
- $355,000 for electrical.

F.1.3 Validation

On-site validation of the UV equipment was completed in October 2003, which was prior to the promulgation of the LT2ESWTR. The validation was based on a previous draft of this guidance document. Because the guidance has changed, any new installations should follow the validation protocol described previously in this manual and not follow the example given in this section.

Two validation tests were performed at this facility. Contract validation testing was conducted to confirm that the equipment met the design criteria specified in the UV equipment procurement document. Expanded validation testing was also conducted to assess whether energy efficiency could be improved by modifying the lamp operating strategies and UV facility maintenance. The expanded validation testing was co-funded by the City of Albany and the New York State Energy Research and Development Authority (NYSERDA).

Trojan Technologies, Inc. conducted the validation testing with Dr. James Malley, Jr. (University of New Hampshire, Durham) providing third-party oversight for the contract validation testing. Christine Cotton of Malcolm Pirnie, Inc., provided third-party oversight for the NYSERDA validation testing.

F.1.3.1 Contract Validation Conditions

The validation testing procedures were based on the UV Disinfection Guidance Manual (UVDGM) Proposal Draft (USEPA 2003). The validation testing procedures in this manual and the protocol followed for Albany's on-site validation testing did not significantly differ. However, the data analysis and Validation Factor calculations do differ from those in this manual.

The validation testing was conducted at the reservoir. The challenge microorganism used in the testing was MS2 phage. Dissolved instant coffee, a UV absorber, was used to adjust the UV transmittance to the desired test conditions. There was no residual chlorine in the water; therefore, the water did not need to be dechlorinated.

Following is a summary of the range of validation conditions:

- Lamps were operated at 0 percent (off), 60 percent (to account for lamp aging and fouling effects), or 100 percent (full power) of their nominal output during the validation testing.
- Flow rates ranged from 2.0 – 10.3 mgd.
- UVT ranged from 88 – 99 percent.
- Target MS2 RED values ranged from 0 to 150 mJ/cm^2.

The test conditions and results for the validation tests are summarized in Table F.4. The UV equipment passed the contract validation testing.

F.1.3.2 NYSERDA Validation Conditions

The validation testing procedures used in the NYSERDA validation testing were the same as in the contract validation testing. The NYSERDA testing conditions follow:

- Four or six (of eight possible) lamps in the unit were energized.
- Lamps were operated at 0 percent, 60 percent, 80 percent, or 100 percent of their nominal output.
- Flow rates ranged from 2.0 – 10.0 mgd.
- UVT ranged from 87 – 100 percent.
- Target MS2 RED values ranged from 0 – 150 mJ/cm^2.

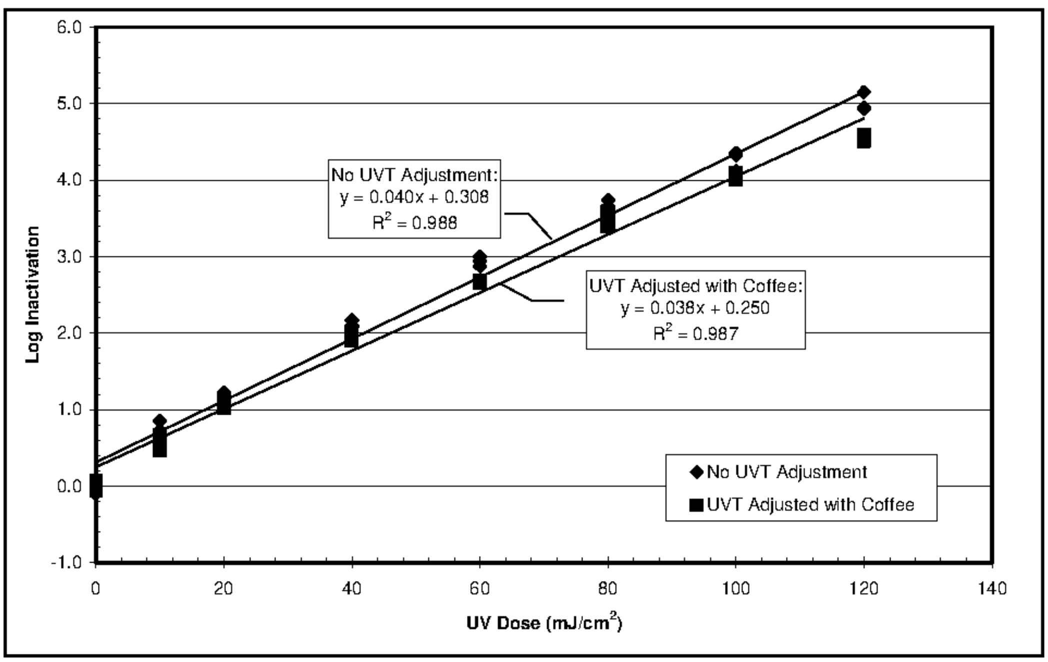
Table F.4. Validation Testing Conditions and Results for Contract Validation

Run No.	Flow (mgd)	Configur-ation	UVT Modifier	Test Organism	Lamp Power (%)	UVT (%)	Influent MS2[1] (log PFU/mL[2])	Effluent MS2[1] (log PFU/mL)	Log Reduction	MS2 RED (mJ/cm^2)
1	9.8	8 lamps on	None	None	0	98.5	0	3.15	0.00	0
2	9.7	8 lamps on	None	MS2	0	98.3	6.16	6.25	-0.09	-9.4
3	9.9	8 lamps on	None	MS2	100	98.5	6.14	0	6.14	150.3
4	9.8	8 lamps on	None	MS2	60	98.6	6.08	0	6.08	148.7
5	9.7	8 lamps on	Coffee	MS2	60	87.4	6.19	4.37	1.82	39.4
6	9.9	8 lamps on	Coffee	MS2	100	87.5	6.21	3.28	2.93	68.0
7	5.0	8 lamps on	None	MS2	60	98.5	5.78	0	5.78	141.0
8	4.9	8 lamps on	Coffee	MS2	60	87.8	5.66	3.10	2.56	58.4
9	2.0	8 lamps on	None	MS2	60	98.1	5.83	0.37	5.44	132.5
10	2.0	8 lamps on	Coffee	MS2	60	88.0	5.79	1.11	4.68	112.7
11	10.3	8 lamps on	None	None	0	98.6	0	2.99	0.00	0

[1] The value shown represents the average of three replicate samples.
[2] plaque forming units per milliliter

The collimated beam dose-response results for an example day of testing (Day 1) are shown in Figure F.6.

Figure F.6. Collimated Beam UV Dose-response Curve



The test conditions and results for the validation tests are summarized in Table F.5. The implications of the NYSERDA validation testing results on operation and maintenance (O&M) are described in Section F.1.3.4. Additional validation data analysis may be completed in the future to determine the validation factor and validated dose in accordance with the validation data analyses described in this manual (Chapter 5).

Table F.5. Validation Testing Conditions and Results for NYSERDA Validation

Run No.	Flow (mgd)	Configur-ation	UVT Modifier	Test Organism	Lamp Power (%)	UVT (%)	Influent MS2[1] (log PFU/mL)	Effluent MS2[1] (log PFU/mL)	Log Reduction	MS2 RED (mJ/cm^2)
1	10.0	6 lamps on	None	None	0	99.0	0	0	0.00	0.00
2	9.9	6 lamps on	None	MS2	0	99.2	6.25	6.18	0.06	-4.7
3	9.9	6 lamps on	None	MS2	60	99.1	5.85	0.30	5.59	140.8
4	9.9	6 lamps on	Coffee	MS2	80	87.5	5.98	3.93	2.04	47.4
5	2.0	6 lamps on	Coffee	MS2	60	87.2	6.55	2.40	4.12	102.1
6	2.0	4 lamps on	Coffee	MS2	60	87.4	6.34	3.89	2.45	58.1
7	10.1	4 lamps on	None	MS2	80	99.0	5.83	0.37	5.83	147.1
8	10.0	4 lamps on	Coffee	None	100	88.7	0	0.60[2]	0.00	0.00
9	10.0	4 lamps on	None	None	0	99.9	0	2.75[2]	0.00	0.00

[1] The value shown represents the average of three replicate samples.
[2] Test microorganisms injected in prior tests had pooled in a deadspace upstream of the UV reactor and later bled back into the main flow stream.

F.1.3.3 Issues Encountered During Validation Testing

During validation testing, the following issues were encountered:

- **Ultrasonic flow meter uncertainty.** Before the start of the contract validation testing, a discrepancy between a flow meter installed on the UV unit to be tested and an existing flow meter farther downstream was noted. The meter manufacturer was contacted, and a representative was sent to the site. A portable strap-on flow meter was installed next to the test unit flow meter; the portable meter was consistent with the test unit meter. The downstream flow meter was determined to be in error, having been set to the diameter of the casing pipe and not the diameter of the internal carrier pipe. Upon resolution of the investigation, the validation testing continued using the test unit flow meter to measure the flow rate.

- **Test organism not injected.** In the test plan, Run No. 8 of the NYSERDA validation testing should have had organisms injected. However, during the testing, no organisms were injected. Instead of re-doing the testing, Run No. 8 was used as an additional control.

F.1.3.4 Validation Implications for Operation and Maintenance

The NYSERDA validation testing results indicated that the UV equipment can achieve (and exceed) the 40 mJ/cm^2 target MS2 RED when operating in a power saving mode with only 4 or 6 (of a possible 8) lamps on and with UVT between 87 and 99 percent. When the data were analyzed in accordance with the UVDGM Proposal Draft (USEPA 2003) guidelines that were available at the time, the testing indicated that 3-log *Cryptosporidium* inactivation and 1.5-log virus inactivation, if desired, could be achieved under expanded lamp control conditions. Validation of the alternative lamp operating configuration is expected to result in cost savings from reduced power usage.

F.1.4 Start-up and Operation of the UV Facility

Construction of the facility was completed in February 2003. Full-scale operation began in March 2003.

F.1.4.1 Start-up and Construction Issues

Although some problems occurred upon initial start-up of the UV equipment, all parties involved worked to resolve the issues to the City's satisfaction. The problems and resolutions are briefly discussed below:

- **Control system.** The manufacturer's control system does not calculate the UV dose correctly during the "fill mode" conditions. Because flow is bi-directional in the inlet/outlet pipe, a negative value for flow was used in the fill condition (a positive value for the "draw mode"). It could be corrected by changing the programming to use an absolute value of the flow input in the calculation.

- **UVT analyzers.** The on-line UVT analyzers initially reported inconsistent readings. Samples were taken at the midpoint and top of the pipe. The samples taken at the top of the pipe were found to be occasionally erroneous due to air bubbles in the sample. To correct the problem, the sample ports for the on-line UVT analyzers were adjusted so that all samples were taken from the midpoint of the pipe.

- **Cleaning system.** The wiper cleaning mechanism originally provided with the UV equipment frequently jammed due to grit entering and binding the threads of a wiper system rod. The UV manufacturer refined the design and provided a replacement wiper drive system with a self-cleaning traversing nut and a rod with a larger thread pitch and depth.

- **Intensity sensors.** In several instances, the coating on the intensity sensors degraded. The UV manufacturer improved the design and provided new UV sensors for the UV reactors. The new sensors were provided prior to validation testing, so re-validation was not necessary.

- **UV lamp failure.** At start-up, approximately thirty percent of the lamps failed to energize. A similar percentage also failed to start in a second shipment of lamps. The UV manufacturer tracked the problem to a batch of lamps with manufacturing defects. The manufacturer corrected the problem and installed a new batch of lamps.

F.1.4.2 Operation and Maintenance

The following operational tasks are regularly performed at Albany's UV facility. These tasks take approximately one hour per day, seven days per week.

- Daily overall visual inspection of the UV equipment.
- Daily check of the control system to ensure it is in automatic mode.
- Daily check of the control panel display for status of UV equipment components and alarms.
- Daily check of on-line analyzers, flow meters, and data recording equipment.
- Daily review of 24-hour monitoring data to ensure that the equipment has been operating properly.
- Daily check of cleaning mechanism operation.
- Daily check of lamp run time.
- Daily check of ballast cooling fans for unusual noise.
- Weekly check of valve operation.

The City of Albany also performs regular maintenance tasks at the UV facility. Due to budget cut-backs, the original maintenance frequencies for several tasks have been reduced. The current scheduled maintenance tasks include the following:

- Monthly calibration check of UV sensors.
- As-needed calibration check of UVT analyzers. Due to the sensitivity of these analyzers and re-calibration difficulties described in Section F.1.4.3, the calibration of these analyzers is checked only when problems are evident (every few months). The calibration was formerly checked weekly.
- Quarterly to annual check of equipment housing, sleeves, and wiper seals for leaks.
- As-needed replacement of the duty sensor with a calibrated back-up sensor. To date, replacement has been unnecessary.

- Annual check of the cleaning system efficiency by inspecting and manually cleaning the sleeves. This maintenance was previously performed quarterly.
- Quarterly check of the cleaning fluid reservoir.
- Annual calibration of the reference sensor by the manufacturer.
- As-needed replacement of lamps that have broken or are at the end of their lamp life (currently replaced after 4,000 hours). Approximately 20 lamps have been replaced in the first 2 years of operation.
- As-needed replacement of sleeves that have broken or fouled. To date, approximately 3 sleeves have been broken and replaced.
- As-needed cleaning of UVT analyzers.
- As-needed inspection of cleaning system drive mechanism.
- As-needed inspection of ballast cooling fan.

Performance of these tasks is currently estimated to take approximately two hours per week per unit (8 hours per week total). An additional 8 hours per month is spent on troubleshooting. Before the cut-backs, performance of these tasks at the recommended frequency (Sections 6.3.1 and 6.4.1.4) took an estimated eight hours per week per unit (32 hours per week total).

F.1.4.3 Operational Challenges

Although the City generally has found the facility to be relatively simple to operate, a few challenging conditions have been encountered:

- **UVT analyzers.** Due to the very high UVT of the water (typically 95 percent), the City's maintenance personnel have difficulty calibrating the UVT analyzers.
- **Wiping collar maintenance.** The City's maintenance personnel have had problems re-aligning the cleaning system's wiper collars on the sleeves when the collars have been completely removed from the equipment for maintenance. Difficulties with this maintenance task have resulted in several broken sleeves.
- **UV equipment draining.** Inadequately sized drains in the UV unit delay maintenance because of the excessive time needed to drain water.

F.1.5 Future UV Facility Plans

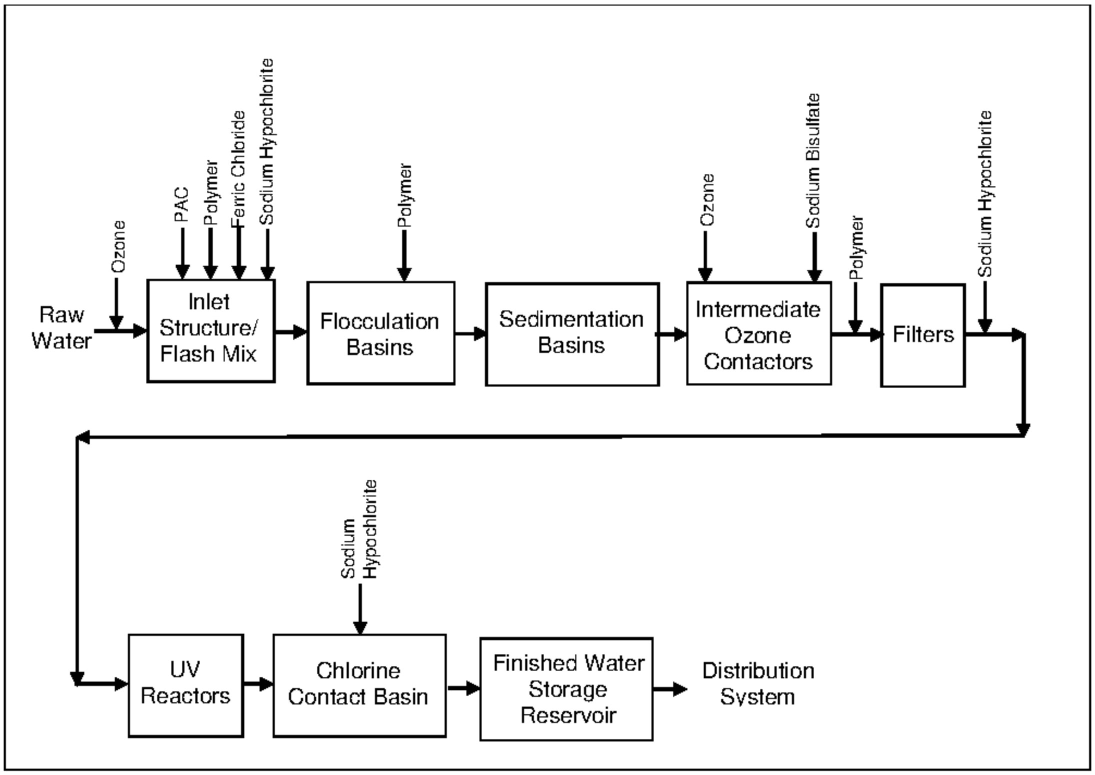
Because very few data were available on the water quality at the reservoir, a conservative UVT of 88 percent was selected for the design of the UV equipment. However, full-scale operating data indicate that the UVT of the water at the reservoir is actually much greater (approximately 95 percent), which enables the City of Albany to target virus inactivation with its UV facility over a larger range of flow rates when the reservoir is functioning as distribution storage. Albany's validation data indicate that the facility can achieve 1.5-log virus inactivation and could likely be validated for greater virus inactivation if an appropriate challenge organism can be identified. Therefore, credit for greater than 1.5-log virus inactivation may be sought in the future.

F.2 Weber Basin Water Conservancy District – LPHO Facility with Off-site Validation

The Weber Basin Water Conservancy District (District) was established in 1950 to provide for the conservation and development of the water resources within the District boundaries and to use these resources to the greatest benefit of the public. The District is currently a drinking water wholesaler, serving a total population of approximately 400,000 people.

The District's Weber WTP No. 3 is a 46-mgd conventional WTP with settled water ozonation for taste and odor control and UV light for enhanced disinfection (Figure F.7). The plant was expanded to its present capacity and other improvements were made in 2001.

Figure F.7. Weber WTP No. 3 Process Flow Diagram



The primary raw water supply for the Weber WTP No. 3 is the Weber River, delivered through the Davis Aqueduct to the plant. Miscellaneous side creeks can also be used by the District to supplement irrigation water or for a raw water supply for the Weber WTP No. 3. The creeks are diverted directly to the plant intake without any upstream storage. There are no independent water quality data on these two supplies.

The raw water quality at the Weber WTP No. 3 can vary significantly throughout the year. Storm events and spring run-off can increase turbidity rapidly. Algal blooms cause taste and odor problems, especially in the late summer and fall. Raw water quality data for 1996 to 1998 is summarized in Table F.6, and Table F.7 summarizes Weber WTP No. 3 filtered water quality.

Table F.6. Summary of Raw Water Quality (1996 – 1998)

Parameter	Units	Average	Minimum	Maximum
Turbidity	NTU	29.2	0.3	3,800
pH	-	7.5	6.6	8.5
Alkalinity	mg/L as $CaCO_3$	177	58	268
Temperature	°C	10.4	2.0	19.6
Total Hardness	mg/L as $CaCO_3$	215	142	264
Calcium Hardness	mg/L as $CaCO_3$	N/A	N/A	N/A
Iron	mg/L	N/A	N/A	N/A
Manganese	mg/L	N/A	N/A	N/A
Total Organic Carbon	mg/L	3.2[(1)]	1.1	7.6

[1] Data collected at Weber WTP No. 3.

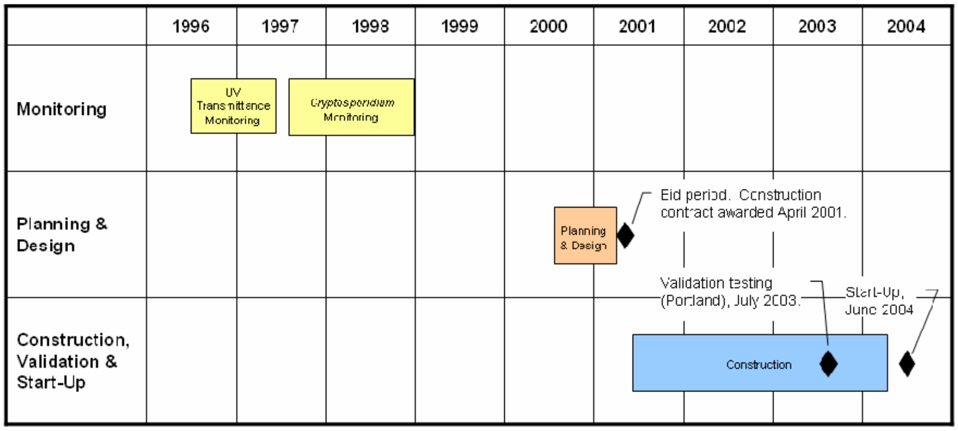
Table F.7. Summary of Filtered Water Quality (2002 – 2004)

Parameter	Units	Average
Turbidity	NTU	< 0.15
pH	–	7.40
Alkalinity	mg/L-$CaCO_3$	180
Temperature	°C	10.7
Total Hardness	mg/L-$CaCO_3$	225
Calcium Hardness	mg/L-$CaCO_3$	N/A
Iron	mg/L	< 0.02
Manganese	mg/L	Below detection limit
Total Organic Carbon	mg/L	< 3

F.2.1 Planning

This section discusses key planning decisions made for Weber Basin's UV facility. Figure F.8 is a timeline of the process the District used to implement UV disinfection.

Figure F.8. Weber WTP No. 3 UV Implementation Timeline



F.2.1.1 UV Disinfection Goals

Raw water monitoring by the District indicated that the water system could be classified as a Bin 2 or Bin 3 system under the LT2ESWTR. (See Section 1.3.1.) For the purposes of the preliminary design, it was assumed that the water system could either initially or ultimately be classified as a Bin 3 system, which would require the UV facility to provide 2.0-log additional *Cryptosporidium* inactivation.

As part of the preliminary design process for the UV facility and other plant improvements, the District reevaluated its *Giardia* treatment. Before the 2001 improvements, the Weber WTP No. 3 used free chlorine for disinfection of *Giardia* and viruses. Following the 2001 improvements, the finished water reservoirs had sufficient capacity to continue to provide the required level of *Giardia* and virus inactivation. However, the use of free chlorine for 3-log *Giardia* inactivation in the finished water reservoirs was discontinued for the following reasons:

- The UV reactors could easily be designed for both *Giardia* and *Cryptosporidium* inactivation.
- Incorporating *Giardia* disinfection with the proposed *Cryptosporidium* disinfection process would make a significant portion of the existing finished water reservoirs available for operational storage to benefit the distribution system.

Table F.8 summarizes the treatment goals for the Weber WTP No. 3.

F.2.1.2 UV Retrofit Location

Because of existing hydraulic constraints, the UV reactors could be installed only downstream of the filters (see Figure F.7).

Table F.8. Disinfection Goals

Process	*Cryptosporidium*	*Giardia*	Virus
Filters	3.5[(1)]	2.5	2.0
UV Light	2.0	2.0	–
Chlorine	–	1.0	4.0
Total Provided	**5.5**	**5.5**	**6.0**

[1] Combined filter effluent turbidity 0.15 NTU in 95 percent of samples each month to provide a second barrier.

F.2.1.3 Key Design Parameters

Water quality, fouling/aging factor, and flow rate are critical parameters to be considered during the planning phase. Table F.9 summarizes key preliminary design parameters for the UV reactor design.

Table F.9. UV Facility Preliminary Design Parameters

Criterion	Unit	Value
UV Transmittance	percent	90
Fouling/Aging Factor	percent	67
Flow Rate	mgd	15.3

Water Quality

Several water quality parameters affect UV dose delivery and, therefore, UV reactor design. (See Table F.7.) The most important is UVT, which is calculated from the UV absorbance at 254 nm (A_{254}) as described in Section 3.4.4.1. Based on the available UV absorbance data, a design UVT of 90 percent (A_{254} of 0.046 cm^{-1}) was selected (Figures F.9 and F.10).

Fouling/Aging Factor

A fouling/aging factor of 67 percent was selected during planning. The factor was incorporated into the design to account for the reduction in lamp output at the end of lamp life and the reduction in lamp output due to irreversible sleeve fouling.

Flow Rate

The UV facility capacity was designed to match the 46-mgd WTP capacity with three units in operation and one unit out of service. Therefore, the design flow rate through each reactor was 15.3 mgd.

Power Quality

To ensure operation of the UV equipment, standby power was provided with a new backup generator. No other power conditioning equipment was needed.

Figure F.9. UVT Data for Weber WTP No. 3 Finished Water

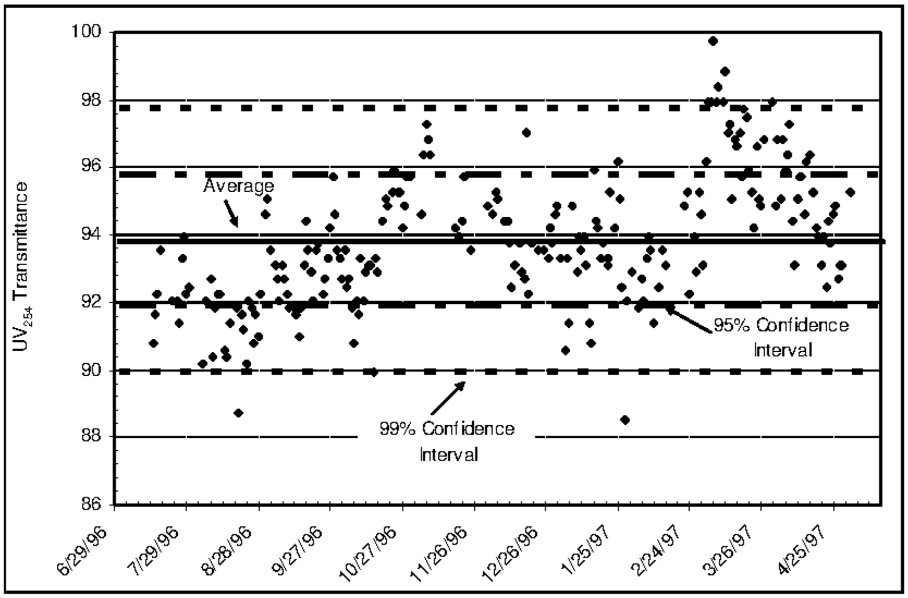
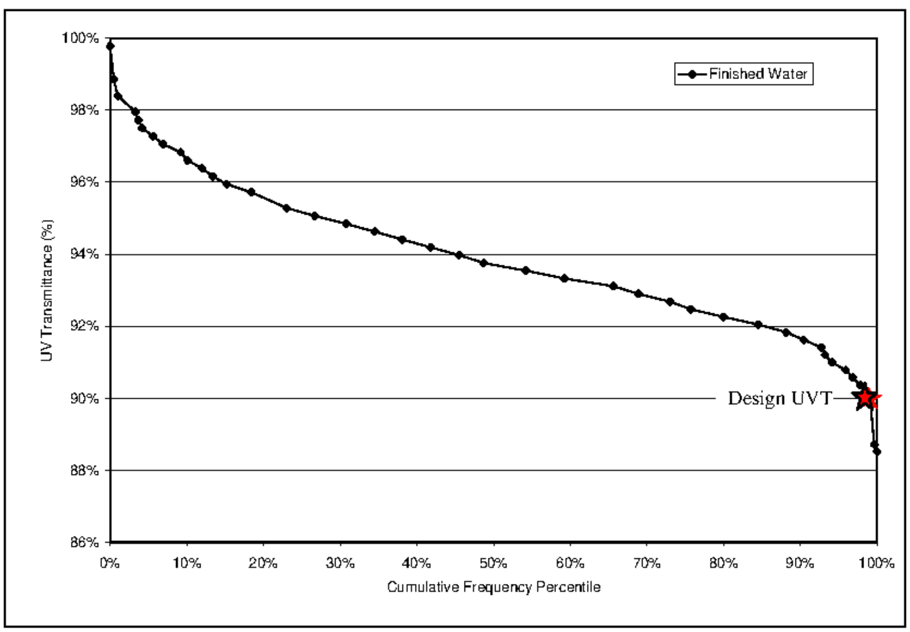


Figure F.10. Cumulative UVT Data for Weber WTP No. 3 Finished Water



F.2.1.4 Equipment and Monitoring Strategy

Because both MP and LPHO reactors were considered for the design, the footprint for the larger LPHO reactors was used for planning. The District selected variable setpoint operation based on flow rate for the UV equipment to conserve power.

F.2.1.5 UV Reactor Validation Options

Off-site validation was selected for the following reasons:

- Discharge of validation test water from on-site validation testing was not feasible.
- At the time, UV disinfection was an innovative process without references for potable water applications in the United States. Therefore, off-site validation prior to delivery was deemed a reasonable validation option.

F.2.1.6 Hydraulics

Changes to the plant's hydraulic profile were made as part of the overall plant expansion and improvements in 2001. The UV reactors fit into the plant's new hydraulic profile at the combined filter effluent without need for additional modifications or intermediate pumping.

F.2.1.7 Selected Configuration

Only UV reactor manufacturers that had validated a reactor were considered for the design, but pre-validation of the proposed UV reactor was not required. A bid specification was written before design of the UV facility. The base bid was for LPHO reactors with alternate bids allowed for MP reactors. Although the UV equipment was not pre-purchased, bids were evaluated, and the detailed design was based on the selected manufacturer (WEDECO Inc.). The selected configuration of the UV reactors is summarized in Table F.10. The target MS2 RED to be verified in validation was selected to target high-level inactivation of various pathogens based on best practices in North America and Europe at the time. The selected configuration has one sensor for every bank of lamps and has one UVT analyzer.

Table F.10. UV Reactor Configuration

Criterion	Unit	Value
UV Lamp Type	–	LPHO
MS2 RED[1]	mJ/cm^2	40
Number of UV Units (Duty + Standby)	number	3 + 1
Design Flow Rate per Unit	mgd	15.3
Number of Banks per Unit	number	6
Number of Lamps per Bank	number	12
Lamp Power (Each)	W	360

[1] The MS2 RED to be proven during validation testing.

F.2.2 Design

The following sections describe the UV facility design in more detail.

F.2.2.1 Facility Hydraulics

The UV reactors were installed on the combined filter effluent to fit into the plant's hydraulic profile. Filtered water from a common header is passively divided into four 30-inch influent pipes to the UV reactors. To compensate for a possible uneven flow split, upstream isolation valves can be manually throttled. The head loss through the UV reactors, ancillary piping, and valves is 2.3 feet of water at maximum plant capacity (46 mgd). Effluent weirs are installed to ensure that the reactors remain submerged.

F.2.2.2 Operational Strategy, Instrumentation and Control

The UV supplier provided a variable setpoint control strategy based on a UV Intensity Setpoint Approach. In this approach, the minimum UV intensity values determined during validation can be set for several flow rate ranges. The UV ballast system has 50 to 100 percent variable power capabilities, allowing the UV reactor to automatically adjust based on relative sensor intensity and flow rate to conserve power (see section F.2.3.1 for details). For the UV reactor to stay in compliance (i.e., to ensure minimum UV dose delivery), the UVT must remain at or above the minimum value (90 percent), the flow rate through the reactor must be less than or equal to the maximum validated flow rate, and the UV sensor values must all be at or above the UV intensity setpoint for that flow rate and number of lamp banks on as determined by the validation data (See Section F.2.3.).

Flow meters and flow control valves were not provided for each reactor. However, each reactor was provided with UV sensors. Additionally, a motorized valve downstream of each reactor remains closed during start-up until the reactor is on and warmed up. Therefore, off-specification water is not delivered to consumers and does not need to be wasted during reactor start-up.

F.2.2.3 Electrical Power Configuration

An electrical engineer reviewed power fluctuations and quality at the WTP and determined that power conditioning equipment was not needed. However, standby power was provided with a new backup generator to ensure continuous UV equipment operation.

F.2.2.4 Capital Costs

The UV facility construction was part of a larger expansion and improvement project. The portion of the construction cost attributed to the UV facility was $2,230,000 in 2006 (ENR BCI = 4356) dollars. Major cost components included:

- $1,210,000 for the UV equipment.

- $400,000 for a new UV building.
- $250,000 for ancillary piping, valves, and controls.
- $370,000 for electrical improvements.

F.2.3 Validation

Off-site validation testing was originally conducted at the Deutsche Vereinigung des Gas- und Wasserfaches (DVGW) facility in Germany. However, validation testing at the DVGW facility proved problematic because the strict DVGW requirements do not allow flexibility in validation or operation setpoints. As such, further validation testing at the Portland Validation Facility was conducted in July 2003. The second validation was in accordance with the U.S. guidelines based on the UVDGM Proposal Draft (USEPA 2003).

The Portland Validation Facility is located at the City of Portland, Oregon Bureau of Water's Groundwater Pumping Station of the Columbia Southshore Wellfield, Portland, Oregon. The Columbia Wellfield is a 90-mgd supplemental drinking water supply that the Portland Water Bureau owns and operates. The wellfield provides up to 43 mgd of continuous flow to the UV reactor test train. Typical water quality of the groundwater is shown in Table F.11

Table F.11. Southshore Wellfield Water Quality Characteristics

Parameter	Unit	Value
UVT	%	96.8 – 98.6 (98.3 average)
Hardness	mg/L	38 – 144
Alkalinity	mg/L $CaCO_3$	34 – 169
pH	unitless	5.8 – 8.8
Chlorine	mg/L	none

The high UVT allowed testing of the full range of operating UVT conditions, and the zero chlorine residual eliminated the need to quench the chlorine prior to adding chlorine-sensitive challenge microorganisms.

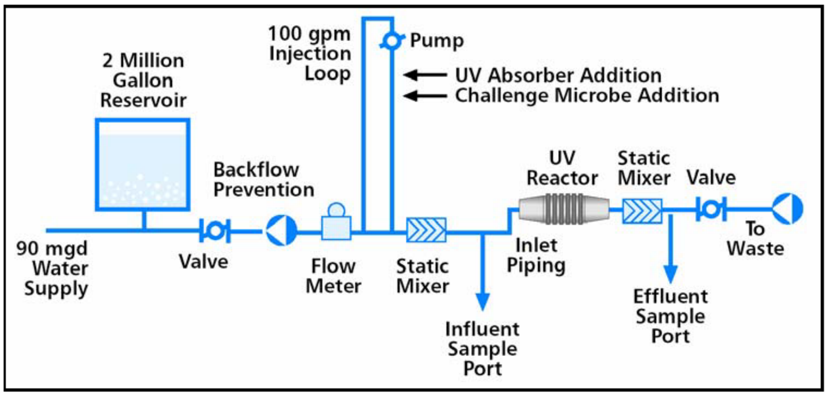
Carollo Engineers conducted the validation testing. Clancy Environmental Consultants (CEC), St. Albans, Vermont, supervised the injection and sampling of the challenge microorganism. CEC prepared all stock solutions of the challenge microorganism, measured challenge microorganism UV dose-response using the collimated beam apparatus, and assayed challenge microorganism concentrations. WEDECO Inc. (Charlotte, North Carolina) operated the UV reactor during biodosimetry testing with oversight by Carollo.

F.2.3.1 Validation Conditions

The Portland Validation Facility allowed testing conditions (e.g., piping configuration) to be defined for each validation test, which allowed the testing to be optimized to US guidelines based on the UVDGM Proposal Draft (USEPA 2003). The Weber WTP No. 3 reactor was validated with inlet piping that included a 90-degree bend located three pipe diameters upstream of the reactor and another 90-degree bend less than three pipe diameters downstream of the reactor. This configuration did not represent the actual piping arrangement at the Weber WTP No. 3 but, instead, represented the "worst case" flow conditions through the UV reactor.

The high UVT of the Columbia Wellfield water allowed the full range of UVT conditions to be tested. Lignin sulfonic acid (LSA), a UV absorber, was used to reduce the UVT as needed. The challenge microorganism used in the validation testing was MS2 phage. Static mixers were used to ensure that additives were well mixed upstream of the reactor inlet sampling port and the reactor exit sampling port. The testing configuration is shown in Figure F.11.

Figure F.11. Validation Testing Configuration



The UV reactor was tested using a range of flow rate, UVT, and operating lamp combinations to validate UV dose delivery and UV sensor measurements. The experimental matrix was designed to validate the vendor's UV intensity setpoint approach with variable setpoint operation for a range of water quality conditions within the defined design criteria. The experimental matrix also was intended to enable the PWS to optimize performance (i.e., deliver the target MS2 RED with a minimal number of lamp banks in operation at a minimum power level).

Following is a summary of the range of validation conditions:

- All lamps were operated at 67 percent of their nominal output during the validation testing to account for lamp aging and fouling effects.
- Flow rates ranged from 0.94 – 20 mgd.

- UVT ranged from 85 – 95 percent.
- The number of lamp banks that were on was 1, 2, 4, 5, and 6 (all banks).
- Target MS2 RED values ranged from 20 – 100 mJ/cm^2.

The test conditions and results for several of the 34 validation tests that were conducted are summarized in Table F.12.

Table F.12. Excerpt of Test Conditions for Validation Testing at the Portland Validation Facility (Total No. of Tests = 34)

Run No.	Flow Rate (mgd)	No. Banks On	UVT (%)	UVT Modifier	Test Organism	Lamp Power (%)
12	2.07	2	84.7	LSA	MS2	67
9	2.36	1	95.0	LSA	MS2	67
3	0.94	1	84.7	LSA	MS2	67
16	17.61	2	94.8	LSA	MS2	67
36	19.57	6	94.8	LSA	MS2	67
22	20.00	4	89.9	LSA	MS2	67
38	14.49	5	90.1	LSA	MS2	67
19	15.65	4	85.0	LSA	MS2	67
29	12.07	6	85.3	LSA	MS2	67

The collimated beam dose-response results for an example day of testing are shown in Figure F.12, and Table F.13 summarizes validation testing results.

UV transmittance measurements were checked using National Institute of Standards and Technology (NIST)-traceable UV absorbance standards. Flow measurements were checked by comparison of manufacturer calibration to internal settings. The UV dose-response of the MS2 phage met bounds described by the UVDGM Proposal Draft (2003) and NWRI (2003). Biodosimetry and sensor testing and data analysis were based on the June 2003 Draft UVDGM recommendations (Tier 2 analysis).

Figure F.12. Collimated Beam UV Dose-response Data

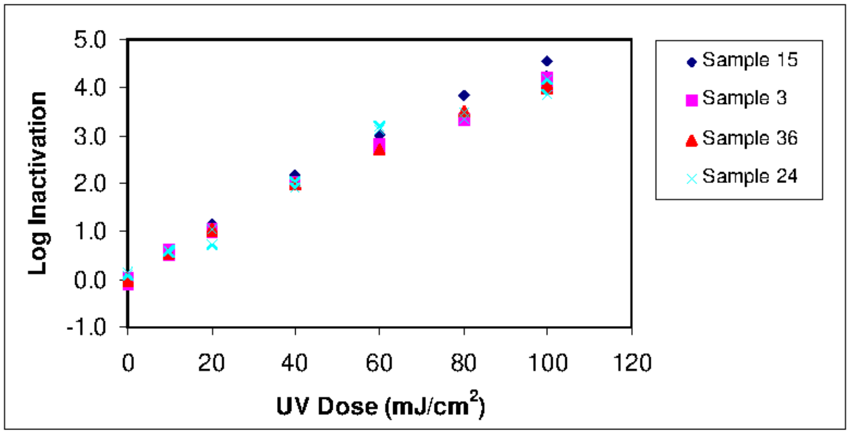


Table F.13. Validation Testing Results

Run No.	Flow Rate (mgd)	No. Banks On	Lamp Power (%)	UVT (%)	Log Infl. MS2 (pfu/mL)	Log Effl. MS2 (pfu/mL)	Log I	MS2 RED (mJ/cm^2)
12	2.07	2	67	84.7	5.04	2.16	2.88	57.9
9	2.36	1	67	95.0	5.29	0.97	4.32	96.0
3	0.94	1	67	84.7	5.38	2.41	2.97	66.9
16	17.61	2	67	94.8	4.69	3.23	1.46	28.4
36	19.57	6	67	94.8	5.32	2.00	3.32	76.7
22	20	4	67	89.9	4.69	3.45	1.24	23.6
38	14.49	5	67	90.1	4.81	2.73	2.07	42.9
19	15.65	4	67	85.0	4.76	3.53	1.23	23.4
29	12.07	6	67	85.3	4.67	2.57	2.09	41.6

The measured relationship between UV sensor measurements and UVT at the 80 percent intensity turn-down reflecting end-of-lamp-life (EOLL) was described using a power function (A and B are constants):

$$UV\ Sensor\ (UVT, EOLL) = e^{A} e^{B \times UVT} \qquad \text{Equation F.1}$$

The functions describing the UV sensor measurements as a function of ballast power setting and UVT were obtained using new lamps, sleeves, and UV sensors in a clean UV reactor. The functions can be compared to measurements made at a WTP to assess the relative output of the lamps compared to the data measured during validation.

The test results were evaluated by plotting measured MS2 RED (mJ/cm^2) as a function of number of operating banks divided by flow rate (Q in mgd), again based on a specific UVT value and at the intensity turn-down reflecting end-of-lamp-life. Statistical analysis was used to determine if data sets obtained with different rows could be combined. The relationship was fitted by a polynomial function (A and B are constants):

$$RED\ (UVT, EOLL) = A\left(\frac{Banks}{Q}\right) + B\left(\frac{Banks}{Q}\right)^2 \qquad \text{Equation F.2}$$

Based on these equations, an automatic UV dose-monitoring strategy was developed that determined the necessary number of banks/rows in operation and the ballast power, so that a selected target MS2 RED (e.g., 40 mJ/cm²) is met.

F.2.3.2 Validation Implications for O&M

The validation testing data were used to develop equations that would automatically determine the needed number of banks in operation and ballast power so that the selected target MS2 RED (e.g., 40 mJ/cm^2) could be provided.

F.2.4 Start-Up and Operation of the UV Facility

Full-scale operation of the facility began in June 2004. Photos of the UV equipment are shown in Figures F.13 and F.14.

Figure F.13. UV Reactors at the Weber WTP No. 3 (3 duty + 1 standby reactor in parallel)

Figure F.14. UV Reactor Electrical Cabinets at the Weber WTP No. 3 (the floor above the UV reactors)

F.2.4.1 Start-up and Construction Issues

Since start-up, the UV facility has been operating as intended (no frequent UV unit shut-downs, lamp failures, or similar mechanical problems). However, as with any new unit process, some problems have been experienced, including the following:

- **UV-monitoring system.** Not all of the low-level alarm settings and controls in the monitoring system software worked properly in the first version of software provided. The vendor subsequently updated the software.

- **Manganese fouling.** Sleeve and sensor fouling was a serious problem when the UV equipment was first started. Although dissolved manganese concentrations were not measured, the problem began when the District began adding ferric chloride for coagulation. Analysis of the foulant indicated that manganese, an impurity present in the coagulant, caused the fouling. To control this problem, hypochlorite was fed upstream of the filters to oxidize the manganese, which was then removed by the filters. The District plans to discontinue the hypochlorite feed once the intermediate ozonation system is fully operational.

- **Cleaning system.** The phosphoric acid chemical cleaning system originally intended for use with the UV reactors was installed on a cart on the upper level of the UV disinfection room. A long hose with a spray-nozzle attachment was to be hand-carried to the lower level and inserted into the UV reactors for cleaning. However, the cleaning system could not provide enough suction to work properly with the cart located on the upper level, and the cart could not be moved to the lower level due to mobility constraints. Therefore, a new chemical cleaning system that could provide appropriate pumping power was constructed on the lower level adjacent to the UV reactor.

- **Control panel.** The UV equipment was designed with one transformer for each ballast enclosure. During the first summer of operation, the enclosures overheated and had to be opened so the transformers could be cooled with box fans. The manufacturer recommends that the temperature in the control room not exceed 100 °F. The temperature in this room was not measured during the first summer of operation, so whether the overheating was due to an inadequate or faulty control panel cooling system or to high temperatures in the control room is unknown. The source of this problem remains under investigation.

- **Training.** The manufacturer did not provide on-site operator training on UV reactor O&M until after the UV equipment had been operating for several months.

F.2.4.2 Operation and Maintenance Requirements

The UV sensors are calibrated monthly, and no sensor drift has been observed since the facility has been operational. Similarly, the online UVT analyzer is also checked monthly and no drift has been observed. No lamps have been replaced since the UV facility began operations, and no chemical cleaning has been performed. Inspections of some of the lamps, however, reveal no signs of fouling. Information on the amount of labor required to perform these O&M tasks was not readily available. No information was readily available on power usage.

F.2.4.3 Operational Challenges

Except for resolving the start-up and construction issues (Section F.2.4.1), the District has generally found the facility to be relatively simple to operate.

F.2.5 Future UV Facility Plans

The District plans to apply to the Utah Department of Environmental Quality for approval of the UV disinfection system for *Cryptosporidium* and *Giardia* credit in the future.

The District may target different *Cryptosporidium* and *Giardia* inactivation levels in the future to respond to future regulatory requirements. The UV manufacturer has provided curves showing flow rate versus number of UV lamp banks in operation for three different MS2 RED (20, 30, and 40 mJ/cm^2) to enable future operational flexibility.

F.3 Clayton County Water Authority – LPHO Facility with On-site Validation

The Clayton County Water Authority (CCWA) owns and operates three WTPs, which serve more than 250,000 people in Clayton County, Georgia. The Freeman Road WTP is a 12-mgd conventional surface WTP. Chlorine dioxide is applied prior to the rapid mix process to oxidize taste and odor compounds and iron and manganese, and free chlorine is applied to the filtered water for disinfection. In 2002 the plant was upgraded to include a UV disinfection facility. The filtered water quality characteristics that were the basis for the UV reactor design are summarized in Table F.14.

Table F.14. Summary of Freeman Road WPP Filtered Water Quality

Parameter	Units	Design Value
Turbidity	NTU	0.18
pH	–	8.1
Alkalinity	mg/L-$CaCO_3$	29
Iron	mg/L	0.1
Manganese	mg/L	0.02
Total Organic Carbon	mg/L	< 2

F.3.1 Planning and Design

This section discusses the key planning and design decisions made for CCWA's UV facility.

F.3.1.1 UV Disinfection Goals

The UV equipment was installed at the Freeman Road WTP to provide an additional pathogen barrier. The basis for the facility design was 2.5-log *Cryptosporidium* inactivation. UV disinfection was selected over other disinfection technologies because of its effectiveness against pathogens and its cost-effectiveness.

F.3.1.2 UV Retrofit Location

The UV reactors were installed on the combined filter effluent piping in a new stand-alone building. As part of the UV retrofit, chemical feeds for lime, fluoride, phosphoric acid, and chlorine were relocated to follow the UV reactors.

F.3.1.3 Key Design Parameters

The UV reactors for the Freeman Road WTP were bid and selected before detailed design of the facility. The bid was open to LPHO and MP reactors. A life cycle cost analysis that incorporated the capital costs and the anticipated energy and maintenance costs was used to select the UV reactors. Ultimately, LPHO reactors were selected for the Freeman Road WTP. After selecting the reactors, one set of plans and specifications was developed for the design. The UV facility consisted of three WEDECO Series K reactors. Key design parameters for the UV reactors are shown in Table F.15. A conservative MS2 RED (50 mJ/cm^2) to be verified during validation testing was selected because the design was to be completed while the LT2ESWTR and this manual were still under development.

Table F.15. UV Reactor Design Parameters

Criterion	Unit	Value
UV Transmittance	percent	91
Fouling/Aging Factor	percent	60
Total Flow Rate	mgd	12
Target MS2 RED[1]	mJ/cm^2	50
Number of UV Units (Duty + Standby)	number	2 + 1
Design Flow Rate per Unit	mgd	6
Number of Lamps per Unit	number	30
Lamp Power (Each)	W	275

[1] The MS2 RED to be proven during validation testing.

Facility Hydraulics

No modifications to the plant hydraulics were required at the Freeman Road WTP because the available head between the filter effluent control weir and the clearwell was sufficient for the UV reactors.

Operational Strategy, Instrumentation and Control

A magnetic flow meter is installed in the piping upstream of each UV reactor to monitor the flow split between the reactors. Each UV reactor is equipped with three UV sensors, one for each bank of lamps. Additionally, an on-line UVT analyzer enables the UV reactors to be operated with either a (1) UV Intensity Setpoint Approach or (2) Calculated Dose Approach. However, the UV equipment has not yet been validated for operation in calculated dose mode.

Electrical Power Configuration and Power Quality

A UPS was provided at the Freeman Road WTP to ensure that the UV equipment remains in continuous operation. No power quality or outage issues have been experienced at the facility.

Capital Cost

The total capital cost for the UV facility at the Freeman Road WTP was approximately $2,170,000 in 2006 (ENR BCI = 4356) dollars. The cost includes all elements related to the UV facility, the building, UV reactors, piping, valves, electrical system, instrumentation and controls, and other ancillary equipment.

F.3.2 Validation

Validation testing was conducted in February 2003. On-site rather than off-site validation was selected to maximize flexibility in selecting the specific operating conditions for testing and in allowing potential future testing as EPA requirements are established.

One of the three reactors was designed to serve as a test reactor for on-site validation. The inlet and outlet piping to the test reactor can be isolated, and the outlet piping allows flow to be routed to waste. The other two UV reactors and their upstream and downstream piping are identical in design to the test reactor, so the testing was representative of each of the other reactors.

Preliminary testing before validation indicated that nearly complete die-off of the MS2 phage had occurred in both the influent and effluent samples from the UV reactor. Although the chlorine dioxide preoxidation system had been shut down several days before testing, jar test results indicated that low levels of chlorate or chlorine dioxide caused the die-off. The jar tests also indicated that the effect of the chlorate or chlorine dioxide on the MS2 could be alleviated by adding LSA, a compound commonly used during validation to reduce UVT. The problem was therefore resolved by spiking the microbial samples with LSA before shipping them to the laboratory for analysis.

The challenge microorganism used in the testing was MS2 phage. A dilute LSA solution was used to reduce the UVT as needed in the filtered water and to prevent die-off in the MS2 samples. The results of the validation testing are shown in Table F.16.

Table F.16. Validation Testing Conditions and Results for CCWA's Freeman Road WTP

Run No.	Flow (mgd)	Configuration[1]	UVT Modifier	Test Organism	Lamp Power (%)	UVT (%)	Influent MS2 (log PFU/mL)	Effluent MS2 (log PFU/mL)	Log Reduction	MS2 RED (mJ/cm^2)
1F	5.41	3 banks on	LSA	MS2	50	91.2	5.35	2.76	2.59	57.2
2F	5.95	3 banks on	LSA	MS2	50	90.8	5.44	2.96	2.48	54.1
3F	6.49	3 banks on	LSA	MS2	50	90.7	5.43	3.30	2.13	44.6
4F	7.29	3 banks on	LSA	MS2	50	91.9	5.48	3.46	2.02	41.7
5F[2]	7.39	3 banks on	LSA	MS2	–	–	5.54	5.57	-0.04	–

[1] Each reactor contains 3 banks with 10 lamps per bank.
[2] Control run

F.3.3 Start-up and Operation of the UV Facility

Construction of the UV facility at the Freeman Road WTP was completed in December 2002, and full-scale operation began in April 2003. At the time of publication, operations and maintenance data were not made available for the Freeman Road WTP.

Although the UV equipment has generally operated well since start-up, an issue requiring a minor change did arise in the first year. In October 2003 after several months of operation, WEDECO replaced the UV lamps in the reactors with a new production model. The new lamps were tested to ensure that the UV intensity of the replacement lamps (following a 100-hour burn-in period) was equal to or better than the intensity of the lamps that had been replaced. However, comparison of the intensity data for the replacement lamps to the data that had been collected during validation indicated that the intensity of the replacement lamps was less than that of the previous lamps.

An investigation of the problem determined that microbubbles in the water passing through the UV reactor were causing the measured decrease in UV intensity, not the replacement lamps. The existing air release valve on each reactor did not sufficiently release entrained air from the water, particularly in colder months due to the higher dissolved oxygen concentration in the water. To alleviate the problem, two additional air release valves were installed on the influent header between the filter control weir (the source of the entrained air) and the UV reactors. The additional air release capability minimized the formation of microbubbles during periods of low water temperature.

F.4 Newark Water Treatment Plant – MP Reactors on Each Filter Effluent Pipe

The Newark WTP, located in Newark, Ohio, is a 15-mgd surface WTP. The Newark WTP has an average daily flow rate of approximately 8 mgd and serves a population of more than 47,500 people. Treatment processes at the Newark WTP include preoxidation with potassium permanganate and powdered activated carbon for removal of taste- and odor-causing contaminants, lime softening, sedimentation, recarbonation, rapid sand filtration, and disinfection with UV light and chlorine.

The filtered water quality characteristics that were the basis for the UV reactor design are summarized in Table F.17.

Table F.17. Summary of Newark WTP Filtered Water Quality

Parameter	Units	Average	Minimum	Maximum
pH	–	7.6	7.2	8.2
Turbidity	NTU	0.23	0.18	0.53
Total Alkalinity	mg/L-$CaCO_3$	60	40	100
Total Hardness	mg/L-$CaCO_3$	120	90	160
Calcium Hardness	mg/L-$CaCO_3$	67.4	75	60
Iron	mg/L	0.03	0.01	0.10
Manganese	mg/L	0.02	0.01	0.03
Temperature	ºF	60	33	80
Total Organic Carbon	mg/L	1 – 2	No data	No data

F.4.1 Planning and Design

This section discusses the key planning and design decisions made for Newark's UV facility.

F.4.1.1 UV Disinfection Goals

UV disinfection was installed at the Newark WTP to provide an additional treatment barrier against pathogens and to ensure public health protection in the event of high turbidity in the raw water. The City's water source has historically experienced turbidity spikes following rainfall events.

F.4.1.2 UV Retrofit Location

Three locations were considered for the UV reactors. Two locations were on the combined filter effluent at the plant's chlorine contact basin that is used to achieve chlorine disinfection requirements. This basin is located prior to the clearwell and finished water pump station. The third location considered was on each of the ten individual filter effluents (IFE). The IFE location was selected because both the capital and O&M costs were less than the costs for the other alternatives. Additionally, the IFE location provided a high degree of redundancy and O&M enhancements due to the number of reactors.

To accommodate the retrofit, filter effluent piping had to be rearranged on four filters to provide the desired straight piping runs upstream and downstream of the reactor. Also, existing valves on two filters had to be rotated 90 degrees to provide sufficient clearance to service the reactors. Figure F.15 illustrates the UV reactor installation on one of the filter effluent pipes.

Figure F.15. UV Reactor at the Newark WTP

F.4.1.3 Key Design Parameters

The UV reactor specification allowed MP reactors only because LPHO reactors could not meet the space constraints of this application. The competitive bid resulted in the selection of Trojan's 12-inch UVSwift™ reactor because the other bidder could not meet the head loss requirement. The UV equipment was selected prior to design and purchased as part of the UV facility construction contract.

Key design parameters for the UV reactor are shown in Table F.18. The target MS2 RED of 40 mJ/cm^2 to be verified in validation was selected based on best practices in North America and Europe at the time to inactivate a range of pathogens.

Table F.18. UV Reactor Design Parameters

Criterion	Unit	Value
UV Transmittance	percent	85
Fouling/Aging Factor	percent	80
Total Flow Rate	mgd	15
MS2 RED[1]	mJ/cm^2	37
Number of UV Units	number	10
Design Flow Rate per Unit	mgd	1.5
Number of Lamps per Unit	number	4
Lamp Power (Each)	kW	1.26

[1] The MS2 RED to be proven during validation testing.

Facility Hydraulics

The head losses created by the UV reactors and the necessary piping modifications were less than 6 inches at the maximum flow rate through the reactors. Therefore, no additional pumping or other hydraulic modifications were required for the addition of the UV reactors. Each reactor was rated for a maximum flow rate of 1.5 mgd, which corresponded to the rated maximum filter capacity of 4 gallons per minute per square foot (gpm/sf).

Operational Strategy, Instrumentation, and Control

The UV equipment operates using the Calculated Dose Approach. The UV reactors automatically adjust to changing conditions to ensure that the calculated dose does not fall below the dose setpoint. Each reactor normally operates for 4 days followed by a day out of operation, corresponding to the normal filter service times. When UV reactors are returned to operation, an isolation valve located upstream of the UV reactor is closed, and plant service water flowing at approximately 20 gpm is used to cool the lamps while the reactor is started up and the lamps return to full power (approximately 10 to 15 minutes). After passing through the reactor, the cooling water enters the process train and is sent to the contact time (CT) basin for primary disinfection and then to the finished water clearwell. Once the lamps reach full power, the upstream isolation valve is opened, and filtered water flows through the UV reactors. The advantage of using plant service water as cooling water during reactor start-up is that because it has previously been treated by UV disinfection, the cooling water does not have to be included in the calculation of off-specification water.

Each reactor was located downstream of an existing flow control valve and flow meter. New isolation valves were installed downstream of each reactor. In addition to UV sensors, each reactor has a level sensor and temperature sensor. The level and temperature sensors protect the UV reactor from running dry or overheating or both. Each reactor was also provided with an auxiliary potable water supply connection to maintain a minimum flow rate of 15 gpm to prevent overheating during reactor start-up and shut-down. Each reactor has a UVT analyzer located on the filter effluent pipe to provide UVT measurements for dose monitoring.

Electrical Power Configuration and Power Quality

Power quality at Newark WTP was assessed over a fifteen-month period (March 2003 – June 2004) as part of an American Water Works Association Research Foundation Project (Cotton et al. 2005). During this time, 240 power quality events occurred. The frequency and classification of the power quality events at the WTP for this fifteen-month period are shown in Table F.19.

Table F.19. Power Quality at Newark WTP

Power Quality Event	City of Newark		
	Total	Monthly Average	Maximum Month
Instantaneous Voltage Sag	215	14.33	75
Momentary Voltage Sag	6	0.4	2
Temporary Voltage Sag	0	0	0
Instantaneous Swell	0	0	0
Instantaneous Interruption	0	0	0
Momentary Interruption	8	0.53	4
Temporary Interruption	3	0.2	1
Sustained Deep Undervoltage	1	0.07	1
Sustained Interruption	7	0.47	4
Total Estimated Time (minutes)	**NA**	**168**	**775**
Estimated % Off-specification Time	**NA**	**0.38**	**1.74**

Approximately 90 percent of the power quality events were instantaneous voltage sags (i.e., voltage sags lasting between 0.5 and 30 cycles). The UV reactors were not operational until May 2004, so the off-specification time shown in Table 4.19 is an estimate calculated by assuming 10 minutes of off-specification time for each voltage sag lasting more than 2 cycles. Although a UPS system was not installed at the Newark WTP, the UV equipment's ballast and electrical design prevents the UV reactors from losing power in many cases. As a result, the WTP is not having trouble meeting the off-specification requirements proposed in this guidance manual.

Capital Cost

The capital cost for adding the UV equipment to the Newark WTP was $1,135,000 (2006 dollars – ENR BCI = 4356). The cost includes modifications to the existing building and piping, UV reactors, piping, valves, instrumentation and controls, and other ancillary equipment.

F.4.2 Validation

No validation testing had been performed at the time of publication because no disinfection credit was needed. Newark may choose to validate the reactors in the future.

F.4.3 Start-up and Operation of the UV Facility

Construction of the UV facility was substantially complete and full-scale operation began in May 2004. The project was completed in July 2004. Overall, the UV equipment has operated smoothly, and only minor issues were encountered during start-up.

Minor issues with the control panels and wiring were resolved by the factory representative and the contractor. Additionally, the automatic backwash sequence programming had to be rewritten to accommodate the UV reactor cooling water. During the reprogramming, problems with existing valve actuators were uncovered that required some actuator limit switches to be adjusted.

Operations and maintenance costs were not readily available at the time of publication.

F.5 City of Winnipeg Water Treatment Plant – MP Facility with On-site Validation

The City of Winnipeg's water supply is obtained from a surface water source and is currently unfiltered. Water is chlorinated, and fluoride and phosphate are also added before it is distributed to the 630,000 people served by the water system.

A new WTP is currently under construction for the City of Winnipeg, which will use the following processes: rapid mix, coagulation, flocculation, dissolved air flotation, ozone, biological activated carbon filtration, UV disinfection, and chloramination. The UV facility was constructed before the rest of the treatment plant (scheduled for completion in 2007) to minimize the risk posed by *Cryptosporidium* and other waterborne pathogens. The UV facility will be integrated within the new WTP when it is constructed.

The raw water quality characteristics that were the basis for the UV reactor design are summarized in Table F.22.

Table F.22. Summary of Raw Water Quality (1989 – 1994)

Parameter	Units	Average	Minimum	Maximum
pH	–	8.2	7.4	9.1
Turbidity	NTU	1.0	0.3	5.3
Total Organic Carbon	mg/L	9.3	5	17
Dissolved Organic Carbon	mg/L	8.3	4	15
Plankton	cells/mL	39,700	200	666,000
Total Alkalinity	mg/L-$CaCO_3$	81	72	95
Total Hardness	mg/L-$CaCO_3$	83	68	97
Color (true)	TCU[1]	< 5	< 5	10

[1] True color units

F.5.1 Planning and Design

This section discusses the key planning and design decisions made for the City of Winnipeg's UV facility.

F.5.1.1 UV Disinfection Goals

The UV reactors were designed to provide 2-log *Cryptosporidium* inactivation in the Deacon Reservoir raw water. The goal will remain unchanged when the UV facility is later used to treat filtered water, even though the facility will be able to treat higher flow rates (at higher UVT).

F.5.1.2 UV Retrofit Location

The UV facility currently treats unfiltered raw water. In 2007 when the WTP is expected to be complete, the UV facility will be located downstream of the combined filter effluent. The equipment was installed in an existing pump station building on the site.

F.5.1.3 UV Reactor Selection

Because of space limitations in the existing building, MP reactors were selected. The MP reactors were selected in a competitive pre-selection/proposal process prior to completion of the final design. A cost/benefit model was used to evaluate the two pre-selected UV equipment alternatives (a typical model summary is shown in Figure F.16). Benefit scores (example values shown in stacked bars in Figure F.16) for non-monetary evaluation criteria were developed in advance of bids for each alternative by assigning relative weights to each criterion and then scoring each alternative against the criteria. The present worth costs for each alternative (example values shown in the line plot in Figure F.16) were then divided by the corresponding benefit score to calculate the cost/benefit ratio (example values shown in line plot in Figure F.16). The supplier that had the lowest cost/benefit ratio (i.e., low cost and high benefit), was then selected.

F.5.1.4 Key Design Parameters

Six Calgon Sentinel® 48-inch UV reactors comprise the UV facility. Key design parameters for the UV reactors are shown in Table F.23. The target MS2 RED to be verified in validation was based on criteria from the UVDGM Proposal Draft (USEPA 2003) for 2-log inactivation of *Cryptosporidium*.

Following construction of Winnipeg's WTP, the design UVT will be increased to 90 percent. The design flow rate per reactor will also be increased; however, the total design flow rate through the facility will be reduced to 106 mgd as reactors are changed to stand-by and other measures are taken to improve UV facility redundancy.

Figure F.16. Cost-Benefit Comparison for Winnipeg's UV Reactors

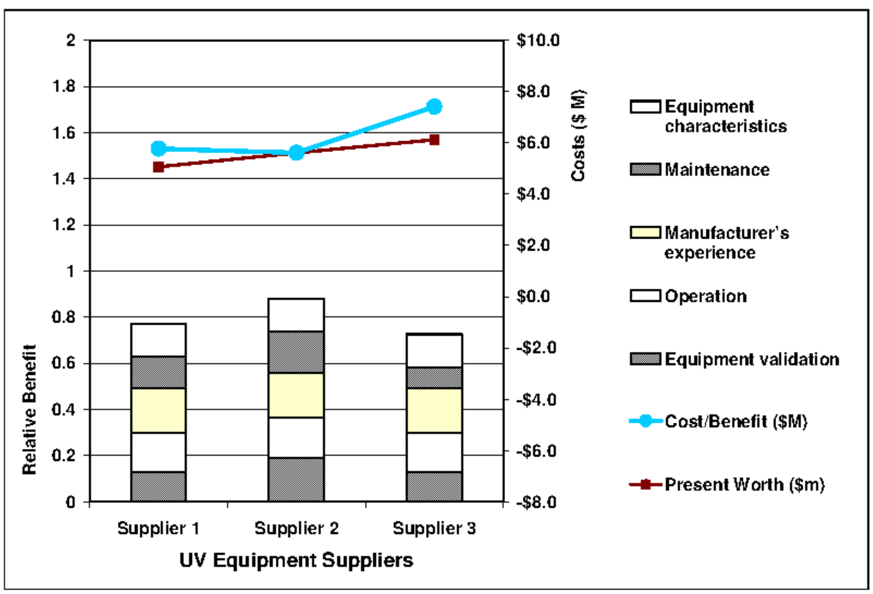


Table F.23. UV Reactor Design Parameters

Criterion	Unit	Value
UV Transmittance	percent	75
Fouling/Aging Factor	percent	70
Total Flow Rate	mgd	130
MS2 RED[1]	mJ/cm^2	28
Number of UV Units (All Duty)	number	6
Design Flow Rate per Unit	mgd	22
Number of Lamps per Unit	number	9
Lamp Power (Each)	kW	21.6

[1] The MS2 RED to be proven during validation testing.

Facility Hydraulics

No modifications to the facility hydraulics were required for the addition of the UV facility at the existing building. Furthermore, the hydraulics of the future WTP will be designed to incorporate the UV facility.

Operational Strategy, Instrumentation, and Control

Control of the UV reactors is based on the UV intensity setpoint (i.e., UV Intensity Setpoint Approach). A UV sensor was provided for each lamp in each reactor to monitor performance. Flow meters and modulating valves on each reactor are used to distribute the water among operating reactors, and isolation valves are located upstream of each reactor.

As the system demand increases and reactors approach their maximum capacities, additional reactors are started up as needed. The procedure is followed in reverse as system demand decreases.

Electrical Power Configuration and Power Quality

Power quality problems are not common at the location of Winnipeg's UV facility, so a UPS was not provided. For initial (unfiltered) operation, a back-up generation system was not provided for the UV facility; therefore, the UV facility is not operational during power outages. A back-up power system will be provided for long-term operation when the WTP is constructed.

Capital Cost

The total capital cost for the City of Winnipeg's UV facility was approximately $5,885,000 in 2006 U.S. dollars (ENR BCI = 4356). The cost includes the UV reactors, piping, valves, instrumentation and controls, and other ancillary equipment.

F.5.2 Validation

Although the UV reactors had been validated off-site before installation, the off-site testing had focused mainly on typical UVT levels, and only a limited number of runs had tested UVT levels below 80 percent. Therefore, the City of Winnipeg made on-site validation testing a bidding requirement. The on-site validation testing focused on lower UVT levels (70 – 78 percent), consistent with the raw water to be treated by the UV facility. The on-site testing included tests at a range of flow rates (6 – 25 mgd) and lamp settings.

The on-site testing was conducted in February 2005. The challenge microorganism was MS2, and SuperHume™ (potassium humate salts) was used to adjust the UVT of the test water. Thirty-eight tests were run, and additional blanks and other quality control samples were also taken. An excerpt of the validation testing conditions and results are shown in Table F.24.

F.5.3 Start-up and Operation of the UV Facility

Construction of the UV facility was completed in December 2004. Although validation has been completed, full-scale operation of the facility will be started up after functional testing has been completed.

Table F.24. Excerpt of the Validation Testing Conditions and Results for the City of Winnipeg

Run No.	Flow (mgd)	Configuration[1]	UVT Modifier	Test Organism	UV Intensity (W/m^2)	UVT (%)	Influent MS2 (log PFU/mL)	Effluent MS2 (log PFU/mL)	Log Reduction	MS2 RED (mJ/cm^2)
1	24.9	3 banks on	SH	MS2	138.0	74.9	4.94	3.18	1.76	32.6
2	25.1	3 banks on	SH	MS2	97.0	74.9	5.02	3.21	1.80	33.4
3	25.0	3 banks on	SH	MS2	155.0	77.5	5.26	3.31	1.94	36.5
4	24.9	3 banks on	SH	MS2	63.0	77.5	5.27	4.27	1.00	17.3
13	25.3	3 banks on	SH	MS2	30.0	70.2	5.35	4.77	0.58	9.4
14	25.0	2 banks on	SH	MS2	87.0	70.0	5.44	4.24	1.21	20.5
16	12.5	3 banks on	SH	MS2	117.0	77.5	5.25	2.84	2.41	48.3
17	12.6	2 banks on	SH	MS2	63.0	77.8	5.26	3.67	1.59	29.7
30	6.3	2 banks on	SH	MS2	63.0	77.7	5.28	3.59	1.70	31.9
31	6.3	3 banks on	SH	MS2	48.0	74.8	5.36	3.22	2.14	41.9

[1] Each reactor contains 3 banks with 3 lamps per bank.
SH – SuperHume™

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Appendix G

Reduction Equivalent Dose Bias Tables

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Tables G.1 – G.17 present RED Bias as a function of water ultraviolet transmittance (UVT) and challenge microorganism UV sensitivity for various log inactivation levels (ranging from 4.0 – 0.5) for *Cryptosporidium, Giardia*, and viruses. Tables G.1 – G.8 present RED Bias values for *Cryptosporidium*, Tables G.9 – G.16 present RED Bias values for *Giardia*, and Table G.17 presents RED Bias values for viruses. The RED Bias values for intermediate UVT values (e.g., UVT between 85 and 90 percent) can be interpolated from the values in the table, if desired.

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Table G.1. RED Bias Values for 4.0-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Cryptosporidium log inactivation credit		4.0						
Required UV dose (mJ/cm^2)		22						
Cryptosporidium UV sensitivity (mJ/cm^2/log I)		5.5						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 4	≤ 6	1.01	1.02	1.03	1.03	1.03	1.03	1.04
> 6	≤ 8	1.05	1.09	1.12	1.14	1.16	1.17	1.18
> 8	≤ 10	1.08	1.15	1.21	1.25	1.27	1.30	1.33
> 10	≤ 12	1.11	1.20	1.29	1.34	1.38	1.42	1.46
> 12	≤ 14	1.13	1.24	1.37	1.44	1.49	1.53	1.60
> 14	≤ 16	1.15	1.28	1.44	1.53	1.59	1.65	1.73
> 16	≤ 18	1.16	1.31	1.50	1.61	1.69	1.76	1.86
> 18	≤ 20	1.17	1.34	1.55	1.69	1.78	1.87	1.99
> 20	≤ 22	1.18	1.36	1.61	1.77	1.87	1.97	2.11
> 22	≤ 24	1.19	1.38	1.66	1.84	1.96	2.08	2.24
> 24	≤ 26	1.20	1.40	1.70	1.91	2.05	2.18	2.36
> 26	≤ 28	1.21	1.41	1.74	1.98	2.14	2.28	2.48
> 28	≤ 30	1.22	1.43	1.78	2.04	2.22	2.38	2.60
> 30	≤ 32	1.22	1.44	1.81	2.10	2.30	2.47	2.73
> 32	≤ 34	1.23	1.45	1.85	2.16	2.38	2.57	2.84

Table G.2. RED Bias Values for 3.5-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Cryptosporidium log inactivation credit		3.5						
Required UV dose (mJ/cm^2)		15						
Cryptosporidium UV sensitivity (mJ/cm^2/log I)		4.3						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 4	≤ 6	1.05	1.08	1.11	1.13	1.14	1.16	1.17
> 6	≤ 8	1.09	1.16	1.23	1.27	1.30	1.33	1.36
> 8	≤ 10	1.11	1.22	1.33	1.40	1.44	1.49	1.55
> 10	≤ 12	1.14	1.27	1.43	1.52	1.58	1.64	1.73
> 12	≤ 14	1.15	1.30	1.51	1.63	1.71	1.79	1.90
> 14	≤ 16	1.17	1.33	1.58	1.73	1.84	1.94	2.07
> 16	≤ 18	1.18	1.36	1.64	1.83	1.96	2.08	2.24
> 18	≤ 20	1.19	1.38	1.70	1.92	2.08	2.21	2.41
> 20	≤ 22	1.20	1.40	1.75	2.01	2.19	2.35	2.58
> 22	≤ 24	1.21	1.42	1.79	2.09	2.30	2.48	2.74
> 24	≤ 26	1.22	1.43	1.83	2.16	2.40	2.61	2.90
> 26	≤ 28	1.23	1.45	1.87	2.23	2.50	2.73	3.07
> 28	≤ 30	1.23	1.46	1.91	2.30	2.60	2.86	3.23
> 30	≤ 32	1.24	1.47	1.94	2.36	2.69	2.98	3.38
> 32	≤ 34	1.24	1.48	1.97	2.42	2.78	3.09	3.54

Table G.3. RED Bias Values for 3.0-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Cryptosporidium **log inactivation credit**		3.0						
Required UV dose (mJ/cm²)		12						
Cryptosporidium **UV sensitivity (mJ/cm²/log I)**		4.0						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 4	≤ 6	1.05	1.10	1.15	1.17	1.19	1.21	1.23
> 6	≤ 8	1.09	1.18	1.27	1.32	1.36	1.40	1.45
> 8	≤ 10	1.12	1.23	1.38	1.47	1.52	1.58	1.66
> 10	≤ 12	1.14	1.27	1.47	1.59	1.68	1.75	1.86
> 12	≤ 14	1.16	1.31	1.55	1.71	1.82	1.92	2.06
> 14	≤ 16	1.17	1.33	1.62	1.82	1.96	2.08	2.26
> 16	≤ 18	1.18	1.36	1.68	1.92	2.09	2.24	2.45
> 18	≤ 20	1.19	1.38	1.73	2.01	2.22	2.39	2.65
> 20	≤ 22	1.20	1.39	1.78	2.10	2.34	2.54	2.84
> 22	≤ 24	1.21	1.41	1.82	2.18	2.45	2.69	3.03
> 24	≤ 26	1.22	1.42	1.85	2.25	2.56	2.83	3.21
> 26	≤ 28	1.22	1.43	1.89	2.32	2.66	2.96	3.40
> 28	≤ 30	1.23	1.44	1.92	2.38	2.76	3.10	3.58
> 30	≤ 32	1.23	1.45	1.95	2.44	2.86	3.23	3.76
> 32	≤ 34	1.24	1.46	1.97	2.50	2.95	3.35	3.94

Table G.4. RED Bias Values for 2.5-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Cryptosporidium* log inactivation credit**		2.5						
Required UV dose (mJ/cm²)		8.5						
***Cryptosporidium* UV sensitivity (mJ/cm²/log I)**		3.4						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.02	1.04	1.06	1.07	1.07	1.08	1.09
> 4	≤ 6	1.07	1.14	1.22	1.27	1.30	1.33	1.37
> 6	≤ 8	1.11	1.21	1.36	1.44	1.50	1.56	1.63
> 8	≤ 10	1.13	1.26	1.46	1.60	1.69	1.77	1.89
> 10	≤ 12	1.15	1.30	1.55	1.74	1.87	1.98	2.15
> 12	≤ 14	1.17	1.32	1.63	1.87	2.03	2.18	2.39
> 14	≤ 16	1.18	1.35	1.69	1.98	2.19	2.37	2.64
> 16	≤ 18	1.19	1.37	1.74	2.08	2.34	2.56	2.88
> 18	≤ 20	1.20	1.38	1.79	2.17	2.47	2.74	3.12
> 20	≤ 22	1.21	1.40	1.83	2.26	2.60	2.91	3.35
> 22	≤ 24	1.21	1.41	1.87	2.33	2.72	3.07	3.58
> 24	≤ 26	1.22	1.42	1.90	2.40	2.84	3.23	3.81
> 26	≤ 28	1.23	1.43	1.93	2.47	2.95	3.39	4.03
> 28	≤ 30	1.23	1.44	1.95	2.53	3.05	3.54	4.26
> 30	≤ 32	1.23	1.45	1.97	2.58	3.15	3.68	4.48
> 32	≤ 34	1.24	1.45	1.99	2.63	3.24	3.82	4.70

Table G.5. RED Bias Values for 2.0-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Cryptosporidium **log inactivation credit**		2.0						
Required UV dose (mJ/cm^2)		5.8						
Cryptosporidium **UV sensitivity (mJ/cm^2/log I)**		2.9						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.04	1.08	1.12	1.14	1.16	1.18	1.20
> 4	≤ 6	1.09	1.17	1.30	1.37	1.42	1.47	1.54
> 6	≤ 8	1.12	1.23	1.43	1.57	1.66	1.75	1.87
> 8	≤ 10	1.14	1.27	1.53	1.74	1.88	2.00	2.19
> 10	≤ 12	1.16	1.31	1.62	1.88	2.08	2.25	2.50
> 12	≤ 14	1.17	1.33	1.68	2.01	2.26	2.48	2.80
> 14	≤ 16	1.18	1.35	1.74	2.12	2.43	2.70	3.10
> 16	≤ 18	1.19	1.37	1.78	2.22	2.58	2.91	3.40
> 18	≤ 20	1.20	1.38	1.82	2.30	2.73	3.11	3.69
> 20	≤ 22	1.21	1.39	1.85	2.38	2.86	3.31	3.97
> 22	≤ 24	1.21	1.40	1.88	2.45	2.98	3.49	4.25
> 24	≤ 26	1.22	1.41	1.91	2.51	3.09	3.66	4.53
> 26	≤ 28	1.23	1.42	1.93	2.57	3.20	3.83	4.80
> 28	≤ 30	1.23	1.42	1.95	2.62	3.30	3.99	5.06
> 30	≤ 32	1.23	1.43	1.97	2.67	3.39	4.14	5.33
> 32	≤ 34	1.24	1.44	1.99	2.71	3.48	4.29	5.59

Table G.6. RED Bias Values for 1.5-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Cryptosporidium* log inactivation credit**		1.5						
Required UV dose (mJ/cm²)		3.9						
***Cryptosporidium* UV sensitivity (mJ/cm²/log I)**		2.6						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.05	1.10	1.17	1.21	1.24	1.26	1.30
> 4	≤ 6	1.10	1.18	1.34	1.46	1.54	1.60	1.71
> 6	≤ 8	1.12	1.23	1.47	1.66	1.80	1.92	2.10
> 8	≤ 10	1.14	1.27	1.56	1.83	2.04	2.21	2.48
> 10	≤ 12	1.16	1.30	1.63	1.97	2.25	2.49	2.85
> 12	≤ 14	1.17	1.32	1.68	2.09	2.43	2.74	3.21
> 14	≤ 16	1.18	1.33	1.73	2.18	2.60	2.98	3.56
> 16	≤ 18	1.19	1.35	1.77	2.27	2.75	3.21	3.90
> 18	≤ 20	1.20	1.36	1.80	2.35	2.89	3.42	4.24
> 20	≤ 22	1.20	1.37	1.83	2.41	3.01	3.62	4.57
> 22	≤ 24	1.21	1.37	1.85	2.47	3.13	3.80	4.89
> 24	≤ 26	1.21	1.38	1.87	2.53	3.23	3.98	5.21
> 26	≤ 28	1.22	1.39	1.89	2.57	3.33	4.15	5.52
> 28	≤ 30	1.22	1.39	1.90	2.62	3.42	4.31	5.82
> 30	≤ 32	1.22	1.40	1.92	2.66	3.51	4.46	6.12
> 32	≤ 34	1.23	1.40	1.93	2.69	3.59	4.60	6.41

Table G.7. RED Bias Values for 1.0-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Cryptosporidium* log inactivation credit**		1.0						
Required UV dose (mJ/cm²)		2.5						
***Cryptosporidium* UV sensitivity (mJ/cm²/log I)**		2.5						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.05	1.10	1.18	1.24	1.28	1.32	1.37
> 4	≤ 6	1.09	1.17	1.34	1.49	1.60	1.69	1.83
> 6	≤ 8	1.12	1.21	1.45	1.68	1.87	2.04	2.28
> 8	≤ 10	1.14	1.24	1.52	1.83	2.10	2.35	2.71
> 10	≤ 12	1.15	1.26	1.58	1.95	2.30	2.63	3.12
> 12	≤ 14	1.16	1.28	1.62	2.05	2.47	2.89	3.53
> 14	≤ 16	1.17	1.29	1.66	2.13	2.63	3.12	3.91
> 16	≤ 18	1.18	1.30	1.69	2.20	2.76	3.34	4.29
> 18	≤ 20	1.18	1.31	1.71	2.26	2.88	3.54	4.66
> 20	≤ 22	1.19	1.32	1.73	2.32	2.99	3.73	5.01
> 22	≤ 24	1.19	1.33	1.75	2.36	3.09	3.90	5.36
> 24	≤ 26	1.20	1.33	1.76	2.40	3.18	4.06	5.69
> 26	≤ 28	1.20	1.34	1.78	2.44	3.26	4.22	6.02
> 28	≤ 30	1.20	1.34	1.79	2.47	3.33	4.36	6.33
> 30	≤ 32	1.21	1.35	1.80	2.50	3.40	4.49	6.64
> 32	≤ 34	1.21	1.35	1.81	2.53	3.47	4.62	6.94

Table G.8. RED Bias Values for 0.5-log *Cryptosporidium* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Cryptosporidium* log inactivation credit**		0.5						
Required UV dose (mJ/cm^2)		1.6						
***Cryptosporidium* UV sensitivity (mJ/cm^2/log I)**		3.2						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.02	1.04	1.07	1.10	1.13	1.15	1.18
> 4	≤ 6	1.06	1.10	1.19	1.30	1.40	1.49	1.62
> 6	≤ 8	1.08	1.13	1.27	1.44	1.61	1.78	2.04
> 8	≤ 10	1.10	1.15	1.32	1.55	1.79	2.03	2.42
> 10	≤ 12	1.11	1.17	1.36	1.63	1.93	2.24	2.79
> 12	≤ 14	1.12	1.18	1.39	1.69	2.04	2.43	3.13
> 14	≤ 16	1.12	1.19	1.41	1.74	2.15	2.60	3.45
> 16	≤ 18	1.13	1.20	1.43	1.79	2.23	2.75	3.76
> 18	≤ 20	1.14	1.21	1.45	1.83	2.31	2.89	4.06
> 20	≤ 22	1.14	1.21	1.46	1.86	2.38	3.02	4.33
> 22	≤ 24	1.14	1.22	1.47	1.89	2.44	3.13	4.60
> 24	≤ 26	1.15	1.22	1.48	1.91	2.49	3.24	4.86
> 26	≤ 28	1.15	1.23	1.49	1.93	2.54	3.33	5.10
> 28	≤ 30	1.15	1.23	1.50	1.95	2.58	3.43	5.34
> 30	≤ 32	1.16	1.23	1.51	1.97	2.62	3.51	5.56
> 32	≤ 34	1.16	1.23	1.51	1.98	2.66	3.59	5.78

Table G.9. RED Bias Values for 4.0-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Giardia* log inactivation credit**		4.0						
Required UV dose (mJ/cm^2)		22						
***Giardia* UV sensitivity (mJ/cm^2/log I)**		5.5						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 4	≤ 6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 6	≤ 8	1.01	1.02	1.03	1.03	1.03	1.03	1.04
> 8	≤ 10	1.05	1.09	1.12	1.14	1.16	1.17	1.18
> 10	≤ 12	1.08	1.15	1.21	1.25	1.27	1.30	1.33
> 12	≤ 14	1.11	1.20	1.29	1.34	1.38	1.42	1.46
> 14	≤ 16	1.13	1.24	1.37	1.44	1.49	1.53	1.60
> 16	≤ 18	1.15	1.28	1.44	1.53	1.59	1.65	1.73
> 18	≤ 20	1.16	1.31	1.50	1.61	1.69	1.76	1.86
> 20	≤ 22	1.17	1.34	1.55	1.69	1.78	1.87	1.99
> 22	≤ 24	1.18	1.36	1.61	1.77	1.87	1.97	2.11
> 24	≤ 26	1.19	1.38	1.66	1.84	1.96	2.08	2.24
> 26	≤ 28	1.20	1.40	1.70	1.91	2.05	2.18	2.36
> 28	≤ 30	1.21	1.41	1.74	1.98	2.14	2.28	2.48
> 30	≤ 32	1.22	1.43	1.78	2.04	2.22	2.38	2.60
> 32	≤ 34	1.22	1.44	1.81	2.10	2.30	2.47	2.73

Table G.10. RED Bias Values for 3.5-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Giardia log inactivation credit		3.5						
Required UV dose (mJ/cm^2)		15						
Giardia UV sensitivity (mJ/cm^2/log I)		4.3						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 4	≤ 6	1.05	1.08	1.11	1.13	1.14	1.16	1.17
> 6	≤ 8	1.09	1.16	1.23	1.27	1.30	1.33	1.36
> 8	≤ 10	1.11	1.22	1.33	1.40	1.44	1.49	1.55
> 10	≤ 12	1.14	1.27	1.43	1.52	1.58	1.64	1.73
> 12	≤ 14	1.15	1.30	1.51	1.63	1.71	1.79	1.90
> 14	≤ 16	1.17	1.33	1.58	1.73	1.84	1.94	2.07
> 16	≤ 18	1.18	1.36	1.64	1.83	1.96	2.08	2.24
> 18	≤ 20	1.19	1.38	1.70	1.92	2.08	2.21	2.41
> 20	≤ 22	1.20	1.40	1.75	2.01	2.19	2.35	2.58
> 22	≤ 24	1.21	1.42	1.79	2.09	2.30	2.48	2.74
> 24	≤ 26	1.22	1.43	1.83	2.16	2.40	2.61	2.90
> 26	≤ 28	1.23	1.45	1.87	2.23	2.50	2.73	3.07
> 28	≤ 30	1.23	1.46	1.91	2.30	2.60	2.86	3.23
> 30	≤ 32	1.24	1.47	1.94	2.36	2.69	2.98	3.38
> 32	≤ 34	1.24	1.48	1.97	2.42	2.78	3.09	3.54

Table G.11. RED Bias Values for 3.0-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Giardia **log inactivation credit**		3.0						
Required UV dose (mJ/cm²)		11						
Giardia **UV sensitivity (mJ/cm²/log I)**		3.7						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.01	1.02	1.03	1.03	1.03	1.03	1.04
> 4	≤ 6	1.07	1.12	1.18	1.21	1.23	1.25	1.28
> 6	≤ 8	1.10	1.20	1.31	1.37	1.41	1.45	1.51
> 8	≤ 10	1.13	1.25	1.42	1.52	1.58	1.65	1.74
> 10	≤ 12	1.15	1.29	1.51	1.65	1.74	1.83	1.95
> 12	≤ 14	1.16	1.32	1.59	1.77	1.90	2.01	2.17
> 14	≤ 16	1.18	1.35	1.66	1.89	2.04	2.18	2.38
> 16	≤ 18	1.19	1.37	1.72	1.99	2.18	2.34	2.59
> 18	≤ 20	1.20	1.39	1.77	2.08	2.31	2.51	2.79
> 20	≤ 22	1.21	1.41	1.81	2.17	2.43	2.66	2.99
> 22	≤ 24	1.22	1.42	1.85	2.25	2.55	2.81	3.19
> 24	≤ 26	1.22	1.44	1.89	2.32	2.66	2.96	3.39
> 26	≤ 28	1.23	1.45	1.92	2.39	2.77	3.11	3.59
> 28	≤ 30	1.24	1.46	1.95	2.46	2.87	3.25	3.78
> 30	≤ 32	1.24	1.47	1.98	2.52	2.97	3.38	3.98
> 32	≤ 34	1.25	1.47	2.00	2.57	3.06	3.52	4.17

Table G.12. RED Bias Values for 2.5-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Giardia* log inactivation credit**		2.5						
Required UV dose (mJ/cm^2)		7.7						
***Giardia* UV sensitivity (mJ/cm^2/log I)**		3.1						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.03	1.06	1.09	1.11	1.12	1.13	1.14
> 4	≤ 6	1.08	1.16	1.26	1.32	1.35	1.39	1.44
> 6	≤ 8	1.12	1.23	1.40	1.50	1.57	1.63	1.73
> 8	≤ 10	1.14	1.28	1.51	1.67	1.77	1.87	2.00
> 10	≤ 12	1.16	1.32	1.60	1.81	1.96	2.09	2.27
> 12	≤ 14	1.18	1.34	1.67	1.94	2.13	2.30	2.54
> 14	≤ 16	1.19	1.37	1.74	2.06	2.29	2.50	2.80
> 16	≤ 18	1.20	1.39	1.79	2.16	2.45	2.70	3.06
> 18	≤ 20	1.21	1.40	1.83	2.25	2.59	2.88	3.31
> 20	≤ 22	1.22	1.42	1.87	2.34	2.72	3.07	3.56
> 22	≤ 24	1.22	1.43	1.91	2.41	2.85	3.24	3.81
> 24	≤ 26	1.23	1.44	1.94	2.48	2.97	3.41	4.05
> 26	≤ 28	1.23	1.45	1.97	2.55	3.08	3.57	4.30
> 28	≤ 30	1.24	1.46	1.99	2.61	3.18	3.73	4.53
> 30	≤ 32	1.24	1.46	2.01	2.66	3.28	3.88	4.77
> 32	≤ 34	1.25	1.47	2.03	2.71	3.38	4.02	5.00

Table G.13. RED Bias Values for 2.0-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

	Giardia log inactivation credit	2.0						
	Required UV dose (mJ/cm²)	5.2						
	Giardia UV sensitivity (mJ/cm²/log I)	2.6						
	UVT (%)	≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.05	1.11	1.17	1.20	1.22	1.24	1.27
> 4	≤ 6	1.10	1.20	1.35	1.44	1.50	1.56	1.64
> 6	≤ 8	1.13	1.26	1.48	1.65	1.76	1.85	1.99
> 8	≤ 10	1.15	1.30	1.59	1.82	1.99	2.13	2.34
> 10	≤ 12	1.17	1.33	1.67	1.97	2.19	2.39	2.67
> 12	≤ 14	1.18	1.36	1.74	2.10	2.39	2.64	3.00
> 14	≤ 16	1.20	1.37	1.79	2.21	2.56	2.87	3.32
> 16	≤ 18	1.21	1.39	1.84	2.31	2.72	3.09	3.64
> 18	≤ 20	1.21	1.40	1.87	2.40	2.87	3.30	3.95
> 20	≤ 22	1.22	1.41	1.91	2.48	3.01	3.51	4.25
> 22	≤ 24	1.23	1.42	1.94	2.55	3.13	3.70	4.55
> 24	≤ 26	1.23	1.43	1.96	2.61	3.25	3.88	4.85
> 26	≤ 28	1.24	1.44	1.98	2.67	3.36	4.06	5.14
> 28	≤ 30	1.24	1.45	2.01	2.72	3.46	4.22	5.43
> 30	≤ 32	1.24	1.45	2.02	2.77	3.56	4.38	5.71
> 32	≤ 34	1.25	1.46	2.04	2.81	3.65	4.54	5.98

Table G.14. RED Bias Values for 1.5-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

***Giardia* log inactivation credit**		1.5						
Required UV dose (mJ/cm^2)		3.0						
***Giardia* UV sensitivity (mJ/cm^2/log I)**		2.0						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		**RED Bias**						
Lower	**Upper**							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.08	1.16	1.28	1.35	1.40	1.45	1.51
> 4	≤ 6	1.13	1.25	1.47	1.63	1.75	1.84	1.99
> 6	≤ 8	1.15	1.30	1.60	1.86	2.05	2.21	2.45
> 8	≤ 10	1.17	1.33	1.69	2.04	2.31	2.55	2.89
> 10	≤ 12	1.19	1.36	1.77	2.19	2.54	2.86	3.32
> 12	≤ 14	1.20	1.38	1.82	2.31	2.75	3.15	3.75
> 14	≤ 16	1.21	1.39	1.87	2.42	2.93	3.42	4.16
> 16	≤ 18	1.22	1.41	1.91	2.51	3.10	3.68	4.56
> 18	≤ 20	1.23	1.42	1.94	2.59	3.25	3.92	4.96
> 20	≤ 22	1.23	1.43	1.96	2.66	3.39	4.14	5.34
> 22	≤ 24	1.24	1.43	1.99	2.72	3.51	4.35	5.72
> 24	≤ 26	1.24	1.44	2.01	2.78	3.63	4.55	6.08
> 26	≤ 28	1.25	1.45	2.03	2.83	3.74	4.74	6.44
> 28	≤ 30	1.25	1.45	2.04	2.87	3.84	4.92	6.80
> 30	≤ 32	1.25	1.46	2.06	2.91	3.93	5.09	7.14
> 32	≤ 34	1.26	1.46	2.07	2.95	4.01	5.25	7.48

Table G.15. RED Bias Values for 1.0-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

Giardia log inactivation credit		1.0						
Required UV dose (mJ/cm^2)		2.1						
Giardia UV sensitivity (mJ/cm^2/log I)		2.1						
UVT (%)		≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm^2/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.07	1.14	1.26	1.34	1.40	1.45	1.52
> 4	≤ 6	1.11	1.21	1.42	1.61	1.75	1.86	2.04
> 6	≤ 8	1.14	1.25	1.53	1.82	2.04	2.24	2.53
> 8	≤ 10	1.16	1.28	1.61	1.98	2.29	2.58	3.01
> 10	≤ 12	1.17	1.30	1.67	2.10	2.51	2.89	3.47
> 12	≤ 14	1.18	1.32	1.72	2.21	2.70	3.17	3.91
> 14	≤ 16	1.19	1.33	1.75	2.30	2.86	3.43	4.35
> 16	≤ 18	1.20	1.34	1.78	2.37	3.01	3.67	4.77
> 18	≤ 20	1.20	1.35	1.81	2.44	3.14	3.89	5.17
> 20	≤ 22	1.21	1.36	1.83	2.49	3.25	4.10	5.57
> 22	≤ 24	1.21	1.37	1.84	2.54	3.36	4.29	5.95
> 24	≤ 26	1.22	1.37	1.86	2.58	3.46	4.47	6.32
> 26	≤ 28	1.22	1.38	1.87	2.62	3.55	4.63	6.68
> 28	≤ 30	1.22	1.38	1.89	2.66	3.63	4.79	7.03
> 30	≤ 32	1.22	1.38	1.90	2.69	3.70	4.94	7.38
> 32	≤ 34	1.23	1.39	1.91	2.72	3.77	5.08	7.71

Table G.16. RED Bias Values for 0.5-log *Giardia* Inactivation Credit as a Function of UVT and UV Challenge Microorganism Sensitivity

	Giardia log inactivation credit	0.5						
	Required UV dose (mJ/cm²)	1.5						
	Giardia UV sensitivity (mJ/cm²/log I)	3.0						
	UVT (%)	≥ 98	≥ 95	≥ 90	≥ 85	≥ 80	≥ 75	≥ 65
Challenge UV sensitivity (mJ/cm²/log I)		RED Bias						
Lower	Upper							
0	≤ 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 2	≤ 4	1.03	1.05	1.09	1.14	1.17	1.20	1.24
> 4	≤ 6	1.06	1.11	1.22	1.34	1.45	1.55	1.70
> 6	≤ 8	1.09	1.14	1.29	1.49	1.67	1.85	2.13
> 8	≤ 10	1.10	1.16	1.35	1.59	1.85	2.11	2.54
> 10	≤ 12	1.11	1.18	1.39	1.68	2.00	2.34	2.92
> 12	≤ 14	1.12	1.19	1.42	1.74	2.12	2.54	3.28
> 14	≤ 16	1.13	1.20	1.44	1.80	2.23	2.72	3.63
> 16	≤ 18	1.14	1.21	1.46	1.84	2.32	2.88	3.95
> 18	≤ 20	1.14	1.22	1.48	1.88	2.40	3.02	4.26
> 20	≤ 22	1.15	1.22	1.49	1.91	2.47	3.15	4.56
> 22	≤ 24	1.15	1.23	1.50	1.94	2.53	3.28	4.84
> 24	≤ 26	1.15	1.23	1.51	1.97	2.59	3.39	5.11
> 26	≤ 28	1.16	1.24	1.52	1.99	2.64	3.49	5.37
> 28	≤ 30	1.16	1.24	1.53	2.01	2.69	3.58	5.62
> 30	≤ 32	1.16	1.24	1.53	2.03	2.73	3.67	5.86
> 32	≤ 34	1.16	1.25	1.54	2.04	2.77	3.76	6.09

Table G.17. RED Bias Values for Virus Inactivation Credit as a Function of UV Challenge Microorganism Sensitivity

Virus log inactivation credit		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Required UV dose (mJ/cm^2)		39	58	79	100	121	143	163	186
Virus UV sensitivity (mJ/cm^2/log I)		78	58	53	50	48	48	47	47
Challenge UV sensitivity (mJ/cm^2/log I)		RED Bias							
Lower	Upper								
> 1	≤ 25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
> 25	≤ 50	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01
> 50	≤ 60	1.00	1.00	1.02	1.03	1.03	1.03	1.04	1.04
> 60	≤ 70	1.00	1.02	1.04	1.05	1.05	1.05	1.06	1.06
> 70	≤ 80	1.00	1.04	1.05	1.06	1.07	1.07	1.07	1.07
> 80	≤ 90	1.01	1.05	1.06	1.07	1.08	1.08	1.08	1.08
> 90	≤ 100	1.02	1.06	1.07	1.08	1.09	1.09	1.09	1.09
> 90	≤ 100	1.02	1.06	1.07	1.08	1.09	1.09	1.09	1.09

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10242

59

Date Submitted	02/11/2022	**Section**	454.1.9.2.3.6	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Deletes pump reservoir langue for plunge pools. Reserves the code section.

Rationale

Pump reservoirs are no longer required on plunge pools, so sentence talking about a connection between them should be deleted.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Simplifies code by removing a no longer necessary section.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code by removing a no longer necessary section.

Impact to industry relative to the cost of compliance with code

None, simplifies code by removing a no longer necessary section.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Simplifies code by removing a no longer necessary section.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Simplifies code by removing a no longer necessary section.

454.1.9.2.3.6

~~The pump reservoir shall be fed by main drains within the plunge pool itself (either in the floor or side wall). They shall have the maximum flow velocity of 11/2 feet per second (457 mm/s) through the main drain grating and 3 feet per second (3962 mm/s) through the reservoir piping.~~ Reserved.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10302

60

Date Submitted	02/12/2022	**Section**	454.1.9.2.5	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Deletes pump reservoir, as they are no longer required for plunge pools.

Rationale

Pump reservoirs are no longer required on plunge pools, references to pump reservoirs should be deleted.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None, deletes no longer relevant code language.
Impact to building and property owners relative to cost of compliance with code
None, deletes no longer relevant code language.
Impact to industry relative to the cost of compliance with code
None, deletes no longer relevant code language.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Deletes unneeded code language, simplifies the code.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Deletes unneeded code language, simplifies the code.
Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Does not specify particular materials, products, methods, or systems of construction.
Does not degrade the effectiveness of the code
Deletes unneeded code language, simplifies the code.

454.1.9.2.5 Perimeter overflow gutters or skimmers.

Plunge pools ~~and pump reservoirs~~shall have perimeter overflow gutter system or skimmer which shall be an integral part of the filtration system.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10303

61

Date Submitted	02/12/2022	**Section**	454.1.9.2.5.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Floating skimmer requirement for pump reservoirs deleted.

Rationale

There is no NSF-approved floating skimmer, so the requirement to put a skimmer on a pump reservoir should be deleted. The requirements for skimmers on plunge pools are repetitive and should simply refer back to the part of the code they came from

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.9.2.5.2 Surface skimmers.

Surface skimmers may be used in lieu of perimeter overflow gutters. The provisions of 454.1.6.5.3.2 shall apply, except no maximum width or maximum area shall apply to plunge pools. ~~and shall be appropriately spaced and located according to the structural design. Unless an overflow gutter system is used, surface skimmers shall be provided in the plunge pool and in the pump reservoir and the skimmer system shall be designed to carry 60 percent of the filtration system design flow rate with each skimmer carrying a minimum 30 gpm (2 L/s). All surface skimmers shall meet the requirements for NSF commercial approval as set forth in NSF/ANSI Standard 50, Circulation System Components and Related Materials for Swimming Pools, Spas/Hot Tubs, which is incorporated by reference in these rules, including an equalizer valve in the skimmer and an equalizer line to the pool wall on systems with direct connection to pump suction.~~

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10304

62

Date Submitted	02/12/2022	**Section**	454.1.9.2.6.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Specifies recirculation rates for water slide plunge pools.

Rationale

Turnover rate should depend on slide ending. Waterslide with runout lane endings tend to see have more users per hour than slides that terminate in to plunge pools therefore the water should turned over more frequently.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies and clarifies code requirements for water slide ending areas.

Impact to building and property owners relative to cost of compliance with code

Makes code compliance easier by simplifying and clarifying code requirements.

Impact to industry relative to the cost of compliance with code

Makes code compliance easier by simplifying and clarifying code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Recirculation rate is a key factor in water sanitization which affects bather health and safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Makes code compliance easier by simplifying and clarifying code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Makes code compliance easier by simplifying and clarifying code requirements.

454.1.9.2.6.1 Recirculation rate.

The recirculation-filtration system of water slides plunge pools shall ~~recirculate and filter a water volume equal to the total water volume of the facility~~turn the water over in a period of 2 hours or less. The turnover rate for slides with runout lanes shall be one hour or less. For swimming pools that are not dedicated as plunge pools, but include a recreational water slide as part of the design, the total water volume shall include the water in the plunge pool dimensions stipulated by code, plus the slide water.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10305

63

Date Submitted	02/12/2022	**Section**	454.1.9.2.6.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Summary of Modification

Removes water NTU monitoring from the building code.

Rationale

References to turbidity should be moved to Florida Administrative Code 64E-9. All pools should have the opportunity to reduce filter flow rate when turbidity is measured to be low, but this should be in F.A.C. 64E-9.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None removes water code language that properly belongs in the Florida Administrative Code.

Impact to building and property owners relative to cost of compliance with code

None removes water code language that properly belongs in the Florida Administrative Code.

Impact to industry relative to the cost of compliance with code

None removes water code language that properly belongs in the Florida Administrative Code.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Water quality and sanitization directly affects bather health and safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Removes code langue that properly belongs in the Florida Administrative Code 64E-9, not the building code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Removes code langue that properly belongs in the Florida Administrative Code 64E-9, not the building code.

Alternate Language

1st Comment Period History

SW10305-A1

Proponent bob vincent **Submitted** 4/17/2022 5:37:42 PM **Attachments** Yes

Rationale:

Florida Department of Health is not in favor of this mod. The water turbidity meter is a building code required measurement device for water clarity that must be submitted for review on the design plans, permitted, and installed at construction, so deletion of this phrase of the existing code would prevent that; thus is unacceptable.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, water clarity affects patron safety and water quality sanitation.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade.

454.1.9.2.6.2 Filter performance.
~~The filtration system shall be capable of returning the pool water turbidity to 5/10 (0.50) NTU within 8 hours or less after peak bather load.~~ A continuous readout/electronic recording in-line turbidity meter shall be installed per manufacturer's specifications and used to determine compliance with ~~this NTU~~ Florida Administrative Code 64E-9 water quality criteria for clarity.~~,~~ ~~o~~Otherwise if not installed, the recirculation turnover rate ~~in~~ of the plunge pool’s ~~total~~ water volume~~,~~ as defined in Section 454.1.9.2.6.1, must be enhanced to 1 hour or less.

454.1.9.2.6.2 ~~Filter performance.~~

~~The filtration system shall be capable of returning the pool water turbidity to 5/10 (0.50) NTU within 8 hours or less after peak bather load. A continuous readout/electronic recording in-line turbidity meter shall be installed and used to determine compliance with this NTU criteria, otherwise the turnover rate in the plunge pool's total water volume, as defined in Section 454.1.9.2.6.1, must be 1 hour or less.~~ Reserved.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10306

64

Date Submitted	02/12/2022	**Section**	454.1.9.6.4	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Simplifies "No Entry" marker design and placement.

Rationale

“No Entry, Shallow water” text is too long to be placed every 15 ft. “No Entry” is enough. There is no need to block access to the water when the step down is small like a step. “No Entry” tiles are commercially available with 2” high letters, but not 4” letters, so the code should accommodate these smaller letters, with a closer spacing. “No entry” markers should be optional if another obstruction is present. If “no entry” markers are already required in less than 3’ of water, “no diving” is not needed because it’s already implied.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, clarifies code requirements, removes unnecessary complications.

Impact to building and property owners relative to cost of compliance with code

None, clarifies code requirements, removes unnecessary complications. Makes it easier to comply with code requirements.

Impact to industry relative to the cost of compliance with code

None, clarifies code requirements, removes unnecessary complications. Makes it easier to comply with code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Water depth information and information about possible dangers improves bather health and safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies code requirements, removes unnecessary complications. Makes it easier to comply with code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

None, clarifies code requirements, removes unnecessary complications. Makes it easier to comply with code requirements.

1st Comment Period History

SW10306-G1

Proponent	bob vincent	Submitted	4/17/2022 3:29:50 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of mod as written. Blocking visibility of shallow zones with plants over 2' high where non-swimmers often play creates a new hazard for care-takers that oversee the non-swimmers from the pool deck. If planters can be landscaped with low growing plants or artificial plants, and trees without branches below 6' high; the safety risk would be lowered.

454.1.9.6.4

"No Entry~~, Shallow Water~~" ~~signs~~markers shall be provided along the pool wall edge where the water depth is more than 10 inches (254 mm) but less than 3 feet (914 mm) deep~~.~~ unless stairs and handrails are provided. No entry ~~signs~~ markers shall be slip-resistant, shall have 4~~2~~-inch high (~~102~~51 mm) letters, shall be located within 2 feet (610 mm) of the pool edge and shall be spaced no more than 8 feet (2438 mm) apart, or 15 feet (4572 mm) apart~~.~~ if 4 inch high (102 mm) letters are provided. Other obstructions, such as planters, may be used along these edges, in lieu of "No Entry" markers. Such obstructions shall not count towards the twenty percent limit of 454.1.3.1.6, and may be up to 30 feet (9144 mm) long. "NO DIVING" markers are not required around the zero entry area.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10307

65

Date Submitted	02/12/2022	**Section**	454.1.9.6.5	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Summary of Modification

Specifies flow rate for areas less than 18 inches deep in zero depth entry swimming pools.

Rationale

Clarifying the turnover rate for zero depth entry areas. The current standard is unclear and goes largely unenforced. This changes clarifies the standard by simplifying the calculation.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Simplifies code requirements, improving enforcement.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Water quality and sanitization directly affects bather health and safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

Alternate Language

1st Comment Period History

SW10307-A1

Proponent Michael Weinbaum **Submitted** 4/15/2022 3:13:30 PM **Attachments** Yes

Rationale:

The current code requires the engineer and the building official to calculate the volume in a sun shelf or zero entry area under 18", and then assume a certain flow per inlet, and check the turnover rate. This revision would require the engineer and the building official to only check distances between inlets. The spacing requirements are selected to produce a 1 hour turnover of water in each case, assuming that each inlet flows at 15 gpm. In the worst case, there would be one inlet per 100 square feet, the average depth would be 12 inches, giving 748 gallons. 748 gallons / 15 gpm = 49 minutes ~ 1 hour.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Makes code enforcement much simpler

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Ensures clean water in the areas that have the highest tendency to get dirty

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

SW10307-A1Text Modification

454.1.2.8.4 Sun shelf turnover rate. Additional inlets shall be provided in the sun shelf area. The spacing between adjacent inlets, or between floor inlets and adjacent walls, shall not exceed 10 ft (3048 mm). If this area is more than 20 ft (6096 mm) wide, floor inlets shall be provided.~~The numbers and location shall be such as to ensure the volume of water in the shelf is filtered and chemically treated once every 60 minutes (1 hour) or less.~~

...

454.1.9.6.5 ~~Additional inlets shall be provided in areas of less than 18 inches (457 mm) deep. The numbers and location shall be such as to double the flow rate into this area.~~ In areas that are less than 18 inches (457 mm) deep, the spacing between adjacent inlets, or between floor inlets and adjacent walls, shall not exceed 10 ft (3048 mm). If this area is more than 20 ft (6096 mm) wide, floor inlets shall be provided.

454.1.9.6.5

Additional inlets shall be provided in areas of less than 18 inches (457 mm) deep. The numbers and location shall be such as to ~~double the flow rate into this area~~ensure a 1 hour turnover in this area.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10308

66

Date Submitted	02/12/2022	**Section**	454.1.2.3.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Removes subjective swimming pool logo criteria.

Rationale

The acceptability of a design or logo should not be left up to human judgement. It should be measurable. Logo design requirements will be moved to 454.1.2.4 Color

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Simplifies enforcement by removing subjective standards.

Impact to building and property owners relative to cost of compliance with code

Simplifies code compliance by eliminating subjective standards.

Impact to industry relative to the cost of compliance with code

Simplifies code compliance by eliminating subjective standards.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Pool color and logo designs can affect bather safety by obstructing the view of the pool or bathers in distress.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by eliminating subjective criteria.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by eliminating subjective criteria.

1st Comment Period History

SW10308-G1

Proponent	bob vincent	Submitted	4/17/2022 12:59:42 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this deletion. FDOH has an expert Advisory Review Board appointed by the Governor under section 513.028, F.S., to review proposals. The US Centers for Disease Control (CDC) 2018 Model Aquatic Health Code, section 4.5.11 addressees the floor and wall color: 4.5.11 Color and Finish 4.5.11.1A White or Light Pastel Floors and walls below the water line shall be white or light pastel in color such that from the POOL DECK a BATHER is visible on the POOL floor and the following items can be identified: 1) Algae growth, debris or dirt within the POOL, and 2) CRACKS in the surface finish of the POOL, and 3) Marker tiles defined in MAHC 4.5.1.2. 4.5.11.1.1A Munsell Color Value The finish shall be at least 6.5 on the Munsell color value scale. 4.5.11.1.2 Exceptions An exception shall be made for the following AQUATIC VENUE components: 1) Competitive lane markings, 2) Dedicated competitive diving well floors, 3) Step or bench edge markings, 4) POOLS shallower than 24 inches (61.0 cm), 5) Water line tiles, 6) WAVE POOL and SURF POOL depth change indicator tiles, or 7) Other approved designs.

454.1.2.3.2 ~~Designs or logos.~~

~~Any design or logo on the pool floor or walls shall be such that it will not hinder the detection of a human in distress, algae, sediment, or other objects in the pool.~~ Reserved.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10309

67

Date Submitted	02/12/2022	**Section**	454.1.2.4	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Sets objective criteria for swimming pool logo designs.

Rationale

Provides for an objective criteria for logos to be designed to. This will eliminate un inconsistent results in approval of swimming pool logo designs.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Simplifies code enforcement by setting objective criteria to evaluate proposed swimming pool logos.

Impact to building and property owners relative to cost of compliance with code

Simplifies code compliance by setting objective criteria to evaluate proposed swimming pool logos.

Impact to industry relative to the cost of compliance with code

Simplifies code compliance by setting objective criteria to evaluate proposed swimming pool logos.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool color and logo design affects the ability to see the pool floor or identify bathers in distress.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code by setting objective criteria to evaluate proposed swimming pool logos.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves code by setting objective criteria to evaluate proposed swimming pool logos.

1st Comment Period History

SW10309-G1

Proponent	bob vincent	Submitted	4/17/2022 1:05:58 PM	Attachments	Yes

Comment:

Florida Department of Health is not in favor of this mod. FDOH has an expert Advisory Review Board appointed by the Governor under section 513.028, F.S., to review proposals. The US Centers for Disease Control (CDC) 2018 Model Aquatic Health Code, section 4.5.11 on page 39 addressees the floor color: 4.5.11 Color and Finish 4.5.11.1A White or Light Pastel Floors and walls below the water line shall be white or light pastel in color such that from the POOL DECK a BATHER is visible on the POOL floor and the following items can be identified: 1) Algae growth, debris or dirt within the POOL, and 2) CRACKS in the surface finish of the POOL, and 3) Marker tiles defined in MAHC 4.5.1.2. 4.5.11.1.1A Munsell Color Value The finish shall be at least 6.5 on the Munsell color value scale. 4.5.11.1.2 Exceptions An exception shall be made for the following AQUATIC VENUE components: 1) Competitive lane markings, 2) Dedicated competitive diving well floors, 3) Step or bench edge markings, 4) POOLS shallower than 24 inches (61.0 cm), 5) Water line tiles, 6) WAVE POOL and SURF POOL depth change indicator tiles, or 7) Other approved designs.

454.1.2.4Color.

Pool floors and walls shall be white or light pastel in color and shall have the characteristic of reflecting rather than absorbing light. The interior finish coating floors and walls shall be comprised of a nonpigmented white cementitious binder component together with a sand/aggregate component. ~~The finish coating~~White or pastel in colorshall ~~have~~mean a dry lightness level (CIE L value) of 80.0 or greater and a wet luminous reflectance value (CIE Y value) of 50.0 or greater, as determined by test results provided by the manufacturer, utilizing testing methodology from American Standard ASTM D4086, ASTM E1477, ASTM E1347. Pools constructed of fiberglass, thermoplastic, or stainless steel shall be subject to the same interior finish color requirements. A minimum 4-inch (102 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, shall be installed at the water line, but shall not exceed 12 inches (305 mm) in height if a dark color is used. Gutter-type pools may substitute a 2-inch (51 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, along the pool wall edge of the gutter lip. A design or logo may be placed on the pool surface, but areas that are not white or pastel in color shall not exceed 6 inches (152 mm) in width, and any 4 foot by 4 foot (1219 mm by 1219 mm) square within the logo area shall be at least 75% white or pastel in color.

2018 Model Aquatic Health Code

Code Language

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

3rd Edition, July 2018

CS288986-A

2018 Model Aquatic Health Code, 3rd Edition
CODE LANGUAGE
Posted on 07/18/2018

This information is distributed solely as guidance for the purpose of assisting state and local health departments, aquatic facility inspection programs, building officials, the aquatics sector, and other interested parties in improving the health and safety at public aquatic facilities. This document does not address all health and safety concerns associated with its use. It is the responsibility of the user of this document to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to each use.

Foreword

Swimming, soaking, and playing in water have been global pastimes throughout written history. Twentieth-century advances in aquatics—combining disinfection, recirculation, and filtration systems—led to an explosion in recreational use of residential and public disinfected water. As backyard and community pool use has swept across the United States, leisure time with family and friends around the pool has increased. Advances in public aquatic facility design have pushed the horizons of treated aquatic facilities from the traditional rectangular community pool to the diverse multi-venue waterpark hosting tens of thousands of users a day. The expansion of indoor aquatic facilities has now made the pool and waterpark into year-round attractions. At the same time, research has demonstrated the social, physical, and psychological benefits of aquatics for all age groups.

However, these aquatics sector changes—combined with changes in the general population, chlorine-tolerant pathogens, and imperfect bather hygiene—have resulted in significant increases in reports of waterborne outbreaks, with the greatest increase occurring in man-made disinfected aquatic venues. Drowning continues to claim the lives of far too many, especially children, and thousands of people visit hospitals every year for pool chemical-associated injuries. Aquatic facility operation can still be improved through education and training. The increase in outbreaks and continued injuries suggests there would be benefits from building stronger public health regulatory programs and supporting them with strong partnerships to implement health promotion efforts, conduct research, and develop prevention guidance. It also would be useful for public health officials to continue to play their strong role in overseeing design and construction, advising on operation and maintenance, and helping inform policy and management. Working in close collaboration with building code officials strengthens the overall coordination needed to prioritize health and safety at public aquatic facilities.

The 3rd Edition of the Model Aquatic Health Code (MAHC) is the latest effort to improve the MAHC, which is a set of voluntary guidelines based on science and best practices. The MAHC was developed to help programs that regulate public aquatic facilities reduce the risk of disease, injury, and drowning in their communities. The MAHC is a leap forward from the Centers for Disease Control and Prevention's (CDC) operational and technical manuals published in 1959, 1976, and 1981 and a logical progression of CDC's Healthy Swimming Program started in 2001. The 2018 MAHC 3rd Edition underscores CDC's long-term involvement and commitment to improving aquatic health and safety. The MAHC guidance document stemmed from concern about the increasing number of pool-associated outbreaks, particularly of cryptosporidiosis, starting in the mid-1990s. Creation of the MAHC was the major recommendation of a 2005 national workshop held in Atlanta, Georgia charged with developing recommendations to reduce these outbreaks. Federal, state, and local public health officials and the aquatics sector formed an unprecedented 7-year collaboration to create the MAHC for release in 2014. The MAHC is now being regularly updated using input from the national stakeholder partnership created and maintained by the Council for the Model Aquatic Health Code (CMAHC). The CMAHC was formed to keep the MAHC up to date and current with the latest advances in the aquatics industry while also responding to public health reports of disease and injury. The CMAHC has now led two national aquatics stakeholder conferences in 2015 and 2017 to solicit, review, and vote on proposed updates to the MAHC. CDC appreciates the breadth of input and commitment to excellence that serves as the foundation for the CMAHC's work. The process and quality of recommendations have improved each time and the CMAHC is making its mark as a pre-eminent force in the aquatics arena. As CDC documents adoption of MAHC-specific guidance components and observes its impact on the aquatics sector, even ahead of adoption, it is clear that the MAHC is filling a gap in public health and safety. The partnership between public health, the aquatics sector, the CMAHC, and academia strengthens the opportunity for achieving the MAHC vision of "Healthy and Safe Aquatic Experiences for Everyone".

CDC

Atlanta, GA, 2018

Acknowledgments

The 2018 MAHC 3rd Edition utilized the CMAHC conference process to collect, assess, and relay MAHC Change Request recommendations to CDC and plans to utilize the CMAHC conference process to update all future versions of the MAHC. The second CMAHC *Vote on the Code* Biennial Conference was held October 17-18, 2017 in Broomfield, Colorado. CDC would like to acknowledge the hard work and dedication of the CMAHC Executive Director, CMAHC Technical Review Committee, CMAHC Technical Support Committees, CMAHC Board of Directors, and CMAHC membership for their dedication and time spent developing, reviewing, and voting on MAHC Change Requests. It is only through the dedicated efforts and contributions of experienced professionals that a scientifically sound, well-focused, and up-to-date MAHC is possible. CDC acknowledges with immense gratitude the substantial assistance of those who contributed to public health and aquatic safety in the development of the 2018 MAHC 3rd Edition. They deserve our heartfelt thanks and appreciation for volunteering their time, energy, and creativity to create the 2018 MAHC 3rd Edition. In addition, we would like to also give our thanks to all the reviewers across the country who provided public comments, and spent a great deal of time combing through the detail of the MAHC code and annex to submit Change Requests for improvement. Their effort was worth the time investment; the MAHC has again been greatly improved after the Conference process and associated public comment periods. As part of the 2017 CMAHC Conference, it was decided to move to a 3-year cycle to allow coordination with other code writing bodies and allow more time for substantive committee work to develop Change Requests; the next CMAHC Conference will be in October 2020. See MAHC Annex Appendix 4: Acknowledgement of MAHC Development Members. This Appendix recognizes CDC's continued gratitude towards the individuals who gave their time and expertise over 7 years to develop the MAHC from dream to product.

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PREFACE

CS288986-A

1.0 Preface *Note: Section numbers with superscript "A" (e.g., 1.0A) denote a corresponding discussion in the* **Annex to the Model Aquatic Health Code.**

1.1 Introduction

1.1.1A Rationale In recent decades, public health practitioners have seen a dramatic increase in waterborne disease outbreaks associated with public DISINFECTED AQUATIC FACILITIES *(e.g. swimming POOLS, water parks, hot tubs, etc.)*. As a result, public health investigations have revealed that many diseases can be prevented by proper maintenance and water treatment and by more modern disease prevention practices. Drowning and falling, diving, chemical use, and suction injuries continue to be major public health injuries associated with public AQUATIC FACILITIES, particularly for young children. In this context, the health and SAFETY at public AQUATIC FACILITIES is regulated by state and local jurisdictions since, in the United States, there is no federal regulatory authority responsible for these public AQUATIC FACILITIES. All public POOL CODES are developed, reviewed, and approved by state and/or local public health officials or legislatures. Consequently, there is no uniform national guidance informing the design, construction, operation, and maintenance of public swimming POOLS and other public DISINFECTED AQUATIC FACILITIES. As a result, the CODE requirements for preventing and responding to recreational water illnesses *(RWIs)* and injuries can vary significantly among local and state agencies. State and local jurisdictions spend a great deal of time, personnel, and resources creating and updating their individual CODES on a periodic basic.

1.1.2 Need for Further Guidance Based on illness tracking data, outbreak reporting, and stakeholder feedback, CDC believed further prevention-oriented planning and action were needed. CDC worked with the Council of State and Territorial Epidemiologists *(CSTE)* to get agreement on the need for a national workshop to develop guidance for preventing future RWI outbreaks. This CSTE position statement was passed in 2004 and CDC was tasked with organizing the national workshop, which was held in 2005. The workshop recommendation to create national guidance for aquatic facility design, operation, and management resulted in the effort to create the Model Aquatic Health Code (The MAHC) that was started in 2007. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.1.3 Responsibility of User This document does not address all SAFETY or public health concerns associated with its use. It is the responsibility of the user of this document to establish appropriate health and SAFETY practices and determine the applicability of regulatory limitations prior to each use.

1.1.4 Original Manufacturer Intent In the absence of exceptions or further guidance, all fixtures and equipment shall be installed according to original manufacturer intent.

1.1.5 Local Jurisdiction The MAHC refers to existing local CODES in the jurisdiction for specific needs. In the absence of existing local CODES, the AUTHORITY HAVING JURISDICTION *(AHJ)* should specify an appropriate CODE reference.

1.2 Recreational Water-Associated Illness Outbreaks and Injuries

1.2.1A RWI Outbreaks Large numbers of recreational water illness (RWI)-related outbreaks are documented annually, which is a significant increase over the past several decades.

1.2.2A Significance of *Cryptosporidium* *Cryptosporidium* causes a diarrheal disease spread from one person to another or, at AQUATIC VENUES, by ingestion of fecally-contaminated water. This pathogen is tolerant of CHLORINE and other halogen DISINFECTANTS. *Cryptosporidium* has emerged as the leading cause of POOL-associated outbreaks in the United States.

1.2.3A Drowning and Injuries Drowning, falling, diving, POOL chemical use, and suction injuries continue to be documented as major public health issues associated with AQUATIC FACILITIES. Drowning is a leading cause of injury death for young children and a leading cause of unintentional injury death for people of all ages.

1.2.4A Pool Chemical-Related Injuries POOL chemical-related injuries occur regularly and can be prevented if POOL chemicals are stored and used as recommended.

1.3 Model Aquatic Health Code

1.3.1[A] Background All POOL CODES in the United States are reviewed and approved by state and/or local public health officials with no uniform national public health STANDARDS governing design, construction, operation, maintenance, policies, or management of public swimming POOLS and other public AQUATIC FACILITIES.

The effort to create the MAHC stems from a CDC-sponsored national workshop called "Recreational Water Illness Prevention at Disinfected Swimming Venues" that was convened on February 15-17, 2005, in Atlanta, Georgia. The workshop assembled persons from different disciplines working in state, local, and federal public health agencies, the aquatics sector, and academia to discuss ways to minimize the spread of RWIs at DISINFECTED AQUATIC FACILITIES. The major recommendation from this workshop was that CDC lead a national partnership to create an open access model guidance document that helps local and state agencies incorporate science and BEST PRACTICES into their swimming POOL CODES and programs without having to "recreate the wheel" each time they create or revise their POOL CODES. The attendees also recommended that this effort be all-encompassing so that it covered the spread of illness but also included drowning and injury prevention. Such an effort should increase the evidence base for AQUATIC FACILITY design, construction, operation, and maintenance while reducing the time, personnel, and resources needed to create and regularly update POOL CODES across the country.

Starting in 2007, CDC worked with the public health sector, the aquatics sector, and academic representatives from across the United States to create this guidance document. Although, the initial workshop was responding to the significant increases in infectious disease outbreaks at AQUATIC FACILITIES, the MAHC is a comprehensive complete AQUATIC FACILITY guidance document with the goal of reducing the spread of infectious disease and occurrence of drowning, injuries, and chemical exposures at public AQUATIC FACILITIES. Based on stakeholder feedback and recommendations, CDC agreed that public health improvements would be aided by development of such a guidance document. The guidance would be an open access, comprehensive, systematic, collaboratively developed guidance document based on science and BEST PRACTICES covering AQUATIC FACILITY design and construction, operation and maintenance, and policies and management to address existing, emerging, and future public health threats. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.3.2 MAHC Vision and Mission The MAHC vision is “Healthy and Safe Aquatic Experiences for Everyone”. The MAHC’s mission is to incorporate science and BEST PRACTICES into guidance on how state and local officials can transform a typical health department POOL program into a data-driven, knowledge-based, risk reduction effort to prevent disease and injuries and promote healthy recreational water experiences. The MAHC provides local and state agencies with uniform guidelines and wording for the design and construction, operation and maintenance, and policies and management of swimming POOLS, SPAS and other public DISINFECTED AQUATIC FACILITIES.

1.3.3 Science and Best Practice The availability of the MAHC should provide state and local agencies with the best available guidance for protecting public health using the latest science and BEST PRACTICES so they can use it to create or update their swimming POOL CODES.

1.3.4 Development Process The MAHC development process created comprehensive consensus risk reduction guidance for AQUATIC FACILITIES based upon national interaction and discussion. The development plan encompassed design, construction, alteration, replacement, operation, and management of these facilities. The MAHC is driven by scientific data and BEST PRACTICES. It was developed by a process that included input from all sectors and levels of public health, the aquatics sector, academia, and the general public. It was open for two 60-day public comment periods during the process. It is national and comprehensive in scope and the guidance can be used to write or update POOL CODES across the United States. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.3.5 Open Access The MAHC is an open access document (www.cdc.gov/mahc) that any interested individual, agency, or organization can freely copy, adapt, or fully incorporate MAHC wording into their

AQUATIC FACILITY oversight documents. As a federal agency, CDC does not copyright this material.

1.3.6 Updating the MAHC The MAHC will be updated on a continuing basis through an inclusive, transparent, all-stakeholder process. This was a recommendation from the original national workshop and is essential to ensure that the MAHC stays current with the latest science, industry advances, and public health findings. To support this recommendation, CDC supported the 2013 creation of the Council for the Model Aquatic Health Code *(CMAHC; www.cmahc.org)*, a 501(c)(3) non-profit organization, to facilitate collecting, assessing, and relaying national input on needed MAHC revisions back to CDC for final consideration for acceptance. The CMAHC was created to manage the national partnership of MAHC participants and gather recommendations from this partnership on how to improve and continually update the MAHC. The first biennial update conference was held in 2015. The results of the CMAHC membership change requests and vote were delivered to CDC in January 2016 and were incorporated into the MAHC to make the 2016 MAHC (2nd Edition). The second biennial update conference was held in 2017. The results of the CMAHC membership change requests and vote were delivered to CDC in January 2018. These changes were used to create the 2018 MAHC 3rd Edition. It was decided at the 2nd biennial conference in 2017 that the update cycle would be altered to occur every 3 years to better synchronize with other code update processes and allow more time for committee work to develop new change requests. The next CMAHC triennial conference will be in 2020 and the 4th Edition of the MAHC will be released in 2021.

1.3.7 Authority Regulatory agencies like state and local governments have the authority to regulate AQUATIC FACILITIES in their jurisdiction.

1.3.8 CDC Role The MAHC is hosted by the Centers for Disease Control and Prevention *(CDC)*, a federal agency whose mission is "to work 24/7 to protect America from health, safety and security threats, both foreign and in the United States. Whether diseases start at home or abroad, are chronic or acute, curable or preventable, human error or deliberate attack, CDC fights disease and supports communities and citizens to do the same." Furthermore, CDC has been involved in developing swimming POOL-related guidance since the 1950s (www.cdc.gov/healthywater/swimming/publications.html) and officially tracking waterborne disease outbreaks associated with AQUATIC FACILITY use since 1978 (www.cdc.gov/healthywater/surveillance/rec-water-surveillance-reports.html). CDC's aim is to improve the knowledge, practices, and procedures of environmental health department staff and programs and reduce aquatic health and safety concerns. CDC collects recreational water venue inspection data from state and local public health departments for periodic analysis and dissemination. CDC operates the Healthy Swimming Program to reduce illness and injury associated with recreational water use and has overseen the Healthy Swimming website since its creation in 2001 *(www.cdc.gov/healthyswimming)*. CDC has also established a specific MAHC website *(www.cdc.gov/mahc)* to house the MAHC and all materials to assist MAHC users.

1.3.8.1 Public Health Role CDC is "the primary Federal agency for conducting and supporting public health activities in the United States"; however, CDC is not a regulatory agency.

1.3.8.2 Model Guidance The MAHC is intended to be open access guidance that state and local public health agencies can use to write or update their POOL CODES in part or in full as fits their jurisdiction's needs. The CDC adopted this project because no other U.S. federal agency has commission over public DISINFECTED AQUATIC FACILITIES. Considering CDC's mission and historical interest in aquatics, this organization was the best qualified to lead a national consortia to create such a document.

1.4 Public Health and Consumer Expectations

1.4.1 Aquatics Sector & Government Responsibility Both the aquatics sector and the government share the responsibility of offering AQUATIC FACILITIES that provide consumers and aquatics workers with safe and healthy recreational water experiences and job sites and that do not become sources for the spread of infectious diseases, outbreaks, or the cause of injuries. This shared responsibility extends to working to meet consumer expectations that AQUATIC FACILITIES are properly designed, constructed, operated, and maintained.

1.4.2 Swimmer Responsibility The PATRON or BATHER shares a responsibility in maintaining a healthy swimming environment by practicing the CDC-recommended healthy swimming behaviors to improve hygiene and reduce the spread of disease. Consumers and BATHERS also share responsibility for using AQUATIC

FACILITIES in a healthy and safe manner to reduce the incidence of injuries.

1.5 Advantages of Uniform Guidance

1.5.1[A] Sector Agreement The aquatics sector and public health officials recognize the value in uniform, consensus guidance created by multi-sector discussion and agreement – both for getting the best possible information and gaining sector acceptance. Since most public AQUATIC FACILITIES are already regulated, the MAHC is intended to be guidance to assist, strengthen, and streamline resource use by state and local CODE officials or legislatures that already regulate AQUATIC FACILITIES but need to regularly update and improve their AQUATIC FACILITY oversight and regulation. Uniform, consensus guidance using the latest science and BEST PRACTICES helps all public sectors, including businesses and consumers, resulting in the best product and experiences.

In addition, the MAHC's combination of performance-based recommendations and prescriptive measures gives AQUATIC FACILITIES freedom to use innovative approaches to achieve acceptable results. However, AQUATIC FACILITIES must ensure that these recommendations are still being met, whatever the approach may be, although innovation should be encouraged to achieve outlined performance-based requirements.

1.5.2 MAHC Provisions The MAHC provides guidance on AQUATIC FACILITY design STANDARDS & construction, operation & maintenance, and policies & management that can be uniformly adopted in part or in whole for the aquatics sector.

The MAHC:

- Is the collective result of the efforts and recommendations of many individuals, public health agencies, and organizations within the aquatics sector,
- Embraces the concept that safe and healthy recreational water experiences by the public are directly affected by how we collectively design, construct, operate, and maintain our AQUATIC FACILITIES, and
- Is updated triennially based on input from CMAHC members.

1.5.3 Aquatic Facility Requirements Model performance-based recommendations essentially define public aquatic health and SAFETY expectations, usually in terms of how dangerous a pathogen or injury is to the public. By using a combination of performance-based recommendations and prescriptive measures, AQUATIC FACILITIES are free to use innovative approaches to provide healthy and safe AQUATIC FACILITIES whereas traditional evaluations mandate how AQUATIC FACILITIES achieve acceptable results. However, to show compliance with the model performance-based recommendation, the AQUATIC FACILITY must demonstrate that control measures are in place to ensure that the recommendations are being met. The underlying theme of the MAHC is that it should be based on the latest science where possible, BEST PRACTICES, and that change will be gradual so all parties can prepare for upcoming changes; "Evolution, not revolution."

1.6 Modifications and Improvements in the 2018 MAHC

1.6.1 Structural Changes ***(Note: CR refers to the CMAHC Change Request number that proposed the change. Individual CMAHC change requests from the 2017 Biennial CMAHC Conference can be viewed at www.cmahc.org/display-change-request-vote.php).***

1.6.1.1 Color Scheme The 2018 Code and Annex covers are slightly different colors from the 2016 MAHC so they can be readily differentiated.

1.6.1.2 Layout

1.6.1.2.1 Table of Contents Table of Contents has been reduced to three header levels.

1.6.1.2.2 Glossary MAHC 3.3 in the CODE and Annex has been updated to include full references, names, and years of applicable CODES, STANDARDS, and laws.

1.6.1.2.3 Resources MAHC Annex 7.1 has been moved to MAHC Annex 8.0 and edited to include only guidelines cited. All cited CODES, STANDARDS, and laws have been moved to the new section MAHC 3.3.

1.6.1.2.4 ***Margins*** Margins have been reduced to 1 inch on the left and 0.5 inch on the top, right, and bottom.

1.6.1.2.5 ***Headers and Body Text*** Body text has been moved up to the same line as headers to help shorten the document.

1.6.1.3 Code Changes and Improvements

1.6.1.3.1 ***Throughout Text*** Font has been changed to Times New Roman, 11 point, and Code text has been wrapped with headings to reduce the page count of the guidance.

1.6.1.3.2 ***Specific Sections***

- 4.5.4.5: Stair tread dimensions made uniform.
- 4.6.1.1: Adds acoustic criteria to natatorium design to reduce noise levels.
- 4.5.10.2: Adds certification for pool lifts.
- 4.7.3.2.1.3/5.7.2.2.4.1.1/5.7.3.2.1.1.1/5.7.3.2.2.6/5.7.3.5.1.2/5.7.3.5.1.4.1/6.4.1.6: Added wording to improve chemical control and feed system interlocks and no/low flow deactivation.
- 4.7.3.2.2.2-0003/4.7.3.2.2.3/5.7.3.5.1.5: Provides performance criteria for disinfectant feeders with sizing dependent on stated chlorine demand factors.
- 4.7.3.3.2: Secondary disinfection performance changed to minimum 2-log reduction for all venues except interactive water play aquatic venues.
- 4.8.6.3.1.1/4.8.6.3.1.2/4.8.6.3.7-0002: Improves enclosure requirement language and delineates exceptions
- 4.12.5.2.2-0001/4.12.5.2.2-0002: Clarifies handhold wording for lazy rivers.
- 4.12.10/5.12.10: Provides guidance for regulation of floatation tanks.
- 5.4.1.1.1/5.4.1.1.2/5.4.1.1.3: Clarifies requirements for closure and reopening.
- 5.6.1.2.1.1. Clarifies glare assessment for lifeguard positions.
- 5.7.3: Specifies that numerous pool chemicals *(stabilizers, pool-grade salt, clarifiers, flocculants, defoamers, pH adjustment chemicals)* must meet NSF/ANSI Standard 50 or 60.
- 5.7.4.4.3: Calcium hardness levels raised to 2500ppm.
- 5.8.5.3.9: Lifeguard PPE must be on person or rescue tube.
- 6.3.2.1-0001: Lifeguards required if alcohol served in aquatic venue.
- 6.5.3.6: Guidance for responding to *Legionella* contamination

1.7 MAHC Adoption at State or Local Level

1.7.1[A] **MAHC Adoption at State or Local Level** The MAHC is provided as guidance for voluntary use by governing bodies at all levels to regulate public AQUATIC FACILITIES. At the state and local levels, the MAHC may be used in part or in whole to:

1) Enact into statute as an act of the state legislative body; or
2) Promulgate as a regulation, rule or CODE; or
3) Adopt as an ordinance.

CDC is committed to offering, at a minimum, assistance to states and localities in interpreting and implementing the MAHC either directly or through the CMAHC. CDC welcomes suggestions for how it could best assist localities in using this guidance in the future. CDC also offers a MAHC toolkit *(including sample forms and checklists)* and is available to give operational guidance to public health POOL programs when needed. CDC is committed to expanding its support of the MAHC and ensuring timely updates and improvements.

1.7.2 **Council for the Model Aquatic Health Code (CMAHC)** Other assistance to localities will also be available. The Council for the Model Aquatic Health Code (CMAHC*; www.cmahc.org)*, an independent, nonprofit 501(c)(3) organization, was created with CDC support in 2013 with the vision of "an up-to-date, knowledge-based Model Aquatic Health Code (MAHC) that supports healthy and safe aquatic experiences for everyone and is used by pool programs across the United States". The CMAHC's role is to serve as a national clearinghouse for input and advice on needed improvements to CDC's MAHC. The CMAHC will fulfill this vision by:

1) Collecting, assessing, and relaying national input on needed MAHC improvements back to CDC for final consideration for acceptance,
2) Advocating for improved health and SAFETY at swimming facilities,
3) Providing assistance to health departments, boards of health, legislatures, and other partners on MAHC uses, benefits, and implementation,
4) Providing assistance to the aquatics industry on uses, interpretation, and benefits of the MAHC, and
5) Soliciting, coordinating, and prioritizing MAHC research needs.

CDC and the CMAHC will work together closely to continue to incorporate national input into the MAHC and provide optimal guidance and assistance to public health officials and the aquatics sector.

1.8 The MAHC Revision Process

1.8.1[A] MAHC Revisions Throughout the creation of the MAHC, the CDC accepted concerns and recommendations for modification of the MAHC from any individual or organization through two 60-day public comment periods via the email address MAHC@cdc.gov.

CDC realizes that the MAHC should be an evolving document that is kept up to date with the latest science, industry advances, and public health findings. As the MAHC is used and recommendations are put into practice, MAHC revisions will need to be made. As the future brings new technologies and new aquatic health issues, the CMAHC, with CDC participation, has instituted a triennial change request solicitation process for collecting national input that welcomes all stakeholders to participate in making recommendations to improve the MAHC so it remains comprehensive, easy to understand, and as technically sound as possible. After CMAHC member voting, accepted recommendations will then be sent to CDC and weighed by CDC for final incorporation into the next edition of the MAHC.

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USER GUIDE

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2.0 User Guide *Note: Section numbers with superscript "A" (e.g., 1.0^A) denote a corresponding discussion in the* Annex to the Model Aquatic Health Code.

The provisions of Chapter 4 *(Aquatic Facility Design Standards and Construction)* apply to construction of a new AQUATIC FACILITY or AQUATIC VENUE or SUBSTANTIAL ALTERATION to an existing AQUATIC FACILITY or AQUATIC VENUE, unless otherwise noted.

The provisions of Chapter 5 and 6 apply to all AQUATIC FACILITIES covered by this CODE regardless of when constructed, unless otherwise noted.

2.1 Overview

2.1.1 New Users A new user will find it helpful to review the Table of Contents in order to quickly gain an understanding of the scope and sequence of subjects included in the CODE.

2.1.2 Topic Presentations MAHC provisions address essentially three areas:

1) Aquatic Facility Design & Construction *(Chapter 4)*,
2) Operation & Maintenance *(Chapter 5)*,
3) Policies & Management *(Chapter 6)*.

In addition, an overarching, scientifically referenced explanation of, and rationale for, the MAHC as a risk reduction plan is provided in the Annex using the same numbering format for easy cross reference.

2.2^A MAHC Structure and Format

2.2.1 Numbering System The CODE follows a numeric outline format. The structural numbering system having different indent, font, color, and size in the document is as follows:

1.0 Chapter

1.1 Part

1.1.1 Subpart

1.1.1.1 Section

1.1.1.1.1 Paragraph

1.1.1.1.1.1 Sub-Paragraph

2.2.2 Title, Keyword, Phrase Text On the same line and next to the section number is a title, keyword, or phrase summary showing the information contained in the corresponding MAHC wording below. Each CODE section number that has annex discussion is denoted with a superscript "A" after the section number *(e.g., 2.0^A)* so readers will know to check the *Annex to the Model Aquatic Health Code* for additional explanation.

2.2.3 MAHC Requirement Recommended MAHC requirement wording is shown below the number of title, keyword, or phrase. These requirements usually appear in sentence or paragraph format.

2.2.4 Illustrations Appropriate charts, diagrams, and other illustrative material will also appear in the Annex. This does not include a repeat of those found in the Code unless deemed necessary.

2.2.5 Consistency Between Chapters 4.0 and 5.0 Each Part or Sub-part is repeated throughout CODE Chapters 4.0 *(Design Standards & Construction)* and 5.0 *(Operation & Maintenance)*. For example, the section titled "Disinfection and pH Control," has two parts:

1) Design recommendations and construction aspects, addressed in MAHC 4.7.3 and
2) Operation and maintenance aspects, addressed in MAHC 5.7.3.

If a topic is not applicable then that section is marked with a N/A *(e.g., the size or width of the DECKING is not applicable for Operation & Maintenance versus Design Standards & Construction)*. This is designed to allow MAHC users to see how a topic of interest applies under both chapter headings.

2.2.6 Conventions The following conventions are used in the MAHC:

1) "Shall" means the act is imperative, i.e., "shall" constitutes a command.
2) "May not" means absolute prohibition.
3) "May" is permissive and means the act is allowed.
4) "Means" is followed by a declared fact.

2.2.7 Definitions Both the CODE and annex have a specific glossary of terms used in either code or annex. Defined glossary words and terms are in "SMALL CAPS" in the text of the CODE and annex chapters to alert the reader that there is a specific meaning assigned to those terms and that the meaning of a provision is to be interpreted in the defined context. A concerted effort was also made to place in "SMALL CAPS" all forms and combinations of those defined words and terms that were intended to carry the weight of the definition.

2.3 Annex to the Model Aquatic Health Code

2.3.1[A] Scientific and Best Practices Rationale The *Annex to the Model Aquatic Health Code (Annex)* is provided to:

1) Give further scientific and BEST PRACTICE explanations of why certain recommendations are made;
2) Discuss the rationale for making the MAHC content decisions;
3) Provide a discussion of the scientific basis for selecting certain criteria, as well as discuss why other scientific data may not have been selected, e.g. due to data inconsistencies;
4) State areas where additional research may be needed;
5) Discuss and explain terminology used; and
6) Provide additional material that may not have been appropriately placed in the main body of suggested MAHC recommendations. This would include summaries of scientific studies, charts, graphs, or other illustrative materials.

2.3.2[A] Content The annex was developed to support the MAHC Code language and is meant to provide additional help, guidance, and scientific and BEST PRACTICE rationale to those responsible for using the MAHC. Statements in the annex are intended to be supplements and additional explanations. They are not meant to be interpreted as MAHC Code wording or used to create enforceable CODE language.

2.3.3 Bibliography The MAHC Code and Annex Section 3.3 includes a list of CODES specifically referenced in each respective document. The annex also contains a bibliography of the reference materials, and scientific studies that form the basis for MAHC recommendations.

2.3.4 Appendices The MAHC Annex Appendices supply additional information or tools that may be useful to the reader of the MAHC Annex and Code.

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GLOSSARY

OF ACRONYMS AND TERMS
USED IN THIS CODE

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3.0 Glossary of Acronyms, Initialisms, Terms, Standards, Codes, and Laws Used in the MAHC Code

3.1 Acronyms and Initialisms Used in the MAHC Code

ACCA	Air Conditioning Contractors of America
ACA	American Coatings Association
ACI	American Concrete Institute
ADAAG	Americans with Disabilities Act Accessibility Guidelines
AED	Automated External Defibrillator
AHA	American Heart Association
AHJ	Authority Having Jurisdiction
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
APSP	Association of Pool and Spa Professionals
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	ASTM International *(formerly American Society for Testing and Materials)*
BCDMH	1-bromo-3-chloro-5, 5-dimethylhydantoin
BVM	Bag-Valve Mask
CDC	Centers for Disease Control and Prevention
CEL	Certified Equipment List
CFM	Cubic Feet Per Minute
CFOC	Caring for Our Children
CFR	Code of Federal Regulations
CI	Chlorine Institute
CMAHC	The Council for the Model Aquatic Health Code
CoSTR	Consensus on Science and Treatment Recommendations
CPR	Cardiopulmonary Resuscitation
CPSC	Consumer Product Safety Commission
CYA	Cyanuric Acid
DBDMH	Dibromodimethylhydantoin
DBP	Disinfection By-Product
DCOF	Dynamic Coefficient of Friction
DVGW	Deutscher Verein des Gas- und Wasserfaches e.V. – Technisch wissenschaftlicher Verein *(German Technical and Scientific Association for Gas and Water)*
EAP	Emergency Action Plan
ECC	Emergency Cardiovascular Care
EPA	United States Environmental Protection Agency
FAC	Free Available Chlorine
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FINA	Fédération Internationale de Natation Amateur
GFCI	Ground-Fault Circuit Interrupter
GPM	Gallons Per Minute
HMIS	Hazardous Material Identification System

HOBr	Hypobromous Acid
HOCl	Hypochlorous Acid
HSC	Hazard Communication Standard
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
ICC	International Code Council
IESNA	Illuminating Engineering Society of North America
IFC	International Fire Code
ILCOR	International Liaison Committee on Resuscitation
IMC	International Mechanical Code
IPC	International Plumbing Code
ISO	International Organization for Standardization
ISPSC	International Swimming Pool and Spa Code
MAHC	Model Aquatic Health Code
MERV	Minimum Efficiency Reporting Value
NCAA	National Collegiate Athletic Association
NEC	National Electrical Code
NFHS	National Federation of State High School Associations
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NPSH	Net Positive Suction Head
NRTL	Nationally Recognized Testing Laboratory
NSF	NSF International *(formerly National Sanitation Foundation)*
OEM	Original Equipment Manufacturer
ÖNORM	Österreichisches Normungsinstitut *(Austrian Standards Institute)*
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
POS	Perimeter Overflow System
PPE	Personal Protective Equipment
PPM	Parts Per Million
PVC	Polyvinyl Chloride
PVC-P	Plasticized Polyvinyl Chloride
RED	Reduction Equivalent Dose
RPZ	Reduced Pressure Zone
RWI	Recreational Water Illness
SDS	Safety Data Sheet
SCBA	Self-Contained Breathing Apparatus
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SVRS	Safety Vacuum Release System
TDH	Total Dynamic Head
TDS	Total Dissolved Solids
UL	Underwriters Laboratories
USC	United States Code
UV	Ultraviolet

UVT	Ultraviolet Transmittance
VFD	Variable Frequency Drive
VGB Act	Virginia Graeme Baker Pool and Spa Safety Act
WQTD	Water Quality Testing Device
YMCA	Young Men's Christian Association

3.2 Terms Used in the MAHC Code

"Accessible Route" means access/egress standards as defined by 2010 ADA Standards for Accessible Design.

"**Activity Pool**" *See "Pool."*

"Air Handling System" means equipment that brings in outdoor air into a building and removes air from a building for the purpose of introducing air with fewer contaminants and removing air with contaminants created while bathers are using aquatic venues. The system contains components that move and condition the air for temperature, humidity, and pressure control, and transport and distribute the air to prevent condensation, corrosion, and stratification, provide acceptable indoor air quality, and deliver outside air to the breathing zone.

"Agitated Water" means an aquatic venue with mechanical means *(aquatic features)* to discharge, spray, or move the water's surface above and/or below the static water line of the aquatic venue. Where there is no static water line, movement shall be considered above the deck plane.

"Alpha Bar" see "Average Sound Absorption Coefficient"

"Aquatic Facility" means a physical place that contains one or more aquatic venues and support infrastructure.

"Aquatic Feature" means an individual component within an aquatic venue. Examples include slides, structures designed to be climbed or walked across, and structures that create falling or shooting water.

"Aquatic Facility or Aquatic Venue Enclosure" means an uninterrupted barrier surrounding and securing an aquatic facility or aquatic venue.

"Aquatic Venue" means an artificially constructed structure or modified natural structure where the general public is exposed to water intended for recreational or therapeutic purpose and where the primary intended use is not watering livestock, irrigation, water storage, fishing, or habitat for aquatic life. Such structures do not necessarily contain standing water, so water exposure may occur via contact, ingestion, or aerosolization. Examples include swimming pools, wave pools, lazy rivers, surf pools, spas *(including spa pools and hot tubs)*, therapy pools, waterslide landing pools, spray pads, and other interactive water venues.

- **"Increased Risk Aquatic Venue"** means an aquatic venue which due to its intrinsic characteristics and intended users has a greater likelihood of affecting the health of the bathers of that venue by being at increased risk for microbial contamination *(e.g., by children less than 5 years old)* or being used by people that may be more susceptible to infection *(e.g., therapy patients with open wounds)*. Examples of increased-risk aquatic venues include spray pads, wading pools and other aquatic venues designed for children less than 5 years old as well as therapy pools.
- **"Lazy River"** means a channeled flow of water of near−constant depth in which the water is moved by pumps or other means of propulsion to provide a river−like flow that transports bathers over a defined path. A lazy river may include play features and devices. A lazy river may also be referred to as a tubing pool, leisure river, leisure pool or a current channel.
- **"Spa"** means a structure intended for either warm or cold water where prolonged exposure is not intended. Spa structures are intended to be used for bathing or other recreational uses and are not usually drained and refilled after each use. It may include, but is not limited to, hydrotherapy, air induction bubbles, and recirculation.
- **"Special Use Aquatic Venue"** means aquatic venues that do not meet the intended use and design features of any other aquatic venue or pool listed/identified in this Code.

"Authority Having Jurisdiction" *(AHJ)* means an agency, organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installations, or procedures.

"Automated Controller" means a system of at least one chemical probe, a controller, and auxiliary or integrated component that senses the level of one or more water parameters and provides a signal to other equipment to maintain the parameters within a user-established range.

"**Available Chlorine**" *See "Chlorine."*

"Average Sound Absorption Coefficient" (Alpha Bar) means the weighted average sound absorption coefficient for a room calculated by weighting the sound absorption coefficients of the individual surfaces in the room according to their respective areas and taking the arithmetic average as follows (especially in the 500 Hz and 1,000 Hz frequencies): And m^2 (or ft^2); Where areas of the individual sound absorptive surfaces, m^2 (or ft^2) respective individual absorption coefficients (dimensionless).[i] A sound absorption coefficient is of a surface, in a specified frequency band, the fraction of the randomly incident sound power which is absorbed (or otherwise not reflected) by a material metric: sabin/m^2.

"Backflow" means a hydraulic condition caused by a difference in water pressure that causes an undesirable reversal of the flow as the result of a higher pressure in the system than in its supply.

"Barrier" means an obstacle intended to prevent direct access from one point to another.

"Bather" means a person at an aquatic venue who has contact with water either through spray or partial or total immersion. The term bather as defined, also includes staff members, and refers to those users who can be exposed to contaminated water as well as potentially contaminate the water.

"Bather Count" means the number of bathers in an aquatic venue at any given time.

"Best Practice" means a technique or methodology that, through experience and research, has been proven to reliably lead to a desired result.

"Body of Water" *(per NEC, q.v.)* means any aquatic venue holding standing water, whether permanent or storable.

"Breakpoint Chlorination" means the conversion of inorganic chloramine compounds to nitrogen gas by reaction with Free Available Chlorine. When chlorine is added to water containing ammonia *(from urine, sweat, or the environment, for example)*, it initially reacts with the ammonia to form monochloramine. If more chlorine is added, monochloramine is converted into dichloramine, which decomposes into nitrogen gas, hydrochloric acid and chlorine. The apparent residual chlorine decreases since it is partially reduced to hydrochloric acid. The point at which the drop occurs is referred to as the "breakpoint". The amount of free chlorine that must be added to the water to achieve breakpoint chlorination is approximately 10 times the amount of combined chlorine in the water. As additional chlorine is added, all inorganic combined chlorine compounds disappear, resulting in a decrease in eye irritation potential and "chlorine odors."

"Bulkheads" means a movable partition that physically separates a pool into multiple sections.

"Certified, Listed, and Labeled" means equipment, materials, products, or services included in a list published by an ANSI accredited certification organization where said equipment, material, product, or service is evaluated against specific criteria and whose listing either states that it meets identified standards or has been tested and found suitable for a specified purpose. In sections of this code where equipment, materials, products, or services are referred to with terms such as "approved", "verified" or similar terms to a referenced standard, these terms also mean "certified, listed, and labeled."

"Chemical Storage Space" means a space in an aquatic facility used for the storage of pool chemicals such as acids, salt, or corrosive or oxidizing chemicals.

"Chlorine" means an element that at room temperature and pressure is a heavy greenish yellow gas with a characteristic penetrating and irritating smell; it is extremely toxic. It can be compressed in liquid form and stored in heavy steel tanks. When mixed with water, chlorine gas forms hypochlorous acid (HOCl), the primary chlorine-based disinfecting agent, hypochlorite ion, and hydrochloric acid. HOCl dissociation to hypochlorite ion is highly pH dependent. Chlorine is a general term used in the MAHC which refers to HOCl and hypochlorite ion in aqueous solution derived from chlorine gas or a variety of chlorine-based disinfecting agents.

- **"Available Chlorine"** means the amount of chlorine in the +1 oxidation state, which is the reactive, oxidized form. In contrast, chloride ion *(Cl^-)* is in the -1 oxidation state, which is the inert, reduced state. Available Chlorine is subdivided into Free Available Chlorine and Combined Available Chlorine. Pool chemicals containing Available Chlorine are both oxidizers and disinfectants. Elemental chlorine *(Cl_2)* is defined as containing 100% available chlorine. The concentration of Available Chlorine in water is normally reported as mg/L *(ppm)* "as Cl_2", that is, the concentration is measured on a Cl_2 basis, regardless of the source of the Available Chlorine.
- **"Free Chlorine Residual"** OR **"Free Available Chlorine"** means the portion of the total available chlorine that is not "combined chlorine" and is present as HOCl or hypochlorite ion *(OCl^-)*.The pH of the water determines the relative amounts of HOCl and hypochlorite ion. HOCl is a very effective bactericide and is the active bactericide in pool water. OCl^- is also a bactericide, but acts more slowly than HOCl. Thus, chlorine is a more effective bactericide at low pH than at high pH. A free chlorine residual must be maintained for adequate disinfection.

"Circulation Path" means an exterior or interior way of passage from one part of an aquatic facility to another for pedestrians, including, but not limited to walkways, pathways, decks, and stairways. This must be considered in relation to ADA.

"**Cleansing Shower**" *See "Shower."*

"Code" means a systematic statement of a body of law, especially one given statutory force.

"Combustion Device" means any appliance or equipment using fire. These include, but may not be limited to, gas or oil furnaces, boilers, pool heaters, domestic water heaters, etc.

"Contamination Response Plan" means a plan for handling contamination from formed-stool, diarrheal-stool, vomit, and blood.

"Contaminant" means a substance that soils, stains, corrupts, or infects another substance by contact or association.

"Corrosive Materials" means pool chemicals, fertilizers, cleaning chemicals, oxidizing cleaning materials, salt, de-icing chemicals, other corrosive or oxidizing materials, pesticides, and such other materials which may cause injury to people or damage to the building, air-handling equipment, electrical equipment, safety equipment, or fire-suppression equipment, whether by direct contact or by contact via fumes or vapors, whether in original form or in a foreseeably likely decomposition, pyrolysis, or polymerization form. Refer to labels and SDS forms.

"Crack" means any and all breaks in the structural shell of a pool vessel or deck.

"Cross-Connection" means a connection or arrangement, physical or otherwise, between a potable water supply system and a plumbing fixture, tank, receptor, equipment, or device, through which it may be possible for non-potable, used, unclean, polluted and contaminated water, or other substances to enter into a part of such potable water system under any condition.

"CT Inactivation Value" means a representation of the concentration of the disinfectant *(C)* multiplied by time in minutes *(T)* needed for inactivation of a particular contaminant. The concentration and time are inversely proportional; therefore, the higher the concentration of the disinfectant, the shorter the contact time required for inactivation. The CT Value can vary with pH or temperature change so these values must also be supplied to allow comparison between values.

"Deck" means surface areas serving the aquatic venue, including the dry deck, perimeter deck, and pool deck.

- **"Dry Deck"** means all pedestrian surface areas within the aquatic venue enclosure not subject to frequent splashing or constant wet foot traffic. The dry deck is not perimeter deck or pool deck, which connect the pool to adjacent amenities, entrances, and exits. Landscape areas are not included in this definition.
- **"Perimeter Deck"** means the hardscape surface area immediately adjacent to and within 4 feet *(1.2 m)* of the edge of the swimming pool also known as the "wet deck" area.
- **"Pool Deck"** means surface areas serving the aquatic venue, beyond perimeter deck, which is expected to be regularly trafficked and made wet by bathers.

"Diaper-Changing Station" means a hygiene station that includes a diaper-changing unit, hand-washing sink, soap and dispenser, a means for drying hands, trash receptacle, and disinfectant products to clean after use.

"Diaper-Changing Unit" means a diaper-changing surface that is part of a diaper-changing station.

"Disinfection" means a treatment that kills or irreversibly inactivates microorganisms *(e.g., bacteria, viruses, and parasites)*; in water treatment, a chemical *(commonly chlorine, chloramine, or ozone)* or physical process *(e.g., ultraviolet radiation)* can be used.

"Disinfection By-Product" (DBP) means a chemical compound formed by the reaction of a disinfectant *(e.g. chlorine)* with a precursor *(e.g. natural organic matter, nitrogenous waste from bathers)* in a water system *(pool, water supply)*.

"Diving Pool" *See "Pool."*

"Drop Slide" *See "Slide."*

"Dry Deck" *See "Deck."*

"Emergency Action Plan" (EAP) means a plan that identifies the objectives that need to be met for a specific type of emergency, who will respond, what each person's role will be during the response. and what equipment is required as part of the response.

"Enclosure" means an uninterrupted constructed feature or obstacle used to surround and secure an area that is intended to deter or effectively prevent unpermitted, uncontrolled, and unfettered access . It is designed to resist climbing and to prevent passage through it and under it. Enclosure can apply to aquatic facilities or aquatic venues.

"EPA Registered" means all products regulated and registered under the Federal Insecticide, Fungicide, and Rodenticide Act *(FIFRA)* by the EPA; *https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act*. EPA registered products will have a registration number on the label *(usually it will state "EPA Reg No." followed by a series of numbers)*. This registration number can be verified by using the EPA National Pesticide Information Retrieval System *(http://ppis.ceris.purdue.edu/#)*.

"Equipment Room or Area" means a space intended for the operation of pool pumps, filters, heaters, and controllers. This space is not intended for the storage of hazardous pool chemicals.

"Exit Gate" means an emergency exit, which is a gate or door allowing free exit at all times.

"Expansion Joint" means a watertight joint provided in a pool vessel used to relieve flexural stresses due to movement caused by thermal expansion/contraction.

"Flat Water" means an aquatic venue in which the water line is static except for movement made by users. Diving spargers do not void the flat water definition.

"Floatation Tank" *(a.k.a. Float Tank, Float Room/Pod/Spa/Chamber, Isolation Tank, or Sensory Deprivation Tank)* means a tub that contains a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3, provides a light and sound reduced environment, and is maintained at a temperature of approximately 92-96°F / 33.3-35.6°C.

"Floatation Tank Solution" means a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3.

"Flume" means the riding channels of a waterslide which accommodate riders using or not using mats, tubes, rafts, and other transport vehicles as they slide along a path lubricated by a water flow.

"Foot Baths" means standing water in which bathers or aquatics staff rinse their feet.

"Free Chlorine Residual" OR **"Free Available Chlorine"** *See "Chlorine."*

"Ground-Fault Circuit Interrupter" (GFCI) means a device for protection of personnel that de-energizes an electrical circuit or portion thereof in the event of excessive ground current.

"Hand Wash Station" means a location which has a hand wash sink, adjacent soap with dispenser, hand drying device or paper towels and dispenser, and trash receptacle.

"Hot Water" means an aquatic venue with water temperature over 90 degrees Fahrenheit *(30 degrees Celsius)*.

"Hygiene Facility" means a structure or part of a structure that contains toilet, shower, diaper-changing unit, hand wash station, and dressing capabilities serving bathers and patrons at an aquatic facility.

"Hygiene Fixtures" means all components necessary for hygiene facilities including plumbing fixtures, diaper-changing stations, hand wash stations, trashcans, soap dispensers, paper towel dispensers or hand dryers, and toilet paper dispensers.

"Hyperchlorination" means the intentional and specific raising of chlorine levels for a prolonged period of time to inactivate pathogens following a fecal or vomit release in an aquatic venue as outlined in MAHC 6.5.

"Imminent Health Hazard" means a significant threat or danger to health that is considered to exist when there is evidence sufficient to show that a product, practice, circumstance, or event creates a situation that requires immediate correction or cessation of operation to prevent injury based on the number of potential injuries and the nature, severity, and duration of the anticipated injury or illness.

"Increased Risk Aquatic Venue" *See "Aquatic Venue."*

"Indoor Aquatic Facility" means a physical place that contains one or more aquatic venues and the surrounding bather and spectator/stadium seating areas within a structure that meets the definition of "Building" per the 2012 International Building Code *(IBC)*. It does not include equipment, chemical storage, or bather hygiene rooms or any other rooms with a direct opening to the aquatic facility. Otherwise known as a natatorium.

"Infinity Edge" means a pool wall structure and adjacent perimeter deck that is designed in such a way where the top of the pool wall and adjacent deck are not visible from certain vantage points in the pool or from the opposite side of the pool. Water from the pool flows over the edge and is captured and treated for reuse through the normal pool filtration system. They are often also referred to as "vanishing edges," "negative edges," or "zero edges."

"Inlet" means wall or floor fittings where treated water is returned to the pool.

"Interactive Water Play Aquatic Venue" means any indoor or outdoor installation that includes sprayed, jetted or other water sources contacting bathers and not incorporating standing or captured water as part of the bather activity area. These aquatic venues are also known as splash pads, spray pads, wet decks. For the purposes of the MAHC, only those designed to recirculate water and intended for public use and recreation shall be regulated.

"Interior Space" means any substantially enclosed space having a roof and having a wall or walls which might reduce the free flow of outdoor air. Ventilation openings, fans, blowers, windows, doors, etc., shall not be construed as allowing free flow of outdoor air.

"Island" means a structure inside a pool where the perimeter is completely surrounded by the pool water and the top is above the surface of the pool.

"Landing Pool" *See "Pool."*

"Lazy River" See "Aquatic Venue."

"Lifeguard Supervisor" means an individual responsible for the oversight of lifeguard performance and emergency response at an aquatic facility. A qualified lifeguard supervisor is an individual who has successfully completed a lifeguard supervisor training course and holds an unexpired certificate for such training; and who has met the pre-service and continuing in-service requirements of the aquatic facility according to this code.

"mg/L" means milligrams per liter and is the equivalent metric measure to parts per million *(ppm)*.

"Monitor" means the regular and purposeful observation and checking of systems or facilities and recording of data, including system alerts, excursions from acceptable ranges, and other facility issues. Monitoring includes human or electronic means.

"Moveable Floors" means a pool floor whose depth varies through the use of controls.

"No Diving Marker" means a sign with the words "No Diving" and the universal international symbol for "No Diving" pictured as an image of a diver with a red circle with a slash through it.

"Noise Criterion" means the single number rating that is somewhat sensitive to the relative loudness and speech interference properties of a given noise spectrum. The method consists of a family of criterion curves extending from 63 to 8,000 Hz and a tangency rating procedure. The criterion curves define the limits of octave band spectra that must not be exceeded to meet occupant acceptance in certain spaces.

"Oocyst" means the thick-walled, environmentally resistant structure released in the feces of infected animals that serves to transfer the infectious stages of sporozoan parasites *(e.g., Cryptosporidium)* to new hosts.

"Oxidation" means the process of changing the chemical structure of water contaminants by either increasing the number of oxygen atoms or reducing the number of electrons of the contaminant or other chemical reaction, which allows the contaminant to be more readily removed from the water or made more soluble in the water. It is the "chemical cleaning" of pool water. Oxidation can be achieved by common disinfectants *(e.g., chlorine, bromine)*, secondary disinfection/sanitation systems *(e.g. ozone)* and oxidizers *(e.g. potassium monopersulfate)*.

"Oxidation Reduction Potential" (ORP) means a measure of the tendency for a solution to either gain or lose electrons; higher *(more positive)* oxidation reduction potential indicates a more oxidative solution.

"Patron" means a bather or other person or occupant at an aquatic facility who may or may not have contact with aquatic venue water either through partial or total immersion. Patrons may not have contact with aquatic venue water, but could still be exposed to potential contamination from the aquatic facility air, surfaces, or aerosols.

"Peninsula / Wing Wall" means a structural projection into a pool intended to provide separation within the body of water.

"Perimeter Deck" *See "Deck."*

"Perimeter Gutter System" means the alternative to skimmers as a method to remove water from the pool's surface for treatment. The gutter provides a level structure along the pool perimeter versus intermittent skimmers.

"Plumbing Fixture" means a receptacle, fixture, or device that is connected to a water supply system or discharges to a drainage system or both and may be used for the distribution and use of water; for example: toilets, urinals, showers, and hose bibs. Such receptacles, fixtures, or devices require a supply of water; or discharge liquid waste or liquid-borne solid waste; or require a supply of water and discharge waste to a drainage system.

"pH" means the negative log of the concentration of hydrogen ions. When water ionizes, it produces hydrogen ions *(H+)* and hydroxide ions *(OH-)*. If there is an excess of hydrogen ions the water is acidic. If there is an excess of hydroxide ions the water is basic. pH ranges from 0 to 14. Pure water has a pH of 7.0. If pH is higher than 7.0, the water is said to be basic, or alkaline. If the water's pH is lower than 7.0, the water is acidic. As pH is raised, more HOCl ionization occurs and chlorine disinfectants decrease in effectiveness.

"Pool" means a subset of aquatic venues designed to have standing water for total or partial bather immersion. This does not include spas.

- **"Activity Pool"** means a water attraction designed primarily for play activity that uses constructed features and devices including pad walks, flotation devices, and similar attractions.
- **"Diving Pool"** means a pool used exclusively for diving.
- **"Landing Pool"** means an aquatic venue or designated section of an aquatic venue located at the exit of one or more waterslide flumes. The body of water is intended and designed to receive a bather emerging from the flume for the purpose of terminating the slide action and providing a means of exit to a deck or walkway area.
- **"Skimmer Pool"** means a pool using a skimmer system.
- **"Surf Pool"** means any pool designed to generate waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.
- **"Therapy Pool"** means a pool used exclusively for aquatic therapy, physical therapy, and/or rehabilitation to treat a diagnosed injury, illness, or medical condition, wherein the therapy is provided under the direct supervision of a licensed physical therapist, occupational therapist, or athletic trainer. This could include wound patients or immunocompromised patients whose health could be impacted if there is not additional water quality protection.
- **"Wading Pool"** means any pool used exclusively for wading and intended for use by young children where the depth does not exceed 2 feet *(0.6 m)*.
- **"Wave Pools"** means any pool designed to simulate breaking or cyclic waves for purposes of general play. A wave pool is not the same as a surf pool, which generates waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.

"**Pool Deck**" *See "Deck."*

"Pool Slide" *See "Slide."*

"Public Water Systems" means water systems including community water systems, non-transient/non-community water systems, or transient non-community water systems with exceptions as noted by AHJ and EPA.

"Purge" means to introduce a large volume of outdoor air to flush the interior space.

"Qualified Lifeguard" means an individual who has successfully completed an AHJ-recognized lifeguard training course offered by an AHJ-recognized training agency, holds a current certificate for such training, has met the pre-service requirements, and is participating in continuing in-service training requirements of the aquatic facility.

"Qualified Operator" means an individual responsible for the operation and maintenance of the water and air quality systems and the associated infrastructure of the aquatic facility and who has successfully completed an

AHJ-recognized operator training course to operate an aquatic facility offered by an AHJ-recognized training agency and holds a current certificate for such training.

"Recessed Steps" means a way of ingress/egress for a pool similar to a ladder but the individual treads are recessed into the pool wall.

"Recirculation System" means the combination of the main drain, gutter or skimmer, inlets, piping, pumps, controls, surge tank or balance tank to provide pool water recirculation to and from the pool and the treatment systems.

"Reduction Equivalent Dose *(RED)* bias" means a variable used in UV system validation to account for differences in UV sensitivity between the UV system challenge microbe *(e.g., MS2 virus)* and the actual microbe to be inactivated *(e.g., Cryptosporidium)*.

"Re-entrainment" means a situation where the exhaust*(s)* from a ventilated source such as an indoor aquatic facility is located too close to the air handling system intake*(s)*, which allows the exhausted air to be re-captured by the air handling system so it is transported directly back into the aquatic facility.

"Responsible Supervisor" means an individual on-site that is responsible for water treatment operations when a "qualified operator" is not on-site at an aquatic facility.

"**Rinse Shower**" *See "Shower."*

"Robotic Cleaner" means a modular vacuum system consisting of a motor-driven, in-pool suction device, either self-powered or powered through a low voltage cable, which is connected to a deck-side power supply.

"Runout" means that part of a waterslide where riders are intended to decelerate and/or come to a stop. The runout is a continuation of the waterslide flume surface.

"Safety" *(as it relates to construction items)* means a design standard intended to prevent inadvertent or hazardous operation or use *(i.e., a passive engineering strategy)*.

"Safety Plan" means a written document that has procedures, requirements and/or standards related to safety which the aquatic facility staff shall follow. These plans include training, emergency response, and operations procedures.

"Safety Team" means any employee of the aquatic facility with job responsibilities related to the aquatic facility's emergency action plan.

"Sanitize" means reducing the level of microbes to that considered safe by public health standards *(usually 99.999%)*. This may be achieved through a variety of chemical or physical means including chemical treatment, physical cleaning, or drying.

"Saturation Index" means a mathematical representation or scale representing the ability of water to deposit calcium carbonate, or dissolve metal, concrete or grout.

"Secondary Disinfection Systems" means those disinfection processes or systems installed in addition to the standard systems required on all aquatic venues, which are required to be used for increased risk aquatic venues.

"Shower" means a device that sprays water on the body.

- **"Cleansing Shower"** means a shower located within a hygiene facility using warm water and soap. The purpose of these showers is to remove contaminants including perianal fecal material, sweat, skin cells, personal care products, and dirt before bathers enter the aquatic venue.

- **"Rinse Shower"** means a shower typically located in the pool deck area with ambient temperature water. The main purpose is to remove dirt, sand, or organic material prior to entering the aquatic venue to reduce the introduction of contaminants and the formation of disinfection by-products.

"Skimmer" means a device installed in the pool wall whose purpose is to remove floating debris and surface water to the filter. They shall include a weir to allow for the automatic adjustment to small changes in water level, maintaining skimming of the surface water.

"Skimmer Pool" *See "Pool."*

"Skimmer System" means periodic locations along the top of the pool wall for removal of water from the pool's surface for treatment.

"Slide" means an aquatic feature where users slide down from an elevated height into water.

- **"Drop Slide"** means a slide that drops bathers into the water from a height above the water versus delivering the bather to the water entry point.
- **"Pool Slide"** means a slide having a configuration as defined in The Code of Federal Regulations *(CFR)* Ch. II, Title 16 Part 1207 by CSPC, or is similar in construction to a playground slide used to allow users to slide from an elevated height to a pool. They shall include children's *(tot)* slides and all other non-flume slides that are mounted on the pool deck or within the basin of a public swimming pool.
- **"Waterslide"** means a slide that runs into a landing pool or runout through a fabricated channel with flowing water.

"Sound Absorption" means (1) the process of dissipating sound energy and (2) the property possessed by materials, objects and structures, such as rooms, for absorbing sound energy.

"Spa" See "Aquatic Venue."

"**Special Use Aquatic Venue**" *See "Aquatic Venue."*

"Standard" means something established by authority, custom, or general consent as a model or example.

"Storage" means the condition of remaining in one space for 1 hour or more. Materials in a closed pipe or tube awaiting transfer to another location shall not be considered to be stored.

"Structural Crack" means a break or split in the pool surface that weakens the structural integrity of the vessel.

"Substantial Alteration" means the alteration, modification, or renovation of an aquatic venue *(for outdoor aquatic facilities)* or indoor aquatic facility *(for indoor aquatic facilities)* where the total cost of the work exceeds 50% of the replacement cost of the aquatic venue *(for outdoor aquatic facilities)* or indoor aquatic facility *(for indoor aquatic facilities).*

"Superchlorination" means the addition of large quantities of chlorine-based chemicals to kill algae, destroy odors, or improve the ability to maintain a disinfectant residual. This process is different from hyperchlorination, which is a prescribed amount to achieve a specific CT inactivation value whereas superchlorination is the raising of free chlorine levels for water quality maintenance.

"Supplemental Treatment Systems" means those disinfection processes or systems which are not required on an aquatic venue for health and safety reasons. They may be used to enhance overall system performance and improve water quality.

"Surf Pool" *See "Pool."*

"Theoretical Peak Occupancy" means the anticipated peak number of bathers in an aquatic venue or the anticipated peak number of occupants of the decks of an aquatic facility. This is the lower limit of peak occupancy to be used for design purposes for determining services that support occupants. Theoretical peak occupancy is used to determine the number of showers. For aquatic venues, the theoretical peak occupancy is calculated around the type of water use or space:

- **"Flat Water"** means an aquatic venue in which the water line is static except for movement made by users usually as a horizontal use as in swimming. Diving spargers do not void the flat water definition.
- **"Agitated Water"** means an aquatic venue with mechanical means *(aquatic features)* to discharge, spray, or move the water's surface above and/or below the static water line of the aquatic venue so people are standing or playing vertically. Where there is no static water line, movement shall be considered above the deck plane.
- **"Hot Water"** means an aquatic venue with a water temperature over 90°F *(32°C)*.
- **"Stadium Seating"** means an area of high-occupancy seating provided above the pool level for observation.

"**Therapy Pool**" *See "Pool."*

"Toe Ledge" *See "Underwater Ledge."*

"Turnover" or "Turnover Rate" or "Turnover Time" means the period of time, usually expressed in hours, required to circulate a volume of water equal to the capacity of the aquatic venue.

"Underwater Bench" means a submerged seat with or without hydrotherapy jets.

"Underwater Ledge" or "Underwater Toe Ledge" means a continuous step in the pool wall that allows swimmers to rest by standing without treading water.

"Wading Pool" *See "Pool."*

"Waterslide" *See "Slide."*

"Water Replenishment System" means a way to remove water from the pool as needed and replace with make-up water in order to maintain water quality.

"Water Quality Testing Device" (WQTD) means a product designed to measure the level of a parameter in water. A WQTD includes a device or method to provide a visual indication of a parameter level, and may include one or more reagents and accessory items.

"Wave Pools" *See "Pool."*

"Wing Wall / Peninsula" *See "Peninsula / Wing Wall."*

"Zero Depth Entry" means a sloped entry into a pool from deck level into the interior of the pool as a means of access and egress.

3.3 Codes, Standards, and Laws Referenced in the MAHC Code

Air Conditioning Contractors of America (ACCA)

- ANSI/ACCA 10 Manual SPS-2011 (RA 2017); Manual SPS HVAC Design for Swimming Pools and Spas

Air Movement Control Association (AMCA)

- AMCA 201-02 (R2011), Fans and Systems

American Coatings Association (ACA)

- Hazardous Materials Identification System (HMIS), Fourth Edition

American Concrete Institute (ACI)

- ACI 302.1R-15, Guide to Concrete Floor and Slab Construction

American Heart Association (AHA)

- American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC)
- 2015 AHA Guidelines Update for CPR and ECC
- www.citizencpr.org

American National Standards Institute (ANSI)

- ANSI/ICC A117.1-2017. Accessible and Usable Buildings and Facilities
- ANSI A137.1:2017 American National Standards Specifications for Ceramic Tile

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

- ANSI/ASHRAE Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality
- 2015 *ASHRAE Handbook—HVAC Applications*

American Society of Mechanical Engineers (ASME)

- ASME A112.19.17-2010, Manufactured Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems

ASTM International (formerly American Society for Testing and Materials) (ASTM)

- ASTM F1346 – 91(2010): Standard Performance Specification for Safety Covers and Labeling Requirements for All Covers for Swimming Pools, Spas and Hot Tubs
- ASTM F2285-04 (2016)e1: Standard Consumer Safety Performance Specification for Diaper Changing Tables for Commercial Use
- ASTM F2376-117a (2017): Standard Practice for Classification, Design, Manufacture, Construction and Operation of Water Slides Systems
- ASTM F2387-04 (2012): Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas and Hot Tubs
- ASTM F2461-16e1(2016) Standard Practice for Manufacture, Construction, Operation and Maintenance of Aquatic Play Equipment

Americans with Disabilities Act Accessibility Guidelines (ADAAG)

- 2010 ADA Standards for Accessible Design

Association of Pool and Spa Professionals (APSP)

- ANSI/APSP-16 2011, Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs

Caring for Our Children (CFOC): National Health and Safety Performance Standard

- National Health and Safety Performance Standards; Guidelines for Early Care and Education Programs, Third Edition, 2011 (revised October 1, 2015)
- Also known as *Caring for Our Children*, 3rd Edition (CFOC3)
- Accessed at: http://nrckids.org

Chlorine Institute (CI)

- Pamphlet 82; Recommendations for Using 100 & 150 Pound Chlorine Cylinders at Swimming Pools, Edition 3, January 2015

Consumer Product Safety Commission (CPSC)

- 16 CFR 1207 – Safety Standard for Swimming Pool Slide
  - (Last updated 43 FR 58813, Dec. 18, 1978)

Deutscher Verein des Gas- und Wasserfaches e.V. – Technisch wissenschaftlicher Verein (DVGW)

- German Technical and Scientific Association for Gas and Water

Environmental Protection Agency (EPA)

- EPA 815-R-06-007: *Ultraviolet Disinfectant Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule, November 2006*
- EPA 816-F-09-004: National Primary Drinking Water Regulations, May 2009, (40 CFR 141)
- 7 USC §136 et. seq. (1996), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- 40 CFR Subchapter E – Pesticide Programs

Fédération Internationale de Natation Amateur (FINA)

- Facilities Rules 2017 – 2021, 22 September 2017

Hazardous Materials Identification System (HMIS)

- See American Coatings Association above

Illuminating Engineering Society of North America (IESNA)

- The Lighting Handbook, 10th Edition (2011)

International Association of Plumbing and Mechanical Officials (IAPMO)

- IAPMO/ANSI UMC 1 2015 (2015 Uniform Mechanical Code)
- IAPMO/ANSI UPC 1 2015 (2015 Uniform Plumbing Code)

- IAPMO/ANSI USPSHTC 1 2015 (2015 Uniform Swimming Pool, Spa, and Hot Tub Code)

International Code Council (ICC)

- ICC/ANSI A117.1-2017 Standard for Accessible and Usable Buildings and Facilities
- 2018 International Building Code (IBC)
- 2018 International Fire Code (IFC)
- 2018 International Mechanical Code (IMC)
- 2018 International Plumbing Code (IPC)
- 2018 International Swimming Pool and Spa Code (ISPSC)

International Liaison Commission of Resuscitation (ILCOR)

- 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care With Treatment Recommendations (CoSTR)
- www.ilcor.org

International Organization for Standardization (ISO)

- ISO9000:~~2000~~2015; Quality management systems – Fundamentals and vocabulary

National Collegiate Athletic Association (NCAA)

- 2017-18 and 2018-19 NCAA Men's and Women's Swimming and Diving Rules

National Federation of State High School Associations (NFHS)

- 2017-18 NFHS Swimming and Diving Rules Book

National Fire Protection Association (NFPA)

- NFPA 1: Fire Code, 2018 Edition
- NFPA 70: National Electric Code (NEC), 2017 Edition
- NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response, 2017 Edition

National Institute for Occupational Safety and Health (NIOSH)

- 42 CFR Part 84, Respiratory Protective Devices, 1995
- Certified Equipment List (CEL)

NSF International (NSF)

- NSF/ANSI 14 - 2016b, Plastics Piping System Components and Related Materials
- NSF/ANSI 50 - 16a, Equipment for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities
- NSF/ANSI 60 – 2016, Drinking Water Treatment Chemicals – Health Effects
- NSF/ANSI 61-2014 - 2016, Drinking Water System Components – Health Effects

Occupational Safety and Health Administration (OSHA)

- 29 CFR 1910.304 – Wiring design and protection
  - (Last updated 73 FR 64205, Oct. 29, 2008)
- 29 CFR 1910.1000 Air contaminants
  - (Last updated 81 FR 16861, Mar. 25, 2016)
- 29 CFR 1910.1030~~:~~ - Bloodborne Pathogens
  - (Last updated 77 FR 19934, Apr. 3, 2012)
- 29 CFR 1910.1200 – Hazard Communication Standard (HSC) 2012 HazCom 2012 Final Rule (HazCom 2012)

Österreichisches Normungsinstitut (ÖNORM)

- (Austrian Standards Institute)

Sheet Metal & Air Conditioning Contractors' National Association (SMACNA)

- SMACNA HVAC Systems Duct Design, 4*th* Edition, 2006

Underwriters Laboratories (UL)

- UL 399 2017-03-20 Standard for Drinking-Water Coolers
- UL 1081 2016-08-09 Standard for Swimming Pool Pumps, Filters, and Chlorinators
- UL 2075 2013-03-05 Standard for Gas and Vapor Detectors and Sensors
- UL 2818 2013-03-29 GREENGUARD Certification Program for Chemical Emissions for Building Materials, Finishes, and Furnishings
- UL 60335-2-1000 2017-09-29 Standard for Household and Similar and Similar electrical Appliances: Particular Requirements for Electrically Powered Pool Lifts

USA Diving

- USA Diving Competitive and Technical Rules, 2018

USA Swimming

- USA Swimming 2017 Rulebook

United States Coast Guard

- 33 CFR 175.15; Sept 22, 2014; Personal Floatation Devices

Virginia Graeme Baker Pool and Spa Safety Act (VGB Act)

- 15 USC Chapter 106, Pool and Spa Safety (as amended to 2014)
- Available at: https//poolsafely.gov/wp-content/uploads/2016/04/pssa.pdf/
- Interpretation Guidance: http://poolsafely.gov under Materials, Resource Library, The Act and Rulings

2018 Model Aquatic Health Code

Code Language

DESIGN AND CONSTRUCTION

CS288986-A

4.0[A] Aquatic Facility Design Standards and Construction

The provisions of MAHC Chapter 4 *(Aquatic Facility Design Standards and Construction)* apply to construction of a new AQUATIC FACILITY or AQUATIC VENUE or SUBSTANTIAL ALTERATION to an existing AQUATIC FACILITY or AQUATIC VENUE, unless otherwise noted.

Note: Section numbers with superscript "A" (e.g., 4.0A) denote a corresponding discussion in the Annex to the Model Aquatic Health Code.

4.1 Plan Submittal

4.1.1 Plan Submittal

4.1.1.1 Purpose AQUATIC FACILITY construction plans shall be designed to provide sufficient clarity to indicate the location, nature, and extent of the work proposed.

4.1.1.2 Conform AQUATIC FACILITY construction plans shall show in detail that it will conform to the provisions of this CODE and relevant laws, ordinances, rules, and regulations, as determined by the AHJ and to protect the health and SAFETY of the facility's BATHERS and PATRONS.

4.1.1.3 Approved Plans No person shall begin to construct a new AQUATIC FACILITY or shall SUBSTANTIALLY ALTER an existing AQUATIC FACILITY without first having the construction plans detailing the construction or SUBSTANTIAL ALTERATION submitted to and approved by the AHJ.

4.1.1.4 Plan Preparation All plans shall be prepared by a design professional who is registered or licensed to practice their respective design profession as defined by the state or local laws governing professional practice within the jurisdiction in which the project is to be constructed.

4.1.1.5 Required Statements All construction plans shall include the following statements:

1) "The proposed aquatic facility and all equipment shall be constructed and installed in conformity with the approved plans and specifications or approved amendments," and
2) "No substantial alteration, changes, additions, or equipment not specified in the approved plans can be made or added until the plans for such substantial alteration, changes, additions, or equipment are submitted to and approved by the AHJ."

4.1.2 Content of Design Report

4.1.2.1 Basis of Design Report

4.1.2.1.1[A] Names / Addresses AQUATIC FACILITY plans shall include the name, address, and contact information for the owner, designer, and builder if available at the time of submission.

4.1.2.1.2 Site Information AQUATIC FACILITY plans shall include site information indicating at a minimum the location of all utilities, wells, topography, natural water features, and potential sources of surface drainage and pollution which may affect the proposed AQUATIC FACILITY.

4.1.2.1.3 Plot Plan AQUATIC FACILITY plans shall include a site plot plan including:

1) A general map and detailed scaled drawings of the AQUATIC FACILITY site plan or floor plan with detailed locations of the AQUATIC VENUES and AQUATIC FEATURES; and
2) The locations of all water supply facilities, sources of drinking water, public or private sewers, and relative elevations of paved or other walkways and the EQUIPMENT ROOM floor shall be shown on the plans with the elevations of storm and sanitary sewer inverts and street grade.

4.1.2.2 Plans and Specifications

4.1.2.2.1 Drawings Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall include an AQUATIC VENUE area plan and layout plan along with dimensioned longitudinal and transverse cross sections of the AQUATIC VENUE.

4.1.2.2.1.1 Operating Conditions The design documents shall include a record of operating conditions *(water temperature(s), space temperature, space relative humidity, space dew point)* and intended use for each type of VENUE *(FLAT WATER, AGITATED WATER, HOT WATER)* accepted by both the design engineer and owner/operator.

4.1.2.2.2 Aquatic Venue Attributes Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall include location and type of:

1) INLETS,
2) Overflows,
3) Drains,
4) Suction outlets,
5) Overflow gutters or devices,
6) Piping,
7) Designed POOL water elevation,
8) AQUATIC FEATURES such as ladders, stairs, diving boards, SLIDES, and play features,
9) Lighting,
10) Pool markings, and
11) Surface materials

4.1.2.2.3 Area Design Detailed scaled and dimensional drawings of the AQUATIC FACILITY and for each individual AQUATIC VENUE, as appropriate, shall include location and type of:

1) Design of DECK, curb, or walls enclosing the AQUATIC VENUE,
2) DECK drains,
3) Paved walkways and other hardscape features,
4) Non-slip flooring,
5) AQUATIC VENUE area finishes,
6) Drinking fountains or other sources of drinking water,
7) Entries and exits,
8) Hose bibs,
9) Fences,
10) Telephones, and
11) Area lighting.

4.1.2.2.4 Aquatic Venue Recirculation and Treatment Design Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a flow diagram showing the location, plan, elevation, and schematics of:

1) Filters,
2) Pumps,
3) Chemical feeders and interlocks
4) Chemical controllers and interlocks,
5) SECONDARY DISINFECTION SYSTEMS, if required,
6) Supplemental DISINFECTION systems, if installed,
7) Ventilation devices or AIR HANDLING SYSTEMS,
8) Heaters,
9) Surge tanks, including operating levels,
10) BACKFLOW prevention assemblies and air gaps,
11) Valves,
12) Piping,
13) Flow meters,
14) Gauges,

15) Thermometers,

16) Test cocks,

17) Sight glasses, and

18) Drainage system for the disposal of AQUATIC VENUE water and filter wastewater.

4.1.2.2.5 Equipment Room Design Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a schematic layout of the AQUATIC VENUE EQUIPMENT ROOM *(or EQUIPMENT AREA if permitted by the local AHJ)* showing accessibility for installation and maintenance.

4.1.2.2.6 Chemical Storage Space Design Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a schematic layout of the AQUATIC FACILITY CHEMICAL STORAGE SPACE(S).

4.1.2.2.7 Hygiene Facility Design Detailed scaled and dimensional drawings for each AQUATIC FACILITY shall show the location and number of all available HYGIENE FACILITIES provided including dressing rooms, lockers and basket STORAGE, SHOWERS, lavatory, toilet FIXTURES, and DIAPER-CHANGING STATIONS.

4.1.2.3 Technical Specifications

4.1.2.3.1[A] Accompanying Drawings Technical specifications for the construction of each AQUATIC VENUE and all appurtenances shall accompany the drawings for the AQUATIC FACILITY plans.

4.1.2.3.2[A] Technical Details The following technical specifications shall be provided for each AQUATIC FACILITY:

1) POOL water temperatures,
2) Space design,
3) Dry bulb and dew point temperatures, and
4) Relative humidity.

4.1.2.3.2.1 Details Not Shown on Plans Each AQUATIC VENUE shall include all construction details not shown on the plans that relate to the AQUATIC FACILITY:

4.1.2.3.2.2[A] Intended Use Design of the ventilation and AIR HANDLING SYSTEMS for INDOOR AQUATIC FACILITIES shall include consultation with, and input by, the owner/operator to address intended use, type of VENUE *(FLAT WATER, AGITATED WATER, HOT WATER)* and intended typical operating water temperature.

4.1.2.3.3 Water Sources The technical specifications for each AQUATIC FACILITY shall include the sources of all water supplies.

4.1.2.3.4 Area and Volume Technical specifications shall include the water surface area and volume of each AQUATIC VENUE and associated water features, if applicable.

4.1.2.3.5[A] Theoretical Peak Occupancy The technical specifications for each AQUATIC FACILITY and each AQUATIC VENUE shall include THEORETICAL PEAK OCCUPANCY, respectively.

4.1.2.3.5.1 Used for Designing Systems The THEORETICAL PEAK OCCUPANCY for an AQUATIC VENUE shall be used for designing systems that serve BATHERS and PATRONS. *(Note: The specified density factors are the lower limits for determining THEORETICAL PEAK OCCUPANCY.)*

4.1.2.3.5.2 Incorporate Non-Water Related Areas The THEORETICAL PEAK OCCUPANCY for an AQUATIC FACILITY shall be used for designing systems that serve BATHERS and PATRONS and shall incorporate non-water related areas such as DECKS and other adjacent portions of the AQUATIC FACILITY not associated with the AQUATIC VENUE.

4.1.2.3.5.3 Calculating Theoretical Peak Occupancy The THEORETICAL PEAK OCCUPANCY shall be calculated by dividing the surface area in square feet of the AQUATIC VENUE by the density factor *(D)* that fits the specific AQUATIC VENUE being considered.

THEORETICAL PEAK OCCUPANCY = AQUATIC VENUE Surface Area / D

The density factors *(D)* are:

Water/BATHER-related:

1) FLAT WATER density factor = 20 ft^2 *(1.9 m^2)* per BATHER.
2) AGITATED WATER density factor = 15 ft^2 *(1.4 m^2)* per BATHER.
3) HOT WATER density factor = 10 ft^2 *(0.9 m^2)* per BATHER.
4) WATERSLIDE LANDING POOL density factor = manufacturer-established capacity at any given time.
5) INTERACTIVE WATER PLAY water density factor = 10 ft^2 *(0.9 m^2)* per BATHER on surface.
6) SURF POOL density factor = manufacturer-established capacity at any given time.
7) Non-water/PATRON-related
8) DECK density factor = 50 ft^2 *(4.6 m^2)* per BATHER.
9) STADIUM SEATING density factor = 6.6 ft^2 *(0.6 m^2)* per BATHER.

4.1.2.3.5.3.1 Density Factor Modification The density factors in MAHC 4.1.2.3.5.3 may be modified for higher BATHER or PATRON density, but they shall not be modified to result in less BATHERS per square foot than listed for the factors in MAHC 4.1.2.3.5.3.

4.1.2.3.5.3.2 Aquatic Facility Theoretical Peak Occupancy The THEORETICAL PEAK OCCUPANCY for an AQUATIC FACILITY shall be determined by adding the calculations for each AQUATIC VENUE in the AQUATIC FACILITY.

4.1.2.3.6[A] Equipment Characteristics and Rating The technical specifications and supplemental engineering data for each AQUATIC FACILITY and each AQUATIC VENUE shall include:

1) Detailed information on the type, size, operating characteristics, and rating of all mechanical and electrical equipment;
2) Hydraulic computations for head loss in all piping and recirculation equipment;
3) Pump curves that demonstrate that the selected recirculation pump*(s)* are adequate for the calculated required flows; and
4) For INDOOR AQUATIC FACILITIES, documentation that demonstrates that the INDOOR AQUATIC FACILITY is designed to meet the acoustic design criteria contained in MAHC 4.6.11.
5) Documentation per MAHC 4.7.3.2.2.3 to demonstrate that the selected DISINFECTANT feeders/equipment are of sufficient size and capacity, including evaluation of the CHLORINE demand factors in MAHC 4.7.3.2.2.2.1.

4.1.2.3.7 Recirculation Rate and Turnover The technical specifications for each AQUATIC VENUE shall include the recirculation rate and TURNOVER TIME.

4.1.2.3.8 Filter Media The technical specifications for each AQUATIC VENUE shall include information on the filter media such as diatomaceous earth, sand, gravel or other approved material.

4.1.2.3.9 Equipment Specifications The technical specifications for each AQUATIC VENUE shall include information on each piece of equipment associated with that AQUATIC VENUE.

4.1.2.3.10 Safety Equipment Specifications The technical specifications for each AQUATIC FACILITY shall include information on all aquatic SAFETY equipment.

4.1.2.3.11 Design for Risk Management The layout for zones of PATRON surveillance as specified in MAHC 6.3.3.1.1 shall be included and must show features or design configurations that can impact PATRON surveillance.

4.1.2.3.12 Other Specifications The technical specifications for each AQUATIC FACILITY and each AQUATIC VENUE shall include additional information related to the project requested by the AHJ for the purposes of the construction of the AQUATIC FACILITY and each AQUATIC VENUE and all appurtenances.

4.1.3[A] Plan Approval

4.1.3.1 New Construction

4.1.3.1.1 Approval Limitations The AHJ shall clearly state on the plans the limitations of their approval.

4.1.3.1.2 Other Approvals The approval shall also state that it is independent of all other required approvals such as Building, Zoning, Fire, Electrical, Structural, and any other approvals as required by local or state law or CODE and the applicant must separately obtain all other required approvals and permits.

4.1.3.1.3 Plan Review Coordination The AHJ shall coordinate their AQUATIC FACILITY plan review and communicate their approval with other agencies involved in the AQUATIC FACILITY construction.

4.1.3.1.4 Plan Review Report The AHJ shall provide a plan submission compliance review list to the AQUATIC FACILITY owner with the following information:

1) Categorical items marked satisfactory, unsatisfactory, not applicable, or insufficient information;
2) A comment section keyed to the compliance review list shall detail unsatisfactory and insufficient;
3) Indication of the AHJ approval or disapproval of the AQUATIC FACILITY construction plans;
4) In the case of a disapproval, specific reasons for disapproval and procedure for resubmittal; and
5) Reviewer's name, signature, and date of review.

4.1.3.1.5 Plans Maintained The AQUATIC FACILITY owner shall maintain at least one set of their own approved plans made available to AHJ on file for as long as the AQUATIC FACILITY is in operation.

4.1.3.2 Non-Substantial Alterations

4.1.3.2.1 Alteration Review The AQUATIC FACILITY owner planning a non-SUBSTANTIAL ALTERATION shall contact the AHJ to review proposed changes prior to starting the non-SUBSTANTIAL ALTERATION.

4.1.3.2.2 Alteration Scope The AQUATIC FACILITY operator shall consult with the AHJ to determine if new or modified plans must be submitted for plan review and approval for other non-SUBSTANTIAL ALTERATIONS proposed.

4.1.3.3[A] Replacements

4.1.3.3.1 Replacement Approval Prior to replacing equipment, the AQUATIC FACILITY owner shall submit technical verification to the AHJ that all replacement equipment is equal to that which was originally approved and installed.

4.1.3.3.2 Replacement Equipment Equivalency The replacement of pumps, filters, feeders, controllers, SKIMMERS, flow-meters, valves, or other similar equipment with identical or substantially similar equipment may be done without submission to the AHJ for approval of new or altered AQUATIC FACILITY plans.

4.1.3.3.3 Emergency Replacement In emergencies, the replacement may be made prior to receiving the AHJ's approval, with the owner accepting responsibility for proper immediate replacement, if the equipment is not deemed equivalent by the AHJ.

4.1.3.3.3.1 Documentation Where emergency replacements are installed as per MAHC 4.1.3.3.3, the owner shall submit documentation for review and approval of the replacement to the AHJ within 45 days.

4.1.3.3.4 Replacement Record Maintenance The AHJ shall provide the AQUATIC FACILITY owner written approval or disapproval of the proposed replacement equipment's equivalency.

4.1.3.3.5 Documentation Documentation of proposed, approved, and disapproved replacements shall be maintained in the AHJ's AQUATIC FACILITY files.

4.1.4[A] Compliance Certificate

4.1.4.1 Construction Compliance Certificate A certificate of construction compliance shall be submitted to the AHJ for all AQUATIC FACILITY plans for new construction and SUBSTANTIAL ALTERATIONS requiring AHJ approvals.

4.1.4.2 Certificate Preparation This certificate shall be prepared by a licensed professional and be within the scope of their practice as defined by the state or local laws governing professional practice within the jurisdiction of the permit issuing official.

4.1.4.3 Certificate Statement The certificate shall also include a statement that the AQUATIC FACILITY, all equipment, and appurtenances have been constructed and/or installed in accordance with approved plans and specifications.

4.1.4.4[A] Systems Commissioning If commissioning or testing reports for systems such as AQUATIC FACILITY lighting, air handling, recirculation, filtration, and/or DISINFECTION are conducted, then those reports shall be included in furnished documentation.

4.1.4.5 Maintenance Documentation of AQUATIC FACILITY new construction or SUBSTANTIAL ALTERATION plan compliance shall be maintained in the AHJ's AQUATIC FACILITY files.

4.1.5 Construction Permits

4.1.5.1 Building Permit for Construction Construction permits required in this CODE and all other applicable permits shall be obtained before any AQUATIC FACILITY may be constructed.

4.1.5.2 Remodeling Building Permit A construction permit or other applicable permits may be required from the AHJ before SUBSTANTIAL ALTERATION of an AQUATIC FACILITY.

4.1.5.3 Permit Issuance The AHJ shall issue a permit to the owner to operate the AQUATIC FACILITY:

1) After receiving a certificate of completion from the design professional verifying information submitted, and
2) When new construction, SUBSTANTIAL ALTERATIONS, or annual renewal requirements of this CODE have been met.

4.1.5.4 Permit Denial The permit *(license)* to operate may be withheld, revoked or denied by the AHJ for noncompliance of the AQUATIC FACILITY with the requirements of this CODE, and the owner will be provided:

1) Specific reasons for disapproval and procedure for resubmittal;
2) Notice of the rights to appeal this denial and procedures for requesting an appeal; and
3) Reviewer's name, signature and date of review and denial.

4.1.5.5 Documentation Documentation of AQUATIC FACILITY permit renewal or denial shall be maintained in the AHJ's AQUATIC FACILITY files.

4.2 Materials

4.2.1 Aquatic Venues

4.2.1.1 Construction Material AQUATIC VENUES shall be constructed of reinforced concrete or impervious and structurally sound material*(s),* which provide a smooth, easily cleaned, watertight structure capable of withstanding the anticipated stresses/loads for full and empty conditions taking into consideration climatic, hydrostatic, seismic, and the integration of the AQUATIC VENUE with other structural conditions and as required by applicable CODES.

4.2.1.2 Durability All materials shall be inert, non-toxic, resistant to corrosion, impervious, enduring, and resistant to damages related to environmental conditions of the installation region.

4.2.1.3 Areas Subject to Freezing Where located in areas subject to freezing, AQUATIC VENUES and appurtenances shall be designed to protect against damage due to freezing.

4.2.1.4 Competitive Pools Competitive or lap POOLS may have lane markings and end wall targets installed in accordance with FINA, NCAA, USA Swimming, NFHS, or other recognized STANDARD.

4.2.1.5[A] Design Parameters Any graphics, color, or finish incorporated into the construction of a POOL or painted on the floor or walls shall not prevent the detection of a BATHER in distress, algae, sediment, or other objects in the AQUATIC VENUE.

4.2.1.5.1 Permission in Writing Permission in writing from the AHJ for the use of graphics that do not comply with the requirements of this CODE shall be obtained before the graphics are used.

4.2.1.6 Watertight POOLS shall be designed in such a way to maintain their ability to retain the designed amount of water.

4.2.1.7[A] Smooth Finish All vertical walls shall have a durable finish suitable for regular scrubbing and cleaning at the waterline.

4.2.1.7.1 Daily Cleaning The finish shall be able to withstand daily brushing, scrubbing, and cleaning of the surface in accordance with the manufacturer's recommendations.

4.2.1.7.2 Skimmer Pools SKIMMER POOLS shall have a 6 inch *(152 mm)* to 12 inch *(305 mm)* high waterline finish that meets the requirements of MAHC 4.2.1.7 and 4.2.1.7.1.

4.2.1.7.3 Gutter / Perimeter Overflow Systems Gutter or POS shall have a minimum finish height of 2 inches (*51 mm)* that meets the requirements of MAHC 4.2.1.7 and 4.2.1.7.1.

4.2.1.7.4 Dark Colors If dark colors in excess of what is required in MAHC 4.5.11 of this CODE are used for the POOL finish, these colors shall not extend more than 12 inches *(305 mm)* below the waterline.

4.2.1.8[A] Slip Resistant POOL floors in areas less than 3 feet *(0.9 m)* deep shall have a slip resistant finish with a minimum dynamic coefficient of friction at least equal to the requirements of ANSI A137.1-2012 of 0.42 as measured by the DCOF AcuTest.

4.2.1.9 Stainless Steel, Vinyl, PVC-P or PVC Pools Stainless steel, vinyl, PVC-P, or PVC panel and liner POOL finish systems shall be acceptable provided that the system is installed on top of approved materials and design requirements as listed within this section or approved by the AHJ.

4.2.1.9.1 Damaged If at any time the liner system is damaged or cut in such a way that its integrity is compromised, the POOL shall be shut down until the system is fully repaired.

4.2.1.10 Not Permitted Wood, sand, or earth shall not be permitted as an interior finish.

4.2.2 Indoor Aquatic Facility

4.2.2.1 Interior Finish

4.2.2.1.1 Relative Humidity The interior finish of an INDOOR AQUATIC FACILITY shall be designed for an indoor relative humidity as not less than 80%.

4.2.2.2[A] Condensation Prevention

4.2.2.2.1[A] Cold Weather INDOOR AQUATIC FACILITY building envelope construction shall include a vapor-retarder/insulation arrangement to assist in preventing the condensation of water on inside building surfaces under the coldest outdoor conditions based on the ASHRAE climate data for the project locale or nearest reporting city and the highest design indoor relative humidity.

4.2.2.2.2[A] Paint or Coating Where a paint or coating serves as the vapor retarder of an INDOOR AQUATIC FACILITY, the paint or coating shall be applied so as to produce a permeability rating of 0.2 U.S. perm $(11.4\ ng{\cdot}s^{-1}{\cdot}m^{-2}{\cdot}Pa^{-1})$ or less. All paints and coatings installed inside the air barrier of a facility shall meet the requirements of UL 2818-2013 through testing of products to CDPH/EHLB/Standard Method v1.1 or UL 2818-2013.

4.2.2.2.2.1 Application The paint or coating shall be applied according to the manufacturer's recommendations for use as a vapor retarder.

4.2.2.2.3 ***Perforated Interior-Finish Material*** Where a perforated interior-finish material is used in an INDOOR AQUATIC FACILITY, as for acoustic effects, the perforated material shall not be considered to be a vapor retarder unless it has a listed permeability rating less than 0.2 U.S. perm *(11.4 ng·s⁻¹·m⁻²·Pa⁻¹)*.

4.2.2.3 Mechanical Systems

4.2.2.3.1 ***Equipment Rooms*** For EQUIPMENT ROOMS, see MAHC 4.9.1.

4.2.2.3.2 ***Chemical Storage Spaces*** For CHEMICAL STORAGE SPACES, see MAHC 4.9.2.

4.2.2.3.3A ***Indoor Aquatic Facility Air Pressure*** AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with the 2011 ASHRAE Applications Handbook on Natatorium Design ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, and/or applicable local CODES with additional requirements as stated in section MAHC 4.6.2.

4.2.2.3.3.1 **Chemical Storage Space Air Pressure** AIR HANDLING SYSTEM design for CHEMICAL STORAGE SPACES shall conform to the International Mechanical Code or Uniform Mechanical Code, and either the International Fire Code or the NFPA 1 Fire Code, and any applicable local CODES.

4.2.2.3.4A ***Air Ducts*** Where air ducts are required, they shall be resistant to corrosion from the airborne chemicals.

4.2.2.3.4.1 **Insulated Exterior** Ducts shall be insulated on the exterior of the duct with a mold-resistant material where the surface temperature of the duct is capable of being less than the airstream temperature within the duct.

4.2.2.3.5 ***Filters*** Filters for outdoor-air intake shall be rated moisture-resistant.

4.2.2.4A Indoor Aquatic Facility Doors

4.2.2.4.1 ***Corrosion-Resistant*** INDOOR AQUATIC FACILITY doors shall either be constructed of corrosion-resistant materials or have a covering or coating to withstand humid and CORROSIVE environments which is acceptable to the AHJ.

4.2.2.4.2 ***Uncontrolled Condensation*** INDOOR AQUATIC FACILITY doors which may be exposed to temperatures below INDOOR AQUATIC FACILITY-air dew point shall have thermal breaks, insulation, and/or glazing as necessary to minimize the risk of uncontrolled condensation.

4.2.2.4.2.1 **Heating Systems** ***Exception:*** Other doors shall be acceptable, subject to approval by the AHJ, where heating systems are so arranged as to maintain such doors above the maximum design dew point of the INDOOR AQUATIC FACILITY air.

4.2.2.4.3 ***Biological Contaminants*** INDOOR AQUATIC FACILITY doors and door-frame construction shall not contribute to the growth of biological CONTAMINANTS.

4.2.2.4.4 ***Air Leakage*** INDOOR AQUATIC FACILITY doors and/or door frames shall be equipped with seals and/or gaskets to minimize air leakage when the door is closed.

4.2.2.4.5A ***Automatic Door Closer*** All pedestrian doors around the INDOOR AQUATIC FACILITY perimeter shall be equipped with an automatic door closer capable of closing the door completely without human assistance and a self-latching device designed to engage and keep the door closed without human assistance.

4.2.2.4.5.1 **Difference in Air Pressure** Door closers shall be able to close the door against the specified difference in air pressure between the INDOOR AQUATIC FACILITY and other INTERIOR SPACES.

4.2.2.5A Indoor Aquatic Facility Windows

4.2.2.5.1 ***Frames*** INDOOR AQUATIC FACILITY window frames shall be constructed of suitable materials or shall have a suitable covering or coating to withstand the expected atmosphere.

4.2.2.5.2 ***Biological Contaminants*** INDOOR AQUATIC FACILITY window frames shall be constructed of materials that do not contribute to the growth of biological CONTAMINANTS.

4.2.2.5.3 Thermal Breaks INDOOR AQUATIC FACILITY window frames shall have thermal breaks or be otherwise constructed to minimize the risk of uncontrolled condensation.

4.2.2.6 Indoor Aquatic Facility Electrical Systems and Components *Refer to MAHC 4.6.3*

4.3 Equipment Standards

4.3.1.[A] Accredited Standards Where applicable, all equipment used or proposed for use in AQUATIC FACILITIES governed under this CODE shall be:

1) Of a proven design and construction, and
2) CERTIFIED, LISTED, AND LABELED to a specific STANDARD for the specified equipment use by an ANSI-accredited certification organization.

4.3.2 No Standards Where STANDARDS do not exist, technical documentation shall be submitted to the AHJ to demonstrate acceptability for use in AQUATIC FACILITIES.

4.3.3 Suitable for Intent All equipment and materials used or proposed for use in AQUATIC FACILITIES shall be suitable for their intended use and be installed in accordance with this CODE, as CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization where applicable, and as specified by the manufacturer.

4.3.3.1 Proof of Acceptability The AHJ shall have the authority to require tests, as proof of acceptability.

4.4 Aquatic Facility and Venue Operation and Maintenance [N/A]

4.5 Aquatic Venue Structure

4.5.1[A] Design for Risk Management Design of AQUATIC FACILITIES and/or AQUATIC VENUE*(s)* shall include consultation with and input by the owner and/or an aquatic risk management consultant and address operational considerations such as the layout of zones of PATRON surveillance.

4.5.1.1 Basic Requirements The AQUATIC VENUE shape shall provide for the SAFETY of swimmers, the thorough and complete circulation of the water, the ability to clean and maintain the AQUATIC VENUE, and be considered when planning for effective supervision and surveillance of BATHERS and PATRONS using the AQUATIC VENUE.

4.5.1.2 Water Clarity The water in an AQUATIC VENUE shall be sufficiently clear such that the bottom is visible while the water is static.

4.5.1.2.1 Pools Ten Feet Deep or Less For POOLS 10 feet deep (*3.0 m*) or less, a 4 inch x 4 inch square *(10.2 cm x 10.2 cm)* marker tile in a contrasting color to the POOL floor or main suction outlet shall be located at the deepest part of the POOL.

4.5.1.2.2 Pools Over Ten Feet Deep For POOLS over 10 feet deep *(3.0 m)* an 8 inch by 8 inch square *(20.3 cm x 20.3 cm)* marker tile in a contrasting color to the POOL floor or main suction outlet shall be located at the deepest part of the POOL.

4.5.1.2.3 Visible This reference point shall be visible at all times at any point on the DECK up to 30 feet *(9.1 m)* away in a direct line of sight from the tile or main drain.

4.5.1.2.4 Spas For SPAS, this test shall be performed when the water is in a non-turbulent state and bubbles have been allowed to dissipate.

4.5.2 Bottom Slope

4.5.2.1[A] Under Five Feet In water depths under 5 feet *(1.5 m)*, the slope of the floor of all POOLS shall not exceed 1 foot *(30.5 cm)* vertical drop for every 12 feet *(3.7 m)* horizontal.

4.5.2.2 Five Feet or Over In water depths 5 foot *(1.5 m)* and greater, the slope of the floors of all POOLS shall not exceed 1 foot *(30.5 cm)* vertical to 3 feet *(0.9 m)* horizontal. ***Exception:*** POOLS designed and used for competitive diving shall be designed to meet the STANDARDS of the sanctioning organization *(such as NFHS, NCAA, USA Diving, or FINA)*.

4.5.2.3[A] Drain POOLS shall be designed so that they drain without leaving puddles or trapped standing water.

4.5.3 Pool Access / Egress

4.5.3.1[A] Accessibility Each POOL shall have a minimum of two means of access and egress, with one located within 10 feet *(3.0 m)* of the shallowest end, and one located within 10 feet of the deepest end of the POOL, where applicable, with the exception of:

1) WATERSLIDE landing POOLS,
2) WATERSLIDE RUNOUTS, and
3) WAVE POOLS.

4.5.3.2 Acceptable Means Acceptable means of access / egress shall include stairs / handrails, grab rails / RECESSED STEPS, ladders, ramps, and zero-depth entries.

4.5.3.3 Large Venues For POOLS wider than 30 feet *(9.1 m)*, such means of access / egress shall be provided on each side of the POOL.

4.5.3.3.1 Distance Apart For POOLS wider than 30 feet *(9.1 m)*, such means of access / egress shall not be more than 75 feet *(22.9 m)* apart.

4.5.4 Stairs

4.5.4.1 Slip Resistant Where provided, stairs shall be constructed with slip-resistant materials.

4.5.4.2 Outlined Edges The leading horizontal and vertical edges of stair treads shall be outlined with a continuous slip-resistant contrasting tile or other permanent marking of not less than 1 inch *(25.4 mm)* and not greater than 2 inches *(50.8 mm)*.

4.5.4.3[A] Deep Water Where stairs are provided in POOL water depths greater than 5 feet *(1.5 m)*, they shall be recessed and not protrude into the swimming area of the POOL.

4.5.4.3.1 Lowest Tread Where stairs are provided in POOL water depths greater than 5 feet *(1.5 m)*, the lowest tread shall be not less than 4 feet *(1.2 m)* below normal water elevation.

4.5.4.4 Stairs Stairs shall have a minimum uniform horizontal tread depth of 12 inches *(30.5 cm)*, and a minimum unobstructed tread width of 24 inches *(61.0 cm)*.

4.5.4.5 Dimensions Dimensions of stair treads for other types of stairs shall conform to requirements of

1) MAHC Table 4.5.4.5,
2) MAHC Figure 4.5.4.5.1, and
3) MAHC Figure 4.5.4.5.2

Table 4.5.4.5: Required Dimensions for Stair Treads and Risers

Dimensions	T-1 Standard	T-2	W-1	H-1
Minimum	12 inches *(30.5 cm)*	T-1	24 inches *(61.0 cm)*	6 inches *(15.2 cm)*
Maximum	18 inches *(45.7 cm)*	T-1	N/A	12 inches *(30.5 cm)*

Figure 4.5.4.5.1: Stair Treads and Risers: Side View

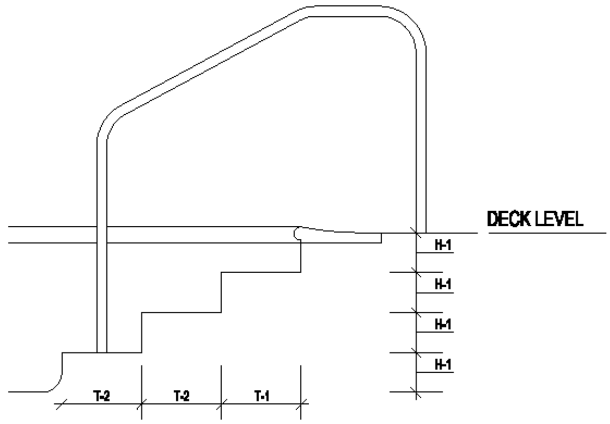
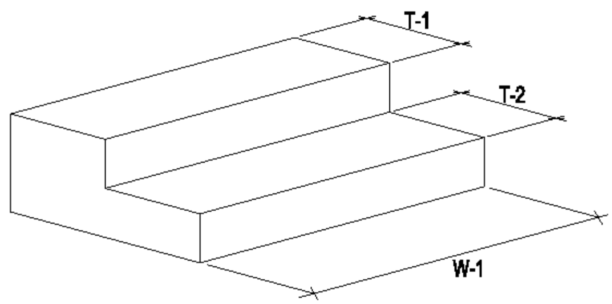


Figure 4.5.4.5.2: Stair Treads: Front View



4.5.4.6 Stair Risers Stair risers shall have a minimum uniform height of 6 inches *(15.2 cm)* and a maximum height of 12 inches *(30.5 cm)*, with a tolerance of ½ inches *(12.7 mm)* between adjacent risers.

4.5.4.6.1 Transitional Areas Stairs shall not be used underwater to transition between two sections of POOL of different depths. ***Note:*** The bottom riser may vary due to potential cross slopes with the POOL floor; however, the bottom step riser may not exceed the maximum allowable height required by this section.

4.5.4.7 Top Surface The top surface of the uppermost stair tread shall be located not more than 12 inches *(30.5 cm)* below the POOL coping or DECK.

4.5.4.8[A] Perimeter Gutter Systems For POOLS with PERIMETER GUTTER SYSTEMS, the gutter may serve as a step, provided that the gutter is provided with a grating or cover and conforms to all construction and dimensional requirements herein specified.

4.5.5 Handrails

4.5.5.1 Provided Handrail*(s)* shall be provided for each set of stairs.

4.5.5.2 Corrosion-resistant Handrails shall be constructed of corrosion-resistant materials, and anchored securely.

4.5.5.3[A] Upper Railing The upper railing surface of handrails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.1 cm)*.

4.5.5.4 Wider Than Five Feet Stairs wider than 5 feet *(1.5 m)* shall have at least one additional handrail for every 12 feet *(3.7 m)* of stair width.

4.5.5.5[A] ADAAG Accessibility Handrail outside dimensions intended to serve as a means of ADAAG accessibility shall conform to requirements of MAHC 4.5.5.6.

4.5.5.6 Support Handrails shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds (90.7 kg) applied in any direction at any location.

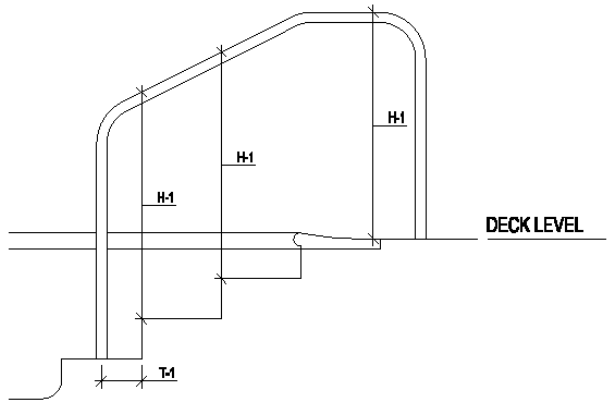
4.5.5.6.1 Transfer Loads Hand rails shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.5.7[A] Dimensions Dimensions of handrails shall conform to requirements of MAHC Table 4.5.5.7 and MAHC Figure 4.5.5.7.1.

Table 4.5.5.7: Stair Handrail Dimensions

Dimensions	T-1	H-1
Minimum	3 inches *(7.6 cm)*	34 inches *(86.4 cm)*
Maximum	N/A	38 inches *(96.5 cm)*

Figure 4.5.5.7.1: Stair Handrails: Side View



4.5.6 Grab Rails

4.5.6.1 Corrosion-Resistant Where grab rails are provided, they shall be constructed of corrosion-resistant materials.

4.5.6.2 Anchored Grab rails shall be anchored securely.

4.5.6.3 Provided Grab rails shall be provided at both sides of RECESSED STEPS.

4.5.6.4 Clear Space The horizontal clear space between grab rails shall be not less than 18 inches *(45.7 cm)* and not more than 24 inches *(61.0 cm)*.

4.5.6.5 Upper Railing The upper railing surface of grab rails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.1 cm)*.

4.5.6.6 Support Grab rails shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds *(90.7 kg)* applied in any direction at any location.

4.5.6.6.1 Transfer Loads Grab rails shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.7 Recessed Steps

4.5.7.1 Slip-Resistant RECESSED STEPS shall be slip-resistant.

4.5.7.2 Easily Cleaned RECESSED STEPS shall be designed to be easily cleaned.

4.5.7.3 Drain RECESSED STEPS shall drain into the POOL.

4.5.7.4 Dimensions Dimensions of RECESSED STEPS shall conform to requirements of:

1) MAHC Table 4.5.7.4,
2) MAHC Figure 4.5.7.4.1, and
3) MAHC Figure 4.5.7.4.2.

Table 4.5.7.4: Recessed Step Dimensions

Dimensions	H-1	H-2	W-1	D-1
Minimum	6 inches *(15.2 cm)*	5 inches *(12.7 cm)*	12 inches *(30.5 cm)*	5 inches *(12.7 cm)*
Maximum	12 inches *(30.5 cm)*	N/A	N/A	N/A

Figure 4.5.7.4.1: Recessed Step Dimensions: Side View

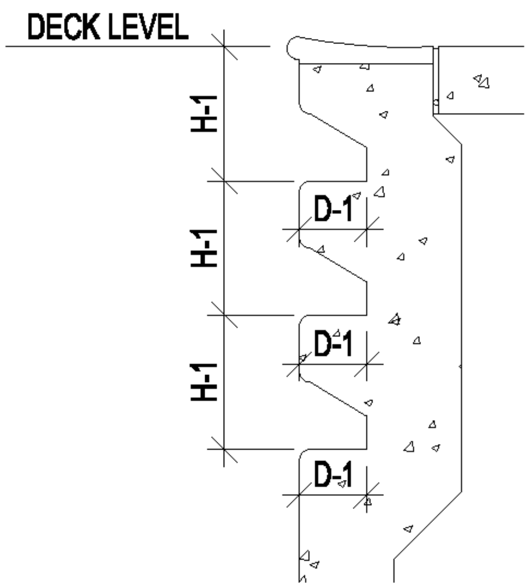
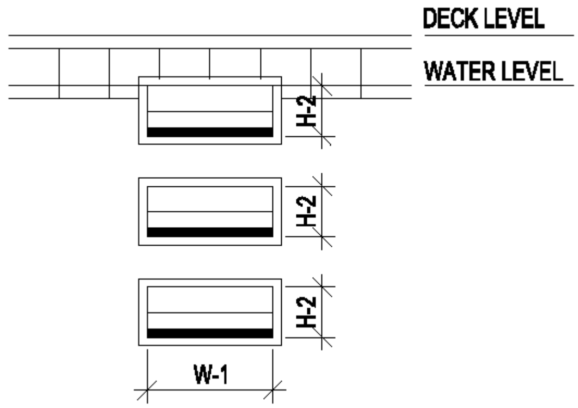


Figure 4.5.7.4.2: Recessed Step Dimensions: Front View



4.5.7.5 Uniformly Spaced RECESSED STEPS shall be uniformly spaced not less than 6 inches *(15.2 cm)* and not more than 12 inches *(30.5 cm)* vertically along the POOL wall.

4.5.7.6 Uppermost Step The top surface of the uppermost RECESSED STEP shall be located not more than 12 inches *(30.5 cm)* below the POOL coping or DECK.

4.5.7.7 Perimeter Gutter Systems For POOLS with PERIMETER GUTTER SYSTEMS, the gutter may serve as a step, provided that the gutter is provided with a grating or cover and conforms to all construction and dimensional requirements herein specified.

4.5.8 Ladders

4.5.8.1 General Guidelines for Ladders

4.5.8.1.1 Corrosion-Resistant Where provided, ladders shall be constructed of corrosion-resistant materials.

4.5.8.1.2 Anchored Ladders shall be anchored securely to the DECK.

4.5.8.2[A] Ladder Handrails

4.5.8.2.1 Two Handrails Provided Ladders shall have two handrails.

4.5.8.2.2 Clear Space The horizontal clear space between handrails shall be not less than 17 inches *(43.2 cm)* and not more than 24 inches *(61.0 cm)*.

4.5.8.2.3 Upper Railing The upper railing surface of handrails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.7 cm)*.

4.5.8.2.4[A] Pool Wall The clear space between handrails and the POOL wall shall be not less than 3 inches *(7.6 cm)* and not more than 6 inches *(15.2 cm)*.

4.5.8.2.5[A] Support Ladders shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds *(90.7 kg)* applied in any direction at any location.

4.5.8.2.5.1 Transfer Loads Ladders shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.8.3 Ladder Treads

4.5.8.3.1 Slip Resistant Ladder treads shall be slip-resistant.

4.5.8.3.2 Tread Depth Ladder treads shall have a minimum horizontal tread depth of 1.5 inches *(3.8 cm)*.

4.5.8.3.2.1 Distance Between Tread and Pool Wall The distance between the horizontal tread and the POOL wall shall not be greater than 4 inches *(10.2 cm)*.

4.5.8.3.3 ***Uniformly Spaced*** Ladder treads shall be uniformly spaced not less than 7 inches *(17.8 cm)* and not more than 12 inches *(30.5 cm)* vertically at the handrails.

4.5.8.3.4 ***Upmost Ladder Tread*** The top surface of the upmost ladder tread shall be located not more than 12 inches *(30.5 cm)* below the POOL coping, gutter, or DECK.

4.5.9 Zero Depth (Sloped) Entries

4.5.9.1 **Slip Resistant** Where ZERO DEPTH ENTRIES are provided, they shall be constructed with slip-resistant materials.

4.5.9.2 **Maximum Floor Slope** ZERO DEPTH ENTRIES shall have a maximum floor slope of 1:12, consistent with the requirements of MAHC 4.5.2.1.

4.5.9.2.1 ***Slope Changes*** Changes in floor slope shall be permitted.

4.5.9.3 **Trench Drains** Trench drains shall be used along ZERO DEPTH ENTRIES at the waterline to facilitate surface skimming.

4.5.9.3.1 ***Flat or Follow Slope*** The trenches may be flat or follow the slope of the ZERO DEPTH ENTRY.

4.5.9.3.2 ***Handholds*** Any handholds that present a trip hazard shall not be continuous along the ZERO DEPTH ENTRY.

4.5.10 Disabled Access

4.5.10.1[A] **Conform to ADA Standards** Access for disabled persons shall conform to ADA Standards as approved by the Department of Justice.

4.5.10.2 **Pool Lifts** All POOL lifts shall be CERTIFIED, LISTED, AND LABELED in accordance with UL 60335-2-1000, and be installed and used in accordance with the manufacturer's installation instructions and ICC/ANSI A117.1.

4.5.11 Color and Finish

4.5.11.1[A] **White or Light Pastel** Floors and walls below the water line shall be white or light pastel in color such that from the POOL DECK a BATHER is visible on the POOL floor and the following items can be identified:

1) Algae growth, debris or dirt within the POOL, and
2) CRACKS in the surface finish of the POOL, and
3) Marker tiles defined in MAHC 4.5.1.2.

4.5.11.1.1[A] ***Munsell Color Value*** The finish shall be at least 6.5 on the Munsell color value scale.

4.5.11.1.2 ***Exceptions*** An exception shall be made for the following AQUATIC VENUE components:

1) Competitive lane markings,
2) Dedicated competitive diving well floors,
3) Step or bench edge markings,
4) POOLS shallower than 24 inches *(61.0 cm)*,
5) Water line tiles,
6) WAVE POOL and SURF POOL depth change indicator tiles, or
7) Other approved designs.

4.5.11.1.3 ***Darker Colors*** Munsell color values less than 6.5 or designs such as rock formations may be permitted by the AHJ as long as the criteria in MAHC 4.5.11.1 are met.

4.5.12 Walls

4.5.12.1 Plumb POOL walls shall be plumb within a +/- 3 degree tolerance to a water depth of at least 5 feet *(1.5 m)*, unless the wall design requires structural support ledges and slopes below to support the upper wall. Refer to MAHC Figure 4.5.12.4.

4.5.12.2 Support Ledges and Slopes All structural support ledges and slopes of the wall shall fall entirely within a plane slope from the water line at not greater than a +/- 3 degree tolerance.

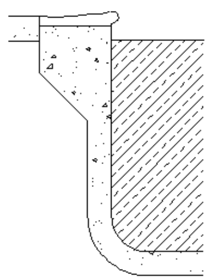
4.5.12.2.1 Contrasting Color A contrasting color shall be provided on the edges of any support ledge to draw attention to the ledge for BATHER SAFETY.

4.5.12.3 Rounded Corners All corners created by adjoining walls shall be rounded or have a radius in both the vertical and horizontal dimensions to eliminate sharp corners.

4.5.12.4[A] No Protrusions, Extensions, Means of Entanglement, or Obstructions There shall be no protrusions, extension, means of entanglement, or other obstructions in the AQUATIC VENUE that may cause the entrapment or injury of the user or interfere with proper POOL operation. Refer to MAHC Figure 4.5.12.4. Plumb Pool Walls.

Figure 4.5.12.1: Plumb Pool Walls: Cross-Section

Plumb within a +/- 3 degree tolerance.



4.5.13[A] Structural Stability

4.5.13.1 Withstand Loads POOLS shall be designed to withstand the reasonably anticipated loads imposed by POOL water, BATHERS, and adjacent soils or structures.

4.5.13.2 Hydrostatic Relief Valve A hydrostatic relief valve and/or suitable under drain system shall be provided where the water table exerts hydrostatic pressure to uplift the POOL when empty or drained.

4.5.13.3 Freezing POOLS and related circulation piping shall be designed with a winterizing strategy when in an area subject to freeze/thaw cycles.

4.5.14[A] Handholds

4.5.14.1 Handholds Provided Where not otherwise exempted, every POOL shall be provided with handholds *(PERIMETER GUTTER SYSTEM, coping, horizontal bars, recessed handholds, cantilevered DECKING)* around the perimeter of the POOL where the water depth at the wall exceeds 24 inches *(61.0 cm)*.

4.5.14.1.1 Installed These handholds shall be installed not greater than 9 inches *(22.9 cm)* above, or 3 inches *(7.6 cm)* below static water level.

4.5.14.2 Horizontal Recesses Horizontal recesses may be used for handholds provided they are a minimum of 24 inches *(61.0 cm)* long, a minimum of 4 inches *(10.2 cm)* high and between 2 inches *(5.1 cm)* and 3 inches *(7.6 cm)* deep.

4.5.14.2.1 Drain Horizontal recesses shall drain into the POOL.

4.5.14.2.2 Consecutive Recesses Horizontal recesses need not be continuous, but consecutive recesses shall be separated by no more than 12 inches *(30.5 cm)* of wall.

4.5.14.3 Decking Where PERIMETER GUTTER SYSTEMS are not provided, a coping or cantilevered DECKING of reinforced concrete or material equivalent in strength and durability, with rounded, slip-resistant edges shall be provided.

4.5.14.4 Coping Dimensions The overhang for coping or cantilevered DECKING shall not be greater than 2 inches *(50 mm)* from the vertical plane of the POOL wall, nor less than 1 inch *(2.5 cm)*.

4.5.14.5 Coping Thickness The overhang for coping or cantilevered DECKING shall not exceed 3.5 inches *(8.9 cm)* in thickness for the last 2 inches *(5.1 cm)* of the overhang.

4.5.15 Infinity Edges

4.5.15.1[A] Perimeter Restrictions Not more than fifty percent *(50%)* of the POOL perimeter shall incorporate an INFINITY EDGE detail, unless an adjacent and PATRON accessible DECK space conforming to MAHC 4.8.1 is provided.

4.5.15.2 Length The length of an INFINITY EDGE shall be no more than 30 feet *(9.1 m)* long when in water depths greater than 5 feet *(1.5 m)*.

4.5.15.2.1 Shallow Water No maximum distance is enforced for the length of INFINITY EDGES in shallow water 5 feet *(1.5 m)* and less.

4.5.15.3[A] Handholds Handholds conforming to the requirements of MAHC 4.5.14 shall be provided for INFINITY EDGES, which may be separate from, or incorporated as part of the INFINITY EDGE detail.

4.5.15.4 Construction Guidelines Where INFINITY EDGES are provided, they shall be constructed of reinforced concrete or other impervious and structurally rigid material*(s)*, and designed to withstand the loads imposed by POOL water, BATHERS, and adjacent soils or structures.

4.5.15.5 Overflow Basins Troughs, basins, or capture drains designed to receive the overflow from INFINITY EDGES shall be watertight and free from STRUCTURAL CRACKS.

4.5.15.5.1 Finish Troughs, basins, or capture drains designed to receive the overflow from INFINITY EDGES shall have a non-toxic, smooth, and slip-resistant finish.

4.5.15.6[A] Maximum Height The maximum height of the wall outside of the INFINITY EDGE shall not exceed 30 inches *(76.2 cm)* to the adjacent grade and capture drain.

4.5.16[A] Underwater Benches

4.5.16.1[A] Slip Resistant Where provided, UNDERWATER BENCHES shall be constructed with slip-resistant materials having a minimum dynamic coefficient of friction at least equal to the requirements of ANSI A137.1-2012 of 0.42 as measured by the DCOF AcuTest.

4.5.16.2 Outlined Edges The leading horizontal and vertical edges of UNDERWATER BENCHES shall be outlined with a continuous slip-resistant color contrasting tile or other permanent marking of not less than ¾ inch *(1.9 cm)* and not greater than 2 inches *(5.1 cm)*.

4.5.16.3[A] Maximum Water Depth UNDERWATER BENCHES may be installed in areas of varying depths, but the maximum POOL water depth in that area shall not exceed 5 feet *(1.5 m)*.

4.5.16.4 Maximum Seat Depth The maximum submerged depth of any seat or sitting bench shall be 20 inches *(50.8 cm)* measured from the water line.

4.5.17 Underwater Ledges

4.5.17.1[A] Slip Resistant Where UNDERWATER TOE LEDGES are provided to enable swimmers in deep water to rest or to provide structural support for an upper wall, they shall be constructed with slip-resistant materials.

4.5.17.2 Protrude UNDERWATER TOE LEDGES for resting that are recessed or protrude beyond the vertical plane of the POOL wall shall meet the criteria for slip resistance and tread depth outlined in this section.

4.5.17.3A Five Feet or Greater UNDERWATER TOE LEDGES for resting shall only be provided within areas of a POOL with water depths of 5 feet *(1.5 m)* or greater.

4.5.17.3.1 Underwater Toe Ledge UNDERWATER TOE LEDGES shall start no earlier than 4 lineal feet *(1.2 m)* to the deep side of the 5 foot *(1.5 m)* slope break.

4.5.17.3.2 Below Water Level UNDERWATER TOE LEDGES shall be at least 4 feet *(1.2 m)* below static water level.

4.5.17.4A Structural Support UNDERWATER LEDGES for structural support of upper walls shall be allowed.

4.5.17.5 Outlined The edges of UNDERWATER TOE LEDGES shall be outlined with a continuous slip-resistant color contrasting tile or other permanent marking of not less than 1 inch *(2.5 cm)* and not greater than 2 inches *(5.1 cm)*.

4.5.17.5.1 Visible If they project past the plane of the POOL wall, the edges of UNDERWATER TOE LEDGES shall be clearly visible from the DECK.

4.5.17.6 Tread Depths UNDERWATER TOE LEDGES shall have a maximum uniform horizontal tread depth of 4 inches *(10.2 cm)*. See MAHC Figure 4.5.12.4.

4.5.18A Underwater Shelves

4.5.18.1 Immediately Adjacent UNDERWATER SHELVES may be constructed immediately adjacent to water shallower than 5 feet *(1.5 m)*.

4.5.18.2 Nosing UNDERWATER SHELVES shall have a slip-resistant, color contrasting nosing at the leading horizontal and vertical edges on both the top of horizontal edges and leading vertical edges and should be viewable from the DECK or from underwater.

4.5.18.3 Maximum Depth UNDERWATER SHELVES shall have a maximum depth of 24 inches *(61.0 cm)*.

4.5.19A Depth Markers and Markings

4.5.19.1 Location

4.5.19.1.1 Markings POOL water depths shall be clearly and permanently marked at the following locations:

1) Minimum depth,
2) Maximum depth,
3) On both sides and at each end of the POOL and,
4) At the break in the floor slope between the shallow and deep portions of the POOL.

4.5.19.1.2A Depth Measurements Depth markers shall be located on the vertical POOL wall and positioned to be read from within the POOL.

4.5.19.1.3A Below Handhold Where depth markings cannot be placed on the vertical wall above the water level, other means shall be used so that the markings will be plainly visible to persons in the POOL.

4.5.19.1.4 Coping or Deck Depth markers shall also be located on the POOL coping or DECK within 18 inches *(45.7 cm)* of the POOL structural wall or perimeter gutter.

4.5.19.1.5 Read on Deck Depth markers shall be positioned to be read while standing on the DECK facing the POOL.

4.5.19.1.6 ***Twenty-Five Foot Intervals*** Depth markers shall be installed at not more than 25 foot *(7.6 m)* intervals around the POOL perimeter edge and according to the requirements of this section.

4.5.19.1.6.1 **Five Feet or Less** For water less than 5 feet *(1.5 m)* in depth, the depth shall be marked at 1 foot *(30.5 cm)* depth intervals.

4.5.19.2 Construction / Size

4.5.19.2.1 ***Durable*** Depth markers shall be constructed of a durable material resistant to local weather conditions.

4.5.19.2.2 ***Slip Resistant*** Depth markers shall be slip resistant when they are located on horizontal surfaces.

4.5.19.2.3[A] ***Color and Height*** Depth markers shall have letters and numbers with a minimum height of 4 inches *(10.2 cm)* of a color contrasting with background.

4.5.19.2.4[A] ***Feet and Inches*** Depth markers shall be marked in units of feet and inches.

4.5.19.2.4.1 **Abbreviations** Abbreviations of “FT” and “IN” may be used in lieu of “FEET” and “INCHES.”

4.5.19.2.4.1.1 **Abbreviations** Symbols for feet *(‘)* and inches *(“)* shall not be permitted on water depth signs.

4.5.19.2.4.2 **Metric** Metric units may be provided in addition to—but not in lieu of—units of feet and inches.

4.5.19.3 **Tolerance** Depth markers shall be located to indicate water depth to the nearest 3 inches *(7.6 cm)*, as measured from the POOL floor 3 feet *(0.9 m)* out from the POOL wall to the gutter lip, mid-point of surface SKIMMER*(S)*, or surge weir*(s)*.

4.5.19.4 No Diving Markers

4.5.19.4.1[A] ***Depths*** For POOL water depths 5 feet *(1.5 m)* or shallower, all DECK depth markers required by MAHC 4.5.19 shall be provided with “NO DIVING” warning signs along with the universal international symbol for “NO DIVING.”

4.5.19.4.1.1 **Spacing** “NO DIVING” warning signs and symbols shall be spaced at no more than 25 foot *(7.6 m)* intervals around the POOL perimeter edge.

4.5.19.4.2 ***Durable*** “NO DIVING” MARKERS shall be constructed of a durable material resistant to local weather conditions.

4.5.19.4.3 ***Slip Resistant*** “NO DIVING” MARKERS shall be slip-resistant when they are located on horizontal surfaces.

4.5.19.4.4 ***At Least Four Inches*** All lettering and symbols shall be at least 4 inches *(10.2 cm)* in height.

4.5.19.5[A] Depth Marking At Break in Floor Slope

4.5.19.5.1 ***Over Five Feet*** For POOLS deeper than 5 feet *(1.5 m)*, a line of contrasting color, not less than 2 inches *(5.1 cm)* and not more than 6 inches *(15.2 cm)* in width, shall be clearly and permanently installed on the POOL floor at the shallow side of the break in the floor slope, and extend up the POOL walls to the waterline.

4.5.19.5.2 ***Durable*** Depth marking at break in floor slope shall be constructed of a durable material resistant to local weather conditions and be slip resistant.

4.5.19.5.3 ***Safety Rope*** One foot *(30.5 cm)* to the shallow water side of the break in floor slope and contrasting band, a SAFETY float rope shall extend across the POOL surface with the exception of WAVE POOLS, SURF POOLS, and WATERSLIDE LANDING POOLS.

4.5.19.6[A] Dual Marking System Symmetrical AQUATIC VENUE designs with the deep point at the center may be allowed by providing a dual depth marking system which indicates the depth at the wall as measured in MAHC 4.5.19.3 and at the deep point.

4.5.19.7 Non-Traditional Aquatic Venues Controlled-access AQUATIC VENUES *(such as ACTIVITY POOLS, LAZY RIVERS, and other AQUATIC VENUES with limited access)* shall only require depth markers on a sign at points of entry.

4.5.19.7.1 Clearly Visible Depth marker signs shall be clearly visible to PATRONS entering the VENUE.

4.5.19.7.2 Lettering and Symbols All lettering and symbols shall be as required for other types of depth markers.

4.5.19.8[A] Wading Pool Depth Markers AQUATIC VENUES where the maximum water depth is 6 inches *(15.2 cm)* of water or less *(such as WADING POOLS and ACTIVITY POOL areas)* shall not be required to have depth markings or "NO DIVING" signage.

4.5.19.9 Movable Floor Depth Markers For AQUATIC VENUES with movable floors, a sign indicating movable floor and/or varied water depth shall be provided and clearly visible from the DECK.

4.5.19.9.1 Vertical Measurement The posted water depth shall be the water level to the floor of the AQUATIC VENUE according to a vertical measurement taken 3 feet *(0.9 m)* from the AQUATIC VENUE wall.

4.5.19.9.2 Signage A sign shall be posted to inform the public that the AQUATIC VENUE has a varied depth and refer to the sign showing the current depth.

4.5.19.10 Spas A minimum of two depth markers shall be provided regardless of the shape or size of the SPA as per MAHC 4.12.1.6.

4.5.20 Aquatic Venue Shell Maintenance [N/A]

4.5.21[A] Special Use Aquatic Venues

4.5.21.1 Adequately Support The design professional shall provide information to adequately support why the SPECIAL USE AQUATIC VENUE does not meet the definition and use characteristics of other categories of AQUATIC VENUES or POOLS listed in the CODE.

4.5.21.2 Justification The design professional shall provide justification for design parameters that do not meet the design STANDARDS and construction requirements listed in MAHC 4.0.

4.6 Indoor / Outdoor Environment

4.6.1 Lighting

4.6.1.1 General Requirements

4.6.1.1.1 Outdoor Aquatic Venues Lighting as described in this subsection shall be provided for all outdoor AQUATIC VENUES open for use from 30 minutes before sunset to 30 minutes after sunrise, or during periods of natural illumination below the levels required in MAHC 4.6.1.3.1.

4.6.1.1.2 Accessible No lighting controls shall be accessible to PATRONS or BATHERS.

4.6.1.2[A] Windows / Natural Light Where natural lighting methods are used to meet the light level requirements of MAHC 4.6.1.3 during portions of the day when adequate natural lighting is available, one of the following methods shall be used to ensure that lights are turned on when natural lighting no longer meets these requirements:

1) Automatic lighting controls based on light levels or time of day, or
2) Written operations procedures where manual controls are used.

4.6.1.3[A] Light Levels POOL water surface and DECK light levels shall meet the following minimum maintained light levels:

1) Indoor Water Surface: 30 horizontal footcandles *(323 lux)*
2) Outdoor Water Surface: 10 horizontal footcandles *(108 lux)*
3) DECK: 10 horizontal footcandles *(108 lux)*.

Note: Higher levels may be advisable for acceptable spectator viewing for competitive swimming and diving events.

4.6.1.4[A] Overhead Lighting

4.6.1.4.1[A] Artificial Lighting Artificial lighting shall be provided at all AQUATIC VENUES which are to be used at night or which do not have adequate natural lighting.

4.6.1.4.2 Aquatic Venue Floor Lighting shall illuminate all parts of the floor of the AQUATIC VENUE to enable a QUALIFIED LIFEGUARD or other person to determine whether a BATHER is on the floor of the AQUATIC VENUE.

4.6.1.4.3 Aquatic Venue Illumination Lighting shall illuminate all parts of the AQUATIC VENUE including the water, the depth markers, signs, entrances, restrooms, SAFETY equipment, and the required DECK area and walkways.

4.6.1.5[A] Underwater Lighting

4.6.1.5.1[A] Minimum Requirements Underwater lighting, where provided, shall be not less than eight initial rated lumens per square foot of POOL water surface area.

4.6.1.5.1.1 Location Such underwater lights, in conjunction with overhead or equivalent DECK lighting, shall be located to provide illumination so that all portions of the AQUATIC VENUE, including the AQUATIC VENUE bottom and drain*(s)*, may be readily seen.

4.6.1.5.1.2 Higher Light Levels Higher underwater light levels shall be considered for deeper water to achieve this outcome.

4.6.1.5.2 Dimmable Lighting Dimmable lighting shall not be used for underwater lighting.

4.6.1.6[A] Night Swimming with No Underwater Lighting

4.6.1.6.1 Minimum Requirements Where outdoor POOLS are open for use from 30 minutes before sunset to 30 minutes after sunrise, or during periods of low illumination, underwater lighting may be excluded where:

1) Maintained POOL surface lighting levels are a minimum of 15 horizontal footcandles *(161 lux),* and
2) All portions of the POOL, including the bottom and drain*(s)*, are readily visible as required in MAHC 5.7.6.1.

4.6.1.7[A] Emergency Lighting

4.6.1.7.1 Emergency Egress Lighting POOL areas requiring lighting shall be provided with emergency egress lighting in compliance with the applicable building CODES.

4.6.1.7.2 Footcandles The path of egress shall be illuminated to at least a value of 0.5 footcandles *(5.4 lux)*.

4.6.1.8[A] Glare Windows and any other features providing natural light into the POOL space and overhead or equivalent DECK lighting shall be designed or arranged to inhibit or reduce glare on the POOL water surface that would prevent seeing objects on the POOL bottom.

4.6.2[A] Indoor Aquatic Facility Ventilation

4.6.2.1[A] Purpose INDOOR AQUATIC FACILITY AIR HANDLING SYSTEMS shall be designed, constructed, and installed to support the health and SAFETY of the building's PATRONS.

4.6.2.2[A] Exemptions INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design requirements do not apply to AQUATIC FACILITIES that do not meet the definition of a "Building" in the IBC 2012.

4.6.2.3 Indoor Aquatic Facility AIR HANDLING SYSTEM design requirements shall apply to new or SUBSTANTIALLY ALTERED INDOOR AQUATIC FACILITIES including the area of the building's AQUATIC VENUES and the surrounding BATHER and spectator/STADIUM SEATING areas.

4.6.2.4 Mechanical Code INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with applicable local CODES.

4.6.2.5[A] ASHRAE 62.1 Compliance INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with ASHRAE Standard 62.1 2013, *Ventilation for Acceptable Indoor Air Quality*, and/or applicable local CODES with additional requirements as stated in MAHC 4.6.2.6.

4.6.2.6 Air Handling System Design

4.6.2.6.1 Mechanical Systems Ventilation shall be provided through mechanical systems and/or engineered openings for natural ventilation.

4.6.2.6.2[A] Design Factors and Performance Requirements The AIR HANDLING SYSTEM design engineer shall provide plan drawings and documentation with the following components showing the design meets the performance requirements per MAHC 4.6.2.7:

1) Building layout identifying the location of the INDOOR AQUATIC FACILITY;
2) INDOOR AQUATIC FACILITY size including area in square feet and volume in cubic feet;
3) The area in square feet for DECK and for STADIUM SEATING sections;
4) THEORETICAL PEAK OCCUPANCY per AQUATIC VENUE and DECK spaces;
5) Placement of AIR HANDLING SYSTEM and other building outdoor air intakes exterior to the building;
6) Placement of AIR HANDLING SYSTEM and other building exhaust vents exterior to the building;
7) Placement of return air intakes within the INDOOR AQUATIC FACILITY;
8) Placement of supply air locations within the INDOOR AQUATIC FACILITY;
9) Identify system capabilities, if utilized, to automatically or manually modulate the amount of outdoor air for the purposes of reducing the number of cfm of outdoor air when occupancy is lower than THEORETICAL PEAK OCCUPANCY; and
10) Identify system design to maintain negative air pressure in the INDOOR AQUATIC FACILITY relative to the indoor areas external to it.

4.6.2.6.3[A] Other Air Handling Systems AIR HANDLING SYSTEM design for CHEMICAL STORAGE SPACES, mechanical, toilet, SHOWER, and dressing rooms are not included in the scope of this section of the CODE, but shall be considered for their effects on the performance requirements of MAHC 4.6.2.7 such as maintaining negative pressure, temperature differences, and contribution to the air volume of the INDOOR AQUATIC FACILITY.

4.6.2.6.4 High Volume, Low Speed Fans AIR HANDLING SYSTEM design may not consider mechanical fans used to push air within the space as part of the outdoor air calculations for the INDOOR AQUATIC FACILITY as defined in MAHC 4.6.2.7.

4.6.2.6.4.1 Air Delivery Rate Mechanical fans used to push air within the space may be used in the calculation for air delivery rate (TURNOVER).

4.6.2.6.5 Occupied and Open All Seasons AIR HANDLING SYSTEM design may include natural ventilation calculated in accordance with the ASHRAE Handbooks to substitute the corresponding portion of mechanical ventilation only if all the calculated exterior openings will be continuously controlled open during all times the INDOOR AQUATIC FACILITY is occupied, regardless of season.

4.6.2.6.6 Air Distribution Design The design of the distribution of supply air and distribution of exhaust or return air shall consider obstacles such as support columns, architectural structures, and AQUATIC FEATURES.

4.6.2.7 Performance Requirements for Air Handling Systems

4.6.2.7.1[A] ***Minimum Outdoor Air Requirements*** The AIR HANDLING SYSTEM shall have a design capability to supply the minimum outdoor air requirements using ASHRAE Standard 62.1 2013, *Ventilation for Acceptable Indoor Air Quality*.

4.6.2.7.2[A] ***System Alarm*** The AIR HANDLING SYSTEM design shall provide system features to notify the operator if the outdoor air flow rate entering the INDOOR AQUATIC FACILITY is below 0.48 cfm/ft^2 *(1.8 m^3/h)*.

4.6.2.7.3 ***Real-Time Occupancy*** Design of the AIR HANDLING SYSTEM shall meet the requirements for the number of cfm/ft^2 based on the THEORETICAL PEAK OCCUPANCY.

4.6.2.7.3.1 **Method to Determine** If a method to determine real-time actual occupancy is available, then the system may modulate to reduce outdoor air cfm to meet the requirement for the actual occupancy for the associated time frame.

4.6.2.7.4 ***Air Delivery Rate*** The AIR HANDLING SYSTEM shall supply an air delivery rate as defined in ASHRAE Handbook – HVAC Applications 2011, *Places of Assembly, Natatoriums*.

4.6.2.7.5 ***Consistent Air Flow*** INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM shall be designed to provide consistent air flow through all parts of the INDOOR AQUATIC FACILITY to preclude any stagnant areas.

4.6.2.7.6[A] ***Relative Humidity*** The AIR HANDLING SYSTEM shall maintain the relative humidity in the space as defined in *ASHRAE Handbook: HVAC Applications, 2011, Places of Assembly, Natatoriums*.

4.6.2.7.6.1 **Dew Point** The AIR HANDLING SYSTEM shall be designed to maintain the dew point of the INTERIOR SPACE less than the dew point of the interior walls at all times so as to prevent damage to structural members and to prevent biological growth on walls.

4.6.2.7.6.2 **Condensation & Mold Control** The AIR HANDLING SYSTEM shall be designed to achieve several objectives including

1) Maintaining space conditions,
2) Delivering the outside air to the breathing area, and
3) Flushing the outside walls and windows, which can have the lowest surface temperature and therefore the greatest chance for condensation.

4.6.2.7.7 ***Negative Air Pressure*** AIR HANDLING SYSTEM air flow shall be designed to maintain negative air pressure in the INDOOR AQUATIC FACILITY relative to the areas external to it *(such as adjacent indoor spaces and outdoor ambient space)*.

4.6.2.7.8[A] ***Disinfection By-Product Removal*** Sufficient return air intakes shall be placed near AQUATIC VENUE surfaces such that they remove the highest concentration of airborne DBP contaminated air.

4.6.2.7.8.1 **Airflow Across Water Surface** The AIR HANDLING SYSTEM shall be designed considering airflow across the water surface to promote removal of DBPS.

4.6.2.7.9 ***Re-Entrainment of Exhaust*** AIR HANDLING SYSTEM outdoor air intakes shall be placed to minimize RE-ENTRAINMENT of exhaust air from building systems back into the facility.

4.6.2.7.9.1 ***System Exhaust*** AIR HANDLING SYSTEM exhaust from CHEMICAL STORAGE SPACES, mechanical, toilet, SHOWER, and dressing rooms shall not be directed into the AQUATIC FACILITY.

4.6.2.7.10 ***Access Control*** The AIR HANDLING SYSTEM shall be designed to provide a means to limit physical or electronic access to system control to the operator and anyone the operator deems to have access.

4.6.2.7.11[A] ***Purge*** The AIR HANDLING SYSTEM shall have the capability to periodically PURGE air for air quality maintenance or for emergency situations.

4.6.2.7.11.1 **Purge Capacity** The AIR HANDLING SYSTEM shall have a PURGE capacity equal or greater than two times the ASHRAE Standard 62.1 2013 level.

4.6.2.7.11.1.1 **Manual Activation** This PURGE shall be capable of being manually activated.

4.6.2.7.11.2 **Outdoor Air** Outdoor air required for PURGE shall not be required to be heated or otherwise treated.

4.6.2.7.12[A] ***Air Handling System Filters*** The AIR HANDLING SYSTEM design shall include filters for outdoor air and recirculated air with a MERV rating of 8.

4.6.2.8 Air Handling System Installation

4.6.2.8.1 ***Air Handling System Procedures*** The contractor installing the INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM shall provide the AQUATIC FACILITY owner with an operating manual from the manufacturer which includes:

1) Startup and shutdown procedures;
2) PURGING and other SAFETY procedures;
3) Cleaning procedures;
4) General maintenance requirements with parts listings and frequency of maintenance *(i.e., filter cleaning frequencies, motor bearing maintenance)*;
5) Pressure differential specifications for filter replacement, filter replacement type, and frequency of cleaning or replacement;
6) Troubleshooting processes;
7) Frequency of required calibration of equipment;
8) Descriptions of general operating schemes; and
9) Contact information for the manufacturer.

4.6.2.9 Air Handling System Commissioning

4.6.2.9.1 ***System Commissioning*** A qualified, licensed professional shall commission the AIR HANDLING SYSTEM to verify that the installed system is operating properly in accordance with the system design.

4.6.2.9.2 ***Written Statement*** A written statement of commissioning shall be provided to the AQUATIC FACILITY owner including but not limited to:

1) The number of cfm of outdoor air flowing into the INDOOR AQUATIC FACILITY at the time of commissioning;
2) The number of cfm of exhaust air flowing through the system at the time of commissioning; and,
3) A statement that the amount of outdoor air meets the performance requirements of MAHC 4.6.2.7.

4.6.3 Indoor/Outdoor Aquatic Facility Electrical Systems and Components

4.6.3.1[A] General Guidelines

4.6.3.1.1 ***NEC Requirements*** Electrical wiring and systems shall comply with the requirements of the NEC.

4.6.3.1.1.1 **Providing Relief** Nothing in this CODE shall be construed as providing relief from any applicable requirements of the NEC or other applicable CODE.

4.6.3.1.2[A] ***Indoor Aquatic Facilities*** An INDOOR AQUATIC FACILITY shall be considered a wet and CORROSIVE environment.

4.6.3.2[A] Electrical Equipment in Interior Chemical Storage Spaces

4.6.3.2.1[A] ***Wet and Corrosive*** CHEMICAL STORAGE SPACES shall be considered wet and CORROSIVE environments.

4.6.3.2.2[A] ***Electrical Conduit*** Electrical conduit shall not enter or pass through an interior

CHEMICAL STORAGE SPACE, except as required to service devices integral to the function of the room, such as pumps, vessels, controls, lighting and SAFETY devices or, if allowed by the NEC.

4.6.3.2.2.1 Sealed and Inert Where required, the electrical conduit in an interior CHEMICAL STORAGE SPACE shall be sealed and made of materials that will not interact with any chemicals in the CHEMICAL STORAGE SPACE.

4.6.3.2.3[A] Electrical Devices Electrical devices or equipment shall not occupy an interior CHEMICAL STORAGE SPACE, except as required to service devices integral to the function of the room, such as pumps, vessels, controls, lighting and SAFETY devices.

4.6.3.2.4[A] Protected Against Breakage Lamps, including fluorescent tubes, installed in interior CHEMICAL STORAGE SPACES shall be protected against breakage with a lens or other cover, or be otherwise protected against the accidental release of hot materials.

4.6.4[A] Pool Water Heating

4.6.4.1[A] High Temperature When designing POOL heating equipment, measures shall be taken to prevent BATHER exposure to water temperatures in excess of 104°F *(40°C)*.

4.6.4.2 Pressure Relief Device Where POOL water heating equipment is installed with valves capable of isolating the heating equipment from the POOL, a listed pressure-relief device shall be installed to limit the pressure on the heating equipment to no more than the maximum value specified by the heating-equipment manufacturer and applicable CODES.

4.6.4.3 Code Compliance POOL-water heating equipment shall be selected and installed to preserve compliance with the applicable CODES, the terms of listing and labeling of equipment, and with the equipment manufacturer's installation instructions and applicable CODES.

4.6.4.4[A] Equipment Room Requirements Where POOL water heaters use COMBUSTION and are located inside a building, the space in which the heater is located shall be considered to be an EQUIPMENT ROOM, and the requirements of MAHC 4.9.1 shall apply.

4.6.4.4.1 Carbon Monoxide Detector A carbon monoxide detector with local alarming, CERTIFIED, LISTED, AND LABELED in accordance with UL 2075, shall be installed in all such EQUIPMENT ROOMS.

4.6.4.4.2 Adjacent Rooms All rooms that are immediately adjacent to spaces containing fuel burning equipment or vents carrying the products of combustion shall also be provided with locally alarming carbon monoxide detectors.

4.6.4.5 Exception Heaters CERTIFIED, LISTED, AND LABELED for the atmosphere shall be acceptable without isolation from chemical fumes and vapors.

4.6.5 First Aid Area

4.6.5.1[A] Station Design Design and construction of new AQUATIC FACILITIES shall include an area designated for first aid equipment and/or treatment.

4.6.6 Emergency Exit

4.6.6.1 Labeling Gates and/or doors which will allow egress without a key shall be clearly and conspicuously labeled in letters at least 4 inches (10.2 cm) high "EMERGENCY EXIT."

4.6.7 Drinking Fountains

4.6.7.1[A] Provided A drinking fountain shall be provided inside an AQUATIC FACILITY and shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 61-2014 and UL 399.

4.6.7.1.1 Alternative Alternate locations or the use of bottled water shall be evaluated by the AHJ.

4.6.7.1.2 Common Use Area If the drinking fountain cannot be provided inside the AQUATIC FACILITY, it shall be provided in a common use building or area adjacent to the AQUATIC FACILITY entrance and on the normal path of BATHERS going to the AQUATIC FACILITY entrance.

4.6.7.2 Readily Accessible The drinking fountain shall be located where it is readily accessible and not a hazard to BATHERS per MAHC 4.10.2.

4.6.7.2.1 Not Located The drinking fountain shall not be located in a SHOWER area or toilet area.

4.6.7.3 Single Fountain A single drinking fountain shall be allowed for one or more AQUATIC VENUES within an AQUATIC FACILITY.

4.6.7.4 Angle Jet Type The drinking fountain shall be an angle jet type installed according to applicable plumbing CODES.

4.6.7.5 Potable Water Supply The drinking fountain shall be supplied with water from an approved potable water supply.

4.6.7.6 Wastewater The wastewater discharged from a drinking fountain shall be routed to an approved sanitary sewer system or other approved disposal area according to applicable plumbing CODES.

4.6.8 Garbage Receptacles

4.6.8.1 Sufficient Number A sufficient number of receptacles shall be provided within an AQUATIC FACILITY to ensure that garbage and refuse can be disposed of properly to maintain safe and sanitary conditions.

4.6.8.2 Number and Location The number and location of receptacles shall be at the discretion of the AQUATIC FACILITY manager.

4.6.8.3 Closable Receptacles shall be designed to be closed with a lid or other cover so they remain closed until intentionally opened.

4.6.9 Food and Drink Concessions

4.6.9.1 Meet AHJ Requirements Concessions for food and drink in an AQUATIC FACILITY shall meet all AHJ requirements.

4.6.10 Spectator Areas

4.6.10.1 Within Aquatic Facility Enclosure An area designed for use by spectators may be located within an AQUATIC FACILITY ENCLOSURE.

4.6.10.2 Deck When a spectator area or an access to a spectator area is located within the AQUATIC FACILITY ENCLOSURE, the DECK adjacent to the area or access shall provide egress width for the spectators in addition to the width required by MAHC 4.8.1.5.

4.6.10.2.1[A] Additional Width The additional width shall be based on the egress requirements in the applicable building CODE based on the THEORETICAL PEAK OCCUPANCY of the AQUATIC FACILITY served with a minimum width of 4 feet *(1.2 m)* and have either of the following qualities outlined in MAHC 4.6.10.2.1.1 or MAHC 4.6.10.2.1.2.

4.6.10.2.1.1 Barrier A BARRIER as defined in MAHC 4.8.6.1 located on the DECK to separate the DECK used by spectators from the PERIMETER DECK used by BATHERS.

4.6.10.2.1.1.1 Openings The BARRIER may have one or more openings directly into the BATHER areas.

4.6.10.2.1.2 Demarcation Line A demarcation line on the DECK that shows the separation between the DECK used by spectators and the PERIMETER DECK used by BATHERS.

4.6.10.3[A] Balcony A spectator or other area located in a balcony within 10 feet *(3.0 m)* of or overhanging any portion of an AQUATIC VENUE shall be designed to deter jumping or diving into the AQUATIC VENUE.

4.6.10.4[A] Bleachers Bleachers in a spectator area shall be designed according to the ICC's most recent version of the 300 Standard or another applicable CODE.

4.6.11 Indoor Aquatic Facility Acoustics

4.6.11.1[A] Acoustic Design Criteria Acoustic design requirements shall apply to a new INDOOR AQUATIC FACILITY or one that undergoes SUBSTANTIAL ALTERATION.

4.6.11.2[A] Sound Absorption INDOOR AQUATIC FACILITIES shall be designed, constructed and installed with an AVERAGE SOUND ABSORPTION COEFFICIENT (ALPHA BAR) of 0.20 or greater.

4.6.11.2.1[A] Facilities Used Primarily by Specific Hearing Populations An ALPHA BAR of 0.25 or greater shall be used for INDOOR AQUATIC FACILITIES designed primarily for use by children, the elderly, or persons with hearing difficulties.

4.6.11.3[A] Noise INDOOR AQUATIC FACILITIES shall be designed, constructed and installed so that the noise generated by the AIR HANDLING SYSTEM does not exceed a NOISE CRITERION level of 50 (NC-50) or 55 dBA at any time while the INDOOR AQUATIC FACILITY is open for use.

4.6.11.4[A] Sound Absorbing Materials When part of the interior finish, acoustical materials or finishes used for SOUND ABSORPTION shall meet the design requirements of MAHC 4.2.2.1.1 and 4.2.2.2.3.

4.6.11.5[A] Concave Room Surfaces The design of INDOOR AQUATIC FACILITIES with a domed roof, gable roof, or other shape that may cause sound focusing, irrespective of the ALPHA BAR, shall address sound focusing, reverberation, and echoes that would interfere with speech intelligibility.

4.7 Recirculation and Water Treatment

4.7.1 Recirculation Systems and Equipment

4.7.1.1[A] General

4.7.1.1.1 Equipped and Operated All AQUATIC VENUES shall be equipped and operated with a recirculation and filtration system capable of meeting the provisions outlined in MAHC 4.7.

4.7.1.1.2 Component Installation The installation of the recirculation and the filtration system components shall be performed in accordance with the designer's and manufacturer's instructions.

4.7.1.1.3 Recirculation System A water RECIRCULATION SYSTEM consisting of one or more pumps, pipes, return INLETS, suction outlets, tanks, filters, and other necessary equipment shall be provided.

4.7.1.2[A] Combined Aquatic Venue Treatment

4.7.1.2.1 Maintain and Measure When treatment systems of multiple AQUATIC VENUES are combined, the design shall include all appurtenances to maintain and measure the required water characteristics including but not limited to flow rate, pH, and DISINFECTANT concentration in each AQUATIC VENUE or AQUATIC FEATURE.

4.7.1.2.2 Secondary Disinfection If SECONDARY DISINFECTION is required for an INCREASED RISK AQUATIC VENUE as per MAHC 4.7.3.3.1.2, then SECONDARY DISINFECTION shall be required for all treatment systems that are combined with the INCREASED RISK AQUATIC VENUE.

4.7.1.2.3 Isolate When multiple AQUATIC VENUES are combined in one treatment system, each AQUATIC VENUE shall be capable of being isolated for maintenance purposes.

4.7.1.3 Inlets

4.7.1.3.1[A] General

4.7.1.3.1.1 Hydraulically Balanced The RECIRCULATION SYSTEM shall be designed with sufficient flexibility to achieve a hydraulic apportionment that will ensure the following:

1) Effective distribution of treated water, and

2) Maintenance of a uniform DISINFECTANT residual and pH throughout the AQUATIC VENUE.

4.7.1.3.1.1.1 **Alternative Design Justification** Alternative designs shall be allowed based on adequate engineering justification.

4.7.1.3.1.2 **Inlets** Effective distribution of treated water shall be accomplished by either a continuous POS with integral INLETS or by means of directionally adjustable INLETS adequate in design, number, and location.

4.7.1.3.1.3 **Adequate Mixing** POOLS shall use wall and/or floor INLETS to provide adequate mixing.

4.7.1.3.1.3.1 **Greater Than Fifty Feet Wide** For POOLS greater than 50 feet wide *(15.2 m)*, floor INLETS shall be required.

4.7.1.3.1.4 **Other Inlet Types** All other types of INLET systems not covered in this section shall be subject to approval by the AHJ with proper engineering justification.

4.7.1.3.1.5 **Hydraulically Sized** INLETS shall be hydraulically sized to provide the design flow rates for each POOL area of multi-zone POOLS based on the required design TURNOVER RATE for each zone.

4.7.1.3.2[A] ***Floor Inlets***

4.7.1.3.2.1 **Uniformly Spaced** Floor INLETS shall be spaced to effectively distribute the treated water throughout the POOL.

4.7.1.3.2.2 **Flush with Bottom** Floor INLETS shall be flush with the bottom of the POOL.

4.7.1.3.2.2.1 **Distance** Distance between floor INLETS shall be no greater than 20 feet *(6.1 m)*.

4.7.1.3.2.2.2 **Row** A row of floor INLETS shall be located within 15 feet *(4.6 m)* of each side wall.

4.7.1.3.2.3 **Spaced** Floor INLETS, used in combination with wall INLETS, shall be spaced no greater than 25 feet *(7.6 m)* from nearest side walls.

4.7.1.3.3 ***Wall Inlets***

4.7.1.3.3.1[A] **Effective Mixing** Wall INLET velocity shall mix the water effectively.

4.7.1.3.3.2 **Adjustable** INLETS shall be directionally adjustable to provide effective distribution of water.

4.7.1.3.3.3[A] **Inlet Spacing** Wall INLETS shall be spaced no greater than 20 feet *(6.1 m)* apart.

4.7.1.3.3.3.1 **Corner** INLETS shall be placed within 5 feet *(1.5 m)* of each corner of the POOL.

4.7.1.3.3.3.2 **Skimmers** INLETS shall be placed at least 5 feet *(1.5 m)* from a SKIMMER.

4.7.1.3.3.3.3 **Isolated** INLETS shall be placed in each recessed or isolated area of the POOL.

4.7.1.3.3.4 **Directional Flow** Wall INLETS shall not require design to provide directional flow if part of a manufactured gutter system in which the filtered return water conduit is contained within the gutter structure.

4.7.1.3.3.5[A] **Dye Testing** The AHJ may require dye testing to evaluate the mixing characteristics of the RECIRCULATION SYSTEM.

4.7.1.3.3.5.1 **Failed Test** If dye test reveals inadequate mixing in the POOL after 20 minutes, the RECIRCULATION SYSTEM shall be adjusted or modified to assure adequate mixing.

4.7.1.4 Perimeter Overflow Systems/Gutters

4.7.1.4.1 ***General***

4.7.1.4.1.1[A] **Skimming** All POOLS shall be designed to provide SKIMMING for the entire POOL surface area with engineering rationale provided by the design professional.

4.7.1.4.1.1.1 **Around Entire Pool** For POOLS that require a POS, the POS shall extend around the entire POOL perimeter except where noted in this CODE.

4.7.1.4.1.2 **Zero Depth Entry** ZERO DEPTH ENTRY POOLS shall have a continuous overflow trench that terminates as close to the side walls as practical including any zero-depth portion of the POOL perimeter.

4.7.1.4.1.2.1 **Ends** Where a POS cannot be continuous, the ends of each section shall terminate as close as practical to each other.

4.7.1.4.2[A] Perimeter Overflow System Size and Shape

4.7.1.4.2.1 **Continuous Water Removal** The gutter system shall be designed to allow continuous removal of water from the POOL'S upper surface at a rate of at least 125 percent of the approved total recirculation flow rate chosen by the designer.

4.7.1.4.2.2 **Inspection** Gutters shall permit ready inspection, cleaning, and repair.

4.7.1.4.3[A] Gutter Outlets Drop boxes, converters, return piping, or FLUMES used to convey water from the gutter shall be designed to:

1) Prevent flooding and BACKFLOW of skimmed water into the POOL, and
2) Handle at least 125 percent of the approved total recirculation flow.

4.7.1.4.4 Surge Tank Capacity

4.7.1.4.4.1[A] **Net Surge Capacity** All POSs shall be designed with an effective net surge capacity of not less than one gallon for each square foot *(40.7 L/m²)* of POOL surface area.

4.7.1.4.4.1.1 **Surge Components** Surge shall be provided within a surge tank, or the gutter or filter above the normal operating level, or elsewhere in the system.

4.7.1.4.4.2 **Tank Capacity** The tank capacity specified shall be the net capacity.

4.7.1.4.4.3 **Tank Levels** The design professional shall define the minimum, maximum, and normal POOL operating water levels in the surge tank.

4.7.1.4.4.3.1 **Marked** The surge tank's minimum, maximum, and normal POOL operating water levels shall be marked on the tank so as to be readily visible for inspection.

4.7.1.4.4.4 **Overflow Pipes** Surge tanks, shall have overflow pipes to convey excess water to waste via an air gap or other approved BACKFLOW prevention device.

4.7.1.4.5[A] Tolerances Gutters shall be level within a tolerance of plus or minus $^1/_{16}$ inch *(1.6 mm)* around the perimeter of the AQUATIC VENUE.

4.7.1.4.6[A] Makeup Water System

4.7.1.4.6.1 **Automatic Makeup** Automatic makeup water supply equipment shall be provided to maintain continuous skimming of POOLS with POSs.

4.7.1.4.6.2 **Air Gap** Makeup water shall be supplied through an air gap or other approved BACKFLOW prevention device.

4.7.1.5 Skimmers and Alternative Gutter Technologies Using In-Pool Surge Capacity

4.7.1.5.1 General

4.7.1.5.1.1 **Manufactured** The use of manufactured direct suction SKIMMERS shall be in accordance with the manufacturer's recommendations.

4.7.1.5.1.2[A] **Provided** Where SKIMMERS are used, at least one surface SKIMMER shall be provided for each 500 square feet *(46 m²)* of surface area or fraction thereof.

4.7.1.5.1.2.1 **Conditions** Additional SKIMMERS may be required to achieve effective skimming under site-specific conditions *(e.g., heavy winds and/or CONTAMINANT loading)* and/or to comply with all applicable building CODES.

4.7.1.5.1.3[A] **Hybrid Systems** Hybrid systems that incorporate surge weirs in the overflow gutters to provide for in-POOL surge shall meet all of the requirements specified for overflow gutters *(with the exception of the surge or balance tank, since the surge capacity requirement will be alternately met by the in-POOL surge capacity)*.

4.7.1.5.1.3.1[A] **Surge Weirs** The number of surge weirs shall be based on the individual surge weir capacity and the operational apportionment of the design recirculation flow rate.

4.7.1.5.1.3.1.1 **Locations** The location of the required number of surge weirs shall be uniformly spaced in the gutter sections.

4.7.1.5.1.4[A] **Design Capacity** When used, the SKIMMER SYSTEM shall be designed to handle up to 100% of the total recirculation flow rate chosen by the designer.

4.7.1.5.1.5 **Pool Width Limitations** POOLS using SKIMMERS shall not exceed 30 feet *(9.1 m)* in width.

4.7.1.5.2 ***Skimmer Location***

4.7.1.5.2.1 **Effective** SKIMMERS shall be so located as to provide effective skimming of the entire water surface.

4.7.1.5.2.2 **Steps and Recessed Areas** SKIMMERS shall be located so as not to be affected by restricted flow in areas such as near steps and within small recesses.

4.7.1.5.2.3 **Wind Direction** Wind direction shall be considered in number and placement of SKIMMERS.

4.7.1.5.3[A] ***Skimmer Flow Rate*** The flow rate for the SKIMMERS shall comply with manufacturer data plates or NSF/ANSI 50 including Annex K.

4.7.1.5.4 ***Control***

4.7.1.5.4.1 **Weir** Each SKIMMER shall have a weir that adjusts automatically to variations in water level over a minimum range of 4 inches *(10.2 cm)*.

4.7.1.5.4.2 **Trimmer Valve** Each SKIMMER shall be equipped with a trimmer valve capable of distributing the total flow between individual SKIMMERS.

4.7.1.5.5 ***Tolerances***

4.7.1.5.5.1 **Skimmer Base** The base of each SKIMMER shall be level with all other SKIMMERS in the POOL within a tolerance of plus or minus ¼ inch *(6.4 mm)*.

4.7.1.6[A] Submerged Suction Outlet

4.7.1.6.1 ***General*** Submerged suction outlets, including sumps and covers, shall be CERTIFIED, LISTED, AND LABELED to the requirements of ANSI/APSP-16 2011.

4.7.1.6.2 ***Number and Spacing***

4.7.1.6.2.1 **Hydraulically Balanced** A minimum of two hydraulically balanced filtration system outlets are required in the bottom.

4.7.1.6.2.1.1 **Located on the Bottom** One of the outlets may be located on the bottom of a side/end wall at the deepest level.

4.7.1.6.2.1.2 **Connected** The outlets shall be connected to a single main suction pipe by branch lines piped to provide hydraulic balance between the drains.

4.7.1.6.2.1.3 **Valved** The branch lines shall not be valved so as to be capable of operating independently.

4.7.1.6.2.2 **Spaced** Outlets shall be equally spaced from the POOL side walls.

4.7.1.6.2.3 **Located** Outlets shall be located no less than 3 feet *(0.9 m)* apart, measuring between the centerlines of the suction outlet covers.

4.7.1.6.3 ***Tank Connection*** Where gravity outlets are used, the main drain outlet shall be connected to a surge tank, collection tank, or balance tank/pipe.

4.7.1.6.4[A] ***Flow Distribution and Control***

4.7.1.6.4.1 **Design Capacity** The main drain system shall be designed at a minimum to handle recirculation flow of 100% of total design recirculation flow rate.

4.7.1.6.4.1.1 **Two Main Drain Outlets** Where there are two main drain outlets, the branch pipe from each main drain outlet shall be designed to carry 100% of the recirculation flow rate.

4.7.1.6.4.1.2 **Three or More Drains** Where three or more main drain outlets are connected by branch piping in accordance with MAHC 4.7.1.6.2.1.1 through MAHC 4.7.1.6.2.1.3, the design flow through each branch pipe from each main drain outlet may be as follows:

1) Q_{max} for each drain= Q*(total recirculation rate) / (number of drains less one)*, and
2) $Q_{max}=Q_{total} / (N-1)$.

4.7.1.6.4.2 **Proportioning Valve** The single main drain suction pipe to the pump shall be equipped with a proportioning valve*(s)* to adjust the flow distribution between the main drain piping and the surface overflow system piping.

4.7.1.6.5 ***Flow Velocities***

4.7.1.6.5.1 **Standards** Flow velocities shall meet ANSI/APSP-16 2011 based on 100% design flow through each main drain cover.

4.7.1.7 **Piping**

4.7.1.7.1 ***Design***

4.7.1.7.1.1 **Materials** Piping system components in contact with swimming POOL water shall be of non-toxic material, resistant to corrosion, able to withstand operating pressures, chemicals, and temperatures.

4.7.1.7.1.2 **Standards** Piping and piping system component materials shall be suitable for potable water contact.

4.7.1.7.1.2.1 **Certified, Listed, and Labeled** Piping and piping system component materials shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 14, NSF/ANSI Standard 50, and NSF/ANSI Standard 61, as applicable.

4.7.1.7.1.2.2 **Certified** Piping and piping system component materials shall be CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization.

4.7.1.7.2 ***Velocity in Pipes***

4.7.1.7.2.1[A] **Discharge Piping** RECIRCULATION SYSTEM piping shall be designed so that water velocities do not exceed 8 feet *(2.4 m)* per second on the discharge side of the recirculation pump unless alternative values have proper engineering justification.

4.7.1.7.2.2[A] **Suction Piping** Suction piping shall be sized so that the water velocity does not exceed 6 feet per second *(1.8 m/s)* unless alternative values have proper engineering justification.

4.7.1.7.2.3[A] **Additional Considerations** Gravity piping shall be sized with consideration of available system head or as demonstrated by detailed hydraulic calculations at the design recirculation flow rate.

4.7.1.7.3[A] ***Drainage and Installation***

4.7.1.7.3.1 **Temperature Variations** Provisions shall be made for expansion and contraction of pipes due to temperature variations.

4.7.1.7.3.2 **Drainage** Provisions shall be made for complete drainage of all AQUATIC VENUE piping.

4.7.1.7.3.3 **Supported** All piping shall be supported continuously or at sufficiently close intervals to prevent sagging and settlement.

4.7.1.7.4 Piping and Component Identification

4.7.1.7.4.1[A] **Clearly Marked** All exposed piping shall be clearly marked to indicate function.

4.7.1.7.4.2 **Flow Direction and Source** All piping shall be clearly marked to indicate type or source of water and direction of flow with clear labeling and/or color coding.

4.7.1.7.4.3 **Valves** All valves shall be clearly marked to indicate function with clear labeling and/or color coding.

4.7.1.7.4.4 **Schematic Displayed** A complete, easily readable schematic of the entire AQUATIC VENUE RECIRCULATION SYSTEM shall be openly displayed in the mechanical room or available to maintenance and inspection personnel.

4.7.1.7.5 Testing

4.7.1.7.5.1 **Static Water Pressure Test** Suction and supply POOL piping shall be subjected to a static hydraulic water pressure test for the duration specified by the design engineer and/or AHJ.

4.7.1.7.5.2 **Greater** Suction and supply AQUATIC VENUE piping shall be able to maintain the greater of the two following amounts of pressure:

1) 25% greater than the maximum design operating pressure of the system, or
2) 25 psi *(172 KPa)*.

4.7.1.8 Strainers and Pumps

4.7.1.8.1 Strainers

4.7.1.8.1.1 **Strainer / Screen** All filter recirculation pumps, except those for vacuum filter installations, shall have a strainer/screen device on the suction side to protect the filtration and pumping equipment.

4.7.1.8.1.2 **Materials** Strainers shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50.

4.7.1.8.2 Pumping Equipment

4.7.1.8.2.1[A] **Variable Frequency Drives** VFDs *may* be installed to control all recirculation and feature pumps.

4.7.1.8.2.2[A] **Total Dynamic Head** The recirculation pump*(s)* shall have adequate capacity to meet the recirculation flow design requirements in accordance with the maximum TDH required by the entire RECIRCULATION SYSTEM under the most extreme operating conditions *(e.g., clogged filters in need of backwashing)*.

4.7.1.8.2.3 **Required Flow Rate** The pump shall be designed to maintain design recirculation flows under all conditions.

4.7.1.8.2.4 **Vacuum Limit Switches** Where vacuum filters are used, a vacuum limit switch shall be provided on the pump suction line.

4.7.1.8.2.5 **Maximum** The vacuum limit switch shall be set for a maximum vacuum of 18 inches *(45.7 cm)* of mercury.

4.7.1.8.2.6 **Pump Priming** All recirculation pumps shall be self-priming or flooded-suction.

4.7.1.8.2.7 **Net Positive Suction Head Requirement** All recirculation pumps shall meet the minimum NPSH requirement for the system.

4.7.1.8.3[A] Operating Gauges

4.7.1.8.3.1 **Vacuum Gauge** A compound vacuum-pressure gauge shall be installed on the pump suction line as close to the pump as possible.

4.7.1.8.3.2 **Suction Lift** A vacuum gauge shall be used for pumps with suction lift.

4.7.1.8.3.3 **Installed** A pressure gauge shall be installed on the pump discharge line adjacent to the pump.

4.7.1.8.3.4 **Easily Read** Gauges shall be installed so they can be easily read.

4.7.1.8.3.5 **Valves** All gauges shall be equipped with valves to allow for servicing under operating conditions.

4.7.1.9 Flow Measurement and Control

4.7.1.9.1[A] ***Flow Meters*** A flow meter accurate to within +/- 5% of the actual design flow shall be provided for each filtration system.

4.7.1.9.1.1 **Certified, Listed, and Labeled** Flow meters shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 50 by an ANSI-accredited certification organization.

4.7.1.9.2 ***Valves*** All pumps shall be installed with a manual adjustable discharge valve to provide a backup means of flow control as well as for system isolation.

4.7.1.10[A] Flow Rates / Turnover Times

Table 4.7.1.10: Aquatic Venue Maximum Allowable Turnover Times

Type of Pools	Turnover Maximum
Activity Pools	2 hours or less
Diving Pools	8 hours or less
Interactive Water Play*	0.5 hours or less
Lazy River	2 hours or less
Plunge Pools	1 hour or less
Runout Slide	1 hour or less
Wading Pools*	1 hour or less
Wave Pools	2 hours or less
All Other Pools	6 hours or less
Surf Pools	Submit engineering justification from equipment manufacturer

*Shall have secondary disinfection systems

Aquatic Venue Maximum Allowable Turnover Times for Spa, Therapy*, & Exercise Pools

Temperatures	*Load*	*Turnover Maximum*
≤ 72°-93°F (22°-34°C)	> 2500 gals/person (9.46 m^3)	4 hours or less
≤ 72°-93°F (22°-34°C)	> 450 gals/person (1.7 m^3)	2 hours or less
≤ 72°-93°F (22°-34°C)	≤ 450 gals/person (1.7 m^3)	1 hour or less
≥ 93-104°F (34°-40°C)	All	0.5 hours or less

*Shall have secondary disinfection systems

4.7.1.10.1 ***Maximum Allowable*** All AQUATIC VENUES shall comply with the above maximum allowable TURNOVER TIMES shown in MAHC Table 4.7.1.10.

4.7.1.10.2[A] ***Calculated*** The TURNOVER TIME shall be calculated based on the total volume of water divided by the flow rate through the filtration process.

4.7.1.10.2.1[A] **Unfiltered Water** Unfiltered water such as water that may be withdrawn from and returned to the AQUATIC VENUE for such AQUATIC FEATURES as SLIDES by a pump separate from the filtration system, shall not factor into TURNOVER TIME.

4.7.1.10.3[A] ***Turnover Times*** TURNOVER TIMES shall be calculated based solely on the flow rate through the filtration system.

4.7.1.10.3.1 **Required** The required TURNOVER TIME shall be the lesser of the following options:

1) The specified time in MAHC Table 4.7.1.10, or
2) The time required for individual components *(e.g., three SKIMMERS with flow rates set by the manufacturer and an additional 20% for the main drains could exceed the minimum value in the table)*.

4.7.1.10.3.2 **Total Volume** The total volume of the AQUATIC VENUE system shall include the AQUATIC VENUE and any surge/balance tank.

4.7.1.10.3.3 **Supply Water** Where water is drawn from the AQUATIC VENUE to supply water to AQUATIC FEATURES *(e.g., SLIDES, tube rides)*, the water may be reused prior to filtration provided the DISINFECTANT and pH levels of the supply water are maintained at required levels.

4.7.1.10.4[A] ***Reuse Ratio*** The ratio of INTERACTIVE WATER PLAY AQUATIC VENUE FEATURE water to filtered water shall be no greater than 3:1 in order to maintain the efficiency of the FILTRATION SYSTEM.

4.7.1.10.5[A] ***Flow Turndown System*** For AQUATIC FACILITIES that intend to reduce the recirculation flow rate below the minimum required design values when the POOL is unoccupied, the flow turndown system shall be designed as follows in MAHC 4.7.1.10.5.1 through MAHC 4.7.1.10.5.2.

4.7.1.10.5.1 **Flowrate** The system flowrate shall not be reduced more than 25% lower than the minimum design requirements and only reduced when the AQUATIC VENUE is unoccupied.

4.7.1.10.5.1.1 **Clarity** The system flowrate shall be based on ensuring the minimum water clarity required under MAHC 5.7.6 is met before opening to the public.

4.7.1.10.5.1.2 **Disinfectant Levels** The turndown system shall be required to maintain required DISINFECTANT and pH levels at all times.

4.7.1.10.5.2 **Increase** When the turndown system is also used to intelligently increase the recirculation flow rate above the minimum requirement *(e.g., in times of peak use to maintain water quality goals more effectively)*, the following requirements shall be met at all times:

1) Velocity requirements inside of pipes *(per MAHC 4.7.1.7.2)*, and
2) Maximum filtration system flows.

4.7.2[A] Filtration

4.7.2.1 All Filters

4.7.2.1.1 ***Required*** Filtration shall be required for all AQUATIC VENUES that recirculate water.

4.7.2.1.2[A] ***Certified, Listed, and Labeled Filters*** All filters shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50 by an ANSI-accredited certification organization.

4.7.2.1.3 ***Appropriate Filter Media*** Filters shall use the appropriate filter media as recommended by the filter manufacturer for maximum clarity and cycle length for AQUATIC VENUE use.

4.7.2.1.4 ***Certified, Listed, and Labeled Filter Media*** All filter media, including alternative filter media, shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 50 by an ANSI-accredited certification organization and within the size specifications provided by the filter manufacturer and NSF/ANSI 50.

4.7.2.2 Granular Media Filters

4.7.2.2.1[A] General

4.7.2.2.1.1 Valves and Piping The granular media filter system shall have valves and piping to allow isolation, venting, complete drainage *(for maintenance or inspections)*, and backwashing of individual filters.

4.7.2.2.1.2 Filtration Accessories Filtration accessories shall include the following items:

1) Influent pressure gauge,
2) Effluent pressure gauge,
3) Backwash sight glass or other means to view backwash water clarity, and
4) Manual air relief system.

4.7.2.2.2[A] Filter Location and Spacing

4.7.2.2.2.1 Installed Filters shall be installed with adequate clearance and facilities for ready and safe inspection, maintenance, disassembly, and repair.

4.7.2.2.2.2 Media Removal A means and access for easy removal of filter media shall be required.

4.7.2.2.3 Filtration and Backwashing Rates

4.7.2.2.3.1[A] Operate High-rate granular media filters shall be designed to operate at no more than 15 GPM per square foot *(37 m/h)* when a minimum bed depth of 15 inches *(38.1 cm)* is provided per manufacturer.

4.7.2.2.3.1.1 Less than Fifteen Inch Bed Depth When a bed depth is less than 15 inches *(38.1 cm)*, filters shall be designed to operate at no more than 12 GPM per square foot (29 m/h).

4.7.2.2.3.2[A] Backwash System Design The granular media filter system shall be designed to backwash each filter at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, unless explicitly prohibited by the filter manufacturer and approved at an alternate rate as specified in their NSF/ANSI 50 listing.

4.7.2.2.4[A] Minimum Filter Media Depth Requirements The minimum depth of filter media cannot be less than the depth specified by the manufacturer.

4.7.2.2.5 Differential Pressure Measurement Gauges

Influent and effluent pressure gauges shall have the capability to measure up to a 20 pounds per square inch *(138 KPa)* increase in the differential pressure across the filter bed in increments of 1 pound per square inch *(6.9 KPa)* or less.

4.7.2.2.6[A] Coagulant Injection Equipment Installation

If coagulant feed systems are used, they shall be installed with the injection point located before the filters as far ahead as possible, with electrical interlocks in accordance with MAHC 4.7.3.2.1.3.

4.7.2.3 Precoat Filters

4.7.2.3.1[A] Filtration Rates

4.7.2.3.1.1 Vacuum Precoat The design filtration rate for vacuum precoat filters shall not be greater than either:

1) 2 GPM per square foot *(4.9 m/h)*, or
2) 2.5 GPM per square foot *(6.1 m/h)* when used with a continuous precoat media feed *(commonly referred to as "body-feed")*.

4.7.2.3.1.2 Pressure Precoat The design filtration rate for pressure precoat filters shall not be greater than two GPM per square foot *(4.9 m/h)* of effective filter surface area.

4.7.2.3.1.3 Calculate The filtration surface area shall be based on the outside surface area of the media with the manufacturer's recommended thickness of precoat media and consistent with their NSF/ANSI 50 listing and labeling.

4.7.2.3.2[A] Precoat Media Introduction System Process The precoat process shall follow the manufacturer's recommendations and requirements of NSF/ANSI Standard 50.

4.7.2.3.3[A] Continuous Filter Media Feed Equipment

4.7.2.3.3.1 Manufacturer Specification If equipment is provided for the continuous feeding of filter media to the filter influent, the equipment shall be used in accordance with the manufacturer's specifications.

4.7.2.3.3.2 Filter Media Discharge All discharged filter media shall be handled in accordance with local and state laws, rules, and regulations.

4.7.2.4 Cartridge Filters

4.7.2.4.1[A] Filtration Rates The design filtration rate for surface-type cartridge filter shall not exceed 0.30 GPM per square foot *(0.20 L/s/m²)*.

4.7.2.4.2[A] Supplied and Sized Filter cartridges shall be supplied and sized in accordance with the filter manufacturer's recommendation for AQUATIC VENUE use.

4.7.2.4.3[A] Spare Cartridge One complete set of spare cartridges shall be maintained on site in a clean and dry condition.

4.7.3[A] Disinfection and pH Control

4.7.3.1 Chemical Addition Methods

4.7.3.1.1 Disinfection and pH DISINFECTION and pH control chemicals shall be automatically introduced through the RECIRCULATION SYSTEM.

4.7.3.1.1.1 Controller Used A chemical controller, as specified in MAHC 4.7.3.2.8 shall be provided and used for MONITORING and control of DISINFECTANT and pH feed equipment.

4.7.3.1.1.2 *Feeder* DISINFECTION and pH control chemicals shall be added using a feeder that meets the requirements outlined in MAHC 4.7.3.2.

4.7.3.2 Feed Equipment

4.7.3.2.1[A] General

4.7.3.2.1.1 Required Chemical feeders shall be required in new or existing AQUATIC FACILITIES upon adoption of this CODE.

4.7.3.2.1.2 Feeders & Devices The AQUATIC FACILITY shall be equipped with chemical feed equipment such as flow-through chemical feeders, electrolytic chemical generators, mechanical chemical feeders, chemical feed pumps, and AUTOMATED CONTROLLERS that are CERTIFIED, LISTED, AND LABELED to NSF-ANSI 50 by an ANSI-accredited certification organization.

4.7.3.2.1.2.1 Specified by Manufacturer Flow-through chemical feeders shall only be used with the chemical *(formulation, brand, size, and shape)* specified by the chemical feeder manufacturer.

4.7.3.2.1.3 Interlock Controls and No or Low Flow Deactivation For all new or SUBSTANTIALLY RENOVATED AQUATIC VENUES and within 1 year of adoption of this CODE for existing facilities, all chemical control and feed systems shall be provided with an automatic means to disable all chemical feeders for each VENUE or portion of a VENUE in the event of a low flow or no flow condition. This shall be accomplished through an electrical interlock consisting of at least two of the following:

1) Recirculation pump power MONITOR,
2) Flow meter/flow switch in the return line,
3) Flow meter/flow switch at the chemical controller.

4.7.3.2.1.3.1 Installed The electrical interlock system shall be installed per manufacturer's instructions and shall never be altered.

4.7.3.2.1.3.2 **Visual Alarm** For new installations and replacement equipment, if the feeder is disabled through the electrical interlock, a visual alarm or other indication shall be initiated that will alert staff on-site for BATHER evacuation.

4.7.3.2.1.4 **Installation** The chemical control and feed systems shall be installed according to the manufacturer's instructions.

4.7.3.2.1.4.1 **Protective Cover** A physical BARRIER shall be installed between chemical feed pumps supplying acid or liquid hypochlorite solution and other POOL components to shield staff and equipment from chemical sprays from leaking connections.

4.7.3.2.2[A] *Sizing of Disinfection Equipment*

4.7.3.2.2.1 **Sizing** Feeders shall be capable of supplying DISINFECTANT and pH control chemicals to the AQUATIC VENUE to maintain the minimum required DISINFECTION levels at all times in accordance with the MAHC.

4.7.3.2.2.2 **Chlorine Dosing** All CHLORINE dosing and generating equipment including erosion feeders, or in line electrolytic and brine/batch generators, shall be designed with a capacity to meet the demand necessary to maintain the minimum required FREE AVAILABLE CHLORINE (FAC) concentrations specified in MAHC 5.7.3.1.1.2 during all times of operation.

4.7.3.2.2.2.1 **Chlorine Demand Factors** Sizing of CHLORINE dosing and generating equipment shall be based on the following CHLORINE demand factors:

1) AQUATIC VENUE surface area;
2) AQUATIC VENUE volume;
3) AQUATIC VENUE type of use/space:
    a. FLAT WATER;
    b. AGITATED WATER;
    c. HOT WATER;
4) AQUATIC VENUE type, for example: POOL, SPA, WADING POOL, WAVE POOL (wave time), WATERSLIDE, INTERACTIVE WATER PLAY VENUE, THERAPY POOL;
5) Indoor or outdoor including maximum hours of sunlight/UV exposure;
6) Anticipated maximum water temperature;
7) Anticipated maximum number of BATHERS per day;
8) Cyanuric acid/stabilizer used;
9) Anticipated atypical water loss; and
10) Anticipated exposure to vegetation and airborne debris.

4.7.3.2.2.3 **Documentation** The Design Professional, who is registered or licensed to practice their respective design profession as defined by the state or local laws governing professional practice within the jurisdiction where the project is to be constructed, shall provide adequate documentation to demonstrate the selected feeders/equipment are of sufficient size and capacity per MAHC 4.7.3.2.2.1 and 4.7.3.2.2.2.

4.7.3.2.2.3.1 **Information Included** This documentation shall include:

1) an evaluation of the DISINFECTION feeder/equipment based on the Design Professional's related professional experience, the DISINFECTION feeder/equipment manufacturer's recommendations, or other industry accepted guidelines in sizing the feeders/equipment, and
2) a discussion of the analysis and use of the CHLORINE demand factors listed in MAHC 4.7.3.2.2.2.1 in sizing the feeders/equipment.

4.7.3.2.2.4 **Upon Operation** If upon operation it is determined that feeders/equipment are not capable of meeting the demand necessary to maintain minimum required DISINFECTION levels at all times, additional capacity shall be provided.

4.7.3.2.3 Introduction of Chemicals

4.7.3.2.3.1 Separation The injection point of DISINFECTION chemicals shall be located before any pH control chemical injection point with sufficient physical separation of the injection points to reduce the likelihood of mixing of these chemicals in the piping during periods of interruption of RECIRCULATION SYSTEM flow.

4.7.3.2.3.2 Backflow Means of injection shall not allow BACKFLOW into the chemical system from the POOL system.

4.7.3.2.3.3 Coagulants Coagulants shall be metered and injected through a pump system prior to the filters per the manufacturer's recommended rate.

4.7.3.2.4 Compressed Chlorine Gas

4.7.3.2.4.1 Prohibited for New Construction Use of compressed CHLORINE gas shall be prohibited for new construction and after SUBSTANTIAL ALTERATION to existing AQUATIC FACILITIES.

4.7.3.2.4.2 In Existing Aquatic Facilities Refer to MAHC 4.9.2.11 on the use of compressed CHLORINE gas in existing AQUATIC FACILITIES.

4.7.3.2.5[A] Types of Feeders

4.7.3.2.5.1 Liquid Solution Feeders Liquid solution feeders shall include positive displacement pumps such as peristaltic pumps, diaphragm pumps, and piston pumps.

4.7.3.2.5.1.1 Feed Rates Feed rates shall be locally adjusted on the pumps and also on/off controlled using an AUTOMATED CONTROLLER.

4.7.3.2.5.1.2 Routed All chemical tubing that runs through areas where staff work shall be routed in PVC piping to support the tubing and/or otherwise supported and protected to prevent leaks.

4.7.3.2.5.1.3 Size The double containment PVC pipe shall be of sufficient size to allow for easy replacement of tubing.

4.7.3.2.5.1.4 Turns Any necessary turns in the piping shall be designed so as to prevent kinking of the tubing.

4.7.3.2.5.2 Erosion Erosion feeders may be pressure, pressure differential, or spray erosion types.

4.7.3.2.5.2.1 Dry Chemical Feeders Dry chemicals shall be granules or tablets.

4.7.3.2.5.2.2 Located Feeders shall have isolation valves on each side of the feeder to be closed before opening the unit.

4.7.3.2.5.2.3 Source Water Erosion feeders shall use AQUATIC VENUE water post-filtration as the source water unless approved by the feeder manufacturer.

4.7.3.2.5.3 Gas Feed Systems Carbon dioxide and ozone are the only gas feed systems permitted in AQUATIC FACILITIES.

4.7.3.2.5.4 Ventilation Proper ventilation shall be required for all gas systems.

4.7.3.2.5.5 Alarms Where CO_2 cylinders are located indoors, a MONITOR and alarm shall be provided to alert PATRONS/operator of high CO_2 and/or low O_2 levels.

4.7.3.2.5.6 UV Systems Where used, UV systems shall be installed in the RECIRCULATION SYSTEM after the filters.

4.7.3.2.5.6.1 Bypass A bypass pipe that is valved on both ends shall be installed to allow maintenance on the UV unit while the POOL is in operation.

4.7.3.2.5.6.2 Interlock UV system operation shall be interlocked with the recirculation pump so that power to the UV system is interrupted when there is no water flow to the UV unit per MAHC 4.7.3.2.1.3.

4.7.3.2.6 Salt Electrolytic Chlorine Generators, Brine Electrolytic Chlorine, or Bromine Generators Halogen generator equipment shall be marked with an EPA establishment number.

4.7.3.2.6.1 Salt Electrolytic Chlorine Generators In-line generator*(s)* or brine *(batch)* generator*(s)* shall be permitted on AQUATIC VENUES.

4.7.3.2.6.2 In-line Method In-line generators shall use POOL-grade salt dosed into the AQUATIC VENUE to produce and introduce CHLORINE into the AQUATIC VENUE treatment loop through an electrolytic chamber.

4.7.3.2.6.3 Batch Method Brine *(Batch)* generators shall produce CHLORINE through an electrolytic cell.

4.7.3.2.6.3.1 Chlorine Production CHLORINE shall be produced from brines composed of POOL-grade salt.

4.7.3.2.6.4 TDS Readout Electrolytic generators shall have a TDS or salt *(NaCl)* readout and a low salt indicator.

4.7.3.2.6.5 Feed Rate The feed rate shall be adjustable from zero *(0)* to full range.

4.7.3.2.6.6 UL Standard The generator unit shall be CERTIFIED, LISTED, AND LABELED to UL 1081 *(for electrical/fire/shock SAFETY)* by an ANSI-accredited certification organization.

4.7.3.2.6.7 Interlock The generator*(s)* shall be interlocked per MAHC 4.7.3.2.1.3.

4.7.3.2.6.8 Installed The generator units shall be installed according to the manufacturer's instructions.

4.7.3.2.6.8.1 Saline Content The saline content of the POOL water shall be maintained in the required range specified by the manufacturer.

4.7.3.2.7[A] Feeders for pH Adjustment

4.7.3.2.7.1 Provided Feeders for pH adjustment shall be provided on all AQUATIC VENUES upon adoption of this CODE as in MAHC 4.7.3.2.1.2.

4.7.3.2.7.2 Approved Substances Approved substances for pH adjustment shall include but not be limited to muriatic *(hydrochloric)* acid, sodium bisulfate, carbon dioxide, sulfuric acid, sodium bicarbonate, and soda ash.

4.7.3.2.7.3 Adjustable pH adjustment feeders shall be adjustable from zero *(0)* to full range.

4.7.3.2.7.4 Marked Reservoirs shall be clearly marked and labeled with contents.

4.7.3.2.8[A] Automated Controllers

4.7.3.2.8.1 Required AUTOMATED CONTROLLERS shall be installed for MONITORING and turning on or off chemical feeders used for pH and DISINFECTANTS at all AQUATIC VENUES.

4.7.3.2.8.1.1 Existing Aquatic Facilities For existing AQUATIC FACILITIES, AUTOMATED CONTROLLERS shall be required within 1 year from adoption of this CODE.

4.7.3.2.8.2 NSF Standard All automated chemical controllers for pH and DISINFECTANT MONITORING/control shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50 by an ANSI-accredited certification organization.

4.7.3.2.8.3 Operation Manuals Operation manuals or other instructions that give clear directions for cleaning and calibrating AUTOMATED CONTROLLER probes and sensors shall be provided in close proximity to the AUTOMATED CONTROLLER.

4.7.3.2.8.4 Set Point A set point shall be used to target the DISINFECTANT level and the pH level.

4.7.3.3 Secondary Disinfection Systems

4.7.3.3.1 General Requirements

4.7.3.3.1.1[A] ANSI Listing and Labeling SECONDARY DISINFECTION SYSTEMS shall be CERTIFIED, LISTED, AND LABELED to ANSI/NSF 50 by an ANSI-accredited certification organization approved by the AHJ.

4.7.3.3.1.1.1 Marked SECONDARY DISINFECTION SYSTEM equipment shall be marked with an EPA establishment number.

4.7.3.3.1.2[A] Required Facilities The new construction or SUBSTANTIAL ALTERATION of the following INCREASED RISK AQUATIC VENUES shall be required to use a SECONDARY DISINFECTION SYSTEM after adoption of this CODE:

1. AQUATIC VENUES designed primarily for children under 5 years old, such as
    a. WADING POOLS,
    b. INTERACTIVE WATER PLAY VENUES with no standing water, and
2. THERAPY POOLS.

4.7.3.3.1.3 Other Aquatic Venues Optional SECONDARY DISINFECTION SYSTEMS may be installed on other AQUATIC VENUES not specified in MAHC 4.7.3.3.1.2.

4.7.3.3.1.4 Labeled If installed and labeled as SECONDARY DISINFECTION SYSTEMS, then they shall conform to all requirements specified under MAHC 4.7.3.3.

4.7.3.3.1.5 Conform If not labeled as SECONDARY DISINFECTION SYSTEMS, then they shall be labeled as SUPPLEMENTAL TREATMENT SYSTEMS and conform to requirements listed under MAHC 4.7.3.4.

4.7.3.3.2[A] Log Inactivation and Oocyst Reduction

4.7.3.3.2.1[A] Log Inactivation SECONDARY DISINFECTION SYSTEMS shall be designed to achieve a minimum 3-log *(99.9%)* reduction in the number of infective *Cryptosporidium parvum* OOCYSTS per pass through the SECONDARY DISINFECTION SYSTEM for INTERACTIVE WATER PLAY AQUATIC VENUES and a minimum 2-log (99%) reduction per pass for all other AQUATIC VENUES.

4.7.3.3.2.2[A] *Installation* The SECONDARY DISINFECTION SYSTEM shall be located in the treatment loop *(post filtration)* and treat a portion *(up to 100%)* of the filtration flow prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE.

4.7.3.3.2.3 Manufacturer's Instructions The SECONDARY DISINFECTION SYSTEM shall be installed according to the manufacturer's directions.

4.7.3.3.2.4[A] Minimum Flow Rate Calculation The flow rate *(Q)* through the SECONDARY DISINFECTION SYSTEM shall be determined based upon the total volume of the AQUATIC VENUE or AQUATIC FEATURE *(V)* and a prescribed dilution time *(T)* for theoretically reducing the number of assumed infective *Cryptosporidium* OOCYSTS from an initial total number of 100 million *(10^8)* OOCYSTS to a concentration of one OOCYST/100 mL.

4.7.3.3.2.5[A] Equation Accounting for a 3-log *(99.9%)* or 2-log (99%) reduction of infective *Cryptosporidium* OOCYSTS through the SECONDARY DISINFECTION SYSTEM with each pass, the SECONDARY DISINFECTION SYSTEM flow rate *(Q)* shall be:

1) Q = V x {[14.8 – ln (V)] / (r x 60 x T)}, where:
    - Q = SECONDARY DISINFECTION SYSTEM flow rate *(gpm)*
    - V = Total water volume of the AQUATIC VENUE or AQUATIC FEATURE, including surge tanks, piping, equipment, etc. *(gals)*
    - r = Efficiency of the system (r = 0.999 for 3-log reduction, r = 0.99 for 2-log reduction)
    - T = Dilution time *(hrs.)*

4.7.3.3.2.6 Time for Dilution Reduction The dilution time shall be the lesser of 9 hours or 75% of the uninterrupted time an AQUATIC VENUE is closed in a 24 hour period.

4.7.3.3.2.7[A] Flow Rate Measurements Where a SECONDARY DISINFECTION SYSTEM is installed, a means shall be installed to confirm the required flow rate to maintain a minimum required log inactivation of infective *Cryptosporidium* OOCYSTS at the minimum flow rate.

4.7.3.3.2.7.1 **Flow Rate Defined** The minimum required flow rate through the SECONDARY DISINFECTION SYSTEM shall be as defined in MAHC 4.7.3.3.2.5.

4.7.3.3.3^A^ ***Ultraviolet Light Systems*** To prevent mercury exposure, UV systems shall be installed to avoid lamp breakage according to the guidelines in EPA 815-R-06-007 Appendix E.

4.7.3.3.3.1^A^ **Third Party Validation** UV equipment shall be third party validated in accordance with the practices outlined in the *EPA Ultraviolet Disinfectant Guidance Manual* dated November, 2006, publication number EPA 815-R-06-007.

4.7.3.3.3.1.1^A^ **Validation Standard** The *EPA Ultraviolet Disinfectant Guidance Manual* shall be considered a recognized national STANDARD in the MAHC.

4.7.3.3.3.2 **Suitable for Intended Use** UV systems and all materials used therein shall be suitable for their intended use and be installed:

1) In accordance with the MAHC,
2) As CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization, and
3) As specified by the manufacturer.

4.7.3.3.3.3 **Installation** The UV equipment shall be installed after the filtration and before addition of primary DISINFECTANT.

4.7.3.3.3.3.1 **Labeled** UV equipment shall be labeled with the following design specifications: maximum flow rate, minimum transmissivity, minimum intensity, and minimum dosage.

4.7.3.3.3.3.2 **Strainer Installation** An inline strainer shall be installed after the UV unit to capture broken lamp glass or sleeves.

4.7.3.3.3.4 **Electrically Interlocked** The equipment shall be electrically interlocked with feature pump*(s)* or automated feature supply valves, such that when the UV equipment fails to produce the required dosage as measured by automated sensor, the water features do not operate.

4.7.3.3.3.4.1^A^ **Alarm/Interlock Setpoint** The UV alarm/interlock setpoint shall be such that it ensures that the minimum required dose is delivered under all possible conditions of water UV transmittance and lamp output at the actual flow rate.

4.7.3.3.3.4.2 **Operation** UV systems shall not operate if the RECIRCULATION SYSTEM is not operating.

4.7.3.3.3.5 **Calibrated UV Sensors** The UV equipment shall be complete with calibrated UV sensors, which record the output of all the UV lamps installed in a system.

4.7.3.3.3.5.1 **Multiple Lamps** Where multiple lamps are fitted, sufficient sensors shall be provided to measure each lamp.

4.7.3.3.3.5.2 **Fewer Sensors** If the design utilizes fewer sensors than lamps, the location of lamps and sensors shall be such that the output of all lamps is adequately measured.

4.7.3.3.3.6 **Automated Shut Down** The automated shut down of the UV equipment for any reason shall initiate a visual alarm or other indication which will alert staff on-site or remotely.

4.7.3.3.3.6.1 **Signage** Signage instructing staff or PATRONS to notify facility management shall be posted adjacent to the visual indication.

4.7.3.3.3.6.2 **Not Staffed** If the AQUATIC FACILITY is not staffed, the sign shall include a means to contact management whenever the AQUATIC FACILITY is in use.

4.7.3.3.3.7 **Reports and Documentation** The UV equipment shall be supplied with the appropriate validation reports and documentation for that equipment model.

4.7.3.3.3.8 **Manufacturer Log Inactivation Chart** This documentation will include a graph or chart indicating the dose at which the required log inactivation is guaranteed for the system in question.

4.7.3.3.3.8.1 **Reduction Equivalent Dose Bias** This dose shall be inclusive of validation factors and RED BIAS.

4.7.3.3.3.8.2 **System Performance Curves** System performance curves that do not include such factors are not considered validated systems.

4.7.3.3.3.9[A] **Minimum RED** Validation records shall include the graph indicating the minimum intensity reading required at the operational flow for the minimum RED required to achieve the required log reduction.

4.7.3.3.3.9.1 **Minimum Intensity Shown** Where systems are validated to a specific dose, the graph shall show the minimum intensity reading required at the operational flow for that dose.

4.7.3.3.3.10 **Recommended Validation Protocol** Based on the recommended validation protocol presented in the EPA Disinfection Guidance Manual, UV reactors certified by ÖNORM and DVGW for a *Bacillus subtilis* RED of 40mJ/cm^2 shall be granted 3-log *Cryptosporidium* and 3-log *Giardia* inactivation credit as required in this CODE.

4.7.3.3.4 Ozone Disinfection

4.7.3.3.4.1[A] **Log Inactivation** SECONDARY DISINFECTION SYSTEMS using ozone shall provide the required inactivation of *Cryptosporidium* in the full flow of the SECONDARY DISINFECTION SYSTEM after any side-stream has remixed into the full flow of the SECONDARY DISINFECTION SYSTEM.

4.7.3.3.4.2[A] **Third Party Validation** Ozone systems shall be validated by an ANSI-accredited third party testing and certification organization to confirm that they provide the required log inactivation of *Cryptosporidium* in the full SECONDARY DISINFECTION SYSTEM flow after any side-stream has remixed into the full SECONDARY DISINFECTION SYSTEM flow and prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE recirculation treatment loop.

4.7.3.3.4.3[A] **Suitable for Use** Ozone systems and all materials used therein shall be suitable for their intended use and be installed:

1) In accordance with all applicable requirements,
2) As CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization, and
3) As specified by the manufacturer.

4.7.3.3.4.4 **Ozone System Components** An ozone system shall be a complete system consisting of the following *(either skid-mounted or components)*:

1) Ozone generator,
2) Injector / injector manifold,
3) Reaction tank *(contact tank)* / mixing tank / degas tower,
4) Degas valve *(if applicable, to vent un-dissolved gaseous ozone)*,
5) Ozone destruct *(to destroy un-dissolved gaseous ozone)*,
6) ORP MONITOR / controller,
7) Ambient ozone MONITOR / controller,
8) Air flow meter / controller, and
9) Water BACKFLOW prevention device in gas delivery system.

4.7.3.3.4.5 **Appropriate Installation** These components *(or skid)* shall be installed as specified by the manufacturer to maintain the required system validation as noted above.

4.7.3.3.4.6 **ORP Monitor** The ozone generating equipment shall be designed, sized, and controlled utilizing an ORP MONITOR / controller *(independent of and in addition to any halogen ORP MONITOR/controller)*.

4.7.3.3.4.6.1 **Placed Downstream** The device shall be placed in the AQUATIC VENUE and AQUATIC FEATURE recirculation water downstream of the ozone side-stream loop and before the halogen feed

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10310

68

Date Submitted	02/12/2022	**Section**	454.1.4.2.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies outdoor lighting requirements.

Rationale

Would allow decorative lighting below illumination minimums where night swimming is prohibited. Would allow special lighting in coastal areas during sea turtle nesting season instead of completely dark pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Swimming pool light affects bathers ability to see the pool floor, walls, and deck.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.4.2.1Outdoor pool lighting.

If night operation is proposed, Llighting shall provide a minimum of 3 footcandles (30 lux) of illumination at the pool water surface and the pool wet deck surface. Underwater lighting shall be a minimum of 1/2 watt incandescent equivalent, or 10 lumens, per square foot of pool water surface area. If signage clearly indicates that night swimming is prohibited, lights less than the minimum amount may be installed for aesthetic or any other non-bathing purpose.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10311

69

Date Submitted	02/12/2022	**Section**	454.1.10.1.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies gutter tile requirements when resurfacing a swimming pool.

Rationale

Gutter tile should be made cleanable and non-slip during resurfacing.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Does not affect enforcement.

Impact to building and property owners relative to cost of compliance with code

Adds a requirement to use non skid gutter title when resurfacing a swimming pool.

Impact to industry relative to the cost of compliance with code

Adds a requirement to use non skid gutter title when resurfacing a swimming pool.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves bather safety.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves bather safety.

454.1.10.1.1

The lip of the gutter must be leveled to within 1/4 inch (6.4 mm) between the highest and lowest point and the downward slope from the lip to the drain must be maintained as originally designed or increased, but shall not exceed new construction standards. The gutter surfaces shall be made to comply with 454.1.6.5.3.1.3.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10312

70

Date Submitted	02/12/2022	**Section**	454.1.10.1.8	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Requires handrails to be updated during resurfacing projects.

Rationale

Would require handrails and grab rails to be brought up to code during resurfacing projects. Ensures that all handrails and grab rails meeting current standards.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Add an additional item to check compliance of when reviewing a resurfacing project.

Impact to building and property owners relative to cost of compliance with code

Adds an additional requirement when conducting a resurfacing project.

Impact to industry relative to the cost of compliance with code

Adds an additional requirement when conducting a resurfacing project.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Hand rails and grab rails are important to bather safety entering, exiting, and navigating swimming pools and spas.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves safety of Florida public swimming pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves safety of Florida public swimming pools.

454.1.10.1.8

Handrails and Grabrails that do not meet the requirements of 454.1.2.5.5 shall be brought into compliance with 454.1.2.5.5 or removed if not needed for compliance with 454.1.2.5.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10313

71

Date Submitted	02/12/2022	**Section**	454.1.10.1.9	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Specifies gutter grate replacement requirements for resurfacing projects.

Rationale

Gutter grates should be replaced with equal or larger grates during resurfacing.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Adds and additional requirement for swimming pool resurfacing projects.

Impact to building and property owners relative to cost of compliance with code

Adds and additional requirement for swimming pool resurfacing projects.

Impact to industry relative to the cost of compliance with code

Adds and additional requirement for swimming pool resurfacing projects.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Updates code to produce better results.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Updates code to produce better results.

454.1.10.1.9

If gutter grates are replaced, the new gutter grates shall have a total open surface area to meet or exceed the designed flow rate of the pool.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

72

SW10314

Date Submitted	02/12/2022	**Section**	454.1.2.2	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Specifies construction tolerances for commercial swimming pools.

Rationale

Construction tolerances should be applied over the entire Code. This will eliminate many variance requests.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Addition of tolerances will simply enforcement and compliance with the code.

Impact to building and property owners relative to cost of compliance with code

Addition of tolerances will simply enforcement and compliance with the code.

Impact to industry relative to the cost of compliance with code

Addition of tolerances will simply enforcement and compliance with the code.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Simplifies compliance with code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Simplifies compliance with code requirements.

454.1.2.2 Dimensions.

Any dimensional requirement mentioned in section 454.1 of this code may have a construction tolerance of up to 3 inches (76 mm), or 5% of the dimension on the approved drawings, whichever is less. This construction tolerance may be positive or negative, except negative construction tolerances shall not be applied to any part of a diving bowl

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10315

Date Submitted	02/12/2022	**Section**	454.1.2.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Changes slip-resistant tile requirements.

Rationale

Slip-resistant tile should only be used in less than 3.5 ft of water. At a water depth of 3.5 feet there is no significant risk of a slip and fall injury to bathers.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.2.1 Pool structure. Pools shall be constructed of concrete or other impervious and structurally rigid material. All pools shall be watertight, free from structural cracks and shall have a nontoxic smooth and slipresistant finish. All materials shall be installed in accordance with manufacturer's specifications unless such specifications violate Chapter 64E-9, Florida Administrative Code, rule requirements or the approval criteria of NSF/ANSI Standard 50 or NSF/ANSI Standard 60.

(a) Floors and walls shall be white or pastel in color and shall have the characteristics of reflecting rather than absorbing light. Tile used in less than ~~5~~ 3.5 feet (~~1524~~1067 mm) of water must be slipresistant. A minimum 4-inch (102 mm) tile line, each tile a minimum size of 1 inch (25 mm) on all sides, shall be installed at the water line, but shall not exceed 12 inches (305 mm) in height if a dark color is used. Gutter-type pools may substitute 2-inch (51 mm) tile, each a minimum size of 1 inch (25 mm) on all sides, along the pool wall edge of the gutter lip.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10316

74

Date Submitted	02/12/2022	**Section**	454.1.8.15	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Exempts spas with gravity flow drains from NEC emergency cut off switch requirements.

Rationale

Spas with gravity flow drain systems are at extremely low risk for suction entrapment incidents. The inclusion of an unnecessary cutoff switch can lead to unsanitary spa conditions when the switch is accidentally or intentionally erroneously activated. The Florida Department of Health argued for the adoption of gravity flow systems due to their inherent safety.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.8.15 Emergency cutoff switches

Spas equipped with gravity flow drain systems, regardless of when constructed, are exempted from Section 680.41 of NFPA-70.

However, Iif a spa is equipped with an emergency cutoff or kill switch, it shall include provisions for a minimum 80 decibel audible alarm near the spa to sound continuously until deactivated when such device is triggered. The following additional rule sign shall be installed to be visible by the spa which reads “ALARM INDICATES SPA PUMPS OFF. DO NOT USE SPA WHEN ALARM SOUNDS UNTIL ADVISED OTHERWISE.”

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10317

75

Date Submitted	02/12/2022	**Section**	454.1.6.5.13	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Updates flow rate indicator requirements.

Rationale

The change in Blue-White and other manufacturer's flow meters over the past five years has resulting in the need to provide electronic flow meters or a section of a different pipe size to meet this requirement. The FDOH operational requirement is that the flow be +/-20% of the design flow rate. The tighter flow rate requirement for the flow meter would still allow flow monitoring in accordance with code and would facilitate a simpler change from older flow meters and allow compliance on new projects with a greater variety of flow meters. This change would reduce costs and improve measurement of the flow over the range of concern (+/-20% of the design flow rate).

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements

Impact to building and property owners relative to cost of compliance with code

This change would reduce costs and improve measurement of the flow over the range of concern

Impact to industry relative to the cost of compliance with code

This change would reduce costs and improve measurement of the flow over the range of concern

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

1st Comment Period History

SW10317-G1

Proponent	bob vincent	Submitted	4/17/2022 3:39:31 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod as written. Each public pool is required to have it's own recirculation system.

454.1.6.5.13 Rate of flow indicators.

A rate of flow indicator, reading in gpm, shall be installed on the return line. The rate of flow indicator shall be properly sized for the design flow rate and shall be capable of measuring from ~~one-half~~three-quarters to at least one-and one-~~half~~quarter times the design flow rate. The clearances upstream and downstream from the rate of flow indicator shall comply with manufacturer's installation specifications. Multiple pools may share a recirculation and treatment system, however, each pool must have a unique return line with its own rate of flow indicator.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10318

76

Date Submitted	02/12/2022	**Section**	454.1.2.3.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Specifies placement of "No Diving" markers.

Rationale

Some municipalities have required no diving markings to be installed along the pool waterline tile with the depth markers. The code is silent on this issue so the clarification is needed.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

454.1.2.3.1 Depth and markings.

Depth and markings shall meet the following criteria: …..

6. Those areas of the pool that are not part of an approved diving bowl shall have dark contrasting tile, 4-inch-high (102 mm) "NO DIVING" markings installed along the perimeter of the pool on the top of the pool curb or deck within 2 feet (610 mm) of the pool water with a maximum perimeter distance of 25 feet (7620 mm) between markings. A 6-inch (152 mm) tile with a 4-inch (102 mm) or larger red, international "NO DIVING" symbol may be substituted for the "NO DIVING" markings. "NO DIVING" markings are not required within the swimming pool.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10319

77

Date Submitted	02/12/2022	**Section**	454.1.6.5.3.2.4	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Allows for inlet and skimmer alignment tolerance.

Rationale

There has been confusion about what constitutes “directly across” means. The addition of a tolerance will help eliminate conflicts over this confusion and require fewer variance requests on this issue.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

1st Comment Period History

SW10319-G1

Proponent	bob vincent	Submitted	4/17/2022 4:22:47 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod. We prefer language in SW10509 mod for this identical subject.

454.1.6.5.3.2.4Wall-inlet fitting.

A wall-inlet fitting shall be provided directly across from each skimmer. within a tolerance of 5 feet (304.8 mm) measured along the perimeter in either direction from center.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

78

SW10320

Date Submitted	02/12/2022	**Section**	454.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies requirements for collector tank vents.

Rationale

Eliminates the piped venting option for collectors. A four inch vent pipe can be easily caped or clogged eliminating a the safety advantages of the swimming pool's gravity flow drain system.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, clarifies code requirements, removes unnecessary complications.

Impact to building and property owners relative to cost of compliance with code

None, clarifies code requirements, removes unnecessary complications.

Impact to industry relative to the cost of compliance with code

None, clarifies code requirements, removes unnecessary complications.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies code requirements, removes unnecessary complications.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Clarifies code requirements, removes unnecessary complications.

454.1

“Collector tank” means a reservoir, with a minimum of 2.25 square feet (0.2 m2) water surface area, that is ~~vented by piping and/or~~ open to the atmosphere, from which the recirculation or feature pump takes suction, which receives the gravity flow from the main drain line and surface overflow system or feature water source line, and that is cleanable. ~~The vent shall measure a minimum of 12.56 square inches (8103 mm2) in area and shall be equipped with a screen, or equivalent device, to prohibit entry by animals. The vent shall be designed to minimize rainwater entry into the tank. Tanks with vented lids shall not be required to be equipped with a separate vent.~~ Tanks not located in a room or enclosure shall have a lockable lid that has a vent equipped with a screen or equivalent device, to prohibit entry by animals. Tanks shall be constructed of concrete or other impervious and structurally rigid material, with adequate ~~manway~~ accessfor maintenance and cleaning, shall be watertight, shall be free from structural cracks and shall have a nontoxic smooth finish

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10321

79

Date Submitted	02/12/2022	**Section**	454.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Ads resistance exercise pool to definition of "Special purpose pool".

Rationale

Ads pools designed for resistance exercise to the definition of a special purpose pool. There has been confusion of this in some jurisdictions, this change would bring clarity to the code. This will eliminate the need for variances for resistance exercise pools.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This modifications ads specificity to the code where there is currently room for interpretation and dispute

1st Comment Period History

SW10321-G1

Proponent	bob vincent	Submitted	4/17/2022 3:43:34 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod. Special purpose pools require supervision. With code compliant design, a resistance pool can be built today without need for a variance.

454.1

“Special purpose pool” means a public pool used exclusively for a specific, supervised purpose, including springboard or platform diving training, SCUBA diving instruction, and aquatic programs for persons with disabilities, preschool or kindergarten children. Special purpose pool also means a public pool used exclusively for unsupervised resistance exercise.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10322

80

Date Submitted	02/12/2022	**Section**	454.1.6.5.3.1.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies recessed gutter requirements.

Rationale

The first is to require a minimum 4” clearance from the top of the gutter dam wall to the coping above it. This dimension has never been stated in the code, but is a rule of thumb used by most aquatic engineers, and acceptable to the FDOH. It needs clarification in the code, because pool renovations to eliminate old coping has resulted in this clearance to be diminished. For maintenance purposes, the 4” clearance will allow for access to clean the gutter trough and tiles. For safety, it provides a bather a place to grab in case of distress. The clearance also allows the depth marker tiles on the back wall of the gutter to be visible. The second suggestion is to clarify that no part of a recessed gutter, excluding a gutter dam wall, can be visible when looking from a position directly above.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None, simplifies code requirements.
Impact to building and property owners relative to cost of compliance with code
None, simplifies code requirements.
Impact to industry relative to the cost of compliance with code
None, simplifies code requirements.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
How a swimming pool system is designed and construction impact the health and safety of bathers.
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Clarifies code requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Clarifies code requirements.

454.1.6.5.3.1.1

Either recessed-type or open type gutters shall be used. Special designs can be approved provided they are within limits of sound engineering practice. Recessed-type gutters open areasshall be at least 4 inches (102 mm) deep and 4 inches (102 mm) wide, with a minimum 4 inches (102 mm) clearance for cleaning. ~~No part of~~ ~~t~~The open area of the recessed gutter, excluding the gutter front dam wall, shall not be visible from a position directly above the gutter sighting vertically down the edge of the deck or curb. Open-type gutters shall be at least 6 inches (150 mm) deep and 12 inches (305 mm) wide. The gutter shall slope 2 inches (51 mm), +/-$^{1}/_{4}$inch (+/-6 mm), from the lip to the drains. The gutter drains shall be located at the deepest part of the gutter.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

81

SW10323

Date Submitted	02/12/2022	**Section**	454.1.2.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Ads damp-proofing requirement for elevated swimming pools.

Rationale

All elevated above-grade pools and spas require waterproofing/dampproofing. The Surfside tragedy brings to focus the importance of protecting concrete from water intrusion. This should apply to all elevated pools during resurfacing or new construction

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Ads an additional requirement for newly constructed elevated swimming pools.

Impact to building and property owners relative to cost of compliance with code

Ads an additional requirement for newly constructed elevated swimming pools.

Impact to industry relative to the cost of compliance with code

Ads an additional requirement for newly constructed elevated swimming pools.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Protects swimming pools and buildings from water intrusion.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Protects swimming pools and buildings from water intrusion.

454.1.2.1Pool structure.

Pools shall be constructed of concrete or other impervious and structurally rigid material. All pools shall be watertight, shall be free from structural cracks and shall have a nontoxic smooth and slip-resistant finish. All elevated above-grade concrete pool walls and floors shall have waterproofing/dampproofing installed prior to the final surface application. All materials shall be installed in accordance with manufacturer's specifications unless such specifications violate Chapter 64E-9, Florida Administrative Code, rule requirements or the approval criteria of NSF/ANSI Standard 50 or NSF/ANSI Standard 60.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10324

82

Date Submitted	02/12/2022	**Section**	454.1.10.1.10	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Requires damp-proofing for elevated swimming pools during resurfacing.

Rationale

All elevated above-grade pools and spas require waterproofing/dampproofing. The Surfside tragedy brings to focus the importance of protecting concrete from water intrusion. This should apply to all elevated pools during resurfacing or new construction

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Ads an additional requirement during resurfacing projects.

Impact to building and property owners relative to cost of compliance with code

Ads an additional requirement during resurfacing projects.

Impact to industry relative to the cost of compliance with code

Ads an additional requirement during resurfacing projects.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Protects swimming pools and buildings from water intrusion.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Protects swimming pools and buildings from water intrusion.

454.1.10.1.10

All elevated above-grade concrete pool walls and floors shall have waterproofing/dampproofing installed prior to the final surface application.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10325

83

Date Submitted	02/12/2022	**Section**	454.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarifies definition of a public pool.

Rationale

Clarifies the definition of a public swimming pool. Will prevent, conflict with regulators and swimming pool builders.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to building and property owners relative to cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to industry relative to the cost of compliance with code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

This modifications ads specificity to the code where there is currently room for interpretation and dispute.

1st Comment Period History

SW10325-G1

Proponent	bob vincent	Submitted	4/17/2022 9:35:58 PM	Attachments	No

Comment:

Florida Department of Health is not in favor of this mod. This definition of a public pool is found in Florida Statutes section 514.011(2) and should not be edited.

454.1

A **"public swimming pool"** or **"public pool"** means a ~~single~~ watertight structure of concrete, masonry or other approved materials that is located either indoors or outdoors, used for bathing or swimming by humans, and filled with a filtered and disinfected water supply, <u>with a single, continuous water surface,</u> together with buildings, appurtenances and equipment used in connection therewith. A public swimming pool or public pool shall mean a conventional pool, spa-type pool, wading pool, special purpose pool, interactive water feature or water recreation attraction, to which admission may be gained with or without payment of a fee and includes, but is not limited to, pools operated by or serving camps, churches, cities, counties, day care centers, group home facilities for eight or more clients, health spas, institutions, parks, state agencies, schools, subdivisions, or the cooperative living-type projects of five or more living units, such as apartments, boardinghouses, hotels, mobile home parks, motels, recreational vehicle parks, and townhouses. The term does not include a swimming pool located on the grounds of a private residence.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10326

84

Date Submitted	02/12/2022	**Section**	454.1.6.5.19	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Ads the requirement for newly built pools to use ORP/PH controllers.

Rationale

ORP and PH controllers ensure consistent reliable water chemical balance and sanitization. The addition of ORP and PH controllers on public swimming pools will increase bather safety.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Ads an additional requirement for newly built swimming pools.

Impact to building and property owners relative to cost of compliance with code

Ads an additional requirement for newly built swimming pools.

Impact to industry relative to the cost of compliance with code

Ads an additional requirement for newly built swimming pools.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The addition of ORP and PH controllers on public swimming pools will increase bather safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The addition of ORP and PH controllers on public swimming pools will increase bather safety.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

The addition of ORP and PH controllers on public swimming pools will increase bather safety.

<u>454.1.6.5.19</u>

<u>Automated oxidation reduction potential (ORP) and pH controllers with sensing probes shall be provided on all newly built public swimming pools to assist in maintaining proper disinfection and pH levels.</u>

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10327

85

Date Submitted	02/12/2022	**Section**	454.1.6.5.3	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Creates and exception when a bottom drain is used in conjunction with a wall main drain carrying 100% of the recirculation flow.

Rationale

Upper-level pools have no clearances to install deep sumps at the bottom of the slab, this allows for system designs that do not rely on deep sumps to work properly.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

How a swimming pool system is designed and construction impact the health and safety of bathers.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

454.1.6.5.3System design.

The design pattern of recirculation flow shall be 100 percent through the main drain piping and 100 percent through the perimeter overflow system or 60 percent through the skimmer system. Except when a bottom drain is used in conjunction with a wall main drain carrying 100% of the recirculation flow.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10374

86

Date Submitted	02/14/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

SW9942, SW9857

Summary of Modification

Allow permanent tables, chairs, and similar structures to be built into the pool.

Rationale

Tables and chairs should be allowed to be built into pools so long as they are properly marked and supervised.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

There is minimal impact here. These structures would have to be marked like a bench. The code enforcement official could think of them as benches that are not at the edge of the pool

Impact to building and property owners relative to cost of compliance with code

There is no impact.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The provision requires dark contrasting markings to prevent people from stumbling, and non-slip to prevent them from slipping.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes, this allows a condition that owners in other jurisdictions are permitted to create, while maintaining safety.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The safety conditions included in this change will maintain the effectiveness of the Code.

1st Comment Period History

SW10374-G1

Proponent	Michael Weinbaum	Submitted	4/13/2022 10:31:54 AM	Attachments	No

Comment:

This proposal is identical to SW9943. It does not need to be considered a second time.

1st Comment Period History

SW10374-G2

Proponent	Dallas Thiesen	Submitted	4/14/2022 3:54:49 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification.

1st Comment Period History

SW10374-G3

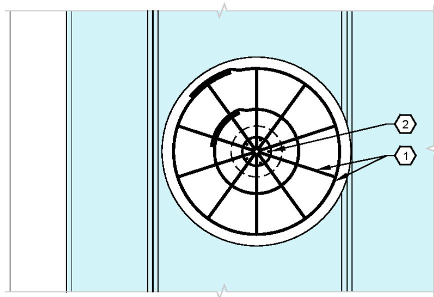
Proponent	bob vincent	Submitted	4/17/2022 3:52:28 PM	Attachments	No

Comment:

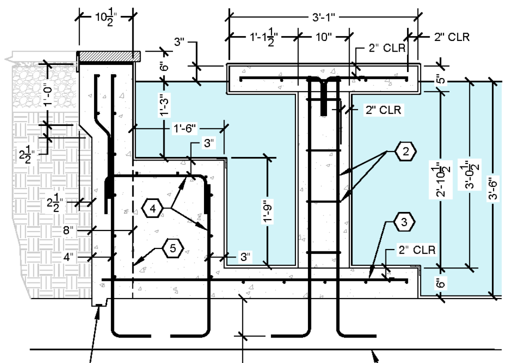
Florida Department of Health opposes this mod. See SW9943-G2 comments

454.1.2.6 Obstructions.The pool water area shall be unobstructed by any … structure unless justified by engineering design as a part of the recirculation system, or intended for seating. Any structure intended for seating in the pool shall have 2 inch (51 mm) horizontal and 2 inch (51 mm) vertical markings in contrasting color, and be structurally rigid, impervious, non-toxic, and smooth. All horizontal or near horizontal surfaces shall be slip resistant. Engineering design and material specifications shall show that such structures will not endanger the pool patron, can be maintained in a sanitary condition and will not create a problem for sanitary maintenance of any part of the pool, pool water, or pool facilities. ... If any obstruction includes a surface that overhangs by more than 2 inches (51 mm), a lifeguard safety plan shall be submitted to the health department for approval and implemented by the owner/operator.

SW10374Rationale



PLAN



SECTION

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TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10382

87

Date Submitted	02/14/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

10374

Summary of Modification

Allowing swim up bars within certain limitations.

Rationale

Swim up bars are becoming popular in the Caribbean as well as Las Vegas. Florida should maintain its competitive advantage in tourism with these areas.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This adds a new category for them to consider.

Impact to building and property owners relative to cost of compliance with code

This does not increase the costs for owners, however it creates massive new revenue opportunities.

Impact to industry relative to the cost of compliance with code

There is no impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Food and drink spilled into the pool could encourage the growth of pathogens, and people under the influence of alcohol are at a greater risk of injury in a pool, however, we need to manage these risks rather than attempt to ban them.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

The code is improved.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code

The code's effectiveness in this area is questionable, as many people defy the rules about food and drinks in spite of what the rules signs say. This would direct those people to pools designed and supervised for that purpose.

Alternate Language

1st Comment Period History

SW10382-A1

Proponent Michael Weinbaum **Submitted** 4/15/2022 1:03:51 PM **Attachments** Yes

Rationale:

This is almost identical to the original proposal. The alternate language adds two more subsections to this new section. The first addition describes what the designer has to do to safely combine a swim up bar with another pool type, and the second section ensures that bodies intended to be separate from a swim up bar will not allow food and beverage. The second addition allows permanent stools and tables to be built into the floor of the swim up bar.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Same as original proposal

Impact to building and property owners relative to cost of compliance with code

No impact

Impact to industry relative to the cost of compliance with code

No impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Yes

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not.

Does not degrade the effectiveness of the code

Does not.

1st Comment Period History

SW10382-G1

Proponent Dallas Thiesen Submitted 4/14/2022 3:55:38 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW10382-G2

Proponent bob vincent Submitted 4/17/2022 9:48:27 PM Attachments Yes

Comment:

Florida Department of Health is not in favor of this mod as written. Draft DOH rule 64E-9, FAC, for this subject is attached.

"Swim-up Bar" means a public pool used for the consumption of food and beverages by people, that may include a permanent bar or counter from which food and beverages are served to people in the pool.
...
454.1.3.1.7 Food or drink service facilities shall not be located within 12 feet (3658 mm) of the water's edge. Any pool with food or drink service within 12 feet (3658 mm) of the water's edge must comply with 454.1.9.9 for Swim Up Bars.
...
454.1.9.9Swim Up Bars

454.1.9.9.1A swim-up bar shall be constructed within the limits of sound engineering practice. The maximum pool depth shall not exceed 5 feet (1524 mm) and the recirculation turnover time shall be 2 hours or less.The disinfection equipment shall be capable of feeding 12 mg/L of halogen to the continuous recirculation flow of the filtration system. Attendants or lifeguards shall be provided in accordance with a safety/lifeguard plan approved by the Department of Health.
454.1.9.9.2A rules sign complying with 454.1.2.3.5 shall be provided, except, the first rule shall read:

Food and Drink are consumed in this pool. All drinks shall be in plastic or aluminum containers.

454.1.9.9.3If the bar or counter is built into the edge of the pool, pool access complying with 454.1.2.5 shall be provided at both ends of the bar. Deck complying with 454.1.3.1 shall be provided, except, up to 50% of the pool perimeter may be obstructed by the bar. Gutters or skimmers are not required at or under the bar counter, however, they are required at the rest of the pool. An automatic water level controller shall be provided, and an overfill waste line with air gap shall be provided.
454.1.9.9.4 A swim up bar may be physically combined or connected with other pool types, however, food and drink must be permitted over the entire body of water and the requirements of 454.1.9.9.1 shall apply to the entire water volume. A swim up bar's water must not mix with any body of water that is not a swim up bar and does not allow the consumption of food and beverages.
454.1.9.9.5 A swim up bar may include obstructions intended for seating. Any structure intended for seating in the pool shall have 2 inch (51 mm) horizontal and 2 inch (51 mm) vertical markings in contrasting color on every edge, and be structurally rigid, impervious, non-toxic, smooth, and slip resistant. The edges of such obstructions shall not overhang into the water by more than 1.5 inches (38 mm).

"Swim-up Bar" means a public pool used for the consumption of food and beverages by people, that may include a permanent bar or counter from which food and beverages are served to people in the pool.

...

454.1.3.1.7 Food or drink service facilities shall not be located within 12 feet (3658 mm) of the water's edge. Exception: Any pool with food or drink service within 12 feet (3658 mm) of the water's edge must comply with 454.1.9.9 for Swim Up Bars.

...

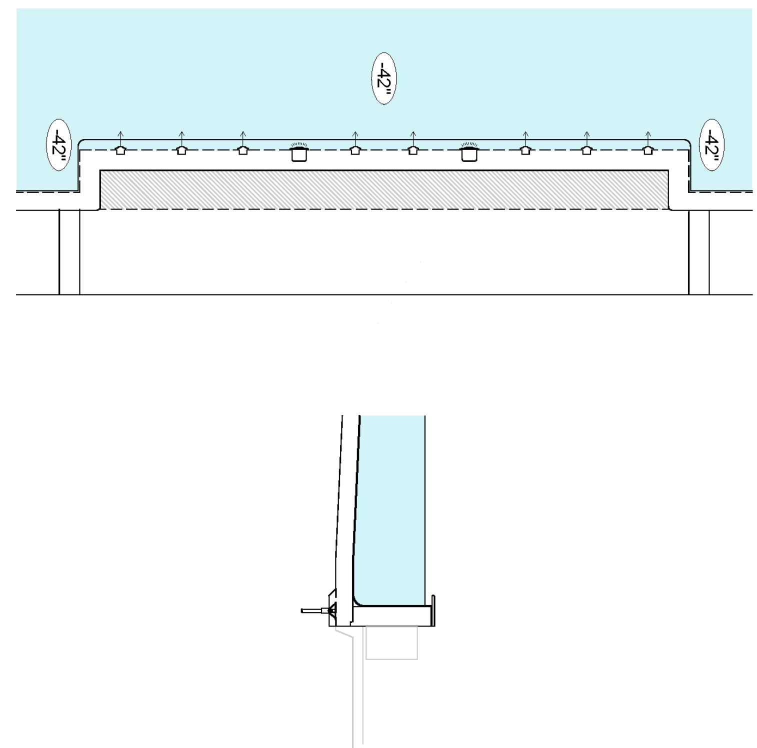
454.1.9.9 Swim Up Bars

454.1.9.9.1 A swim-up bar shall be constructed within the limits of sound engineering practice. The maximum pool depth shall not exceed 5 feet (1524 mm) and the recirculation turnover time shall be 2 hours or less.The disinfection equipment shall be capable of feeding 12 mg/L of halogen to the continuous recirculation flow of the filtration system. Attendants or lifeguards shall be provided in accordance with a safety/lifeguard plan approved by the Department of Health.

454.1.9.9.2 A rules sign complying with 454.1.2.3.5 shall be provided, except, the first rule shall read:

Food and Drink are consumed in this pool. All drinks shall be in plastic or aluminum containers.

454.1.9.9.3 If the bar or counter is built into the edge of the pool, pool access complying with 454.1.2.5 shall be provided at both ends of the bar. Deck complying with 454.1.3.1 shall be provided, except, up to 50% of the pool perimeter may be obstructed by the bar. Gutters or skimmers are not required at or under the bar counter, however, they are required at the rest of the pool. An automatic water level controller shall be provided, and an overfill waste line with air gap shall be provided.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64E-9.004(4) Food, beverages, glass containers, and animals are prohibited in the pool and on the wet deck area, except as provided here and in (5) below.

(a) Commercially bottled water in plastic bottles is allowed on the pool wet deck for pool patron hydration.

(b) Individuals with a disability and service animal trainers may be accompanied by a service animal, as defined in section ~~Chapter~~ 413.08, F.S., but the service animal is not allowed to enter the pool water or onto the drained area of an interactive water feature (IWF) in order to prevent a direct threat to the health of pool patrons.

(5) Swim-up bars are permitted as provided in this subsection. A "swim-up bar" means a public swimming pool used for the consumption of food or beverage by people and may include a permanent bar or counter within the pool area from which food and beverage are served to people in the pool. Swim-up bars must meet with the following criteria:

(a) Swim-up bars are only permitted at transient public lodging establishments licensed under s. 509.013(4)(a)1., F.S, or at a theme park or entertainment complex as defined in s. 509.013(9), F.S.

(b) Food and beverages are allowed on the wet deck area and in the pool and must be provided to patrons in spill-proof containers that are not made of glass or other vitreous materials, that if broken could result in patron injury.

(c) A smooth, easily cleanable poolside surface must be provided for patrons to place their food and beverage containers upon.

(d) Signage must be posted to inform patrons that the public swimming pool has a swim-up bar that provides food and beverages, that spillages should be reported to staff for rapid cleanup, and that consumption of alcoholic beverages may cause drowsiness.

(e) Swim-up bar water quality shall be enhanced by providing a recirculation system with a maximum time of two (2) hours for turnover of the entire pool water volume.

(f) Swim-up bar water quality shall be continuously sustained in accordance with subparagraphs (1)(d)1. – 3. above through the use of an automated controller with chemical sensing probes for disinfection and pH control.

(g) The maximum depth of the swim-up bar must be no more than 54 inches.

(h) Lifeguard(s) certified in accordance with Rule 64E-9.008(2), F.A.C., must be present to aid patrons when a swim-up bar is open for use by patrons. The lifeguard(s) must be capable of overseeing the pool water area along the bar-obstructed wet deck area and the pool water areas adjacent to the swim-up bar.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10385

88

Date Submitted	02/14/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

The nature of the 5' walkway around runout lanes needs to be clarified.

Rationale

Run out lanes may be provided as part of aquaplay structures that are meant to be installed in standing water. The existing language doesn't explicitly require the walkway to be dry, however, DOH has decided to enforce it this way.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This will reduce the need for variances.

Impact to building and property owners relative to cost of compliance with code

No impact.

Impact to industry relative to the cost of compliance with code

No impact.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, walkways need to be provided for people getting out of run out lanes, however, a little bit of water over the walkway should be acceptable.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This allows equivalent methods of construction.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination.

Does not degrade the effectiveness of the code
The code remains effective.

1st Comment Period History

SW10385-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:05:08 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.9.2.2.1 Run out lanes may be utilized in lieu of or within a plunge pool system, provided they are constructed to the slide manufacturer's specifications and are approved by the design engineer of record.

454.1.9.2.2.2 Five-foot-wide (1524 mm) walkways shall be provided adjacent to run out lanes, as either dry deck or as part of a pool with up to 12 inches (305 mm) of water depth in this area.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

89

SW10387

Date Submitted	02/14/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

SW10237, SW10241

Summary of Modification

The language of the IWF hydraulics section is confusing and out-of-date.

Rationale

The language here can be clarified in terms of what water is going where. Also, updates are needed because NSF 50 has changed and "validated" is no longer a clear term.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This simplifies enforcement because they can use up-to-date standards with clearer language.

Impact to building and property owners relative to cost of compliance with code

This may reduce their costs because existing discrimination is eliminated.

Impact to industry relative to the cost of compliance with code

This reduces cost to industry because they would only have to comply with the latest NSF 50 standards rather than something older that is Florida-specific.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

The NSF 50 tests have been updated providing two levels of certification for the elimination of pathogens. Florida's code should incorporate these two levels.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This updates the code and allows new products that weren't made in 2006 to be used.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

This eliminates an existing discrimination where some believe that only one manufacturer makes "validated" UV systems.

Does not degrade the effectiveness of the code

By switching from the Florida-specific standard of "validated" to the new national standard of "certified for secondary disinfection," cryptosporidium can be killed by products from at least 5 manufacturers that have recently entered this market.

1st Comment Period History

SW10387-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:05:51 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW10387-G2

Proponent	bob vincent	Submitted	4/17/2022 4:39:48 PM	Attachments	Yes

Comment:

Florida Department of Health is opposed to this mod. Better alternatives are offered. The Centers for Disease Control 2018 Model Aquatic Health Code offers code language on UV disinfection for the "secondary disinfection system" at section 4.7.3.3. Plus for "supplemental treatment systems" at 4.7.3.4. The 2018 MAHC is attached.

SW10387Text Modification

454.1.9.8.6 Hydraulics.

454.1.9.8.6.1 All (100 percent) of the water from the collector tankto the spray features shall be treated by a UV disinfectant unit described in Section 454.1.6.5.16.6 on the spray feature pump. If the UV disinfectant unit is not certified under NSF 50 for secondary disinfection, the spray feature water must also be first filtered, treated by an NSF Standard 50 certified UV disinfection unit with a minimum 40 mJ/cm^2 dose, and then final treatment provided by disinfectant and pH adjustment chemicals before any of this treated water is piped to the water spray features.

454.1.9.8.6.2 In the design above and the alternative below: eExcess water not required by the water features shall be returned to the collector tank.;tThe recirculation system shall be sized to filter andtreat the contained volume of water based upon amaximum30 minute turnover with a chlorine feeder/generator capable of producing a dosage of at least 12ppm; and the UV disinfection equipment shall be electrically interconnected such that whenever it fails to produce the required UV dosage, the water spray features pump(s) and flow will be immediately stopped.

454.1.9.8.6.3 In lieu of Section 454.1.9.8.6.1, the recirculation system must be designed to continuously return 100 percent of the water to the collector tank after all (100 percent) of the water is first filtered, treated by a validated UV disinfectant unit with a minimum 40 mJ/cm^2 dose described in Section 454.1.6.5.16.6 on each feature pump and then final treatment with disinfectant and pH adjustment chemicals, before any of this treated water is piped to the water features. UV flow capacity must meet the spray feature pump(s) flow capacity.

2018 Model Aquatic Health Code

Code Language

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

3rd Edition, July 2018

CS288986-A

2018 Model Aquatic Health Code, 3rd Edition
CODE LANGUAGE
Posted on 07/18/2018

This information is distributed solely as guidance for the purpose of assisting state and local health departments, aquatic facility inspection programs, building officials, the aquatics sector, and other interested parties in improving the health and safety at public aquatic facilities. This document does not address all health and safety concerns associated with its use. It is the responsibility of the user of this document to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to each use.

Foreword

Swimming, soaking, and playing in water have been global pastimes throughout written history. Twentieth-century advances in aquatics—combining disinfection, recirculation, and filtration systems—led to an explosion in recreational use of residential and public disinfected water. As backyard and community pool use has swept across the United States, leisure time with family and friends around the pool has increased. Advances in public aquatic facility design have pushed the horizons of treated aquatic facilities from the traditional rectangular community pool to the diverse multi-venue waterpark hosting tens of thousands of users a day. The expansion of indoor aquatic facilities has now made the pool and waterpark into year-round attractions. At the same time, research has demonstrated the social, physical, and psychological benefits of aquatics for all age groups.

However, these aquatics sector changes—combined with changes in the general population, chlorine-tolerant pathogens, and imperfect bather hygiene—have resulted in significant increases in reports of waterborne outbreaks, with the greatest increase occurring in man-made disinfected aquatic venues. Drowning continues to claim the lives of far too many, especially children, and thousands of people visit hospitals every year for pool chemical-associated injuries. Aquatic facility operation can still be improved through education and training. The increase in outbreaks and continued injuries suggests there would be benefits from building stronger public health regulatory programs and supporting them with strong partnerships to implement health promotion efforts, conduct research, and develop prevention guidance. It also would be useful for public health officials to continue to play their strong role in overseeing design and construction, advising on operation and maintenance, and helping inform policy and management. Working in close collaboration with building code officials strengthens the overall coordination needed to prioritize health and safety at public aquatic facilities.

The 3rd Edition of the Model Aquatic Health Code (MAHC) is the latest effort to improve the MAHC, which is a set of voluntary guidelines based on science and best practices. The MAHC was developed to help programs that regulate public aquatic facilities reduce the risk of disease, injury, and drowning in their communities. The MAHC is a leap forward from the Centers for Disease Control and Prevention's (CDC) operational and technical manuals published in 1959, 1976, and 1981 and a logical progression of CDC's Healthy Swimming Program started in 2001. The 2018 MAHC 3rd Edition underscores CDC's long-term involvement and commitment to improving aquatic health and safety. The MAHC guidance document stemmed from concern about the increasing number of pool-associated outbreaks, particularly of cryptosporidiosis, starting in the mid-1990s. Creation of the MAHC was the major recommendation of a 2005 national workshop held in Atlanta, Georgia charged with developing recommendations to reduce these outbreaks. Federal, state, and local public health officials and the aquatics sector formed an unprecedented 7-year collaboration to create the MAHC for release in 2014. The MAHC is now being regularly updated using input from the national stakeholder partnership created and maintained by the Council for the Model Aquatic Health Code (CMAHC). The CMAHC was formed to keep the MAHC up to date and current with the latest advances in the aquatics industry while also responding to public health reports of disease and injury. The CMAHC has now led two national aquatics stakeholder conferences in 2015 and 2017 to solicit, review, and vote on proposed updates to the MAHC. CDC appreciates the breadth of input and commitment to excellence that serves as the foundation for the CMAHC's work. The process and quality of recommendations have improved each time and the CMAHC is making its mark as a pre-eminent force in the aquatics arena. As CDC documents adoption of MAHC-specific guidance components and observes its impact on the aquatics sector, even ahead of adoption, it is clear that the MAHC is filling a gap in public health and safety. The partnership between public health, the aquatics sector, the CMAHC, and academia strengthens the opportunity for achieving the MAHC vision of "Healthy and Safe Aquatic Experiences for Everyone".

CDC

Atlanta, GA, 2018

Acknowledgments

The 2018 MAHC 3rd Edition utilized the CMAHC conference process to collect, assess, and relay MAHC Change Request recommendations to CDC and plans to utilize the CMAHC conference process to update all future versions of the MAHC. The second CMAHC *Vote on the Code* Biennial Conference was held October 17-18, 2017 in Broomfield, Colorado. CDC would like to acknowledge the hard work and dedication of the CMAHC Executive Director, CMAHC Technical Review Committee, CMAHC Technical Support Committees, CMAHC Board of Directors, and CMAHC membership for their dedication and time spent developing, reviewing, and voting on MAHC Change Requests. It is only through the dedicated efforts and contributions of experienced professionals that a scientifically sound, well-focused, and up-to-date MAHC is possible. CDC acknowledges with immense gratitude the substantial assistance of those who contributed to public health and aquatic safety in the development of the 2018 MAHC 3rd Edition. They deserve our heartfelt thanks and appreciation for volunteering their time, energy, and creativity to create the 2018 MAHC 3rd Edition. In addition, we would like to also give our thanks to all the reviewers across the country who provided public comments, and spent a great deal of time combing through the detail of the MAHC code and annex to submit Change Requests for improvement. Their effort was worth the time investment; the MAHC has again been greatly improved after the Conference process and associated public comment periods. As part of the 2017 CMAHC Conference, it was decided to move to a 3-year cycle to allow coordination with other code writing bodies and allow more time for substantive committee work to develop Change Requests; the next CMAHC Conference will be in October 2020. See MAHC Annex Appendix 4: Acknowledgement of MAHC Development Members. This Appendix recognizes CDC's continued gratitude towards the individuals who gave their time and expertise over 7 years to develop the MAHC from dream to product.

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PREFACE

CS288986-A

1.0 Preface

***Note: Section numbers with superscript "A" (e.g., 1.0[A]) denote a corresponding discussion in the* Annex to the Model Aquatic Health Code.**

1.1 Introduction

1.1.1[A] Rationale In recent decades, public health practitioners have seen a dramatic increase in waterborne disease outbreaks associated with public DISINFECTED AQUATIC FACILITIES *(e.g. swimming POOLS, water parks, hot tubs, etc.)*. As a result, public health investigations have revealed that many diseases can be prevented by proper maintenance and water treatment and by more modern disease prevention practices. Drowning and falling, diving, chemical use, and suction injuries continue to be major public health injuries associated with public AQUATIC FACILITIES, particularly for young children. In this context, the health and SAFETY at public AQUATIC FACILITIES is regulated by state and local jurisdictions since, in the United States, there is no federal regulatory authority responsible for these public AQUATIC FACILITIES. All public POOL CODES are developed, reviewed, and approved by state and/or local public health officials or legislatures. Consequently, there is no uniform national guidance informing the design, construction, operation, and maintenance of public swimming POOLS and other public DISINFECTED AQUATIC FACILITIES. As a result, the CODE requirements for preventing and responding to recreational water illnesses *(RWIs)* and injuries can vary significantly among local and state agencies. State and local jurisdictions spend a great deal of time, personnel, and resources creating and updating their individual CODES on a periodic basic.

1.1.2 Need for Further Guidance Based on illness tracking data, outbreak reporting, and stakeholder feedback, CDC believed further prevention-oriented planning and action were needed. CDC worked with the Council of State and Territorial Epidemiologists *(CSTE)* to get agreement on the need for a national workshop to develop guidance for preventing future RWI outbreaks. This CSTE position statement was passed in 2004 and CDC was tasked with organizing the national workshop, which was held in 2005. The workshop recommendation to create national guidance for aquatic facility design, operation, and management resulted in the effort to create the Model Aquatic Health Code (The MAHC) that was started in 2007. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.1.3 Responsibility of User This document does not address all SAFETY or public health concerns associated with its use. It is the responsibility of the user of this document to establish appropriate health and SAFETY practices and determine the applicability of regulatory limitations prior to each use.

1.1.4 Original Manufacturer Intent In the absence of exceptions or further guidance, all fixtures and equipment shall be installed according to original manufacturer intent.

1.1.5 Local Jurisdiction The MAHC refers to existing local CODES in the jurisdiction for specific needs. In the absence of existing local CODES, the AUTHORITY HAVING JURISDICTION *(AHJ)* should specify an appropriate CODE reference.

1.2 Recreational Water-Associated Illness Outbreaks and Injuries

1.2.1[A] RWI Outbreaks Large numbers of recreational water illness (RWI)-related outbreaks are documented annually, which is a significant increase over the past several decades.

1.2.2[A] Significance of *Cryptosporidium* *Cryptosporidium* causes a diarrheal disease spread from one person to another or, at AQUATIC VENUES, by ingestion of fecally-contaminated water. This pathogen is tolerant of CHLORINE and other halogen DISINFECTANTS. *Cryptosporidium* has emerged as the leading cause of POOL-associated outbreaks in the United States.

1.2.3[A] Drowning and Injuries Drowning, falling, diving, POOL chemical use, and suction injuries continue to be documented as major public health issues associated with AQUATIC FACILITIES. Drowning is a leading cause of injury death for young children and a leading cause of unintentional injury death for people of all ages.

1.2.4[A] Pool Chemical-Related Injuries POOL chemical-related injuries occur regularly and can be prevented if POOL chemicals are stored and used as recommended.

1.3 Model Aquatic Health Code

1.3.1[A] Background All POOL CODES in the United States are reviewed and approved by state and/or local public health officials with no uniform national public health STANDARDS governing design, construction, operation, maintenance, policies, or management of public swimming POOLS and other public AQUATIC FACILITIES.

The effort to create the MAHC stems from a CDC-sponsored national workshop called "Recreational Water Illness Prevention at Disinfected Swimming Venues" that was convened on February 15-17, 2005, in Atlanta, Georgia. The workshop assembled persons from different disciplines working in state, local, and federal public health agencies, the aquatics sector, and academia to discuss ways to minimize the spread of RWIs at DISINFECTED AQUATIC FACILITIES. The major recommendation from this workshop was that CDC lead a national partnership to create an open access model guidance document that helps local and state agencies incorporate science and BEST PRACTICES into their swimming POOL CODES and programs without having to "recreate the wheel" each time they create or revise their POOL CODES. The attendees also recommended that this effort be all-encompassing so that it covered the spread of illness but also included drowning and injury prevention. Such an effort should increase the evidence base for AQUATIC FACILITY design, construction, operation, and maintenance while reducing the time, personnel, and resources needed to create and regularly update POOL CODES across the country.

Starting in 2007, CDC worked with the public health sector, the aquatics sector, and academic representatives from across the United States to create this guidance document. Although, the initial workshop was responding to the significant increases in infectious disease outbreaks at AQUATIC FACILITIES, the MAHC is a comprehensive complete AQUATIC FACILITY guidance document with the goal of reducing the spread of infectious disease and occurrence of drowning, injuries, and chemical exposures at public AQUATIC FACILITIES. Based on stakeholder feedback and recommendations, CDC agreed that public health improvements would be aided by development of such a guidance document. The guidance would be an open access, comprehensive, systematic, collaboratively developed guidance document based on science and BEST PRACTICES covering AQUATIC FACILITY design and construction, operation and maintenance, and policies and management to address existing, emerging, and future public health threats. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.3.2 MAHC Vision and Mission The MAHC vision is "Healthy and Safe Aquatic Experiences for Everyone". The MAHC's mission is to incorporate science and BEST PRACTICES into guidance on how state and local officials can transform a typical health department POOL program into a data-driven, knowledge-based, risk reduction effort to prevent disease and injuries and promote healthy recreational water experiences. The MAHC provides local and state agencies with uniform guidelines and wording for the design and construction, operation and maintenance, and policies and management of swimming POOLS, SPAS and other public DISINFECTED AQUATIC FACILITIES.

1.3.3 Science and Best Practice The availability of the MAHC should provide state and local agencies with the best available guidance for protecting public health using the latest science and BEST PRACTICES so they can use it to create or update their swimming POOL CODES.

1.3.4 Development Process The MAHC development process created comprehensive consensus risk reduction guidance for AQUATIC FACILITIES based upon national interaction and discussion. The development plan encompassed design, construction, alteration, replacement, operation, and management of these facilities. The MAHC is driven by scientific data and BEST PRACTICES. It was developed by a process that included input from all sectors and levels of public health, the aquatics sector, academia, and the general public. It was open for two 60-day public comment periods during the process. It is national and comprehensive in scope and the guidance can be used to write or update POOL CODES across the United States. The 1st Edition of the MAHC was released in 2014 and the 2nd Edition was released in 2016.

1.3.5 Open Access The MAHC is an open access document (www.cdc.gov/mahc) that any interested individual, agency, or organization can freely copy, adapt, or fully incorporate MAHC wording into their

AQUATIC FACILITY oversight documents. As a federal agency, CDC does not copyright this material.

1.3.6 Updating the MAHC The MAHC will be updated on a continuing basis through an inclusive, transparent, all-stakeholder process. This was a recommendation from the original national workshop and is essential to ensure that the MAHC stays current with the latest science, industry advances, and public health findings. To support this recommendation, CDC supported the 2013 creation of the Council for the Model Aquatic Health Code *(CMAHC; www.cmahc.org)*, a 501(c)(3) non-profit organization, to facilitate collecting, assessing, and relaying national input on needed MAHC revisions back to CDC for final consideration for acceptance. The CMAHC was created to manage the national partnership of MAHC participants and gather recommendations from this partnership on how to improve and continually update the MAHC. The first biennial update conference was held in 2015. The results of the CMAHC membership change requests and vote were delivered to CDC in January 2016 and were incorporated into the MAHC to make the 2016 MAHC (2nd Edition). The second biennial update conference was held in 2017. The results of the CMAHC membership change requests and vote were delivered to CDC in January 2018. These changes were used to create the 2018 MAHC 3rd Edition. It was decided at the 2nd biennial conference in 2017 that the update cycle would be altered to occur every 3 years to better synchronize with other code update processes and allow more time for committee work to develop new change requests. The next CMAHC triennial conference will be in 2020 and the 4th Edition of the MAHC will be released in 2021.

1.3.7 Authority Regulatory agencies like state and local governments have the authority to regulate AQUATIC FACILITIES in their jurisdiction.

1.3.8 CDC Role The MAHC is hosted by the Centers for Disease Control and Prevention *(CDC)*, a federal agency whose mission is "to work 24/7 to protect America from health, safety and security threats, both foreign and in the United States. Whether diseases start at home or abroad, are chronic or acute, curable or preventable, human error or deliberate attack, CDC fights disease and supports communities and citizens to do the same." Furthermore, CDC has been involved in developing swimming POOL-related guidance since the 1950s (www.cdc.gov/healthywater/swimming/publications.html) and officially tracking waterborne disease outbreaks associated with AQUATIC FACILITY use since 1978 (www.cdc.gov/healthywater/surveillance/rec-water-surveillance-reports.html). CDC's aim is to improve the knowledge, practices, and procedures of environmental health department staff and programs and reduce aquatic health and safety concerns. CDC collects recreational water venue inspection data from state and local public health departments for periodic analysis and dissemination. CDC operates the Healthy Swimming Program to reduce illness and injury associated with recreational water use and has overseen the Healthy Swimming website since its creation in 2001 *(www.cdc.gov/healthyswimming)*. CDC has also established a specific MAHC website *(www.cdc.gov/mahc)* to house the MAHC and all materials to assist MAHC users.

1.3.8.1 Public Health Role CDC is "the primary Federal agency for conducting and supporting public health activities in the United States"; however, CDC is not a regulatory agency.

1.3.8.2 Model Guidance The MAHC is intended to be open access guidance that state and local public health agencies can use to write or update their POOL CODES in part or in full as fits their jurisdiction's needs. The CDC adopted this project because no other U.S. federal agency has commission over public DISINFECTED AQUATIC FACILITIES. Considering CDC's mission and historical interest in aquatics, this organization was the best qualified to lead a national consortia to create such a document.

1.4 Public Health and Consumer Expectations

1.4.1 Aquatics Sector & Government Responsibility Both the aquatics sector and the government share the responsibility of offering AQUATIC FACILITIES that provide consumers and aquatics workers with safe and healthy recreational water experiences and job sites and that do not become sources for the spread of infectious diseases, outbreaks, or the cause of injuries. This shared responsibility extends to working to meet consumer expectations that AQUATIC FACILITIES are properly designed, constructed, operated, and maintained.

1.4.2 Swimmer Responsibility The PATRON or BATHER shares a responsibility in maintaining a healthy swimming environment by practicing the CDC-recommended healthy swimming behaviors to improve hygiene and reduce the spread of disease. Consumers and BATHERS also share responsibility for using AQUATIC

FACILITIES in a healthy and safe manner to reduce the incidence of injuries.

1.5 Advantages of Uniform Guidance

1.5.1[A] Sector Agreement The aquatics sector and public health officials recognize the value in uniform, consensus guidance created by multi-sector discussion and agreement – both for getting the best possible information and gaining sector acceptance. Since most public AQUATIC FACILITIES are already regulated, the MAHC is intended to be guidance to assist, strengthen, and streamline resource use by state and local CODE officials or legislatures that already regulate AQUATIC FACILITIES but need to regularly update and improve their AQUATIC FACILITY oversight and regulation. Uniform, consensus guidance using the latest science and BEST PRACTICES helps all public sectors, including businesses and consumers, resulting in the best product and experiences.

In addition, the MAHC's combination of performance-based recommendations and prescriptive measures gives AQUATIC FACILITIES freedom to use innovative approaches to achieve acceptable results. However, AQUATIC FACILITIES must ensure that these recommendations are still being met, whatever the approach may be, although innovation should be encouraged to achieve outlined performance-based requirements.

1.5.2 MAHC Provisions The MAHC provides guidance on AQUATIC FACILITY design STANDARDS & construction, operation & maintenance, and policies & management that can be uniformly adopted in part or in whole for the aquatics sector.

The MAHC:

- Is the collective result of the efforts and recommendations of many individuals, public health agencies, and organizations within the aquatics sector,
- Embraces the concept that safe and healthy recreational water experiences by the public are directly affected by how we collectively design, construct, operate, and maintain our AQUATIC FACILITIES, and
- Is updated triennially based on input from CMAHC members.

1.5.3 Aquatic Facility Requirements Model performance-based recommendations essentially define public aquatic health and SAFETY expectations, usually in terms of how dangerous a pathogen or injury is to the public. By using a combination of performance-based recommendations and prescriptive measures, AQUATIC FACILITIES are free to use innovative approaches to provide healthy and safe AQUATIC FACILITIES whereas traditional evaluations mandate how AQUATIC FACILITIES achieve acceptable results. However, to show compliance with the model performance-based recommendation, the AQUATIC FACILITY must demonstrate that control measures are in place to ensure that the recommendations are being met. The underlying theme of the MAHC is that it should be based on the latest science where possible, BEST PRACTICES, and that change will be gradual so all parties can prepare for upcoming changes; "Evolution, not revolution."

1.6 Modifications and Improvements in the 2018 MAHC

1.6.1 Structural Changes ***(Note: CR refers to the CMAHC Change Request number that proposed the change. Individual CMAHC change requests from the 2017 Biennial CMAHC Conference can be viewed at www.cmahc.org/display-change-request-vote.php).***

1.6.1.1 Color Scheme The 2018 Code and Annex covers are slightly different colors from the 2016 MAHC so they can be readily differentiated.

1.6.1.2 Layout

1.6.1.2.1 Table of Contents Table of Contents has been reduced to three header levels.

1.6.1.2.2 Glossary MAHC 3.3 in the CODE and Annex has been updated to include full references, names, and years of applicable CODES, STANDARDS, and laws.

1.6.1.2.3 Resources MAHC Annex 7.1 has been moved to MAHC Annex 8.0 and edited to include only guidelines cited. All cited CODES, STANDARDS, and laws have been moved to the new section MAHC 3.3.

1.6.1.2.4 Margins Margins have been reduced to 1 inch on the left and 0.5 inch on the top, right, and bottom.

1.6.1.2.5 Headers and Body Text Body text has been moved up to the same line as headers to help shorten the document.

1.6.1.3 Code Changes and Improvements

1.6.1.3.1 Throughput Text Font has been changed to Times New Roman, 11 point, and Code text has been wrapped with headings to reduce the page count of the guidance.

1.6.1.3.2 Specific Sections

- 4.5.4.5: Stair tread dimensions made uniform.
- 4.6.1.1: Adds acoustic criteria to natatorium design to reduce noise levels.
- 4.5.10.2: Adds certification for pool lifts.
- 4.7.3.2.1.3/5.7.2.2.4.1.1/5.7.3.2.1.1.1/5.7.3.2.2.6/5.7.3.5.1.2/5.7.3.5.1.4.1/6.4.1.6: Added wording to improve chemical control and feed system interlocks and no/low flow deactivation.
- 4.7.3.2.2.2-0003/4.7.3.2.2.3/5.7.3.5.1.5: Provides performance criteria for disinfectant feeders with sizing dependent on stated chlorine demand factors.
- 4.7.3.3.2: Secondary disinfection performance changed to minimum 2-log reduction for all venues except interactive water play aquatic venues.
- 4.8.6.3.1.1/4.8.6.3.1.2/4.8.6.3.7-0002: Improves enclosure requirement language and delineates exceptions
- 4.12.5.2.2-0001/4.12.5.2.2-0002: Clarifies handhold wording for lazy rivers.
- 4.12.10/5.12.10: Provides guidance for regulation of floatation tanks.
- 5.4.1.1.1/5.4.1.1.2/5.4.1.1.3: Clarifies requirements for closure and reopening.
- 5.6.1.2.1.1. Clarifies glare assessment for lifeguard positions.
- 5.7.3: Specifies that numerous pool chemicals *(stabilizers, pool-grade salt, clarifiers, flocculants, defoamers, pH adjustment chemicals)* must meet NSF/ANSI Standard 50 or 60.
- 5.7.4.4.3: Calcium hardness levels raised to 2500ppm.
- 5.8.5.3.9: Lifeguard PPE must be on person or rescue tube.
- 6.3.2.1-0001: Lifeguards required if alcohol served in aquatic venue.
- 6.5.3.6: Guidance for responding to *Legionella* contamination

1.7 MAHC Adoption at State or Local Level

1.7.1[A] MAHC Adoption at State or Local Level The MAHC is provided as guidance for voluntary use by governing bodies at all levels to regulate public AQUATIC FACILITIES. At the state and local levels, the MAHC may be used in part or in whole to:

1) Enact into statute as an act of the state legislative body; or
2) Promulgate as a regulation, rule or CODE; or
3) Adopt as an ordinance.

CDC is committed to offering, at a minimum, assistance to states and localities in interpreting and implementing the MAHC either directly or through the CMAHC. CDC welcomes suggestions for how it could best assist localities in using this guidance in the future. CDC also offers a MAHC toolkit *(including sample forms and checklists)* and is available to give operational guidance to public health POOL programs when needed. CDC is committed to expanding its support of the MAHC and ensuring timely updates and improvements.

1.7.2 Council for the Model Aquatic Health Code (CMAHC) Other assistance to localities will also be available. The Council for the Model Aquatic Health Code (CMAHC*; www.cmahc.org)*, an independent, nonprofit 501(c)(3) organization, was created with CDC support in 2013 with the vision of “an up-to-date, knowledge-based Model Aquatic Health Code (MAHC) that supports healthy and safe aquatic experiences for everyone and is used by pool programs across the United States". The CMAHC's role is to serve as a national clearinghouse for input and advice on needed improvements to CDC's MAHC. The CMAHC will fulfill this vision by:

1) Collecting, assessing, and relaying national input on needed MAHC improvements back to CDC for final consideration for acceptance,
2) Advocating for improved health and SAFETY at swimming facilities,
3) Providing assistance to health departments, boards of health, legislatures, and other partners on MAHC uses, benefits, and implementation,
4) Providing assistance to the aquatics industry on uses, interpretation, and benefits of the MAHC, and
5) Soliciting, coordinating, and prioritizing MAHC research needs.

CDC and the CMAHC will work together closely to continue to incorporate national input into the MAHC and provide optimal guidance and assistance to public health officials and the aquatics sector.

1.8 The MAHC Revision Process

1.8.1[A] MAHC Revisions Throughout the creation of the MAHC, the CDC accepted concerns and recommendations for modification of the MAHC from any individual or organization through two 60-day public comment periods via the email address MAHC@cdc.gov.

CDC realizes that the MAHC should be an evolving document that is kept up to date with the latest science, industry advances, and public health findings. As the MAHC is used and recommendations are put into practice, MAHC revisions will need to be made. As the future brings new technologies and new aquatic health issues, the CMAHC, with CDC participation, has instituted a triennial change request solicitation process for collecting national input that welcomes all stakeholders to participate in making recommendations to improve the MAHC so it remains comprehensive, easy to understand, and as technically sound as possible. After CMAHC member voting, accepted recommendations will then be sent to CDC and weighed by CDC for final incorporation into the next edition of the MAHC.

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USER GUIDE

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2.0 User Guide *Note: Section numbers with superscript "A" (e.g., 1.0^A) denote a corresponding discussion in the* **Annex to the Model Aquatic Health Code.**

The provisions of Chapter 4 *(Aquatic Facility Design Standards and Construction)* apply to construction of a new AQUATIC FACILITY or AQUATIC VENUE or SUBSTANTIAL ALTERATION to an existing AQUATIC FACILITY or AQUATIC VENUE, unless otherwise noted.

The provisions of Chapter 5 and 6 apply to all AQUATIC FACILITIES covered by this CODE regardless of when constructed, unless otherwise noted.

2.1 Overview

2.1.1 New Users A new user will find it helpful to review the Table of Contents in order to quickly gain an understanding of the scope and sequence of subjects included in the CODE.

2.1.2 Topic Presentations MAHC provisions address essentially three areas:

1) Aquatic Facility Design & Construction *(Chapter 4)*,
2) Operation & Maintenance *(Chapter 5)*,
3) Policies & Management *(Chapter 6)*.

In addition, an overarching, scientifically referenced explanation of, and rationale for, the MAHC as a risk reduction plan is provided in the Annex using the same numbering format for easy cross reference.

2.2^A MAHC Structure and Format

2.2.1 Numbering System The CODE follows a numeric outline format. The structural numbering system having different indent, font, color, and size in the document is as follows:

1.0 Chapter

1.1 Part

1.1.1 Subpart

1.1.1.1 Section

1.1.1.1.1 Paragraph

1.1.1.1.1.1 Sub-Paragraph

2.2.2 Title, Keyword, Phrase Text On the same line and next to the section number is a title, keyword, or phrase summary showing the information contained in the corresponding MAHC wording below. Each CODE section number that has annex discussion is denoted with a superscript "A" after the section number *(e.g., 2.0^A)* so readers will know to check the *Annex to the Model Aquatic Health Code* for additional explanation.

2.2.3 MAHC Requirement Recommended MAHC requirement wording is shown below the number of title, keyword, or phrase. These requirements usually appear in sentence or paragraph format.

2.2.4 Illustrations Appropriate charts, diagrams, and other illustrative material will also appear in the Annex. This does not include a repeat of those found in the Code unless deemed necessary.

2.2.5 Consistency Between Chapters 4.0 and 5.0 Each Part or Sub-part is repeated throughout CODE Chapters 4.0 *(Design Standards & Construction)* and 5.0 *(Operation & Maintenance)*. For example, the section titled "Disinfection and pH Control," has two parts:

1) Design recommendations and construction aspects, addressed in MAHC 4.7.3 and
2) Operation and maintenance aspects, addressed in MAHC 5.7.3.

If a topic is not applicable then that section is marked with a N/A *(e.g., the size or width of the DECKING is not applicable for Operation & Maintenance versus Design Standards & Construction)*. This is designed to allow MAHC users to see how a topic of interest applies under both chapter headings.

2.2.6 Conventions The following conventions are used in the MAHC:

1) "Shall" means the act is imperative, i.e., "shall" constitutes a command.
2) "May not" means absolute prohibition.
3) "May" is permissive and means the act is allowed.
4) "Means" is followed by a declared fact.

2.2.7 Definitions Both the CODE and annex have a specific glossary of terms used in either code or annex. Defined glossary words and terms are in "SMALL CAPS" in the text of the CODE and annex chapters to alert the reader that there is a specific meaning assigned to those terms and that the meaning of a provision is to be interpreted in the defined context. A concerted effort was also made to place in "SMALL CAPS" all forms and combinations of those defined words and terms that were intended to carry the weight of the definition.

2.3 Annex to the Model Aquatic Health Code

2.3.1[A] Scientific and Best Practices Rationale The *Annex to the Model Aquatic Health Code (Annex)* is provided to:

1) Give further scientific and BEST PRACTICE explanations of why certain recommendations are made;
2) Discuss the rationale for making the MAHC content decisions;
3) Provide a discussion of the scientific basis for selecting certain criteria, as well as discuss why other scientific data may not have been selected, e.g. due to data inconsistencies;
4) State areas where additional research may be needed;
5) Discuss and explain terminology used; and
6) Provide additional material that may not have been appropriately placed in the main body of suggested MAHC recommendations. This would include summaries of scientific studies, charts, graphs, or other illustrative materials.

2.3.2[A] Content The annex was developed to support the MAHC Code language and is meant to provide additional help, guidance, and scientific and BEST PRACTICE rationale to those responsible for using the MAHC. Statements in the annex are intended to be supplements and additional explanations. They are not meant to be interpreted as MAHC Code wording or used to create enforceable CODE language.

2.3.3 Bibliography The MAHC Code and Annex Section 3.3 includes a list of CODES specifically referenced in each respective document. The annex also contains a bibliography of the reference materials, and scientific studies that form the basis for MAHC recommendations.

2.3.4 Appendices The MAHC Annex Appendices supply additional information or tools that may be useful to the reader of the MAHC Annex and Code.

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GLOSSARY

OF ACRONYMS AND TERMS USED IN THIS CODE

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3.0 Glossary of Acronyms, Initialisms, Terms, Standards, Codes, and Laws Used in the MAHC Code

3.1 Acronyms and Initialisms Used in the MAHC Code

ACCA	Air Conditioning Contractors of America
ACA	American Coatings Association
ACI	American Concrete Institute
ADAAG	Americans with Disabilities Act Accessibility Guidelines
AED	Automated External Defibrillator
AHA	American Heart Association
AHJ	Authority Having Jurisdiction
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
APSP	Association of Pool and Spa Professionals
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	ASTM International *(formerly American Society for Testing and Materials)*
BCDMH	1-bromo-3-chloro-5, 5-dimethylhydantoin
BVM	Bag-Valve Mask
CDC	Centers for Disease Control and Prevention
CEL	Certified Equipment List
CFM	Cubic Feet Per Minute
CFOC	Caring for Our Children
CFR	Code of Federal Regulations
CI	Chlorine Institute
CMAHC	The Council for the Model Aquatic Health Code
CoSTR	Consensus on Science and Treatment Recommendations
CPR	Cardiopulmonary Resuscitation
CPSC	Consumer Product Safety Commission
CYA	Cyanuric Acid
DBDMH	Dibromodimethylhydantoin
DBP	Disinfection By-Product
DCOF	Dynamic Coefficient of Friction
DVGW	Deutscher Verein des Gas- und Wasserfaches e.V. – Technisch wissenschaftlicher Verein *(German Technical and Scientific Association for Gas and Water)*
EAP	Emergency Action Plan
ECC	Emergency Cardiovascular Care
EPA	United States Environmental Protection Agency
FAC	Free Available Chlorine
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FINA	Fédération Internationale de Natation Amateur
GFCI	Ground-Fault Circuit Interrupter
GPM	Gallons Per Minute
HMIS	Hazardous Material Identification System

HOBr	Hypobromous Acid
HOCl	Hypochlorous Acid
HSC	Hazard Communication Standard
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
ICC	International Code Council
IESNA	Illuminating Engineering Society of North America
IFC	International Fire Code
ILCOR	International Liaison Committee on Resuscitation
IMC	International Mechanical Code
IPC	International Plumbing Code
ISO	International Organization for Standardization
ISPSC	International Swimming Pool and Spa Code
MAHC	Model Aquatic Health Code
MERV	Minimum Efficiency Reporting Value
NCAA	National Collegiate Athletic Association
NEC	National Electrical Code
NFHS	National Federation of State High School Associations
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NPSH	Net Positive Suction Head
NRTL	Nationally Recognized Testing Laboratory
NSF	NSF International *(formerly National Sanitation Foundation)*
OEM	Original Equipment Manufacturer
ÖNORM	Österreichisches Normungsinstitut *(Austrian Standards Institute)*
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
POS	Perimeter Overflow System
PPE	Personal Protective Equipment
PPM	Parts Per Million
PVC	Polyvinyl Chloride
PVC-P	Plasticized Polyvinyl Chloride
RED	Reduction Equivalent Dose
RPZ	Reduced Pressure Zone
RWI	Recreational Water Illness
SDS	Safety Data Sheet
SCBA	Self-Contained Breathing Apparatus
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SVRS	Safety Vacuum Release System
TDH	Total Dynamic Head
TDS	Total Dissolved Solids
UL	Underwriters Laboratories
USC	United States Code
UV	Ultraviolet

UVT	Ultraviolet Transmittance
VFD	Variable Frequency Drive
VGB Act	Virginia Graeme Baker Pool and Spa Safety Act
WQTD	Water Quality Testing Device
YMCA	Young Men's Christian Association

3.2 Terms Used in the MAHC Code

"Accessible Route" means access/egress standards as defined by 2010 ADA Standards for Accessible Design.

"**Activity Pool**" *See "Pool."*

"Air Handling System" means equipment that brings in outdoor air into a building and removes air from a building for the purpose of introducing air with fewer contaminants and removing air with contaminants created while bathers are using aquatic venues. The system contains components that move and condition the air for temperature, humidity, and pressure control, and transport and distribute the air to prevent condensation, corrosion, and stratification, provide acceptable indoor air quality, and deliver outside air to the breathing zone.

"Agitated Water" means an aquatic venue with mechanical means *(aquatic features)* to discharge, spray, or move the water's surface above and/or below the static water line of the aquatic venue. Where there is no static water line, movement shall be considered above the deck plane.

"Alpha Bar" see "Average Sound Absorption Coefficient"

"Aquatic Facility" means a physical place that contains one or more aquatic venues and support infrastructure.

"Aquatic Feature" means an individual component within an aquatic venue. Examples include slides, structures designed to be climbed or walked across, and structures that create falling or shooting water.

"Aquatic Facility or Aquatic Venue Enclosure" means an uninterrupted barrier surrounding and securing an aquatic facility or aquatic venue.

"Aquatic Venue" means an artificially constructed structure or modified natural structure where the general public is exposed to water intended for recreational or therapeutic purpose and where the primary intended use is not watering livestock, irrigation, water storage, fishing, or habitat for aquatic life. Such structures do not necessarily contain standing water, so water exposure may occur via contact, ingestion, or aerosolization. Examples include swimming pools, wave pools, lazy rivers, surf pools, spas *(including spa pools and hot tubs)*, therapy pools, waterslide landing pools, spray pads, and other interactive water venues.

- **"Increased Risk Aquatic Venue"** means an aquatic venue which due to its intrinsic characteristics and intended users has a greater likelihood of affecting the health of the bathers of that venue by being at increased risk for microbial contamination *(e.g., by children less than 5 years old)* or being used by people that may be more susceptible to infection *(e.g., therapy patients with open wounds)*. Examples of increased-risk aquatic venues include spray pads, wading pools and other aquatic venues designed for children less than 5 years old as well as therapy pools.
- **"Lazy River"** means a channeled flow of water of near−constant depth in which the water is moved by pumps or other means of propulsion to provide a river−like flow that transports bathers over a defined path. A lazy river may include play features and devices. A lazy river may also be referred to as a tubing pool, leisure river, leisure pool or a current channel.
- **"Spa"** means a structure intended for either warm or cold water where prolonged exposure is not intended. Spa structures are intended to be used for bathing or other recreational uses and are not usually drained and refilled after each use. It may include, but is not limited to, hydrotherapy, air induction bubbles, and recirculation.
- **"Special Use Aquatic Venue"** means aquatic venues that do not meet the intended use and design features of any other aquatic venue or pool listed/identified in this Code.

"Authority Having Jurisdiction" *(AHJ)* means an agency, organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installations, or procedures.

"Automated Controller" means a system of at least one chemical probe, a controller, and auxiliary or integrated component that senses the level of one or more water parameters and provides a signal to other equipment to maintain the parameters within a user-established range.

"**Available Chlorine**" *See "Chlorine."*

"Average Sound Absorption Coefficient" (Alpha Bar) means the weighted average sound absorption coefficient for a room calculated by weighting the sound absorption coefficients of the individual surfaces in the room according to their respective areas and taking the arithmetic average as follows (especially in the 500 Hz and 1,000 Hz frequencies): And m^2 (or ft^2); Where areas of the individual sound absorptive surfaces, m^2 (or ft^2) respective individual absorption coefficients (dimensionless).[i] A sound absorption coefficient is of a surface, in a specified frequency band, the fraction of the randomly incident sound power which is absorbed (or otherwise not reflected) by a material metric: sabin/m^2.

"Backflow" means a hydraulic condition caused by a difference in water pressure that causes an undesirable reversal of the flow as the result of a higher pressure in the system than in its supply.

"Barrier" means an obstacle intended to prevent direct access from one point to another.

"Bather" means a person at an aquatic venue who has contact with water either through spray or partial or total immersion. The term bather as defined, also includes staff members, and refers to those users who can be exposed to contaminated water as well as potentially contaminate the water.

"Bather Count" means the number of bathers in an aquatic venue at any given time.

"Best Practice" means a technique or methodology that, through experience and research, has been proven to reliably lead to a desired result.

"Body of Water" *(per NEC, q.v.)* means any aquatic venue holding standing water, whether permanent or storable.

"Breakpoint Chlorination" means the conversion of inorganic chloramine compounds to nitrogen gas by reaction with Free Available Chlorine. When chlorine is added to water containing ammonia *(from urine, sweat, or the environment, for example)*, it initially reacts with the ammonia to form monochloramine. If more chlorine is added, monochloramine is converted into dichloramine, which decomposes into nitrogen gas, hydrochloric acid and chlorine. The apparent residual chlorine decreases since it is partially reduced to hydrochloric acid. The point at which the drop occurs is referred to as the "breakpoint". The amount of free chlorine that must be added to the water to achieve breakpoint chlorination is approximately 10 times the amount of combined chlorine in the water. As additional chlorine is added, all inorganic combined chlorine compounds disappear, resulting in a decrease in eye irritation potential and "chlorine odors."

"Bulkheads" means a movable partition that physically separates a pool into multiple sections.

"Certified, Listed, and Labeled" means equipment, materials, products, or services included in a list published by an ANSI accredited certification organization where said equipment, material, product, or service is evaluated against specific criteria and whose listing either states that it meets identified standards or has been tested and found suitable for a specified purpose. In sections of this code where equipment, materials, products, or services are referred to with terms such as "approved", "verified" or similar terms to a referenced standard, these terms also mean "certified, listed, and labeled."

"Chemical Storage Space" means a space in an aquatic facility used for the storage of pool chemicals such as acids, salt, or corrosive or oxidizing chemicals.

"Chlorine" means an element that at room temperature and pressure is a heavy greenish yellow gas with a characteristic penetrating and irritating smell; it is extremely toxic. It can be compressed in liquid form and stored in heavy steel tanks. When mixed with water, chlorine gas forms hypochlorous acid (HOCl), the primary chlorine-based disinfecting agent, hypochlorite ion, and hydrochloric acid. HOCl dissociation to hypochlorite ion is highly pH dependent. Chlorine is a general term used in the MAHC which refers to HOCl and hypochlorite ion in aqueous solution derived from chlorine gas or a variety of chlorine-based disinfecting agents.

- **"Available Chlorine"** means the amount of chlorine in the +1 oxidation state, which is the reactive, oxidized form. In contrast, chloride ion *(Cl^-)* is in the -1 oxidation state, which is the inert, reduced state. Available Chlorine is subdivided into Free Available Chlorine and Combined Available Chlorine. Pool chemicals containing Available Chlorine are both oxidizers and disinfectants. Elemental chlorine *(Cl_2)* is defined as containing 100% available chlorine. The concentration of Available Chlorine in water is normally reported as mg/L *(ppm)* "as Cl_2", that is, the concentration is measured on a Cl_2 basis, regardless of the source of the Available Chlorine.
- **"Free Chlorine Residual"** OR **"Free Available Chlorine"** means the portion of the total available chlorine that is not "combined chlorine" and is present as HOCl or hypochlorite ion *(OCl^-)*.The pH of the water determines the relative amounts of HOCl and hypochlorite ion. HOCl is a very effective bactericide and is the active bactericide in pool water. OCl^- is also a bactericide, but acts more slowly than HOCl. Thus, chlorine is a more effective bactericide at low pH than at high pH. A free chlorine residual must be maintained for adequate disinfection.

"Circulation Path" means an exterior or interior way of passage from one part of an aquatic facility to another for pedestrians, including, but not limited to walkways, pathways, decks, and stairways. This must be considered in relation to ADA.

"**Cleansing Shower**" *See "Shower."*

"Code" means a systematic statement of a body of law, especially one given statutory force.

"Combustion Device" means any appliance or equipment using fire. These include, but may not be limited to, gas or oil furnaces, boilers, pool heaters, domestic water heaters, etc.

"Contamination Response Plan" means a plan for handling contamination from formed-stool, diarrheal-stool, vomit, and blood.

"Contaminant" means a substance that soils, stains, corrupts, or infects another substance by contact or association.

"Corrosive Materials" means pool chemicals, fertilizers, cleaning chemicals, oxidizing cleaning materials, salt, de-icing chemicals, other corrosive or oxidizing materials, pesticides, and such other materials which may cause injury to people or damage to the building, air-handling equipment, electrical equipment, safety equipment, or fire-suppression equipment, whether by direct contact or by contact via fumes or vapors, whether in original form or in a foreseeably likely decomposition, pyrolysis, or polymerization form. Refer to labels and SDS forms.

"Crack" means any and all breaks in the structural shell of a pool vessel or deck.

"Cross-Connection" means a connection or arrangement, physical or otherwise, between a potable water supply system and a plumbing fixture, tank, receptor, equipment, or device, through which it may be possible for non-potable, used, unclean, polluted and contaminated water, or other substances to enter into a part of such potable water system under any condition.

"CT Inactivation Value" means a representation of the concentration of the disinfectant *(C)* multiplied by time in minutes *(T)* needed for inactivation of a particular contaminant. The concentration and time are inversely proportional; therefore, the higher the concentration of the disinfectant, the shorter the contact time required for inactivation. The CT Value can vary with pH or temperature change so these values must also be supplied to allow comparison between values.

"Deck" means surface areas serving the aquatic venue, including the dry deck, perimeter deck, and pool deck.

- **"Dry Deck"** means all pedestrian surface areas within the aquatic venue enclosure not subject to frequent splashing or constant wet foot traffic. The dry deck is not perimeter deck or pool deck, which connect the pool to adjacent amenities, entrances, and exits. Landscape areas are not included in this definition.
- **"Perimeter Deck"** means the hardscape surface area immediately adjacent to and within 4 feet *(1.2 m)* of the edge of the swimming pool also known as the "wet deck" area.
- **"Pool Deck"** means surface areas serving the aquatic venue, beyond perimeter deck, which is expected to be regularly trafficked and made wet by bathers.

"Diaper-Changing Station" means a hygiene station that includes a diaper-changing unit, hand-washing sink, soap and dispenser, a means for drying hands, trash receptacle, and disinfectant products to clean after use.

"Diaper-Changing Unit" means a diaper-changing surface that is part of a diaper-changing station.

"Disinfection" means a treatment that kills or irreversibly inactivates microorganisms *(e.g., bacteria, viruses, and parasites)*; in water treatment, a chemical *(commonly chlorine, chloramine, or ozone)* or physical process *(e.g., ultraviolet radiation)* can be used.

"Disinfection By-Product" (DBP) means a chemical compound formed by the reaction of a disinfectant *(e.g. chlorine)* with a precursor *(e.g. natural organic matter, nitrogenous waste from bathers)* in a water system *(pool, water supply).*

"Diving Pool" *See "Pool."*

"Drop Slide" *See "Slide."*

"Dry Deck" *See "Deck."*

"Emergency Action Plan" (EAP) means a plan that identifies the objectives that need to be met for a specific type of emergency, who will respond, what each person's role will be during the response. and what equipment is required as part of the response.

"Enclosure" means an uninterrupted constructed feature or obstacle used to surround and secure an area that is intended to deter or effectively prevent unpermitted, uncontrolled, and unfettered access . It is designed to resist climbing and to prevent passage through it and under it. Enclosure can apply to aquatic facilities or aquatic venues.

"EPA Registered" means all products regulated and registered under the Federal Insecticide, Fungicide, and Rodenticide Act *(FIFRA)* by the EPA*; https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act*. EPA registered products will have a registration number on the label *(usually it will state "EPA Reg No." followed by a series of numbers)*. This registration number can be verified by using the EPA National Pesticide Information Retrieval System *(http://ppis.ceris.purdue.edu/#)*.

"Equipment Room or Area" means a space intended for the operation of pool pumps, filters, heaters, and controllers. This space is not intended for the storage of hazardous pool chemicals.

"Exit Gate" means an emergency exit, which is a gate or door allowing free exit at all times.

"Expansion Joint" means a watertight joint provided in a pool vessel used to relieve flexural stresses due to movement caused by thermal expansion/contraction.

"Flat Water" means an aquatic venue in which the water line is static except for movement made by users. Diving spargers do not void the flat water definition.

"Floatation Tank" *(a.k.a. Float Tank, Float Room/Pod/Spa/Chamber, Isolation Tank, or Sensory Deprivation Tank)* means a tub that contains a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3, provides a light and sound reduced environment, and is maintained at a temperature of approximately 92-96°F / 33.3-35.6°C.

"Floatation Tank Solution" means a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3.

"Flume" means the riding channels of a waterslide which accommodate riders using or not using mats, tubes, rafts, and other transport vehicles as they slide along a path lubricated by a water flow.

"Foot Baths" means standing water in which bathers or aquatics staff rinse their feet.

"Free Chlorine Residual" OR **"Free Available Chlorine"** *See "Chlorine."*

"Ground-Fault Circuit Interrupter" (GFCI) means a device for protection of personnel that de-energizes an electrical circuit or portion thereof in the event of excessive ground current.

"Hand Wash Station" means a location which has a hand wash sink, adjacent soap with dispenser, hand drying device or paper towels and dispenser, and trash receptacle.

"Hot Water" means an aquatic venue with water temperature over 90 degrees Fahrenheit *(30 degrees Celsius)*.

"Hygiene Facility" means a structure or part of a structure that contains toilet, shower, diaper-changing unit, hand wash station, and dressing capabilities serving bathers and patrons at an aquatic facility.

"Hygiene Fixtures" means all components necessary for hygiene facilities including plumbing fixtures, diaper-changing stations, hand wash stations, trashcans, soap dispensers, paper towel dispensers or hand dryers, and toilet paper dispensers.

"Hyperchlorination" means the intentional and specific raising of chlorine levels for a prolonged period of time to inactivate pathogens following a fecal or vomit release in an aquatic venue as outlined in MAHC 6.5.

"Imminent Health Hazard" means a significant threat or danger to health that is considered to exist when there is evidence sufficient to show that a product, practice, circumstance, or event creates a situation that requires immediate correction or cessation of operation to prevent injury based on the number of potential injuries and the nature, severity, and duration of the anticipated injury or illness.

"Increased Risk Aquatic Venue" *See "Aquatic Venue."*

"Indoor Aquatic Facility" means a physical place that contains one or more aquatic venues and the surrounding bather and spectator/stadium seating areas within a structure that meets the definition of "Building" per the 2012 International Building Code *(IBC)*. It does not include equipment, chemical storage, or bather hygiene rooms or any other rooms with a direct opening to the aquatic facility. Otherwise known as a natatorium.

"Infinity Edge" means a pool wall structure and adjacent perimeter deck that is designed in such a way where the top of the pool wall and adjacent deck are not visible from certain vantage points in the pool or from the opposite side of the pool. Water from the pool flows over the edge and is captured and treated for reuse through the normal pool filtration system. They are often also referred to as "vanishing edges," "negative edges," or "zero edges."

"Inlet" means wall or floor fittings where treated water is returned to the pool.

"Interactive Water Play Aquatic Venue" means any indoor or outdoor installation that includes sprayed, jetted or other water sources contacting bathers and not incorporating standing or captured water as part of the bather activity area. These aquatic venues are also known as splash pads, spray pads, wet decks. For the purposes of the MAHC, only those designed to recirculate water and intended for public use and recreation shall be regulated.

"Interior Space" means any substantially enclosed space having a roof and having a wall or walls which might reduce the free flow of outdoor air. Ventilation openings, fans, blowers, windows, doors, etc., shall not be construed as allowing free flow of outdoor air.

"Island" means a structure inside a pool where the perimeter is completely surrounded by the pool water and the top is above the surface of the pool.

"Landing Pool" *See "Pool."*

"Lazy River" See "Aquatic Venue."

"Lifeguard Supervisor" means an individual responsible for the oversight of lifeguard performance and emergency response at an aquatic facility. A qualified lifeguard supervisor is an individual who has successfully completed a lifeguard supervisor training course and holds an unexpired certificate for such training; and who has met the pre-service and continuing in-service requirements of the aquatic facility according to this code.

"mg/L" means milligrams per liter and is the equivalent metric measure to parts per million *(ppm)*.

"Monitor" means the regular and purposeful observation and checking of systems or facilities and recording of data, including system alerts, excursions from acceptable ranges, and other facility issues. Monitoring includes human or electronic means.

"Moveable Floors" means a pool floor whose depth varies through the use of controls.

"No Diving Marker" means a sign with the words "No Diving" and the universal international symbol for "No Diving" pictured as an image of a diver with a red circle with a slash through it.

"Noise Criterion" means the single number rating that is somewhat sensitive to the relative loudness and speech interference properties of a given noise spectrum. The method consists of a family of criterion curves extending from 63 to 8,000 Hz and a tangency rating procedure. The criterion curves define the limits of octave band spectra that must not be exceeded to meet occupant acceptance in certain spaces.

"Oocyst" means the thick-walled, environmentally resistant structure released in the feces of infected animals that serves to transfer the infectious stages of sporozoan parasites *(e.g., Cryptosporidium)* to new hosts.

"Oxidation" means the process of changing the chemical structure of water contaminants by either increasing the number of oxygen atoms or reducing the number of electrons of the contaminant or other chemical reaction, which allows the contaminant to be more readily removed from the water or made more soluble in the water. It is the "chemical cleaning" of pool water. Oxidation can be achieved by common disinfectants *(e.g., chlorine, bromine)*, secondary disinfection/sanitation systems *(e.g. ozone)* and oxidizers *(e.g. potassium monopersulfate)*.

"Oxidation Reduction Potential" (ORP) means a measure of the tendency for a solution to either gain or lose electrons; higher *(more positive)* oxidation reduction potential indicates a more oxidative solution.

"Patron" means a bather or other person or occupant at an aquatic facility who may or may not have contact with aquatic venue water either through partial or total immersion. Patrons may not have contact with aquatic venue water, but could still be exposed to potential contamination from the aquatic facility air, surfaces, or aerosols.

"Peninsula / Wing Wall" means a structural projection into a pool intended to provide separation within the body of water.

"Perimeter Deck" *See "Deck."*

"Perimeter Gutter System" means the alternative to skimmers as a method to remove water from the pool's surface for treatment. The gutter provides a level structure along the pool perimeter versus intermittent skimmers.

"Plumbing Fixture" means a receptacle, fixture, or device that is connected to a water supply system or discharges to a drainage system or both and may be used for the distribution and use of water; for example: toilets, urinals, showers, and hose bibs. Such receptacles, fixtures, or devices require a supply of water; or discharge liquid waste or liquid-borne solid waste; or require a supply of water and discharge waste to a drainage system.

"pH" means the negative log of the concentration of hydrogen ions. When water ionizes, it produces hydrogen ions *(H+)* and hydroxide ions *(OH-)*. If there is an excess of hydrogen ions the water is acidic. If there is an excess of hydroxide ions the water is basic. pH ranges from 0 to 14. Pure water has a pH of 7.0. If pH is higher than 7.0, the water is said to be basic, or alkaline. If the water's pH is lower than 7.0, the water is acidic. As pH is raised, more HOCl ionization occurs and chlorine disinfectants decrease in effectiveness.

"Pool" means a subset of aquatic venues designed to have standing water for total or partial bather immersion. This does not include spas.

- **"Activity Pool"** means a water attraction designed primarily for play activity that uses constructed features and devices including pad walks, flotation devices, and similar attractions.
- **"Diving Pool"** means a pool used exclusively for diving.
- **"Landing Pool"** means an aquatic venue or designated section of an aquatic venue located at the exit of one or more waterslide flumes. The body of water is intended and designed to receive a bather emerging from the flume for the purpose of terminating the slide action and providing a means of exit to a deck or walkway area.
- **"Skimmer Pool"** means a pool using a skimmer system.
- **"Surf Pool"** means any pool designed to generate waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.
- **"Therapy Pool"** means a pool used exclusively for aquatic therapy, physical therapy, and/or rehabilitation to treat a diagnosed injury, illness, or medical condition, wherein the therapy is provided under the direct supervision of a licensed physical therapist, occupational therapist, or athletic trainer. This could include wound patients or immunocompromised patients whose health could be impacted if there is not additional water quality protection.
- **"Wading Pool"** means any pool used exclusively for wading and intended for use by young children where the depth does not exceed 2 feet *(0.6 m)*.
- **"Wave Pools"** means any pool designed to simulate breaking or cyclic waves for purposes of general play. A wave pool is not the same as a surf pool, which generates waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.

"**Pool Deck**" *See "Deck."*

"Pool Slide" *See "Slide."*

"Public Water Systems" means water systems including community water systems, non-transient/non-community water systems, or transient non-community water systems with exceptions as noted by AHJ and EPA.

"Purge" means to introduce a large volume of outdoor air to flush the interior space.

"Qualified Lifeguard" means an individual who has successfully completed an AHJ-recognized lifeguard training course offered by an AHJ-recognized training agency, holds a current certificate for such training, has met the pre-service requirements, and is participating in continuing in-service training requirements of the aquatic facility.

"Qualified Operator" means an individual responsible for the operation and maintenance of the water and air quality systems and the associated infrastructure of the aquatic facility and who has successfully completed an

AHJ-recognized operator training course to operate an aquatic facility offered by an AHJ-recognized training agency and holds a current certificate for such training.

"Recessed Steps" means a way of ingress/egress for a pool similar to a ladder but the individual treads are recessed into the pool wall.

"Recirculation System" means the combination of the main drain, gutter or skimmer, inlets, piping, pumps, controls, surge tank or balance tank to provide pool water recirculation to and from the pool and the treatment systems.

"Reduction Equivalent Dose *(RED)* bias" means a variable used in UV system validation to account for differences in UV sensitivity between the UV system challenge microbe *(e.g., MS2 virus)* and the actual microbe to be inactivated *(e.g., Cryptosporidium)*.

"Re-entrainment" means a situation where the exhaust*(s)* from a ventilated source such as an indoor aquatic facility is located too close to the air handling system intake*(s)*, which allows the exhausted air to be re-captured by the air handling system so it is transported directly back into the aquatic facility.

"Responsible Supervisor" means an individual on-site that is responsible for water treatment operations when a "qualified operator" is not on-site at an aquatic facility.

"**Rinse Shower**" *See "Shower."*

"Robotic Cleaner" means a modular vacuum system consisting of a motor-driven, in-pool suction device, either self-powered or powered through a low voltage cable, which is connected to a deck-side power supply.

"Runout" means that part of a waterslide where riders are intended to decelerate and/or come to a stop. The runout is a continuation of the waterslide flume surface.

"Safety" *(as it relates to construction items)* means a design standard intended to prevent inadvertent or hazardous operation or use *(i.e., a passive engineering strategy)*.

"Safety Plan" means a written document that has procedures, requirements and/or standards related to safety which the aquatic facility staff shall follow. These plans include training, emergency response, and operations procedures.

"Safety Team" means any employee of the aquatic facility with job responsibilities related to the aquatic facility's emergency action plan.

"Sanitize" means reducing the level of microbes to that considered safe by public health standards *(usually 99.999%)*. This may be achieved through a variety of chemical or physical means including chemical treatment, physical cleaning, or drying.

"Saturation Index" means a mathematical representation or scale representing the ability of water to deposit calcium carbonate, or dissolve metal, concrete or grout.

"Secondary Disinfection Systems" means those disinfection processes or systems installed in addition to the standard systems required on all aquatic venues, which are required to be used for increased risk aquatic venues.

"Shower" means a device that sprays water on the body.

- **"Cleansing Shower"** means a shower located within a hygiene facility using warm water and soap. The purpose of these showers is to remove contaminants including perianal fecal material, sweat, skin cells, personal care products, and dirt before bathers enter the aquatic venue.

- **"Rinse Shower"** means a shower typically located in the pool deck area with ambient temperature water. The main purpose is to remove dirt, sand, or organic material prior to entering the aquatic venue to reduce the introduction of contaminants and the formation of disinfection by-products.

"Skimmer" means a device installed in the pool wall whose purpose is to remove floating debris and surface water to the filter. They shall include a weir to allow for the automatic adjustment to small changes in water level, maintaining skimming of the surface water.

"Skimmer Pool" *See "Pool."*

"Skimmer System" means periodic locations along the top of the pool wall for removal of water from the pool's surface for treatment.

"Slide" means an aquatic feature where users slide down from an elevated height into water.

- **"Drop Slide"** means a slide that drops bathers into the water from a height above the water versus delivering the bather to the water entry point.
- **"Pool Slide"** means a slide having a configuration as defined in The Code of Federal Regulations *(CFR)* Ch. II, Title 16 Part 1207 by CSPC, or is similar in construction to a playground slide used to allow users to slide from an elevated height to a pool. They shall include children's *(tot)* slides and all other non-flume slides that are mounted on the pool deck or within the basin of a public swimming pool.
- **"Waterslide"** means a slide that runs into a landing pool or runout through a fabricated channel with flowing water.

"Sound Absorption" means (1) the process of dissipating sound energy and (2) the property possessed by materials, objects and structures, such as rooms, for absorbing sound energy.

"Spa" See "Aquatic Venue."

"**Special Use Aquatic Venue**" *See "Aquatic Venue."*

"Standard" means something established by authority, custom, or general consent as a model or example.

"Storage" means the condition of remaining in one space for 1 hour or more. Materials in a closed pipe or tube awaiting transfer to another location shall not be considered to be stored.

"Structural Crack" means a break or split in the pool surface that weakens the structural integrity of the vessel.

"Substantial Alteration" means the alteration, modification, or renovation of an aquatic venue *(for outdoor aquatic facilities)* or indoor aquatic facility *(for indoor aquatic facilities)* where the total cost of the work exceeds 50% of the replacement cost of the aquatic venue *(for outdoor aquatic facilities)* or indoor aquatic facility *(for indoor aquatic facilities).*

"Superchlorination" means the addition of large quantities of chlorine-based chemicals to kill algae, destroy odors, or improve the ability to maintain a disinfectant residual. This process is different from hyperchlorination, which is a prescribed amount to achieve a specific CT inactivation value whereas superchlorination is the raising of free chlorine levels for water quality maintenance.

"Supplemental Treatment Systems" means those disinfection processes or systems which are not required on an aquatic venue for health and safety reasons. They may be used to enhance overall system performance and improve water quality.

"Surf Pool" *See "Pool."*

"Theoretical Peak Occupancy" means the anticipated peak number of bathers in an aquatic venue or the anticipated peak number of occupants of the decks of an aquatic facility. This is the lower limit of peak occupancy to be used for design purposes for determining services that support occupants. Theoretical peak occupancy is used to determine the number of showers. For aquatic venues, the theoretical peak occupancy is calculated around the type of water use or space:

- **"Flat Water"** means an aquatic venue in which the water line is static except for movement made by users usually as a horizontal use as in swimming. Diving spargers do not void the flat water definition.
- **"Agitated Water"** means an aquatic venue with mechanical means *(aquatic features)* to discharge, spray, or move the water's surface above and/or below the static water line of the aquatic venue so people are standing or playing vertically. Where there is no static water line, movement shall be considered above the deck plane.
- **"Hot Water"** means an aquatic venue with a water temperature over 90°F *(32°C)*.
- **"Stadium Seating"** means an area of high-occupancy seating provided above the pool level for observation.

"**Therapy Pool**" *See "Pool."*

"Toe Ledge" *See "Underwater Ledge."*

"Turnover" or "Turnover Rate" or "Turnover Time" means the period of time, usually expressed in hours, required to circulate a volume of water equal to the capacity of the aquatic venue.

"Underwater Bench" means a submerged seat with or without hydrotherapy jets.

"Underwater Ledge" or "Underwater Toe Ledge" means a continuous step in the pool wall that allows swimmers to rest by standing without treading water.

"Wading Pool" *See "Pool."*

"Waterslide" *See "Slide."*

"Water Replenishment System" means a way to remove water from the pool as needed and replace with make-up water in order to maintain water quality.

"Water Quality Testing Device" (WQTD) means a product designed to measure the level of a parameter in water. A WQTD includes a device or method to provide a visual indication of a parameter level, and may include one or more reagents and accessory items.

"Wave Pools" *See "Pool."*

"Wing Wall / Peninsula" *See "Peninsula / Wing Wall."*

"Zero Depth Entry" means a sloped entry into a pool from deck level into the interior of the pool as a means of access and egress.

3.3 Codes, Standards, and Laws Referenced in the MAHC Code

Air Conditioning Contractors of America (ACCA)

- ANSI/ACCA 10 Manual SPS-2011 (RA 2017); Manual SPS HVAC Design for Swimming Pools and Spas

Air Movement Control Association (AMCA)

- AMCA 201-02 (R2011), Fans and Systems

American Coatings Association (ACA)

- Hazardous Materials Identification System (HMIS), Fourth Edition

American Concrete Institute (ACI)

- ACI 302.1R-15, Guide to Concrete Floor and Slab Construction

American Heart Association (AHA)

- American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC)
- 2015 AHA Guidelines Update for CPR and ECC
- www.citizencpr.org

American National Standards Institute (ANSI)

- ANSI/ICC A117.1-2017. Accessible and Usable Buildings and Facilities
- ANSI A137.1:2017 American National Standards Specifications for Ceramic Tile

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

- ANSI/ASHRAE Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality
- 2015 *ASHRAE Handbook—HVAC Applications*

American Society of Mechanical Engineers (ASME)

- ASME A112.19.17-2010, Manufactured Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems

ASTM International (formerly American Society for Testing and Materials) (ASTM)

- ASTM F1346 – 91(2010): Standard Performance Specification for Safety Covers and Labeling Requirements for All Covers for Swimming Pools, Spas and Hot Tubs
- ASTM F2285-04 (2016)e1: Standard Consumer Safety Performance Specification for Diaper Changing Tables for Commercial Use
- ASTM F2376-117a (2017): Standard Practice for Classification, Design, Manufacture, Construction and Operation of Water Slides Systems
- ASTM F2387-04 (2012): Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas and Hot Tubs
- ASTM F2461-16e1(2016) Standard Practice for Manufacture, Construction, Operation and Maintenance of Aquatic Play Equipment

Americans with Disabilities Act Accessibility Guidelines (ADAAG)

- 2010 ADA Standards for Accessible Design

Association of Pool and Spa Professionals (APSP)

- ANSI/APSP-16 2011, Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs

Caring for Our Children (CFOC): National Health and Safety Performance Standard

- National Health and Safety Performance Standards; Guidelines for Early Care and Education Programs, Third Edition, 2011 (revised October 1, 2015)
- Also known as *Caring for Our Children*, 3rd Edition (CFOC3)
- Accessed at: http://nrckids.org

Chlorine Institute (CI)

- Pamphlet 82; Recommendations for Using 100 & 150 Pound Chlorine Cylinders at Swimming Pools, Edition 3, January 2015

Consumer Product Safety Commission (CPSC)

- 16 CFR 1207 – Safety Standard for Swimming Pool Slide
    - (Last updated 43 FR 58813, Dec. 18, 1978)

Deutscher Verein des Gas- und Wasserfaches e.V. – Technisch wissenschaftlicher Verein (DVGW)

- German Technical and Scientific Association for Gas and Water

Environmental Protection Agency (EPA)

- EPA 815-R-06-007: *Ultraviolet Disinfectant Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule, November 2006*
- EPA 816-F-09-004: National Primary Drinking Water Regulations, May 2009, (40 CFR 141)
- 7 USC §136 et. seq. (1996), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- 40 CFR Subchapter E – Pesticide Programs

Fédération Internationale de Natation Amateur (FINA)

- Facilities Rules 2017 – 2021, 22 September 2017

Hazardous Materials Identification System (HMIS)

- See American Coatings Association above

Illuminating Engineering Society of North America (IESNA)

- The Lighting Handbook, 10th Edition (2011)

International Association of Plumbing and Mechanical Officials (IAPMO)

- IAPMO/ANSI UMC 1 2015 (2015 Uniform Mechanical Code)
- IAPMO/ANSI UPC 1 2015 (2015 Uniform Plumbing Code)

- IAPMO/ANSI USPSHTC 1 2015 (2015 Uniform Swimming Pool, Spa, and Hot Tub Code)

International Code Council (ICC)

- ICC/ANSI A117.1-2017 Standard for Accessible and Usable Buildings and Facilities
- 2018 International Building Code (IBC)
- 2018 International Fire Code (IFC)
- 2018 International Mechanical Code (IMC)
- 2018 International Plumbing Code (IPC)
- 2018 International Swimming Pool and Spa Code (ISPSC)

International Liaison Commission of Resuscitation (ILCOR)

- 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care With Treatment Recommendations (CoSTR)
- www.ilcor.org

International Organization for Standardization (ISO)

- ISO9000:~~2000~~2015; Quality management systems – Fundamentals and vocabulary

National Collegiate Athletic Association (NCAA)

- 2017-18 and 2018-19 NCAA Men's and Women's Swimming and Diving Rules

National Federation of State High School Associations (NFHS)

- 2017-18 NFHS Swimming and Diving Rules Book

National Fire Protection Association (NFPA)

- NFPA 1: Fire Code, 2018 Edition
- NFPA 70: National Electric Code (NEC), 2017 Edition
- NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response, 2017 Edition

National Institute for Occupational Safety and Health (NIOSH)

- 42 CFR Part 84, Respiratory Protective Devices, 1995
- Certified Equipment List (CEL)

NSF International (NSF)

- NSF/ANSI 14 - 2016b, Plastics Piping System Components and Related Materials
- NSF/ANSI 50 - 16a, Equipment for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities
- NSF/ANSI 60 – 2016, Drinking Water Treatment Chemicals – Health Effects
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Occupational Safety and Health Administration (OSHA)

- 29 CFR 1910.304 – Wiring design and protection
  - (Last updated 73 FR 64205, Oct. 29, 2008)
- 29 CFR 1910.1000 Air contaminants
  - (Last updated 81 FR 16861, Mar. 25, 2016)
- 29 CFR 1910.1030~~:~~ - Bloodborne Pathogens
  - (Last updated 77 FR 19934, Apr. 3, 2012)
- 29 CFR 1910.1200 – Hazard Communication Standard (HSC) 2012 HazCom 2012 Final Rule (HazCom 2012)

Österreichisches Normungsinstitut (ÖNORM)

- (Austrian Standards Institute)

Sheet Metal & Air Conditioning Contractors' National Association (SMACNA)

- SMACNA HVAC Systems Duct Design, 4th Edition, 2006

Underwriters Laboratories (UL)

- UL 399 2017-03-20 Standard for Drinking-Water Coolers
- UL 1081 2016-08-09 Standard for Swimming Pool Pumps, Filters, and Chlorinators
- UL 2075 2013-03-05 Standard for Gas and Vapor Detectors and Sensors
- UL 2818 2013-03-29 GREENGUARD Certification Program for Chemical Emissions for Building Materials, Finishes, and Furnishings
- UL 60335-2-1000 2017-09-29 Standard for Household and Similar and Similar electrical Appliances: Particular Requirements for Electrically Powered Pool Lifts

USA Diving

- USA Diving Competitive and Technical Rules, 2018

USA Swimming

- USA Swimming 2017 Rulebook

United States Coast Guard

- 33 CFR 175.15; Sept 22, 2014; Personal Floatation Devices

Virginia Graeme Baker Pool and Spa Safety Act (VGB Act)

- 15 USC Chapter 106, Pool and Spa Safety (as amended to 2014)
- Available at: https//poolsafely.gov/wp-content/uploads/2016/04/pssa.pdf/
- Interpretation Guidance: http://poolsafely.gov under Materials, Resource Library, The Act and Rulings

2018 Model Aquatic Health Code

Code Language

DESIGN AND CONSTRUCTION

CS288986-A

4.0[A] Aquatic Facility Design Standards and Construction

The provisions of MAHC Chapter 4 *(Aquatic Facility Design Standards and Construction)* apply to construction of a new AQUATIC FACILITY or AQUATIC VENUE or SUBSTANTIAL ALTERATION to an existing AQUATIC FACILITY or AQUATIC VENUE, unless otherwise noted.

Note: Section numbers with superscript "A" (e.g., 4.0A) denote a corresponding discussion in the Annex to the Model Aquatic Health Code.

4.1 Plan Submittal

4.1.1 Plan Submittal

4.1.1.1 Purpose AQUATIC FACILITY construction plans shall be designed to provide sufficient clarity to indicate the location, nature, and extent of the work proposed.

4.1.1.2 Conform AQUATIC FACILITY construction plans shall show in detail that it will conform to the provisions of this CODE and relevant laws, ordinances, rules, and regulations, as determined by the AHJ and to protect the health and SAFETY of the facility's BATHERS and PATRONS.

4.1.1.3 Approved Plans No person shall begin to construct a new AQUATIC FACILITY or shall SUBSTANTIALLY ALTER an existing AQUATIC FACILITY without first having the construction plans detailing the construction or SUBSTANTIAL ALTERATION submitted to and approved by the AHJ.

4.1.1.4 Plan Preparation All plans shall be prepared by a design professional who is registered or licensed to practice their respective design profession as defined by the state or local laws governing professional practice within the jurisdiction in which the project is to be constructed.

4.1.1.5 Required Statements All construction plans shall include the following statements:

1) "The proposed aquatic facility and all equipment shall be constructed and installed in conformity with the approved plans and specifications or approved amendments," and
2) "No substantial alteration, changes, additions, or equipment not specified in the approved plans can be made or added until the plans for such substantial alteration, changes, additions, or equipment are submitted to and approved by the AHJ."

4.1.2 Content of Design Report

4.1.2.1 Basis of Design Report

4.1.2.1.1[A] Names / Addresses AQUATIC FACILITY plans shall include the name, address, and contact information for the owner, designer, and builder if available at the time of submission.

4.1.2.1.2 Site Information AQUATIC FACILITY plans shall include site information indicating at a minimum the location of all utilities, wells, topography, natural water features, and potential sources of surface drainage and pollution which may affect the proposed AQUATIC FACILITY.

4.1.2.1.3 Plot Plan AQUATIC FACILITY plans shall include a site plot plan including:

1) A general map and detailed scaled drawings of the AQUATIC FACILITY site plan or floor plan with detailed locations of the AQUATIC VENUES and AQUATIC FEATURES; and
2) The locations of all water supply facilities, sources of drinking water, public or private sewers, and relative elevations of paved or other walkways and the EQUIPMENT ROOM floor shall be shown on the plans with the elevations of storm and sanitary sewer inverts and street grade.

4.1.2.2 Plans and Specifications

4.1.2.2.1 Drawings Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall include an AQUATIC VENUE area plan and layout plan along with dimensioned longitudinal and transverse cross sections of the AQUATIC VENUE.

4.1.2.2.1.1 Operating Conditions The design documents shall include a record of operating conditions *(water temperature(s), space temperature, space relative humidity, space dew point)* and intended use for each type of VENUE *(FLAT WATER, AGITATED WATER, HOT WATER)* accepted by both the design engineer and owner/operator.

4.1.2.2.2 ***Aquatic Venue Attributes*** Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall include location and type of:

1) INLETS,
2) Overflows,
3) Drains,
4) Suction outlets,
5) Overflow gutters or devices,
6) Piping,
7) Designed POOL water elevation,
8) AQUATIC FEATURES such as ladders, stairs, diving boards, SLIDES, and play features,
9) Lighting,
10) Pool markings, and
11) Surface materials

4.1.2.2.3 ***Area Design*** Detailed scaled and dimensional drawings of the AQUATIC FACILITY and for each individual AQUATIC VENUE, as appropriate, shall include location and type of:

1) Design of DECK, curb, or walls enclosing the AQUATIC VENUE,
2) DECK drains,
3) Paved walkways and other hardscape features,
4) Non-slip flooring,
5) AQUATIC VENUE area finishes,
6) Drinking fountains or other sources of drinking water,
7) Entries and exits,
8) Hose bibs,
9) Fences,
10) Telephones, and
11) Area lighting.

4.1.2.2.4 ***Aquatic Venue Recirculation and Treatment Design*** Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a flow diagram showing the location, plan, elevation, and schematics of:

1) Filters,
2) Pumps,
3) Chemical feeders and interlocks
4) Chemical controllers and interlocks,
5) SECONDARY DISINFECTION SYSTEMS, if required,
6) Supplemental DISINFECTION systems, if installed,
7) Ventilation devices or AIR HANDLING SYSTEMS,
8) Heaters,
9) Surge tanks, including operating levels,
10) BACKFLOW prevention assemblies and air gaps,
11) Valves,
12) Piping,
13) Flow meters,
14) Gauges,

15) Thermometers,

16) Test cocks,

17) Sight glasses, and

18) Drainage system for the disposal of AQUATIC VENUE water and filter wastewater.

4.1.2.2.5 Equipment Room Design Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a schematic layout of the AQUATIC VENUE EQUIPMENT ROOM *(or EQUIPMENT AREA if permitted by the local AHJ)* showing accessibility for installation and maintenance.

4.1.2.2.6 Chemical Storage Space Design Detailed scaled and dimensional drawings for each individual AQUATIC VENUE shall contain a schematic layout of the AQUATIC FACILITY CHEMICAL STORAGE SPACE(S).

4.1.2.2.7 Hygiene Facility Design Detailed scaled and dimensional drawings for each AQUATIC FACILITY shall show the location and number of all available HYGIENE FACILITIES provided including dressing rooms, lockers and basket STORAGE, SHOWERS, lavatory, toilet FIXTURES, and DIAPER-CHANGING STATIONS.

4.1.2.3 Technical Specifications

4.1.2.3.1[A] Accompanying Drawings Technical specifications for the construction of each AQUATIC VENUE and all appurtenances shall accompany the drawings for the AQUATIC FACILITY plans.

4.1.2.3.2[A] Technical Details The following technical specifications shall be provided for each AQUATIC FACILITY:

1) POOL water temperatures,
2) Space design,
3) Dry bulb and dew point temperatures, and
4) Relative humidity.

4.1.2.3.2.1 Details Not Shown on Plans Each AQUATIC VENUE shall include all construction details not shown on the plans that relate to the AQUATIC FACILITY:

4.1.2.3.2.2[A] Intended Use Design of the ventilation and AIR HANDLING SYSTEMS for INDOOR AQUATIC FACILITIES shall include consultation with, and input by, the owner/operator to address intended use, type of VENUE *(FLAT WATER, AGITATED WATER, HOT WATER)* and intended typical operating water temperature.

4.1.2.3.3 Water Sources The technical specifications for each AQUATIC FACILITY shall include the sources of all water supplies.

4.1.2.3.4 Area and Volume Technical specifications shall include the water surface area and volume of each AQUATIC VENUE and associated water features, if applicable.

4.1.2.3.5[A] Theoretical Peak Occupancy The technical specifications for each AQUATIC FACILITY and each AQUATIC VENUE shall include THEORETICAL PEAK OCCUPANCY, respectively.

4.1.2.3.5.1 Used for Designing Systems The THEORETICAL PEAK OCCUPANCY for an AQUATIC VENUE shall be used for designing systems that serve BATHERS and PATRONS. *(Note: The specified density factors are the lower limits for determining THEORETICAL PEAK OCCUPANCY.)*

4.1.2.3.5.2 Incorporate Non-Water Related Areas The THEORETICAL PEAK OCCUPANCY for an AQUATIC FACILITY shall be used for designing systems that serve BATHERS and PATRONS and shall incorporate non-water related areas such as DECKS and other adjacent portions of the AQUATIC FACILITY not associated with the AQUATIC VENUE.

4.1.2.3.5.3 Calculating Theoretical Peak Occupancy The THEORETICAL PEAK OCCUPANCY shall be calculated by dividing the surface area in square feet of the AQUATIC VENUE by the density factor *(D)* that fits the specific AQUATIC VENUE being considered.

THEORETICAL PEAK OCCUPANCY = AQUATIC VENUE Surface Area / D

The density factors *(D)* are:

Water/BATHER-related:

1) FLAT WATER density factor = 20 ft^2 *(1.9 m^2)* per BATHER.
2) AGITATED WATER density factor = 15 ft^2 *(1.4 m^2)* per BATHER.
3) HOT WATER density factor = 10 ft^2 *(0.9 m^2)* per BATHER.
4) WATERSLIDE LANDING POOL density factor = manufacturer-established capacity at any given time.
5) INTERACTIVE WATER PLAY water density factor = 10 ft^2 *(0.9 m^2)* per BATHER on surface.
6) SURF POOL density factor = manufacturer-established capacity at any given time.
7) Non-water/PATRON-related
8) DECK density factor = 50 ft^2 *(4.6 m^2)* per BATHER.
9) STADIUM SEATING density factor = 6.6 ft^2 *(0.6 m^2)* per BATHER.

4.1.2.3.5.3.1 Density Factor Modification The density factors in MAHC 4.1.2.3.5.3 may be modified for higher BATHER or PATRON density, but they shall not be modified to result in less BATHERS per square foot than listed for the factors in MAHC 4.1.2.3.5.3.

4.1.2.3.5.3.2 Aquatic Facility Theoretical Peak Occupancy The THEORETICAL PEAK OCCUPANCY for an AQUATIC FACILITY shall be determined by adding the calculations for each AQUATIC VENUE in the AQUATIC FACILITY.

4.1.2.3.6[A] Equipment Characteristics and Rating The technical specifications and supplemental engineering data for each AQUATIC FACILITY and each AQUATIC VENUE shall include:

1) Detailed information on the type, size, operating characteristics, and rating of all mechanical and electrical equipment;
2) Hydraulic computations for head loss in all piping and recirculation equipment;
3) Pump curves that demonstrate that the selected recirculation pump*(s)* are adequate for the calculated required flows; and
4) For INDOOR AQUATIC FACILITIES, documentation that demonstrates that the INDOOR AQUATIC FACILITY is designed to meet the acoustic design criteria contained in MAHC 4.6.11.
5) Documentation per MAHC 4.7.3.2.2.3 to demonstrate that the selected DISINFECTANT feeders/equipment are of sufficient size and capacity, including evaluation of the CHLORINE demand factors in MAHC 4.7.3.2.2.2.1.

4.1.2.3.7 Recirculation Rate and Turnover The technical specifications for each AQUATIC VENUE shall include the recirculation rate and TURNOVER TIME.

4.1.2.3.8 Filter Media The technical specifications for each AQUATIC VENUE shall include information on the filter media such as diatomaceous earth, sand, gravel or other approved material.

4.1.2.3.9 Equipment Specifications The technical specifications for each AQUATIC VENUE shall include information on each piece of equipment associated with that AQUATIC VENUE.

4.1.2.3.10 Safety Equipment Specifications The technical specifications for each AQUATIC FACILITY shall include information on all aquatic SAFETY equipment.

4.1.2.3.11 Design for Risk Management The layout for zones of PATRON surveillance as specified in MAHC 6.3.3.1.1 shall be included and must show features or design configurations that can impact PATRON surveillance.

4.1.2.3.12 Other Specifications The technical specifications for each AQUATIC FACILITY and each AQUATIC VENUE shall include additional information related to the project requested by the AHJ for the purposes of the construction of the AQUATIC FACILITY and each AQUATIC VENUE and all appurtenances.

4.1.3[A] Plan Approval

4.1.3.1 New Construction

4.1.3.1.1 Approval Limitations The AHJ shall clearly state on the plans the limitations of their approval.

4.1.3.1.2 Other Approvals The approval shall also state that it is independent of all other required approvals such as Building, Zoning, Fire, Electrical, Structural, and any other approvals as required by local or state law or CODE and the applicant must separately obtain all other required approvals and permits.

4.1.3.1.3 Plan Review Coordination The AHJ shall coordinate their AQUATIC FACILITY plan review and communicate their approval with other agencies involved in the AQUATIC FACILITY construction.

4.1.3.1.4 Plan Review Report The AHJ shall provide a plan submission compliance review list to the AQUATIC FACILITY owner with the following information:

1) Categorical items marked satisfactory, unsatisfactory, not applicable, or insufficient information;
2) A comment section keyed to the compliance review list shall detail unsatisfactory and insufficient;
3) Indication of the AHJ approval or disapproval of the AQUATIC FACILITY construction plans;
4) In the case of a disapproval, specific reasons for disapproval and procedure for resubmittal; and
5) Reviewer's name, signature, and date of review.

4.1.3.1.5 Plans Maintained The AQUATIC FACILITY owner shall maintain at least one set of their own approved plans made available to AHJ on file for as long as the AQUATIC FACILITY is in operation.

4.1.3.2 Non-Substantial Alterations

4.1.3.2.1 Alteration Review The AQUATIC FACILITY owner planning a non-SUBSTANTIAL ALTERATION shall contact the AHJ to review proposed changes prior to starting the non-SUBSTANTIAL ALTERATION.

4.1.3.2.2 Alteration Scope The AQUATIC FACILITY operator shall consult with the AHJ to determine if new or modified plans must be submitted for plan review and approval for other non-SUBSTANTIAL ALTERATIONS proposed.

4.1.3.3[A] Replacements

4.1.3.3.1 Replacement Approval Prior to replacing equipment, the AQUATIC FACILITY owner shall submit technical verification to the AHJ that all replacement equipment is equal to that which was originally approved and installed.

4.1.3.3.2 Replacement Equipment Equivalency The replacement of pumps, filters, feeders, controllers, SKIMMERS, flow-meters, valves, or other similar equipment with identical or substantially similar equipment may be done without submission to the AHJ for approval of new or altered AQUATIC FACILITY plans.

4.1.3.3.3 Emergency Replacement In emergencies, the replacement may be made prior to receiving the AHJ's approval, with the owner accepting responsibility for proper immediate replacement, if the equipment is not deemed equivalent by the AHJ.

4.1.3.3.3.1 Documentation Where emergency replacements are installed as per MAHC 4.1.3.3.3, the owner shall submit documentation for review and approval of the replacement to the AHJ within 45 days.

4.1.3.3.4 Replacement Record Maintenance The AHJ shall provide the AQUATIC FACILITY owner written approval or disapproval of the proposed replacement equipment's equivalency.

4.1.3.3.5 Documentation Documentation of proposed, approved, and disapproved replacements shall be maintained in the AHJ's AQUATIC FACILITY files.

4.1.4[A] Compliance Certificate

4.1.4.1 Construction Compliance Certificate A certificate of construction compliance shall be submitted to the AHJ for all AQUATIC FACILITY plans for new construction and SUBSTANTIAL ALTERATIONS requiring AHJ approvals.

4.1.4.2 Certificate Preparation This certificate shall be prepared by a licensed professional and be within the scope of their practice as defined by the state or local laws governing professional practice within the jurisdiction of the permit issuing official.

4.1.4.3 Certificate Statement The certificate shall also include a statement that the AQUATIC FACILITY, all equipment, and appurtenances have been constructed and/or installed in accordance with approved plans and specifications.

4.1.4.4[A] Systems Commissioning If commissioning or testing reports for systems such as AQUATIC FACILITY lighting, air handling, recirculation, filtration, and/or DISINFECTION are conducted, then those reports shall be included in furnished documentation.

4.1.4.5 Maintenance Documentation of AQUATIC FACILITY new construction or SUBSTANTIAL ALTERATION plan compliance shall be maintained in the AHJ's AQUATIC FACILITY files.

4.1.5 Construction Permits

4.1.5.1 Building Permit for Construction Construction permits required in this CODE and all other applicable permits shall be obtained before any AQUATIC FACILITY may be constructed.

4.1.5.2 Remodeling Building Permit A construction permit or other applicable permits may be required from the AHJ before SUBSTANTIAL ALTERATION of an AQUATIC FACILITY.

4.1.5.3 Permit Issuance The AHJ shall issue a permit to the owner to operate the AQUATIC FACILITY:

1) After receiving a certificate of completion from the design professional verifying information submitted, and
2) When new construction, SUBSTANTIAL ALTERATIONS, or annual renewal requirements of this CODE have been met.

4.1.5.4 Permit Denial The permit *(license)* to operate may be withheld, revoked or denied by the AHJ for noncompliance of the AQUATIC FACILITY with the requirements of this CODE, and the owner will be provided:

1) Specific reasons for disapproval and procedure for resubmittal;
2) Notice of the rights to appeal this denial and procedures for requesting an appeal; and
3) Reviewer's name, signature and date of review and denial.

4.1.5.5 Documentation Documentation of AQUATIC FACILITY permit renewal or denial shall be maintained in the AHJ's AQUATIC FACILITY files.

4.2 Materials

4.2.1 Aquatic Venues

4.2.1.1 Construction Material AQUATIC VENUES shall be constructed of reinforced concrete or impervious and structurally sound material*(s),* which provide a smooth, easily cleaned, watertight structure capable of withstanding the anticipated stresses/loads for full and empty conditions taking into consideration climatic, hydrostatic, seismic, and the integration of the AQUATIC VENUE with other structural conditions and as required by applicable CODES.

4.2.1.2 Durability All materials shall be inert, non-toxic, resistant to corrosion, impervious, enduring, and resistant to damages related to environmental conditions of the installation region.

4.2.1.3 Areas Subject to Freezing Where located in areas subject to freezing, AQUATIC VENUES and appurtenances shall be designed to protect against damage due to freezing.

4.2.1.4 Competitive Pools Competitive or lap POOLS may have lane markings and end wall targets installed in accordance with FINA, NCAA, USA Swimming, NFHS, or other recognized STANDARD.

4.2.1.5[A] Design Parameters Any graphics, color, or finish incorporated into the construction of a POOL or painted on the floor or walls shall not prevent the detection of a BATHER in distress, algae, sediment, or other objects in the AQUATIC VENUE.

4.2.1.5.1 Permission in Writing Permission in writing from the AHJ for the use of graphics that do not comply with the requirements of this CODE shall be obtained before the graphics are used.

4.2.1.6 Watertight POOLS shall be designed in such a way to maintain their ability to retain the designed amount of water.

4.2.1.7[A] Smooth Finish All vertical walls shall have a durable finish suitable for regular scrubbing and cleaning at the waterline.

4.2.1.7.1 Daily Cleaning The finish shall be able to withstand daily brushing, scrubbing, and cleaning of the surface in accordance with the manufacturer's recommendations.

4.2.1.7.2 Skimmer Pools SKIMMER POOLS shall have a 6 inch *(152 mm)* to 12 inch *(305 mm)* high waterline finish that meets the requirements of MAHC 4.2.1.7 and 4.2.1.7.1.

4.2.1.7.3 Gutter / Perimeter Overflow Systems Gutter or POS shall have a minimum finish height of 2 inches (*51 mm)* that meets the requirements of MAHC 4.2.1.7 and 4.2.1.7.1.

4.2.1.7.4 Dark Colors If dark colors in excess of what is required in MAHC 4.5.11 of this CODE are used for the POOL finish, these colors shall not extend more than 12 inches *(305 mm)* below the waterline.

4.2.1.8[A] Slip Resistant POOL floors in areas less than 3 feet *(0.9 m)* deep shall have a slip resistant finish with a minimum dynamic coefficient of friction at least equal to the requirements of ANSI A137.1-2012 of 0.42 as measured by the DCOF AcuTest.

4.2.1.9 Stainless Steel, Vinyl, PVC-P or PVC Pools Stainless steel, vinyl, PVC-P, or PVC panel and liner POOL finish systems shall be acceptable provided that the system is installed on top of approved materials and design requirements as listed within this section or approved by the AHJ.

4.2.1.9.1 Damaged If at any time the liner system is damaged or cut in such a way that its integrity is compromised, the POOL shall be shut down until the system is fully repaired.

4.2.1.10 Not Permitted Wood, sand, or earth shall not be permitted as an interior finish.

4.2.2 Indoor Aquatic Facility

4.2.2.1 Interior Finish

4.2.2.1.1 Relative Humidity The interior finish of an INDOOR AQUATIC FACILITY shall be designed for an indoor relative humidity as not less than 80%.

4.2.2.2[A] Condensation Prevention

4.2.2.2.1[A] Cold Weather INDOOR AQUATIC FACILITY building envelope construction shall include a vapor-retarder/insulation arrangement to assist in preventing the condensation of water on inside building surfaces under the coldest outdoor conditions based on the ASHRAE climate data for the project locale or nearest reporting city and the highest design indoor relative humidity.

4.2.2.2.2[A] Paint or Coating Where a paint or coating serves as the vapor retarder of an INDOOR AQUATIC FACILITY, the paint or coating shall be applied so as to produce a permeability rating of 0.2 U.S. perm *($11.4\ ng{\cdot}s^{-1}{\cdot}m^{-2}{\cdot}Pa^{-1}$)* or less. All paints and coatings installed inside the air barrier of a facility shall meet the requirements of UL 2818-2013 through testing of products to CDPH/EHLB/Standard Method v1.1 or UL 2818-2013.

4.2.2.2.2.1 Application The paint or coating shall be applied according to the manufacturer's recommendations for use as a vapor retarder.

4.2.2.2.3 ***Perforated Interior-Finish Material*** Where a perforated interior-finish material is used in an INDOOR AQUATIC FACILITY, as for acoustic effects, the perforated material shall not be considered to be a vapor retarder unless it has a listed permeability rating less than 0.2 U.S. perm *(11.4 ng·s⁻¹·m⁻²·Pa⁻¹)*.

4.2.2.3 Mechanical Systems

4.2.2.3.1 ***Equipment Rooms*** For EQUIPMENT ROOMS, see MAHC 4.9.1.

4.2.2.3.2 ***Chemical Storage Spaces*** For CHEMICAL STORAGE SPACES, see MAHC 4.9.2.

4.2.2.3.3A ***Indoor Aquatic Facility Air Pressure*** AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with the 2011 ASHRAE Applications Handbook on Natatorium Design ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, and/or applicable local CODES with additional requirements as stated in section MAHC 4.6.2.

4.2.2.3.3.1 **Chemical Storage Space Air Pressure** AIR HANDLING SYSTEM design for CHEMICAL STORAGE SPACES shall conform to the International Mechanical Code or Uniform Mechanical Code, and either the International Fire Code or the NFPA 1 Fire Code, and any applicable local CODES.

4.2.2.3.4A ***Air Ducts*** Where air ducts are required, they shall be resistant to corrosion from the airborne chemicals.

4.2.2.3.4.1 **Insulated Exterior** Ducts shall be insulated on the exterior of the duct with a mold-resistant material where the surface temperature of the duct is capable of being less than the airstream temperature within the duct.

4.2.2.3.5 ***Filters*** Filters for outdoor-air intake shall be rated moisture-resistant.

4.2.2.4A Indoor Aquatic Facility Doors

4.2.2.4.1 ***Corrosion-Resistant*** INDOOR AQUATIC FACILITY doors shall either be constructed of corrosion-resistant materials or have a covering or coating to withstand humid and CORROSIVE environments which is acceptable to the AHJ.

4.2.2.4.2 ***Uncontrolled Condensation*** INDOOR AQUATIC FACILITY doors which may be exposed to temperatures below INDOOR AQUATIC FACILITY-air dew point shall have thermal breaks, insulation, and/or glazing as necessary to minimize the risk of uncontrolled condensation.

4.2.2.4.2.1 **Heating Systems** ***Exception:*** Other doors shall be acceptable, subject to approval by the AHJ, where heating systems are so arranged as to maintain such doors above the maximum design dew point of the INDOOR AQUATIC FACILITY air.

4.2.2.4.3 ***Biological Contaminants*** INDOOR AQUATIC FACILITY doors and door-frame construction shall not contribute to the growth of biological CONTAMINANTS.

4.2.2.4.4 ***Air Leakage*** INDOOR AQUATIC FACILITY doors and/or door frames shall be equipped with seals and/or gaskets to minimize air leakage when the door is closed.

4.2.2.4.5A ***Automatic Door Closer*** All pedestrian doors around the INDOOR AQUATIC FACILITY perimeter shall be equipped with an automatic door closer capable of closing the door completely without human assistance and a self-latching device designed to engage and keep the door closed without human assistance.

4.2.2.4.5.1 **Difference in Air Pressure** Door closers shall be able to close the door against the specified difference in air pressure between the INDOOR AQUATIC FACILITY and other INTERIOR SPACES.

4.2.2.5A Indoor Aquatic Facility Windows

4.2.2.5.1 ***Frames*** INDOOR AQUATIC FACILITY window frames shall be constructed of suitable materials or shall have a suitable covering or coating to withstand the expected atmosphere.

4.2.2.5.2 ***Biological Contaminants*** INDOOR AQUATIC FACILITY window frames shall be constructed of materials that do not contribute to the growth of biological CONTAMINANTS.

4.2.2.5.3 ***Thermal Breaks*** INDOOR AQUATIC FACILITY window frames shall have thermal breaks or be otherwise constructed to minimize the risk of uncontrolled condensation.

4.2.2.6 Indoor Aquatic Facility Electrical Systems and Components *Refer to MAHC 4.6.3*

4.3 Equipment Standards

4.3.1.[A] Accredited Standards Where applicable, all equipment used or proposed for use in AQUATIC FACILITIES governed under this CODE shall be:

1) Of a proven design and construction, and
2) CERTIFIED, LISTED, AND LABELED to a specific STANDARD for the specified equipment use by an ANSI-accredited certification organization.

4.3.2 No Standards Where STANDARDS do not exist, technical documentation shall be submitted to the AHJ to demonstrate acceptability for use in AQUATIC FACILITIES.

4.3.3 Suitable for Intent All equipment and materials used or proposed for use in AQUATIC FACILITIES shall be suitable for their intended use and be installed in accordance with this CODE, as CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization where applicable, and as specified by the manufacturer.

4.3.3.1 Proof of Acceptability The AHJ shall have the authority to require tests, as proof of acceptability.

4.4 Aquatic Facility and Venue Operation and Maintenance [N/A]

4.5 Aquatic Venue Structure

4.5.1[A] Design for Risk Management Design of AQUATIC FACILITIES and/or AQUATIC VENUE*(s)* shall include consultation with and input by the owner and/or an aquatic risk management consultant and address operational considerations such as the layout of zones of PATRON surveillance.

4.5.1.1 Basic Requirements The AQUATIC VENUE shape shall provide for the SAFETY of swimmers, the thorough and complete circulation of the water, the ability to clean and maintain the AQUATIC VENUE, and be considered when planning for effective supervision and surveillance of BATHERS and PATRONS using the AQUATIC VENUE.

4.5.1.2 Water Clarity The water in an AQUATIC VENUE shall be sufficiently clear such that the bottom is visible while the water is static.

4.5.1.2.1 ***Pools Ten Feet Deep or Less*** For POOLS 10 feet deep (*3.0 m*) or less, a 4 inch x 4 inch square *(10.2 cm x 10.2 cm)* marker tile in a contrasting color to the POOL floor or main suction outlet shall be located at the deepest part of the POOL.

4.5.1.2.2 ***Pools Over Ten Feet Deep*** For POOLS over 10 feet deep *(3.0 m)* an 8 inch by 8 inch square *(20.3 cm x 20.3 cm)* marker tile in a contrasting color to the POOL floor or main suction outlet shall be located at the deepest part of the POOL.

4.5.1.2.3 ***Visible*** This reference point shall be visible at all times at any point on the DECK up to 30 feet *(9.1 m)* away in a direct line of sight from the tile or main drain.

4.5.1.2.4 ***Spas*** For SPAS, this test shall be performed when the water is in a non-turbulent state and bubbles have been allowed to dissipate.

4.5.2 Bottom Slope

4.5.2.1[A] Under Five Feet In water depths under 5 feet *(1.5 m)*, the slope of the floor of all POOLS shall not exceed 1 foot *(30.5 cm)* vertical drop for every 12 feet *(3.7 m)* horizontal.

4.5.2.2 Five Feet or Over In water depths 5 foot *(1.5 m)* and greater, the slope of the floors of all POOLS shall not exceed 1 foot *(30.5 cm)* vertical to 3 feet *(0.9 m)* horizontal. ***Exception:*** POOLS designed and used for competitive diving shall be designed to meet the STANDARDS of the sanctioning organization *(such as NFHS, NCAA, USA Diving, or FINA)*.

4.5.2.3[A] Drain POOLS shall be designed so that they drain without leaving puddles or trapped standing water.

4.5.3 Pool Access / Egress

4.5.3.1[A] Accessibility Each POOL shall have a minimum of two means of access and egress, with one located within 10 feet *(3.0 m)* of the shallowest end, and one located within 10 feet of the deepest end of the POOL, where applicable, with the exception of:

1) WATERSLIDE landing POOLS,
2) WATERSLIDE RUNOUTS, and
3) WAVE POOLS.

4.5.3.2 Acceptable Means Acceptable means of access / egress shall include stairs / handrails, grab rails / RECESSED STEPS, ladders, ramps, and zero-depth entries.

4.5.3.3 Large Venues For POOLS wider than 30 feet *(9.1 m)*, such means of access / egress shall be provided on each side of the POOL.

4.5.3.3.1 Distance Apart For POOLS wider than 30 feet *(9.1 m)*, such means of access / egress shall not be more than 75 feet *(22.9 m)* apart.

4.5.4 Stairs

4.5.4.1 Slip Resistant Where provided, stairs shall be constructed with slip-resistant materials.

4.5.4.2 Outlined Edges The leading horizontal and vertical edges of stair treads shall be outlined with a continuous slip-resistant contrasting tile or other permanent marking of not less than 1 inch *(25.4 mm)* and not greater than 2 inches *(50.8 mm)*.

4.5.4.3[A] Deep Water Where stairs are provided in POOL water depths greater than 5 feet *(1.5 m)*, they shall be recessed and not protrude into the swimming area of the POOL.

4.5.4.3.1 Lowest Tread Where stairs are provided in POOL water depths greater than 5 feet *(1.5 m)*, the lowest tread shall be not less than 4 feet *(1.2 m)* below normal water elevation.

4.5.4.4 Stairs Stairs shall have a minimum uniform horizontal tread depth of 12 inches *(30.5 cm)*, and a minimum unobstructed tread width of 24 inches *(61.0 cm)*.

4.5.4.5 Dimensions Dimensions of stair treads for other types of stairs shall conform to requirements of

1) MAHC Table 4.5.4.5,
2) MAHC Figure 4.5.4.5.1, and
3) MAHC Figure 4.5.4.5.2

Table 4.5.4.5: Required Dimensions for Stair Treads and Risers

Dimensions	T-1 Standard	T-2	W-1	H-1
Minimum	12 inches *(30.5 cm)*	T-1	24 inches *(61.0 cm)*	6 inches *(15.2 cm)*
Maximum	18 inches *(45.7 cm)*	T-1	N/A	12 inches *(30.5 cm)*

Figure 4.5.4.5.1: Stair Treads and Risers: Side View

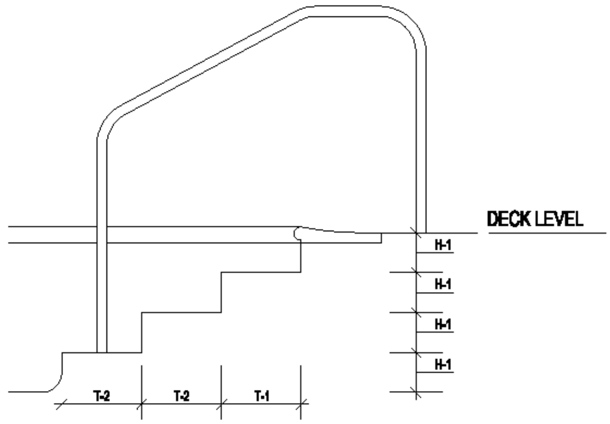
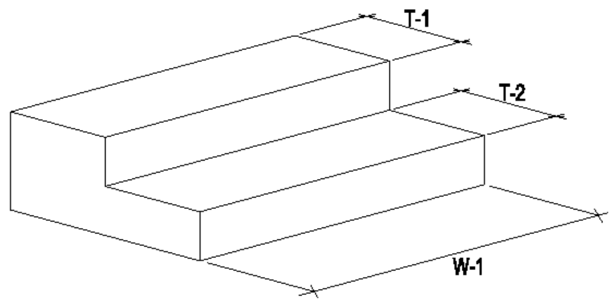


Figure 4.5.4.5.2: Stair Treads: Front View



4.5.4.6 Stair Risers Stair risers shall have a minimum uniform height of 6 inches *(15.2 cm)* and a maximum height of 12 inches *(30.5 cm)*, with a tolerance of ½ inches *(12.7 mm)* between adjacent risers.

4.5.4.6.1 Transitional Areas Stairs shall not be used underwater to transition between two sections of POOL of different depths. ***Note:*** The bottom riser may vary due to potential cross slopes with the POOL floor; however, the bottom step riser may not exceed the maximum allowable height required by this section.

4.5.4.7 Top Surface The top surface of the uppermost stair tread shall be located not more than 12 inches *(30.5 cm)* below the POOL coping or DECK.

4.5.4.8[A] Perimeter Gutter Systems For POOLS with PERIMETER GUTTER SYSTEMS, the gutter may serve as a step, provided that the gutter is provided with a grating or cover and conforms to all construction and dimensional requirements herein specified.

4.5.5 Handrails

4.5.5.1 Provided Handrail*(s)* shall be provided for each set of stairs.

4.5.5.2 Corrosion-resistant Handrails shall be constructed of corrosion-resistant materials, and anchored securely.

4.5.5.3[A] Upper Railing The upper railing surface of handrails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.1 cm)*.

4.5.5.4 Wider Than Five Feet Stairs wider than 5 feet *(1.5 m)* shall have at least one additional handrail for every 12 feet *(3.7 m)* of stair width.

4.5.5.5[A] ADAAG Accessibility Handrail outside dimensions intended to serve as a means of ADAAG accessibility shall conform to requirements of MAHC 4.5.5.6.

4.5.5.6 Support Handrails shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds (90.7 kg) applied in any direction at any location.

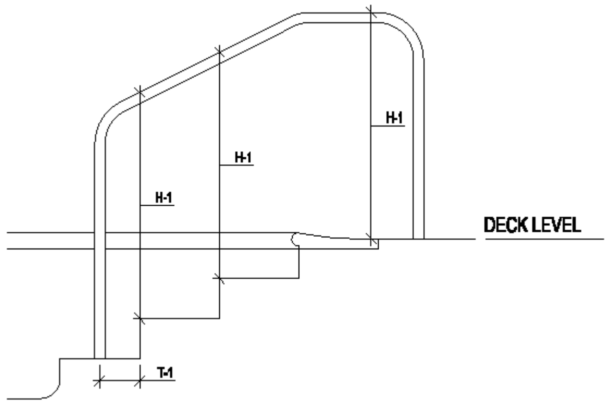
4.5.5.6.1 Transfer Loads Hand rails shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.5.7[A] Dimensions Dimensions of handrails shall conform to requirements of MAHC Table 4.5.5.7 and MAHC Figure 4.5.5.7.1.

Table 4.5.5.7: Stair Handrail Dimensions

Dimensions	T-1	H-1
Minimum	3 inches *(7.6 cm)*	34 inches *(86.4 cm)*
Maximum	N/A	38 inches *(96.5 cm)*

Figure 4.5.5.7.1: Stair Handrails: Side View



4.5.6 Grab Rails

4.5.6.1 Corrosion-Resistant Where grab rails are provided, they shall be constructed of corrosion-resistant materials.

4.5.6.2 Anchored Grab rails shall be anchored securely.

4.5.6.3 Provided Grab rails shall be provided at both sides of RECESSED STEPS.

4.5.6.4 Clear Space The horizontal clear space between grab rails shall be not less than 18 inches *(45.7 cm)* and not more than 24 inches *(61.0 cm)*.

4.5.6.5 Upper Railing The upper railing surface of grab rails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.1 cm)*.

4.5.6.6 Support Grab rails shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds *(90.7 kg)* applied in any direction at any location.

4.5.6.6.1 Transfer Loads Grab rails shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.7 Recessed Steps

4.5.7.1 Slip-Resistant RECESSED STEPS shall be slip-resistant.

4.5.7.2 Easily Cleaned RECESSED STEPS shall be designed to be easily cleaned.

4.5.7.3 Drain RECESSED STEPS shall drain into the POOL.

4.5.7.4 Dimensions Dimensions of RECESSED STEPS shall conform to requirements of:

1) MAHC Table 4.5.7.4,
2) MAHC Figure 4.5.7.4.1, and
3) MAHC Figure 4.5.7.4.2.

Table 4.5.7.4: Recessed Step Dimensions

Dimensions	H-1	H-2	W-1	D-1
Minimum	6 inches *(15.2 cm)*	5 inches *(12.7 cm)*	12 inches *(30.5 cm)*	5 inches *(12.7 cm)*
Maximum	12 inches *(30.5 cm)*	N/A	N/A	N/A

Figure 4.5.7.4.1: Recessed Step Dimensions: Side View

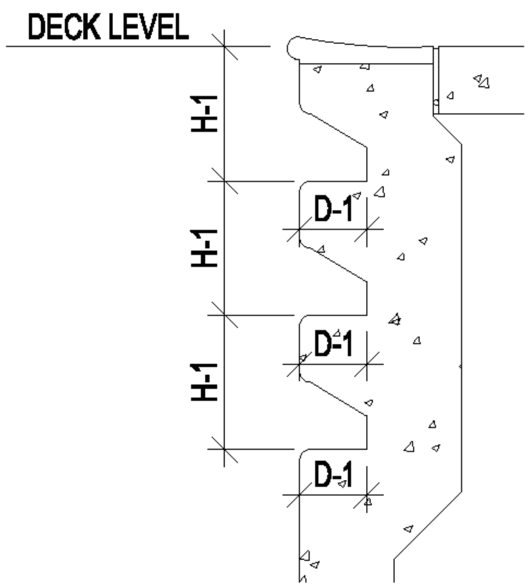
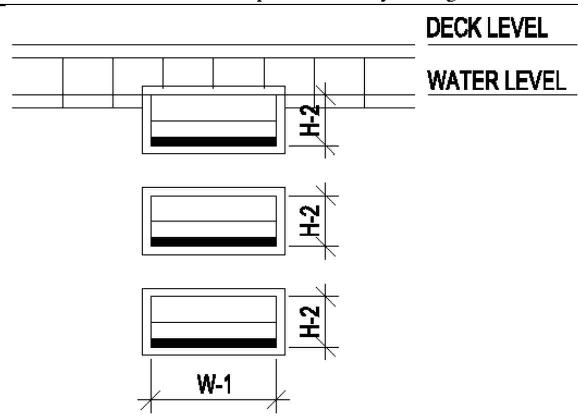


Figure 4.5.7.4.2: Recessed Step Dimensions: Front View



4.5.7.5 Uniformly Spaced RECESSED STEPS shall be uniformly spaced not less than 6 inches *(15.2 cm)* and not more than 12 inches *(30.5 cm)* vertically along the POOL wall.

4.5.7.6 Uppermost Step The top surface of the uppermost RECESSED STEP shall be located not more than 12 inches *(30.5 cm)* below the POOL coping or DECK.

4.5.7.7 Perimeter Gutter Systems For POOLS with PERIMETER GUTTER SYSTEMS, the gutter may serve as a step, provided that the gutter is provided with a grating or cover and conforms to all construction and dimensional requirements herein specified.

4.5.8 Ladders

4.5.8.1 General Guidelines for Ladders

4.5.8.1.1 Corrosion-Resistant Where provided, ladders shall be constructed of corrosion-resistant materials.

4.5.8.1.2 Anchored Ladders shall be anchored securely to the DECK.

4.5.8.2[A] Ladder Handrails

4.5.8.2.1 Two Handrails Provided Ladders shall have two handrails.

4.5.8.2.2 Clear Space The horizontal clear space between handrails shall be not less than 17 inches *(43.2 cm)* and not more than 24 inches *(61.0 cm)*.

4.5.8.2.3 Upper Railing The upper railing surface of handrails shall extend above the POOL coping or DECK a minimum of 28 inches *(71.7 cm)*.

4.5.8.2.4[A] Pool Wall The clear space between handrails and the POOL wall shall be not less than 3 inches *(7.6 cm)* and not more than 6 inches *(15.2 cm)*.

4.5.8.2.5[A] Support Ladders shall be designed to resist a load of 50 pounds *(22.7 kg)* per linear foot applied in any direction and independently a single concentrated load of 200 pounds *(90.7 kg)* applied in any direction at any location.

4.5.8.2.5.1 Transfer Loads Ladders shall be designed to transfer these loads through the supports to the POOL or DECK structure.

4.5.8.3 Ladder Treads

4.5.8.3.1 Slip Resistant Ladder treads shall be slip-resistant.

4.5.8.3.2 Tread Depth Ladder treads shall have a minimum horizontal tread depth of 1.5 inches *(3.8 cm)*.

4.5.8.3.2.1 Distance Between Tread and Pool Wall The distance between the horizontal tread and the POOL wall shall not be greater than 4 inches *(10.2 cm)*.

4.5.8.3.3 ***Uniformly Spaced*** Ladder treads shall be uniformly spaced not less than 7 inches *(17.8 cm)* and not more than 12 inches *(30.5 cm)* vertically at the handrails.

4.5.8.3.4 ***Upmost Ladder Tread*** The top surface of the upmost ladder tread shall be located not more than 12 inches *(30.5 cm)* below the POOL coping, gutter, or DECK.

4.5.9 Zero Depth (Sloped) Entries

4.5.9.1 Slip Resistant Where ZERO DEPTH ENTRIES are provided, they shall be constructed with slip-resistant materials.

4.5.9.2 Maximum Floor Slope ZERO DEPTH ENTRIES shall have a maximum floor slope of 1:12, consistent with the requirements of MAHC 4.5.2.1.

4.5.9.2.1 ***Slope Changes*** Changes in floor slope shall be permitted.

4.5.9.3 Trench Drains Trench drains shall be used along ZERO DEPTH ENTRIES at the waterline to facilitate surface skimming.

4.5.9.3.1 ***Flat or Follow Slope*** The trenches may be flat or follow the slope of the ZERO DEPTH ENTRY.

4.5.9.3.2 ***Handholds*** Any handholds that present a trip hazard shall not be continuous along the ZERO DEPTH ENTRY.

4.5.10 Disabled Access

4.5.10.1[A] Conform to ADA Standards Access for disabled persons shall conform to ADA Standards as approved by the Department of Justice.

4.5.10.2 Pool Lifts All POOL lifts shall be CERTIFIED, LISTED, AND LABELED in accordance with UL 60335-2-1000, and be installed and used in accordance with the manufacturer's installation instructions and ICC/ANSI A117.1.

4.5.11 Color and Finish

4.5.11.1[A] White or Light Pastel Floors and walls below the water line shall be white or light pastel in color such that from the POOL DECK a BATHER is visible on the POOL floor and the following items can be identified:

1) Algae growth, debris or dirt within the POOL, and
2) CRACKS in the surface finish of the POOL, and
3) Marker tiles defined in MAHC 4.5.1.2.

4.5.11.1.1[A] ***Munsell Color Value*** The finish shall be at least 6.5 on the Munsell color value scale.

4.5.11.1.2 ***Exceptions*** An exception shall be made for the following AQUATIC VENUE components:

1) Competitive lane markings,
2) Dedicated competitive diving well floors,
3) Step or bench edge markings,
4) POOLS shallower than 24 inches *(61.0 cm)*,
5) Water line tiles,
6) WAVE POOL and SURF POOL depth change indicator tiles, or
7) Other approved designs.

4.5.11.1.3 ***Darker Colors*** Munsell color values less than 6.5 or designs such as rock formations may be permitted by the AHJ as long as the criteria in MAHC 4.5.11.1 are met.

4.5.12 Walls

4.5.12.1 Plumb POOL walls shall be plumb within a +/- 3 degree tolerance to a water depth of at least 5 feet *(1.5 m)*, unless the wall design requires structural support ledges and slopes below to support the upper wall. Refer to MAHC Figure 4.5.12.4.

4.5.12.2 Support Ledges and Slopes All structural support ledges and slopes of the wall shall fall entirely within a plane slope from the water line at not greater than a +/- 3 degree tolerance.

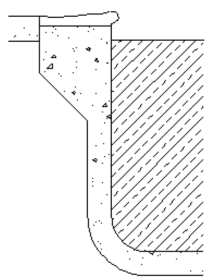
4.5.12.2.1 Contrasting Color A contrasting color shall be provided on the edges of any support ledge to draw attention to the ledge for BATHER SAFETY.

4.5.12.3 Rounded Corners All corners created by adjoining walls shall be rounded or have a radius in both the vertical and horizontal dimensions to eliminate sharp corners.

4.5.12.4[A] No Protrusions, Extensions, Means of Entanglement, or Obstructions There shall be no protrusions, extension, means of entanglement, or other obstructions in the AQUATIC VENUE that may cause the entrapment or injury of the user or interfere with proper POOL operation. Refer to MAHC Figure 4.5.12.4. Plumb Pool Walls.

Figure 4.5.12.1: Plumb Pool Walls: Cross-Section

Plumb within a +/- 3 degree tolerance.



4.5.13[A] Structural Stability

4.5.13.1 Withstand Loads POOLS shall be designed to withstand the reasonably anticipated loads imposed by POOL water, BATHERS, and adjacent soils or structures.

4.5.13.2 Hydrostatic Relief Valve A hydrostatic relief valve and/or suitable under drain system shall be provided where the water table exerts hydrostatic pressure to uplift the POOL when empty or drained.

4.5.13.3 Freezing POOLS and related circulation piping shall be designed with a winterizing strategy when in an area subject to freeze/thaw cycles.

4.5.14[A] Handholds

4.5.14.1 Handholds Provided Where not otherwise exempted, every POOL shall be provided with handholds *(PERIMETER GUTTER SYSTEM, coping, horizontal bars, recessed handholds, cantilevered DECKING)* around the perimeter of the POOL where the water depth at the wall exceeds 24 inches *(61.0 cm)*.

4.5.14.1.1 Installed These handholds shall be installed not greater than 9 inches *(22.9 cm)* above, or 3 inches *(7.6 cm)* below static water level.

4.5.14.2 Horizontal Recesses Horizontal recesses may be used for handholds provided they are a minimum of 24 inches *(61.0 cm)* long, a minimum of 4 inches *(10.2 cm)* high and between 2 inches *(5.1 cm)* and 3 inches *(7.6 cm)* deep.

4.5.14.2.1 Drain Horizontal recesses shall drain into the POOL.

4.5.14.2.2 Consecutive Recesses Horizontal recesses need not be continuous, but consecutive recesses shall be separated by no more than 12 inches *(30.5 cm)* of wall.

4.5.14.3 Decking Where PERIMETER GUTTER SYSTEMS are not provided, a coping or cantilevered DECKING of reinforced concrete or material equivalent in strength and durability, with rounded, slip-resistant edges shall be provided.

4.5.14.4 Coping Dimensions The overhang for coping or cantilevered DECKING shall not be greater than 2 inches *(50 mm)* from the vertical plane of the POOL wall, nor less than 1 inch *(2.5 cm)*.

4.5.14.5 Coping Thickness The overhang for coping or cantilevered DECKING shall not exceed 3.5 inches *(8.9 cm)* in thickness for the last 2 inches *(5.1 cm)* of the overhang.

4.5.15 Infinity Edges

4.5.15.1[A] Perimeter Restrictions Not more than fifty percent *(50%)* of the POOL perimeter shall incorporate an INFINITY EDGE detail, unless an adjacent and PATRON accessible DECK space conforming to MAHC 4.8.1 is provided.

4.5.15.2 Length The length of an INFINITY EDGE shall be no more than 30 feet *(9.1 m)* long when in water depths greater than 5 feet *(1.5 m)*.

4.5.15.2.1 Shallow Water No maximum distance is enforced for the length of INFINITY EDGES in shallow water 5 feet *(1.5 m)* and less.

4.5.15.3[A] Handholds Handholds conforming to the requirements of MAHC 4.5.14 shall be provided for INFINITY EDGES, which may be separate from, or incorporated as part of the INFINITY EDGE detail.

4.5.15.4 Construction Guidelines Where INFINITY EDGES are provided, they shall be constructed of reinforced concrete or other impervious and structurally rigid material*(s)*, and designed to withstand the loads imposed by POOL water, BATHERS, and adjacent soils or structures.

4.5.15.5 Overflow Basins Troughs, basins, or capture drains designed to receive the overflow from INFINITY EDGES shall be watertight and free from STRUCTURAL CRACKS.

4.5.15.5.1 Finish Troughs, basins, or capture drains designed to receive the overflow from INFINITY EDGES shall have a non-toxic, smooth, and slip-resistant finish.

4.5.15.6[A] Maximum Height The maximum height of the wall outside of the INFINITY EDGE shall not exceed 30 inches *(76.2 cm)* to the adjacent grade and capture drain.

4.5.16[A] Underwater Benches

4.5.16.1[A] Slip Resistant Where provided, UNDERWATER BENCHES shall be constructed with slip-resistant materials having a minimum dynamic coefficient of friction at least equal to the requirements of ANSI A137.1-2012 of 0.42 as measured by the DCOF AcuTest.

4.5.16.2 Outlined Edges The leading horizontal and vertical edges of UNDERWATER BENCHES shall be outlined with a continuous slip-resistant color contrasting tile or other permanent marking of not less than ¾ inch *(1.9 cm)* and not greater than 2 inches *(5.1 cm)*.

4.5.16.3[A] Maximum Water Depth UNDERWATER BENCHES may be installed in areas of varying depths, but the maximum POOL water depth in that area shall not exceed 5 feet *(1.5 m)*.

4.5.16.4 Maximum Seat Depth The maximum submerged depth of any seat or sitting bench shall be 20 inches *(50.8 cm)* measured from the water line.

4.5.17 Underwater Ledges

4.5.17.1[A] Slip Resistant Where UNDERWATER TOE LEDGES are provided to enable swimmers in deep water to rest or to provide structural support for an upper wall, they shall be constructed with slip-resistant materials.

4.5.17.2 Protrude UNDERWATER TOE LEDGES for resting that are recessed or protrude beyond the vertical plane of the POOL wall shall meet the criteria for slip resistance and tread depth outlined in this section.

4.5.17.3[A] Five Feet or Greater UNDERWATER TOE LEDGES for resting shall only be provided within areas of a POOL with water depths of 5 feet *(1.5 m)* or greater.

4.5.17.3.1 Underwater Toe Ledge UNDERWATER TOE LEDGES shall start no earlier than 4 lineal feet *(1.2 m)* to the deep side of the 5 foot *(1.5 m)* slope break.

4.5.17.3.2 Below Water Level UNDERWATER TOE LEDGES shall be at least 4 feet *(1.2 m)* below static water level.

4.5.17.4[A] Structural Support UNDERWATER LEDGES for structural support of upper walls shall be allowed.

4.5.17.5 Outlined The edges of UNDERWATER TOE LEDGES shall be outlined with a continuous slip-resistant color contrasting tile or other permanent marking of not less than 1 inch *(2.5 cm)* and not greater than 2 inches *(5.1 cm)*.

4.5.17.5.1 Visible If they project past the plane of the POOL wall, the edges of UNDERWATER TOE LEDGES shall be clearly visible from the DECK.

4.5.17.6 Tread Depths UNDERWATER TOE LEDGES shall have a maximum uniform horizontal tread depth of 4 inches *(10.2 cm)*. See MAHC Figure 4.5.12.4.

4.5.18[A] Underwater Shelves

4.5.18.1 Immediately Adjacent UNDERWATER SHELVES may be constructed immediately adjacent to water shallower than 5 feet *(1.5 m)*.

4.5.18.2 Nosing UNDERWATER SHELVES shall have a slip-resistant, color contrasting nosing at the leading horizontal and vertical edges on both the top of horizontal edges and leading vertical edges and should be viewable from the DECK or from underwater.

4.5.18.3 Maximum Depth UNDERWATER SHELVES shall have a maximum depth of 24 inches *(61.0 cm)*.

4.5.19[A] Depth Markers and Markings

4.5.19.1 Location

4.5.19.1.1 Markings POOL water depths shall be clearly and permanently marked at the following locations:

1) Minimum depth,
2) Maximum depth,
3) On both sides and at each end of the POOL and,
4) At the break in the floor slope between the shallow and deep portions of the POOL.

4.5.19.1.2[A] Depth Measurements Depth markers shall be located on the vertical POOL wall and positioned to be read from within the POOL.

4.5.19.1.3[A] Below Handhold Where depth markings cannot be placed on the vertical wall above the water level, other means shall be used so that the markings will be plainly visible to persons in the POOL.

4.5.19.1.4 Coping or Deck Depth markers shall also be located on the POOL coping or DECK within 18 inches *(45.7 cm)* of the POOL structural wall or perimeter gutter.

4.5.19.1.5 Read on Deck Depth markers shall be positioned to be read while standing on the DECK facing the POOL.

4.5.19.1.6 ***Twenty-Five Foot Intervals*** Depth markers shall be installed at not more than 25 foot *(7.6 m)* intervals around the POOL perimeter edge and according to the requirements of this section.

4.5.19.1.6.1 **Five Feet or Less** For water less than 5 feet *(1.5 m)* in depth, the depth shall be marked at 1 foot *(30.5 cm)* depth intervals.

4.5.19.2 Construction / Size

4.5.19.2.1 ***Durable*** Depth markers shall be constructed of a durable material resistant to local weather conditions.

4.5.19.2.2 ***Slip Resistant*** Depth markers shall be slip resistant when they are located on horizontal surfaces.

4.5.19.2.3^A^ ***Color and Height*** Depth markers shall have letters and numbers with a minimum height of 4 inches *(10.2 cm)* of a color contrasting with background.

4.5.19.2.4^A^ ***Feet and Inches*** Depth markers shall be marked in units of feet and inches.

4.5.19.2.4.1 **Abbreviations** Abbreviations of “FT” and “IN” may be used in lieu of “FEET” and “INCHES.”

4.5.19.2.4.1.1 **Abbreviations** Symbols for feet *(‘)* and inches *(“)* shall not be permitted on water depth signs.

4.5.19.2.4.2 **Metric** Metric units may be provided in addition to—but not in lieu of—units of feet and inches.

4.5.19.3 **Tolerance** Depth markers shall be located to indicate water depth to the nearest 3 inches *(7.6 cm)*, as measured from the POOL floor 3 feet *(0.9 m)* out from the POOL wall to the gutter lip, mid-point of surface SKIMMER*(S)*, or surge weir*(s)*.

4.5.19.4 No Diving Markers

4.5.19.4.1^A^ ***Depths*** For POOL water depths 5 feet *(1.5 m)* or shallower, all DECK depth markers required by MAHC 4.5.19 shall be provided with “NO DIVING” warning signs along with the universal international symbol for “NO DIVING.”

4.5.19.4.1.1 **Spacing** “NO DIVING” warning signs and symbols shall be spaced at no more than 25 foot *(7.6 m)* intervals around the POOL perimeter edge.

4.5.19.4.2 ***Durable*** “NO DIVING” MARKERS shall be constructed of a durable material resistant to local weather conditions.

4.5.19.4.3 ***Slip Resistant*** “NO DIVING” MARKERS shall be slip-resistant when they are located on horizontal surfaces.

4.5.19.4.4 ***At Least Four Inches*** All lettering and symbols shall be at least 4 inches *(10.2 cm)* in height.

4.5.19.5^A^ Depth Marking At Break in Floor Slope

4.5.19.5.1 ***Over Five Feet*** For POOLS deeper than 5 feet *(1.5 m)*, a line of contrasting color, not less than 2 inches *(5.1 cm)* and not more than 6 inches *(15.2 cm)* in width, shall be clearly and permanently installed on the POOL floor at the shallow side of the break in the floor slope, and extend up the POOL walls to the waterline.

4.5.19.5.2 ***Durable*** Depth marking at break in floor slope shall be constructed of a durable material resistant to local weather conditions and be slip resistant.

4.5.19.5.3 ***Safety Rope*** One foot *(30.5 cm)* to the shallow water side of the break in floor slope and contrasting band, a SAFETY float rope shall extend across the POOL surface with the exception of WAVE POOLS, SURF POOLS, and WATERSLIDE LANDING POOLS.

4.5.19.6[A] Dual Marking System Symmetrical AQUATIC VENUE designs with the deep point at the center may be allowed by providing a dual depth marking system which indicates the depth at the wall as measured in MAHC 4.5.19.3 and at the deep point.

4.5.19.7 Non-Traditional Aquatic Venues Controlled-access AQUATIC VENUES *(such as ACTIVITY POOLS, LAZY RIVERS, and other AQUATIC VENUES with limited access)* shall only require depth markers on a sign at points of entry.

4.5.19.7.1 Clearly Visible Depth marker signs shall be clearly visible to PATRONS entering the VENUE.

4.5.19.7.2 Lettering and Symbols All lettering and symbols shall be as required for other types of depth markers.

4.5.19.8[A] Wading Pool Depth Markers AQUATIC VENUES where the maximum water depth is 6 inches *(15.2 cm)* of water or less *(such as WADING POOLS and ACTIVITY POOL areas)* shall not be required to have depth markings or "NO DIVING" signage.

4.5.19.9 Movable Floor Depth Markers For AQUATIC VENUES with movable floors, a sign indicating movable floor and/or varied water depth shall be provided and clearly visible from the DECK.

4.5.19.9.1 Vertical Measurement The posted water depth shall be the water level to the floor of the AQUATIC VENUE according to a vertical measurement taken 3 feet *(0.9 m)* from the AQUATIC VENUE wall.

4.5.19.9.2 Signage A sign shall be posted to inform the public that the AQUATIC VENUE has a varied depth and refer to the sign showing the current depth.

4.5.19.10 Spas A minimum of two depth markers shall be provided regardless of the shape or size of the SPA as per MAHC 4.12.1.6.

4.5.20 Aquatic Venue Shell Maintenance [N/A]

4.5.21[A] Special Use Aquatic Venues

4.5.21.1 Adequately Support The design professional shall provide information to adequately support why the SPECIAL USE AQUATIC VENUE does not meet the definition and use characteristics of other categories of AQUATIC VENUES or POOLS listed in the CODE.

4.5.21.2 Justification The design professional shall provide justification for design parameters that do not meet the design STANDARDS and construction requirements listed in MAHC 4.0.

4.6 Indoor / Outdoor Environment

4.6.1 Lighting

4.6.1.1 General Requirements

4.6.1.1.1 Outdoor Aquatic Venues Lighting as described in this subsection shall be provided for all outdoor AQUATIC VENUES open for use from 30 minutes before sunset to 30 minutes after sunrise, or during periods of natural illumination below the levels required in MAHC 4.6.1.3.1.

4.6.1.1.2 Accessible No lighting controls shall be accessible to PATRONS or BATHERS.

4.6.1.2[A] Windows / Natural Light Where natural lighting methods are used to meet the light level requirements of MAHC 4.6.1.3 during portions of the day when adequate natural lighting is available, one of the following methods shall be used to ensure that lights are turned on when natural lighting no longer meets these requirements:

1) Automatic lighting controls based on light levels or time of day, or
2) Written operations procedures where manual controls are used.

4.6.1.3[A] Light Levels POOL water surface and DECK light levels shall meet the following minimum maintained light levels:

1) Indoor Water Surface: 30 horizontal footcandles *(323 lux)*
2) Outdoor Water Surface: 10 horizontal footcandles *(108 lux)*
3) DECK: 10 horizontal footcandles *(108 lux)*.

Note: Higher levels may be advisable for acceptable spectator viewing for competitive swimming and diving events.

4.6.1.4[A] Overhead Lighting

4.6.1.4.1[A] Artificial Lighting Artificial lighting shall be provided at all AQUATIC VENUES which are to be used at night or which do not have adequate natural lighting.

4.6.1.4.2 Aquatic Venue Floor Lighting shall illuminate all parts of the floor of the AQUATIC VENUE to enable a QUALIFIED LIFEGUARD or other person to determine whether a BATHER is on the floor of the AQUATIC VENUE.

4.6.1.4.3 Aquatic Venue Illumination Lighting shall illuminate all parts of the AQUATIC VENUE including the water, the depth markers, signs, entrances, restrooms, SAFETY equipment, and the required DECK area and walkways.

4.6.1.5[A] Underwater Lighting

4.6.1.5.1[A] Minimum Requirements Underwater lighting, where provided, shall be not less than eight initial rated lumens per square foot of POOL water surface area.

4.6.1.5.1.1 Location Such underwater lights, in conjunction with overhead or equivalent DECK lighting, shall be located to provide illumination so that all portions of the AQUATIC VENUE, including the AQUATIC VENUE bottom and drain*(s)*, may be readily seen.

4.6.1.5.1.2 Higher Light Levels Higher underwater light levels shall be considered for deeper water to achieve this outcome.

4.6.1.5.2 Dimmable Lighting Dimmable lighting shall not be used for underwater lighting.

4.6.1.6[A] Night Swimming with No Underwater Lighting

4.6.1.6.1 Minimum Requirements Where outdoor POOLS are open for use from 30 minutes before sunset to 30 minutes after sunrise, or during periods of low illumination, underwater lighting may be excluded where:

1) Maintained POOL surface lighting levels are a minimum of 15 horizontal footcandles *(161 lux),* and
2) All portions of the POOL, including the bottom and drain*(s)*, are readily visible as required in MAHC 5.7.6.1.

4.6.1.7[A] Emergency Lighting

4.6.1.7.1 Emergency Egress Lighting POOL areas requiring lighting shall be provided with emergency egress lighting in compliance with the applicable building CODES.

4.6.1.7.2 Footcandles The path of egress shall be illuminated to at least a value of 0.5 footcandles *(5.4 lux)*.

4.6.1.8[A] Glare Windows and any other features providing natural light into the POOL space and overhead or equivalent DECK lighting shall be designed or arranged to inhibit or reduce glare on the POOL water surface that would prevent seeing objects on the POOL bottom.

4.6.2[A] Indoor Aquatic Facility Ventilation

4.6.2.1[A] Purpose INDOOR AQUATIC FACILITY AIR HANDLING SYSTEMS shall be designed, constructed, and installed to support the health and SAFETY of the building's PATRONS.

4.6.2.2[A] Exemptions INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design requirements do not apply to AQUATIC FACILITIES that do not meet the definition of a "Building" in the IBC 2012.

4.6.2.3 Indoor Aquatic Facility AIR HANDLING SYSTEM design requirements shall apply to new or SUBSTANTIALLY ALTERED INDOOR AQUATIC FACILITIES including the area of the building's AQUATIC VENUES and the surrounding BATHER and spectator/STADIUM SEATING areas.

4.6.2.4 Mechanical Code INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with applicable local CODES.

4.6.2.5[A] ASHRAE 62.1 Compliance INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design, construction, and installation shall comply with ASHRAE Standard 62.1 2013, *Ventilation for Acceptable Indoor Air Quality*, and/or applicable local CODES with additional requirements as stated in MAHC 4.6.2.6.

4.6.2.6 Air Handling System Design

4.6.2.6.1 Mechanical Systems Ventilation shall be provided through mechanical systems and/or engineered openings for natural ventilation.

4.6.2.6.2[A] Design Factors and Performance Requirements The AIR HANDLING SYSTEM design engineer shall provide plan drawings and documentation with the following components showing the design meets the performance requirements per MAHC 4.6.2.7:

1) Building layout identifying the location of the INDOOR AQUATIC FACILITY;
2) INDOOR AQUATIC FACILITY size including area in square feet and volume in cubic feet;
3) The area in square feet for DECK and for STADIUM SEATING sections;
4) THEORETICAL PEAK OCCUPANCY per AQUATIC VENUE and DECK spaces;
5) Placement of AIR HANDLING SYSTEM and other building outdoor air intakes exterior to the building;
6) Placement of AIR HANDLING SYSTEM and other building exhaust vents exterior to the building;
7) Placement of return air intakes within the INDOOR AQUATIC FACILITY;
8) Placement of supply air locations within the INDOOR AQUATIC FACILITY;
9) Identify system capabilities, if utilized, to automatically or manually modulate the amount of outdoor air for the purposes of reducing the number of cfm of outdoor air when occupancy is lower than THEORETICAL PEAK OCCUPANCY; and
10) Identify system design to maintain negative air pressure in the INDOOR AQUATIC FACILITY relative to the indoor areas external to it.

4.6.2.6.3[A] Other Air Handling Systems AIR HANDLING SYSTEM design for CHEMICAL STORAGE SPACES, mechanical, toilet, SHOWER, and dressing rooms are not included in the scope of this section of the CODE, but shall be considered for their effects on the performance requirements of MAHC 4.6.2.7 such as maintaining negative pressure, temperature differences, and contribution to the air volume of the INDOOR AQUATIC FACILITY.

4.6.2.6.4 High Volume, Low Speed Fans AIR HANDLING SYSTEM design may not consider mechanical fans used to push air within the space as part of the outdoor air calculations for the INDOOR AQUATIC FACILITY as defined in MAHC 4.6.2.7.

4.6.2.6.4.1 Air Delivery Rate Mechanical fans used to push air within the space may be used in the calculation for air delivery rate (TURNOVER).

4.6.2.6.5 Occupied and Open All Seasons AIR HANDLING SYSTEM design may include natural ventilation calculated in accordance with the ASHRAE Handbooks to substitute the corresponding portion of mechanical ventilation only if all the calculated exterior openings will be continuously controlled open during all times the INDOOR AQUATIC FACILITY is occupied, regardless of season.

4.6.2.6.6 Air Distribution Design The design of the distribution of supply air and distribution of exhaust or return air shall consider obstacles such as support columns, architectural structures, and AQUATIC FEATURES.

4.6.2.7 Performance Requirements for Air Handling Systems

4.6.2.7.1[A] Minimum Outdoor Air Requirements The AIR HANDLING SYSTEM shall have a design capability to supply the minimum outdoor air requirements using ASHRAE Standard 62.1 2013, *Ventilation for Acceptable Indoor Air Quality*.

4.6.2.7.2[A] System Alarm The AIR HANDLING SYSTEM design shall provide system features to notify the operator if the outdoor air flow rate entering the INDOOR AQUATIC FACILITY is below 0.48 cfm/ft^2 *(1.8 m^3/h)*.

4.6.2.7.3 Real-Time Occupancy Design of the AIR HANDLING SYSTEM shall meet the requirements for the number of cfm/ft^2 based on the THEORETICAL PEAK OCCUPANCY.

4.6.2.7.3.1 Method to Determine If a method to determine real-time actual occupancy is available, then the system may modulate to reduce outdoor air cfm to meet the requirement for the actual occupancy for the associated time frame.

4.6.2.7.4 Air Delivery Rate The AIR HANDLING SYSTEM shall supply an air delivery rate as defined in ASHRAE Handbook – HVAC Applications 2011, *Places of Assembly, Natatoriums*.

4.6.2.7.5 Consistent Air Flow INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM shall be designed to provide consistent air flow through all parts of the INDOOR AQUATIC FACILITY to preclude any stagnant areas.

4.6.2.7.6[A] Relative Humidity The AIR HANDLING SYSTEM shall maintain the relative humidity in the space as defined in *ASHRAE Handbook: HVAC Applications, 2011, Places of Assembly, Natatoriums*.

4.6.2.7.6.1 Dew Point The AIR HANDLING SYSTEM shall be designed to maintain the dew point of the INTERIOR SPACE less than the dew point of the interior walls at all times so as to prevent damage to structural members and to prevent biological growth on walls.

4.6.2.7.6.2 Condensation & Mold Control The AIR HANDLING SYSTEM shall be designed to achieve several objectives including

1) Maintaining space conditions,
2) Delivering the outside air to the breathing area, and
3) Flushing the outside walls and windows, which can have the lowest surface temperature and therefore the greatest chance for condensation.

4.6.2.7.7 Negative Air Pressure AIR HANDLING SYSTEM air flow shall be designed to maintain negative air pressure in the INDOOR AQUATIC FACILITY relative to the areas external to it *(such as adjacent indoor spaces and outdoor ambient space)*.

4.6.2.7.8[A] Disinfection By-Product Removal Sufficient return air intakes shall be placed near AQUATIC VENUE surfaces such that they remove the highest concentration of airborne DBP contaminated air.

4.6.2.7.8.1 Airflow Across Water Surface The AIR HANDLING SYSTEM shall be designed considering airflow across the water surface to promote removal of DBPS.

4.6.2.7.9 Re-Entrainment of Exhaust AIR HANDLING SYSTEM outdoor air intakes shall be placed to minimize RE-ENTRAINMENT of exhaust air from building systems back into the facility.

4.6.2.7.9.1 System Exhaust AIR HANDLING SYSTEM exhaust from CHEMICAL STORAGE SPACES, mechanical, toilet, SHOWER, and dressing rooms shall not be directed into the AQUATIC FACILITY.

4.6.2.7.10 Access Control The AIR HANDLING SYSTEM shall be designed to provide a means to limit physical or electronic access to system control to the operator and anyone the operator deems to have access.

4.6.2.7.11[A] Purge The AIR HANDLING SYSTEM shall have the capability to periodically PURGE air for air quality maintenance or for emergency situations.

4.6.2.7.11.1 Purge Capacity The AIR HANDLING SYSTEM shall have a PURGE capacity equal or greater than two times the ASHRAE Standard 62.1 2013 level.

4.6.2.7.11.1.1 **Manual Activation** This PURGE shall be capable of being manually activated.

4.6.2.7.11.2 **Outdoor Air** Outdoor air required for PURGE shall not be required to be heated or otherwise treated.

4.6.2.7.12A ***Air Handling System Filters*** The AIR HANDLING SYSTEM design shall include filters for outdoor air and recirculated air with a MERV rating of 8.

4.6.2.8 Air Handling System Installation

4.6.2.8.1 ***Air Handling System Procedures*** The contractor installing the INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM shall provide the AQUATIC FACILITY owner with an operating manual from the manufacturer which includes:

1) Startup and shutdown procedures;
2) PURGING and other SAFETY procedures;
3) Cleaning procedures;
4) General maintenance requirements with parts listings and frequency of maintenance *(i.e., filter cleaning frequencies, motor bearing maintenance)*;
5) Pressure differential specifications for filter replacement, filter replacement type, and frequency of cleaning or replacement;
6) Troubleshooting processes;
7) Frequency of required calibration of equipment;
8) Descriptions of general operating schemes; and
9) Contact information for the manufacturer.

4.6.2.9 Air Handling System Commissioning

4.6.2.9.1 ***System Commissioning*** A qualified, licensed professional shall commission the AIR HANDLING SYSTEM to verify that the installed system is operating properly in accordance with the system design.

4.6.2.9.2 ***Written Statement*** A written statement of commissioning shall be provided to the AQUATIC FACILITY owner including but not limited to:

1) The number of cfm of outdoor air flowing into the INDOOR AQUATIC FACILITY at the time of commissioning;
2) The number of cfm of exhaust air flowing through the system at the time of commissioning; and,
3) A statement that the amount of outdoor air meets the performance requirements of MAHC 4.6.2.7.

4.6.3 Indoor/Outdoor Aquatic Facility Electrical Systems and Components

4.6.3.1A General Guidelines

4.6.3.1.1 ***NEC Requirements*** Electrical wiring and systems shall comply with the requirements of the NEC.

4.6.3.1.1.1 **Providing Relief** Nothing in this CODE shall be construed as providing relief from any applicable requirements of the NEC or other applicable CODE.

4.6.3.1.2A ***Indoor Aquatic Facilities*** An INDOOR AQUATIC FACILITY shall be considered a wet and CORROSIVE environment.

4.6.3.2A Electrical Equipment in Interior Chemical Storage Spaces

4.6.3.2.1A ***Wet and Corrosive*** CHEMICAL STORAGE SPACES shall be considered wet and CORROSIVE environments.

4.6.3.2.2A ***Electrical Conduit*** Electrical conduit shall not enter or pass through an interior

CHEMICAL STORAGE SPACE, except as required to service devices integral to the function of the room, such as pumps, vessels, controls, lighting and SAFETY devices or, if allowed by the NEC.

4.6.3.2.2.1 Sealed and Inert Where required, the electrical conduit in an interior CHEMICAL STORAGE SPACE shall be sealed and made of materials that will not interact with any chemicals in the CHEMICAL STORAGE SPACE.

4.6.3.2.3*[A] *Electrical Devices Electrical devices or equipment shall not occupy an interior CHEMICAL STORAGE SPACE, except as required to service devices integral to the function of the room, such as pumps, vessels, controls, lighting and SAFETY devices.

4.6.3.2.4*[A] *Protected Against Breakage Lamps, including fluorescent tubes, installed in interior CHEMICAL STORAGE SPACES shall be protected against breakage with a lens or other cover, or be otherwise protected against the accidental release of hot materials.

4.6.4[A] Pool Water Heating

4.6.4.1[A] High Temperature When designing POOL heating equipment, measures shall be taken to prevent BATHER exposure to water temperatures in excess of 104°F *(40°C)*.

4.6.4.2 Pressure Relief Device Where POOL water heating equipment is installed with valves capable of isolating the heating equipment from the POOL, a listed pressure-relief device shall be installed to limit the pressure on the heating equipment to no more than the maximum value specified by the heating-equipment manufacturer and applicable CODES.

4.6.4.3 Code Compliance POOL-water heating equipment shall be selected and installed to preserve compliance with the applicable CODES, the terms of listing and labeling of equipment, and with the equipment manufacturer's installation instructions and applicable CODES.

4.6.4.4[A] Equipment Room Requirements Where POOL water heaters use COMBUSTION and are located inside a building, the space in which the heater is located shall be considered to be an EQUIPMENT ROOM, and the requirements of MAHC 4.9.1 shall apply.

4.6.4.4.1 Carbon Monoxide Detector A carbon monoxide detector with local alarming, CERTIFIED, LISTED, AND LABELED in accordance with UL 2075, shall be installed in all such EQUIPMENT ROOMS.

4.6.4.4.2 Adjacent Rooms All rooms that are immediately adjacent to spaces containing fuel burning equipment or vents carrying the products of combustion shall also be provided with locally alarming carbon monoxide detectors.

4.6.4.5 Exception Heaters CERTIFIED, LISTED, AND LABELED for the atmosphere shall be acceptable without isolation from chemical fumes and vapors.

4.6.5 First Aid Area

4.6.5.1[A] Station Design Design and construction of new AQUATIC FACILITIES shall include an area designated for first aid equipment and/or treatment.

4.6.6 Emergency Exit

4.6.6.1 Labeling Gates and/or doors which will allow egress without a key shall be clearly and conspicuously labeled in letters at least 4 inches (10.2 cm) high "EMERGENCY EXIT."

4.6.7 Drinking Fountains

4.6.7.1[A] Provided A drinking fountain shall be provided inside an AQUATIC FACILITY and shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 61-2014 and UL 399.

4.6.7.1.1 Alternative Alternate locations or the use of bottled water shall be evaluated by the AHJ.

4.6.7.1.2 Common Use Area If the drinking fountain cannot be provided inside the AQUATIC FACILITY, it shall be provided in a common use building or area adjacent to the AQUATIC FACILITY entrance and on the normal path of BATHERS going to the AQUATIC FACILITY entrance.

4.6.7.2 **Readily Accessible** The drinking fountain shall be located where it is readily accessible and not a hazard to BATHERS per MAHC 4.10.2.

4.6.7.2.1 ***Not Located*** The drinking fountain shall not be located in a SHOWER area or toilet area.

4.6.7.3 **Single Fountain** A single drinking fountain shall be allowed for one or more AQUATIC VENUES within an AQUATIC FACILITY.

4.6.7.4 **Angle Jet Type** The drinking fountain shall be an angle jet type installed according to applicable plumbing CODES.

4.6.7.5 **Potable Water Supply** The drinking fountain shall be supplied with water from an approved potable water supply.

4.6.7.6 **Wastewater** The wastewater discharged from a drinking fountain shall be routed to an approved sanitary sewer system or other approved disposal area according to applicable plumbing CODES.

4.6.8 Garbage Receptacles

4.6.8.1 **Sufficient Number** A sufficient number of receptacles shall be provided within an AQUATIC FACILITY to ensure that garbage and refuse can be disposed of properly to maintain safe and sanitary conditions.

4.6.8.2 **Number and Location** The number and location of receptacles shall be at the discretion of the AQUATIC FACILITY manager.

4.6.8.3 **Closable** Receptacles shall be designed to be closed with a lid or other cover so they remain closed until intentionally opened.

4.6.9 Food and Drink Concessions

4.6.9.1 **Meet AHJ Requirements** Concessions for food and drink in an AQUATIC FACILITY shall meet all AHJ requirements.

4.6.10 Spectator Areas

4.6.10.1 **Within Aquatic Facility Enclosure** An area designed for use by spectators may be located within an AQUATIC FACILITY ENCLOSURE.

4.6.10.2 **Deck** When a spectator area or an access to a spectator area is located within the AQUATIC FACILITY ENCLOSURE, the DECK adjacent to the area or access shall provide egress width for the spectators in addition to the width required by MAHC 4.8.1.5.

4.6.10.2.1^A^ ***Additional Width*** The additional width shall be based on the egress requirements in the applicable building CODE based on the THEORETICAL PEAK OCCUPANCY of the AQUATIC FACILITY served with a minimum width of 4 feet *(1.2 m)* and have either of the following qualities outlined in MAHC 4.6.10.2.1.1 or MAHC 4.6.10.2.1.2.

4.6.10.2.1.1 **Barrier** A BARRIER as defined in MAHC 4.8.6.1 located on the DECK to separate the DECK used by spectators from the PERIMETER DECK used by BATHERS.

4.6.10.2.1.1.1 **Openings** The BARRIER may have one or more openings directly into the BATHER areas.

4.6.10.2.1.2 **Demarcation Line** A demarcation line on the DECK that shows the separation between the DECK used by spectators and the PERIMETER DECK used by BATHERS.

4.6.10.3[A] **Balcony** A spectator or other area located in a balcony within 10 feet *(3.0 m)* of or overhanging any portion of an AQUATIC VENUE shall be designed to deter jumping or diving into the AQUATIC VENUE.

4.6.10.4[A] **Bleachers** Bleachers in a spectator area shall be designed according to the ICC's most recent version of the 300 Standard or another applicable CODE.

4.6.11 Indoor Aquatic Facility Acoustics

4.6.11.1[A] Acoustic Design Criteria Acoustic design requirements shall apply to a new INDOOR AQUATIC FACILITY or one that undergoes SUBSTANTIAL ALTERATION.

4.6.11.2[A] Sound Absorption INDOOR AQUATIC FACILITIES shall be designed, constructed and installed with an AVERAGE SOUND ABSORPTION COEFFICIENT (ALPHA BAR) of 0.20 or greater.

4.6.11.2.1[A] Facilities Used Primarily by Specific Hearing Populations An ALPHA BAR of 0.25 or greater shall be used for INDOOR AQUATIC FACILITIES designed primarily for use by children, the elderly, or persons with hearing difficulties.

4.6.11.3[A] Noise INDOOR AQUATIC FACILITIES shall be designed, constructed and installed so that the noise generated by the AIR HANDLING SYSTEM does not exceed a NOISE CRITERION level of 50 (NC-50) or 55 dBA at any time while the INDOOR AQUATIC FACILITY is open for use.

4.6.11.4[A] Sound Absorbing Materials When part of the interior finish, acoustical materials or finishes used for SOUND ABSORPTION shall meet the design requirements of MAHC 4.2.2.1.1 and 4.2.2.2.3.

4.6.11.5[A] Concave Room Surfaces The design of INDOOR AQUATIC FACILITIES with a domed roof, gable roof, or other shape that may cause sound focusing, irrespective of the ALPHA BAR, shall address sound focusing, reverberation, and echoes that would interfere with speech intelligibility.

4.7 Recirculation and Water Treatment

4.7.1 Recirculation Systems and Equipment

4.7.1.1[A] General

4.7.1.1.1 Equipped and Operated All AQUATIC VENUES shall be equipped and operated with a recirculation and filtration system capable of meeting the provisions outlined in MAHC 4.7.

4.7.1.1.2 Component Installation The installation of the recirculation and the filtration system components shall be performed in accordance with the designer's and manufacturer's instructions.

4.7.1.1.3 Recirculation System A water RECIRCULATION SYSTEM consisting of one or more pumps, pipes, return INLETS, suction outlets, tanks, filters, and other necessary equipment shall be provided.

4.7.1.2[A] Combined Aquatic Venue Treatment

4.7.1.2.1 Maintain and Measure When treatment systems of multiple AQUATIC VENUES are combined, the design shall include all appurtenances to maintain and measure the required water characteristics including but not limited to flow rate, pH, and DISINFECTANT concentration in each AQUATIC VENUE or AQUATIC FEATURE.

4.7.1.2.2 Secondary Disinfection If SECONDARY DISINFECTION is required for an INCREASED RISK AQUATIC VENUE as per MAHC 4.7.3.3.1.2, then SECONDARY DISINFECTION shall be required for all treatment systems that are combined with the INCREASED RISK AQUATIC VENUE.

4.7.1.2.3 Isolate When multiple AQUATIC VENUES are combined in one treatment system, each AQUATIC VENUE shall be capable of being isolated for maintenance purposes.

4.7.1.3 Inlets

4.7.1.3.1[A] General

4.7.1.3.1.1 Hydraulically Balanced The RECIRCULATION SYSTEM shall be designed with sufficient flexibility to achieve a hydraulic apportionment that will ensure the following:

1) Effective distribution of treated water, and

2) Maintenance of a uniform DISINFECTANT residual and pH throughout the AQUATIC VENUE.

4.7.1.3.1.1.1 **Alternative Design Justification** Alternative designs shall be allowed based on adequate engineering justification.

4.7.1.3.1.2 **Inlets** Effective distribution of treated water shall be accomplished by either a continuous POS with integral INLETS or by means of directionally adjustable INLETS adequate in design, number, and location.

4.7.1.3.1.3 **Adequate Mixing** POOLS shall use wall and/or floor INLETS to provide adequate mixing.

4.7.1.3.1.3.1 **Greater Than Fifty Feet Wide** For POOLS greater than 50 feet wide *(15.2 m)*, floor INLETS shall be required.

4.7.1.3.1.4 **Other Inlet Types** All other types of INLET systems not covered in this section shall be subject to approval by the AHJ with proper engineering justification.

4.7.1.3.1.5 **Hydraulically Sized** INLETS shall be hydraulically sized to provide the design flow rates for each POOL area of multi-zone POOLS based on the required design TURNOVER RATE for each zone.

4.7.1.3.2[A] ***Floor Inlets***

4.7.1.3.2.1 **Uniformly Spaced** Floor INLETS shall be spaced to effectively distribute the treated water throughout the POOL.

4.7.1.3.2.2 **Flush with Bottom** Floor INLETS shall be flush with the bottom of the POOL.

4.7.1.3.2.2.1 **Distance** Distance between floor INLETS shall be no greater than 20 feet *(6.1 m)*.

4.7.1.3.2.2.2 **Row** A row of floor INLETS shall be located within 15 feet *(4.6 m)* of each side wall.

4.7.1.3.2.3 **Spaced** Floor INLETS, used in combination with wall INLETS, shall be spaced no greater than 25 feet *(7.6 m)* from nearest side walls.

4.7.1.3.3 ***Wall Inlets***

4.7.1.3.3.1[A] **Effective Mixing** Wall INLET velocity shall mix the water effectively.

4.7.1.3.3.2 **Adjustable** INLETS shall be directionally adjustable to provide effective distribution of water.

4.7.1.3.3.3[A] **Inlet Spacing** Wall INLETS shall be spaced no greater than 20 feet *(6.1 m)* apart.

4.7.1.3.3.3.1 **Corner** INLETS shall be placed within 5 feet *(1.5 m)* of each corner of the POOL.

4.7.1.3.3.3.2 **Skimmers** INLETS shall be placed at least 5 feet *(1.5 m)* from a SKIMMER.

4.7.1.3.3.3.3 **Isolated** INLETS shall be placed in each recessed or isolated area of the POOL.

4.7.1.3.3.4 **Directional Flow** Wall INLETS shall not require design to provide directional flow if part of a manufactured gutter system in which the filtered return water conduit is contained within the gutter structure.

4.7.1.3.3.5[A] **Dye Testing** The AHJ may require dye testing to evaluate the mixing characteristics of the RECIRCULATION SYSTEM.

4.7.1.3.3.5.1 **Failed Test** If dye test reveals inadequate mixing in the POOL after 20 minutes, the RECIRCULATION SYSTEM shall be adjusted or modified to assure adequate mixing.

4.7.1.4 **Perimeter Overflow Systems/Gutters**

4.7.1.4.1 ***General***

4.7.1.4.1.1[A] **Skimming** All POOLS shall be designed to provide SKIMMING for the entire POOL surface area with engineering rationale provided by the design professional.

4.7.1.4.1.1.1 **Around Entire Pool** For POOLS that require a POS, the POS shall extend around the entire POOL perimeter except where noted in this CODE.

4.7.1.4.1.2 **Zero Depth Entry** ZERO DEPTH ENTRY POOLS shall have a continuous overflow trench that terminates as close to the side walls as practical including any zero-depth portion of the POOL perimeter.

4.7.1.4.1.2.1 **Ends** Where a POS cannot be continuous, the ends of each section shall terminate as close as practical to each other.

4.7.1.4.2[A] Perimeter Overflow System Size and Shape

4.7.1.4.2.1 **Continuous Water Removal** The gutter system shall be designed to allow continuous removal of water from the POOL'S upper surface at a rate of at least 125 percent of the approved total recirculation flow rate chosen by the designer.

4.7.1.4.2.2 **Inspection** Gutters shall permit ready inspection, cleaning, and repair.

4.7.1.4.3[A] Gutter Outlets Drop boxes, converters, return piping, or FLUMES used to convey water from the gutter shall be designed to:

1) Prevent flooding and BACKFLOW of skimmed water into the POOL, and
2) Handle at least 125 percent of the approved total recirculation flow.

4.7.1.4.4 Surge Tank Capacity

4.7.1.4.4.1[A] **Net Surge Capacity** All POSs shall be designed with an effective net surge capacity of not less than one gallon for each square foot *(40.7 L/m^2)* of POOL surface area.

4.7.1.4.4.1.1 **Surge Components** Surge shall be provided within a surge tank, or the gutter or filter above the normal operating level, or elsewhere in the system.

4.7.1.4.4.2 **Tank Capacity** The tank capacity specified shall be the net capacity.

4.7.1.4.4.3 **Tank Levels** The design professional shall define the minimum, maximum, and normal POOL operating water levels in the surge tank.

4.7.1.4.4.3.1 **Marked** The surge tank's minimum, maximum, and normal POOL operating water levels shall be marked on the tank so as to be readily visible for inspection.

4.7.1.4.4.4 **Overflow Pipes** Surge tanks, shall have overflow pipes to convey excess water to waste via an air gap or other approved BACKFLOW prevention device.

4.7.1.4.5[A] Tolerances Gutters shall be level within a tolerance of plus or minus $^1/_{16}$ inch *(1.6 mm)* around the perimeter of the AQUATIC VENUE.

4.7.1.4.6[A] Makeup Water System

4.7.1.4.6.1 **Automatic Makeup** Automatic makeup water supply equipment shall be provided to maintain continuous skimming of POOLS with POSs.

4.7.1.4.6.2 **Air Gap** Makeup water shall be supplied through an air gap or other approved BACKFLOW prevention device.

4.7.1.5 Skimmers and Alternative Gutter Technologies Using In-Pool Surge Capacity

4.7.1.5.1 General

4.7.1.5.1.1 **Manufactured** The use of manufactured direct suction SKIMMERS shall be in accordance with the manufacturer's recommendations.

4.7.1.5.1.2[A] **Provided** Where SKIMMERS are used, at least one surface SKIMMER shall be provided for each 500 square feet *(46 m^2)* of surface area or fraction thereof.

4.7.1.5.1.2.1 **Conditions** Additional SKIMMERS may be required to achieve effective skimming under site-specific conditions *(e.g., heavy winds and/or CONTAMINANT loading)* and/or to comply with all applicable building CODES.

4.7.1.5.1.3[A] **Hybrid Systems** Hybrid systems that incorporate surge weirs in the overflow gutters to provide for in-POOL surge shall meet all of the requirements specified for overflow gutters *(with the exception of the surge or balance tank, since the surge capacity requirement will be alternately met by the in-POOL surge capacity).*

4.7.1.5.1.3.1[A] **Surge Weirs** The number of surge weirs shall be based on the individual surge weir capacity and the operational apportionment of the design recirculation flow rate.

4.7.1.5.1.3.1.1 **Locations** The location of the required number of surge weirs shall be uniformly spaced in the gutter sections.

4.7.1.5.1.4[A] **Design Capacity** When used, the SKIMMER SYSTEM shall be designed to handle up to 100% of the total recirculation flow rate chosen by the designer.

4.7.1.5.1.5 **Pool Width Limitations** POOLS using SKIMMERS shall not exceed 30 feet *(9.1 m)* in width.

4.7.1.5.2 ***Skimmer Location***

4.7.1.5.2.1 **Effective** SKIMMERS shall be so located as to provide effective skimming of the entire water surface.

4.7.1.5.2.2 **Steps and Recessed Areas** SKIMMERS shall be located so as not to be affected by restricted flow in areas such as near steps and within small recesses.

4.7.1.5.2.3 **Wind Direction** Wind direction shall be considered in number and placement of SKIMMERS.

4.7.1.5.3[A] ***Skimmer Flow Rate*** The flow rate for the SKIMMERS shall comply with manufacturer data plates or NSF/ANSI 50 including Annex K.

4.7.1.5.4 ***Control***

4.7.1.5.4.1 **Weir** Each SKIMMER shall have a weir that adjusts automatically to variations in water level over a minimum range of 4 inches *(10.2 cm).*

4.7.1.5.4.2 **Trimmer Valve** Each SKIMMER shall be equipped with a trimmer valve capable of distributing the total flow between individual SKIMMERS.

4.7.1.5.5 ***Tolerances***

4.7.1.5.5.1 **Skimmer Base** The base of each SKIMMER shall be level with all other SKIMMERS in the POOL within a tolerance of plus or minus ¼ inch *(6.4 mm).*

4.7.1.6[A] Submerged Suction Outlet

4.7.1.6.1 ***General*** Submerged suction outlets, including sumps and covers, shall be CERTIFIED, LISTED, AND LABELED to the requirements of ANSI/APSP-16 2011.

4.7.1.6.2 ***Number and Spacing***

4.7.1.6.2.1 **Hydraulically Balanced** A minimum of two hydraulically balanced filtration system outlets are required in the bottom.

4.7.1.6.2.1.1 **Located on the Bottom** One of the outlets may be located on the bottom of a side/end wall at the deepest level.

4.7.1.6.2.1.2 **Connected** The outlets shall be connected to a single main suction pipe by branch lines piped to provide hydraulic balance between the drains.

4.7.1.6.2.1.3 **Valved** The branch lines shall not be valved so as to be capable of operating independently.

4.7.1.6.2.2 **Spaced** Outlets shall be equally spaced from the POOL side walls.

4.7.1.6.2.3 **Located** Outlets shall be located no less than 3 feet *(0.9 m)* apart, measuring between the centerlines of the suction outlet covers.

4.7.1.6.3 ***Tank Connection*** Where gravity outlets are used, the main drain outlet shall be connected to a surge tank, collection tank, or balance tank/pipe.

4.7.1.6.4[A] ***Flow Distribution and Control***

4.7.1.6.4.1 **Design Capacity** The main drain system shall be designed at a minimum to handle recirculation flow of 100% of total design recirculation flow rate.

4.7.1.6.4.1.1 **Two Main Drain Outlets** Where there are two main drain outlets, the branch pipe from each main drain outlet shall be designed to carry 100% of the recirculation flow rate.

4.7.1.6.4.1.2 **Three or More Drains** Where three or more main drain outlets are connected by branch piping in accordance with MAHC 4.7.1.6.2.1.1 through MAHC 4.7.1.6.2.1.3, the design flow through each branch pipe from each main drain outlet may be as follows:

1) Q_{max} for each drain= Q*(total recirculation rate) / (number of drains less one)*, and
2) $Q_{max}=Q_{total}$ / *(N-1)*.

4.7.1.6.4.2 **Proportioning Valve** The single main drain suction pipe to the pump shall be equipped with a proportioning valve*(s)* to adjust the flow distribution between the main drain piping and the surface overflow system piping.

4.7.1.6.5 ***Flow Velocities***

4.7.1.6.5.1 **Standards** Flow velocities shall meet ANSI/APSP-16 2011 based on 100% design flow through each main drain cover.

4.7.1.7 Piping

4.7.1.7.1 ***Design***

4.7.1.7.1.1 **Materials** Piping system components in contact with swimming POOL water shall be of non-toxic material, resistant to corrosion, able to withstand operating pressures, chemicals, and temperatures.

4.7.1.7.1.2 **Standards** Piping and piping system component materials shall be suitable for potable water contact.

4.7.1.7.1.2.1 **Certified, Listed, and Labeled** Piping and piping system component materials shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 14, NSF/ANSI Standard 50, and NSF/ANSI Standard 61, as applicable.

4.7.1.7.1.2.2 **Certified** Piping and piping system component materials shall be CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization.

4.7.1.7.2 ***Velocity in Pipes***

4.7.1.7.2.1[A] **Discharge Piping** RECIRCULATION SYSTEM piping shall be designed so that water velocities do not exceed 8 feet *(2.4 m)* per second on the discharge side of the recirculation pump unless alternative values have proper engineering justification.

4.7.1.7.2.2[A] **Suction Piping** Suction piping shall be sized so that the water velocity does not exceed 6 feet per second *(1.8 m/s)* unless alternative values have proper engineering justification.

4.7.1.7.2.3[A] **Additional Considerations** Gravity piping shall be sized with consideration of available system head or as demonstrated by detailed hydraulic calculations at the design recirculation flow rate.

4.7.1.7.3[A] ***Drainage and Installation***

4.7.1.7.3.1 **Temperature Variations** Provisions shall be made for expansion and contraction of pipes due to temperature variations.

4.7.1.7.3.2 **Drainage** Provisions shall be made for complete drainage of all AQUATIC VENUE piping.

4.7.1.7.3.3 **Supported** All piping shall be supported continuously or at sufficiently close intervals to prevent sagging and settlement.

4.7.1.7.4 *Piping and Component Identification*

4.7.1.7.4.1[A] **Clearly Marked** All exposed piping shall be clearly marked to indicate function.

4.7.1.7.4.2 **Flow Direction and Source** All piping shall be clearly marked to indicate type or source of water and direction of flow with clear labeling and/or color coding.

4.7.1.7.4.3 **Valves** All valves shall be clearly marked to indicate function with clear labeling and/or color coding.

4.7.1.7.4.4 **Schematic Displayed** A complete, easily readable schematic of the entire AQUATIC VENUE RECIRCULATION SYSTEM shall be openly displayed in the mechanical room or available to maintenance and inspection personnel.

4.7.1.7.5 *Testing*

4.7.1.7.5.1 **Static Water Pressure Test** Suction and supply POOL piping shall be subjected to a static hydraulic water pressure test for the duration specified by the design engineer and/or AHJ.

4.7.1.7.5.2 **Greater** Suction and supply AQUATIC VENUE piping shall be able to maintain the greater of the two following amounts of pressure:

1) 25% greater than the maximum design operating pressure of the system, or
2) 25 psi *(172 KPa)*.

4.7.1.8 **Strainers and Pumps**

4.7.1.8.1 *Strainers*

4.7.1.8.1.1 **Strainer / Screen** All filter recirculation pumps, except those for vacuum filter installations, shall have a strainer/screen device on the suction side to protect the filtration and pumping equipment.

4.7.1.8.1.2 **Materials** Strainers shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50.

4.7.1.8.2 *Pumping Equipment*

4.7.1.8.2.1[A] **Variable Frequency Drives** VFDs *may* be installed to control all recirculation and feature pumps.

4.7.1.8.2.2[A] **Total Dynamic Head** The recirculation pump*(s)* shall have adequate capacity to meet the recirculation flow design requirements in accordance with the maximum TDH required by the entire RECIRCULATION SYSTEM under the most extreme operating conditions *(e.g., clogged filters in need of backwashing)*.

4.7.1.8.2.3 **Required Flow Rate** The pump shall be designed to maintain design recirculation flows under all conditions.

4.7.1.8.2.4 **Vacuum Limit Switches** Where vacuum filters are used, a vacuum limit switch shall be provided on the pump suction line.

4.7.1.8.2.5 **Maximum** The vacuum limit switch shall be set for a maximum vacuum of 18 inches *(45.7 cm)* of mercury.

4.7.1.8.2.6 **Pump Priming** All recirculation pumps shall be self-priming or flooded-suction.

4.7.1.8.2.7 **Net Positive Suction Head Requirement** All recirculation pumps shall meet the minimum NPSH requirement for the system.

4.7.1.8.3[A] *Operating Gauges*

4.7.1.8.3.1 **Vacuum Gauge** A compound vacuum-pressure gauge shall be installed on the pump suction line as close to the pump as possible.

4.7.1.8.3.2 **Suction Lift** A vacuum gauge shall be used for pumps with suction lift.

4.7.1.8.3.3 **Installed** A pressure gauge shall be installed on the pump discharge line adjacent to the pump.

4.7.1.8.3.4 **Easily Read** Gauges shall be installed so they can be easily read.

4.7.1.8.3.5 **Valves** All gauges shall be equipped with valves to allow for servicing under operating conditions.

4.7.1.9 Flow Measurement and Control

4.7.1.9.1[A] ***Flow Meters*** A flow meter accurate to within +/- 5% of the actual design flow shall be provided for each filtration system.

4.7.1.9.1.1 **Certified, Listed, and Labeled** Flow meters shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 50 by an ANSI-accredited certification organization.

4.7.1.9.2 ***Valves*** All pumps shall be installed with a manual adjustable discharge valve to provide a backup means of flow control as well as for system isolation.

4.7.1.10[A] Flow Rates / Turnover Times

Table 4.7.1.10: Aquatic Venue Maximum Allowable Turnover Times

Type of Pools	Turnover Maximum
Activity Pools	2 hours or less
Diving Pools	8 hours or less
Interactive Water Play*	0.5 hours or less
Lazy River	2 hours or less
Plunge Pools	1 hour or less
Runout Slide	1 hour or less
Wading Pools*	1 hour or less
Wave Pools	2 hours or less
All Other Pools	6 hours or less
Surf Pools	Submit engineering justification from equipment manufacturer

*Shall have secondary disinfection systems

Aquatic Venue Maximum Allowable Turnover Times for Spa, Therapy*, & Exercise Pools

Temperatures	*Load*	*Turnover Maximum*
≤ 72°-93°F (22°-34°C)	> 2500 gals/person (9.46 m^3)	4 hours or less
≤ 72°-93°F (22°-34°C)	> 450 gals/person (1.7 m^3)	2 hours or less
≤ 72°-93°F (22°-34°C)	≤ 450 gals/person (1.7 m^3)	1 hour or less
≥ 93-104°F (34°-40°C)	All	0.5 hours or less

*Shall have secondary disinfection systems

4.7.1.10.1 ***Maximum Allowable*** All AQUATIC VENUES shall comply with the above maximum allowable TURNOVER TIMES shown in MAHC Table 4.7.1.10.

4.7.1.10.2[A] ***Calculated*** The TURNOVER TIME shall be calculated based on the total volume of water divided by the flow rate through the filtration process.

4.7.1.10.2.1[A] **Unfiltered Water** Unfiltered water such as water that may be withdrawn from and returned to the AQUATIC VENUE for such AQUATIC FEATURES as SLIDES by a pump separate from the filtration system, shall not factor into TURNOVER TIME.

4.7.1.10.3[A] ***Turnover Times*** TURNOVER TIMES shall be calculated based solely on the flow rate through the filtration system.

4.7.1.10.3.1 **Required** The required TURNOVER TIME shall be the lesser of the following options:

1) The specified time in MAHC Table 4.7.1.10, or
2) The time required for individual components *(e.g., three SKIMMERS with flow rates set by the manufacturer and an additional 20% for the main drains could exceed the minimum value in the table)*.

4.7.1.10.3.2 **Total Volume** The total volume of the AQUATIC VENUE system shall include the AQUATIC VENUE and any surge/balance tank.

4.7.1.10.3.3 **Supply Water** Where water is drawn from the AQUATIC VENUE to supply water to AQUATIC FEATURES *(e.g., SLIDES, tube rides)*, the water may be reused prior to filtration provided the DISINFECTANT and pH levels of the supply water are maintained at required levels.

4.7.1.10.4[A] ***Reuse Ratio*** The ratio of INTERACTIVE WATER PLAY AQUATIC VENUE FEATURE water to filtered water shall be no greater than 3:1 in order to maintain the efficiency of the FILTRATION SYSTEM.

4.7.1.10.5[A] ***Flow Turndown System*** For AQUATIC FACILITIES that intend to reduce the recirculation flow rate below the minimum required design values when the POOL is unoccupied, the flow turndown system shall be designed as follows in MAHC 4.7.1.10.5.1 through MAHC 4.7.1.10.5.2.

4.7.1.10.5.1 **Flowrate** The system flowrate shall not be reduced more than 25% lower than the minimum design requirements and only reduced when the AQUATIC VENUE is unoccupied.

4.7.1.10.5.1.1 **Clarity** The system flowrate shall be based on ensuring the minimum water clarity required under MAHC 5.7.6 is met before opening to the public.

4.7.1.10.5.1.2 **Disinfectant Levels** The turndown system shall be required to maintain required DISINFECTANT and pH levels at all times.

4.7.1.10.5.2 **Increase** When the turndown system is also used to intelligently increase the recirculation flow rate above the minimum requirement *(e.g., in times of peak use to maintain water quality goals more effectively)*, the following requirements shall be met at all times:

1) Velocity requirements inside of pipes *(per MAHC 4.7.1.7.2)*, and
2) Maximum filtration system flows.

4.7.2[A] Filtration

4.7.2.1 All Filters

4.7.2.1.1 ***Required*** Filtration shall be required for all AQUATIC VENUES that recirculate water.

4.7.2.1.2[A] ***Certified, Listed, and Labeled Filters*** All filters shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50 by an ANSI-accredited certification organization.

4.7.2.1.3 ***Appropriate Filter Media*** Filters shall use the appropriate filter media as recommended by the filter manufacturer for maximum clarity and cycle length for AQUATIC VENUE use.

4.7.2.1.4 ***Certified, Listed, and Labeled Filter Media*** All filter media, including alternative filter media, shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI Standard 50 by an ANSI-accredited certification organization and within the size specifications provided by the filter manufacturer and NSF/ANSI 50.

4.7.2.2 Granular Media Filters

4.7.2.2.1[A] General

4.7.2.2.1.1 Valves and Piping The granular media filter system shall have valves and piping to allow isolation, venting, complete drainage *(for maintenance or inspections)*, and backwashing of individual filters.

4.7.2.2.1.2 Filtration Accessories Filtration accessories shall include the following items:

1) Influent pressure gauge,
2) Effluent pressure gauge,
3) Backwash sight glass or other means to view backwash water clarity, and
4) Manual air relief system.

4.7.2.2.2[A] Filter Location and Spacing

4.7.2.2.2.1 Installed Filters shall be installed with adequate clearance and facilities for ready and safe inspection, maintenance, disassembly, and repair.

4.7.2.2.2.2 Media Removal A means and access for easy removal of filter media shall be required.

4.7.2.2.3 Filtration and Backwashing Rates

4.7.2.2.3.1[A] Operate High-rate granular media filters shall be designed to operate at no more than 15 GPM per square foot *(37 m/h)* when a minimum bed depth of 15 inches *(38.1 cm)* is provided per manufacturer.

4.7.2.2.3.1.1 Less than Fifteen Inch Bed Depth When a bed depth is less than 15 inches *(38.1 cm)*, filters shall be designed to operate at no more than 12 GPM per square foot (29 m/h).

4.7.2.2.3.2[A] Backwash System Design The granular media filter system shall be designed to backwash each filter at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, unless explicitly prohibited by the filter manufacturer and approved at an alternate rate as specified in their NSF/ANSI 50 listing.

4.7.2.2.4[A] Minimum Filter Media Depth Requirements The minimum depth of filter media cannot be less than the depth specified by the manufacturer.

4.7.2.2.5 Differential Pressure Measurement Gauges

Influent and effluent pressure gauges shall have the capability to measure up to a 20 pounds per square inch *(138 KPa)* increase in the differential pressure across the filter bed in increments of 1 pound per square inch *(6.9 KPa)* or less.

4.7.2.2.6[A] Coagulant Injection Equipment Installation

If coagulant feed systems are used, they shall be installed with the injection point located before the filters as far ahead as possible, with electrical interlocks in accordance with MAHC 4.7.3.2.1.3.

4.7.2.3 Precoat Filters

4.7.2.3.1[A] Filtration Rates

4.7.2.3.1.1 Vacuum Precoat The design filtration rate for vacuum precoat filters shall not be greater than either:

1) 2 GPM per square foot *(4.9 m/h)*, or
2) 2.5 GPM per square foot *(6.1 m/h)* when used with a continuous precoat media feed *(commonly referred to as "body-feed")*.

4.7.2.3.1.2 Pressure Precoat The design filtration rate for pressure precoat filters shall not be greater than two GPM per square foot *(4.9 m/h)* of effective filter surface area.

4.7.2.3.1.3 Calculate The filtration surface area shall be based on the outside surface area of the media with the manufacturer's recommended thickness of precoat media and consistent with their NSF/ANSI 50 listing and labeling.

4.7.2.3.2[A] Precoat Media Introduction System Process The precoat process shall follow the manufacturer's recommendations and requirements of NSF/ANSI Standard 50.

4.7.2.3.3[A] Continuous Filter Media Feed Equipment

4.7.2.3.3.1 Manufacturer Specification If equipment is provided for the continuous feeding of filter media to the filter influent, the equipment shall be used in accordance with the manufacturer's specifications.

4.7.2.3.3.2 Filter Media Discharge All discharged filter media shall be handled in accordance with local and state laws, rules, and regulations.

4.7.2.4 Cartridge Filters

4.7.2.4.1[A] Filtration Rates The design filtration rate for surface-type cartridge filter shall not exceed 0.30 GPM per square foot *(0.20 L/s/m²)*.

4.7.2.4.2[A] Supplied and Sized Filter cartridges shall be supplied and sized in accordance with the filter manufacturer's recommendation for AQUATIC VENUE use.

4.7.2.4.3[A] Spare Cartridge One complete set of spare cartridges shall be maintained on site in a clean and dry condition.

4.7.3[A] Disinfection and pH Control

4.7.3.1 Chemical Addition Methods

4.7.3.1.1 Disinfection and pH DISINFECTION and pH control chemicals shall be automatically introduced through the RECIRCULATION SYSTEM.

4.7.3.1.1.1 Controller Used A chemical controller, as specified in MAHC 4.7.3.2.8 shall be provided and used for MONITORING and control of DISINFECTANT and pH feed equipment.

4.7.3.1.1.2 *Feeder* DISINFECTION and pH control chemicals shall be added using a feeder that meets the requirements outlined in MAHC 4.7.3.2.

4.7.3.2 Feed Equipment

4.7.3.2.1[A] General

4.7.3.2.1.1 Required Chemical feeders shall be required in new or existing AQUATIC FACILITIES upon adoption of this CODE.

4.7.3.2.1.2 Feeders & Devices The AQUATIC FACILITY shall be equipped with chemical feed equipment such as flow-through chemical feeders, electrolytic chemical generators, mechanical chemical feeders, chemical feed pumps, and AUTOMATED CONTROLLERS that are CERTIFIED, LISTED, AND LABELED to NSF-ANSI 50 by an ANSI-accredited certification organization.

4.7.3.2.1.2.1 Specified by Manufacturer Flow-through chemical feeders shall only be used with the chemical *(formulation, brand, size, and shape)* specified by the chemical feeder manufacturer.

4.7.3.2.1.3 Interlock Controls and No or Low Flow Deactivation For all new or SUBSTANTIALLY RENOVATED AQUATIC VENUES and within 1 year of adoption of this CODE for existing facilities, all chemical control and feed systems shall be provided with an automatic means to disable all chemical feeders for each VENUE or portion of a VENUE in the event of a low flow or no flow condition. This shall be accomplished through an electrical interlock consisting of at least two of the following:

1) Recirculation pump power MONITOR,
2) Flow meter/flow switch in the return line,
3) Flow meter/flow switch at the chemical controller.

4.7.3.2.1.3.1 Installed The electrical interlock system shall be installed per manufacturer's instructions and shall never be altered.

4.7.3.2.1.3.2 **Visual Alarm** For new installations and replacement equipment, if the feeder is disabled through the electrical interlock, a visual alarm or other indication shall be initiated that will alert staff on-site for BATHER evacuation.

4.7.3.2.1.4 **Installation** The chemical control and feed systems shall be installed according to the manufacturer's instructions.

4.7.3.2.1.4.1 **Protective Cover** A physical BARRIER shall be installed between chemical feed pumps supplying acid or liquid hypochlorite solution and other POOL components to shield staff and equipment from chemical sprays from leaking connections.

4.7.3.2.2[A] ***Sizing of Disinfection Equipment***

4.7.3.2.2.1 **Sizing** Feeders shall be capable of supplying DISINFECTANT and pH control chemicals to the AQUATIC VENUE to maintain the minimum required DISINFECTION levels at all times in accordance with the MAHC.

4.7.3.2.2.2 **Chlorine Dosing** All CHLORINE dosing and generating equipment including erosion feeders, or in line electrolytic and brine/batch generators, shall be designed with a capacity to meet the demand necessary to maintain the minimum required FREE AVAILABLE CHLORINE (FAC) concentrations specified in MAHC 5.7.3.1.1.2 during all times of operation.

4.7.3.2.2.2.1 **Chlorine Demand Factors** Sizing of CHLORINE dosing and generating equipment shall be based on the following CHLORINE demand factors:

1) AQUATIC VENUE surface area;
2) AQUATIC VENUE volume;
3) AQUATIC VENUE type of use/space:
    a. FLAT WATER;
    b. AGITATED WATER;
    c. HOT WATER;
4) AQUATIC VENUE type, for example: POOL, SPA, WADING POOL, WAVE POOL (wave time), WATERSLIDE, INTERACTIVE WATER PLAY VENUE, THERAPY POOL;
5) Indoor or outdoor including maximum hours of sunlight/UV exposure;
6) Anticipated maximum water temperature;
7) Anticipated maximum number of BATHERS per day;
8) Cyanuric acid/stabilizer used;
9) Anticipated atypical water loss; and
10) Anticipated exposure to vegetation and airborne debris.

4.7.3.2.2.3 **Documentation** The Design Professional, who is registered or licensed to practice their respective design profession as defined by the state or local laws governing professional practice within the jurisdiction where the project is to be constructed, shall provide adequate documentation to demonstrate the selected feeders/equipment are of sufficient size and capacity per MAHC 4.7.3.2.2.1 and 4.7.3.2.2.2.

4.7.3.2.2.3.1 **Information Included** This documentation shall include:

1) an evaluation of the DISINFECTION feeder/equipment based on the Design Professional's related professional experience, the DISINFECTION feeder/equipment manufacturer's recommendations, or other industry accepted guidelines in sizing the feeders/equipment, and
2) a discussion of the analysis and use of the CHLORINE demand factors listed in MAHC 4.7.3.2.2.2.1 in sizing the feeders/equipment.

4.7.3.2.2.4 **Upon Operation** If upon operation it is determined that feeders/equipment are not capable of meeting the demand necessary to maintain minimum required DISINFECTION levels at all times, additional capacity shall be provided.

4.7.3.2.3 Introduction of Chemicals

4.7.3.2.3.1 Separation The injection point of DISINFECTION chemicals shall be located before any pH control chemical injection point with sufficient physical separation of the injection points to reduce the likelihood of mixing of these chemicals in the piping during periods of interruption of RECIRCULATION SYSTEM flow.

4.7.3.2.3.2 Backflow Means of injection shall not allow BACKFLOW into the chemical system from the POOL system.

4.7.3.2.3.3 Coagulants Coagulants shall be metered and injected through a pump system prior to the filters per the manufacturer's recommended rate.

4.7.3.2.4 Compressed Chlorine Gas

4.7.3.2.4.1 Prohibited for New Construction Use of compressed CHLORINE gas shall be prohibited for new construction and after SUBSTANTIAL ALTERATION to existing AQUATIC FACILITIES.

4.7.3.2.4.2 In Existing Aquatic Facilities Refer to MAHC 4.9.2.11 on the use of compressed CHLORINE gas in existing AQUATIC FACILITIES.

4.7.3.2.5[A] Types of Feeders

4.7.3.2.5.1 Liquid Solution Feeders Liquid solution feeders shall include positive displacement pumps such as peristaltic pumps, diaphragm pumps, and piston pumps.

4.7.3.2.5.1.1 Feed Rates Feed rates shall be locally adjusted on the pumps and also on/off controlled using an AUTOMATED CONTROLLER.

4.7.3.2.5.1.2 Routed All chemical tubing that runs through areas where staff work shall be routed in PVC piping to support the tubing and/or otherwise supported and protected to prevent leaks.

4.7.3.2.5.1.3 Size The double containment PVC pipe shall be of sufficient size to allow for easy replacement of tubing.

4.7.3.2.5.1.4 Turns Any necessary turns in the piping shall be designed so as to prevent kinking of the tubing.

4.7.3.2.5.2 Erosion Erosion feeders may be pressure, pressure differential, or spray erosion types.

4.7.3.2.5.2.1 Dry Chemical Feeders Dry chemicals shall be granules or tablets.

4.7.3.2.5.2.2 Located Feeders shall have isolation valves on each side of the feeder to be closed before opening the unit.

4.7.3.2.5.2.3 Source Water Erosion feeders shall use AQUATIC VENUE water post-filtration as the source water unless approved by the feeder manufacturer.

4.7.3.2.5.3 Gas Feed Systems Carbon dioxide and ozone are the only gas feed systems permitted in AQUATIC FACILITIES.

4.7.3.2.5.4 Ventilation Proper ventilation shall be required for all gas systems.

4.7.3.2.5.5 Alarms Where CO_2 cylinders are located indoors, a MONITOR and alarm shall be provided to alert PATRONS/operator of high CO_2 and/or low O_2 levels.

4.7.3.2.5.6 UV Systems Where used, UV systems shall be installed in the RECIRCULATION SYSTEM after the filters.

4.7.3.2.5.6.1 Bypass A bypass pipe that is valved on both ends shall be installed to allow maintenance on the UV unit while the POOL is in operation.

4.7.3.2.5.6.2 Interlock UV system operation shall be interlocked with the recirculation pump so that power to the UV system is interrupted when there is no water flow to the UV unit per MAHC 4.7.3.2.1.3.

4.7.3.2.6 Salt Electrolytic Chlorine Generators, Brine Electrolytic Chlorine, or Bromine Generators Halogen generator equipment shall be marked with an EPA establishment number.

4.7.3.2.6.1 Salt Electrolytic Chlorine Generators In-line generator*(s)* or brine *(batch)* generator*(s)* shall be permitted on AQUATIC VENUES.

4.7.3.2.6.2 In-line Method In-line generators shall use POOL-grade salt dosed into the AQUATIC VENUE to produce and introduce CHLORINE into the AQUATIC VENUE treatment loop through an electrolytic chamber.

4.7.3.2.6.3 Batch Method Brine *(Batch)* generators shall produce CHLORINE through an electrolytic cell.

4.7.3.2.6.3.1 Chlorine Production CHLORINE shall be produced from brines composed of POOL-grade salt.

4.7.3.2.6.4 TDS Readout Electrolytic generators shall have a TDS or salt *(NaCl)* readout and a low salt indicator.

4.7.3.2.6.5 Feed Rate The feed rate shall be adjustable from zero *(0)* to full range.

4.7.3.2.6.6 UL Standard The generator unit shall be CERTIFIED, LISTED, AND LABELED to UL 1081 *(for electrical/fire/shock SAFETY)* by an ANSI-accredited certification organization.

4.7.3.2.6.7 Interlock The generator*(s)* shall be interlocked per MAHC 4.7.3.2.1.3.

4.7.3.2.6.8 Installed The generator units shall be installed according to the manufacturer's instructions.

4.7.3.2.6.8.1 Saline Content The saline content of the POOL water shall be maintained in the required range specified by the manufacturer.

4.7.3.2.7[A] Feeders for pH Adjustment

4.7.3.2.7.1 Provided Feeders for pH adjustment shall be provided on all AQUATIC VENUES upon adoption of this CODE as in MAHC 4.7.3.2.1.2.

4.7.3.2.7.2 Approved Substances Approved substances for pH adjustment shall include but not be limited to muriatic *(hydrochloric)* acid, sodium bisulfate, carbon dioxide, sulfuric acid, sodium bicarbonate, and soda ash.

4.7.3.2.7.3 Adjustable pH adjustment feeders shall be adjustable from zero *(0)* to full range.

4.7.3.2.7.4 Marked Reservoirs shall be clearly marked and labeled with contents.

4.7.3.2.8[A] Automated Controllers

4.7.3.2.8.1 Required AUTOMATED CONTROLLERS shall be installed for MONITORING and turning on or off chemical feeders used for pH and DISINFECTANTS at all AQUATIC VENUES.

4.7.3.2.8.1.1 Existing Aquatic Facilities For existing AQUATIC FACILITIES, AUTOMATED CONTROLLERS shall be required within 1 year from adoption of this CODE.

4.7.3.2.8.2 NSF Standard All automated chemical controllers for pH and DISINFECTANT MONITORING/control shall be CERTIFIED, LISTED, AND LABELED to NSF/ANSI 50 by an ANSI-accredited certification organization.

4.7.3.2.8.3 Operation Manuals Operation manuals or other instructions that give clear directions for cleaning and calibrating AUTOMATED CONTROLLER probes and sensors shall be provided in close proximity to the AUTOMATED CONTROLLER.

4.7.3.2.8.4 Set Point A set point shall be used to target the DISINFECTANT level and the pH level.

4.7.3.3 Secondary Disinfection Systems

4.7.3.3.1 General Requirements

4.7.3.3.1.1[A] **ANSI Listing and Labeling** SECONDARY DISINFECTION SYSTEMS shall be CERTIFIED, LISTED, AND LABELED to ANSI/NSF 50 by an ANSI-accredited certification organization approved by the AHJ.

4.7.3.3.1.1.1 **Marked** SECONDARY DISINFECTION SYSTEM equipment shall be marked with an EPA establishment number.

4.7.3.3.1.2[A] **Required Facilities** The new construction or SUBSTANTIAL ALTERATION of the following INCREASED RISK AQUATIC VENUES shall be required to use a SECONDARY DISINFECTION SYSTEM after adoption of this CODE:

1. AQUATIC VENUES designed primarily for children under 5 years old, such as
   a. WADING POOLS,
   b. INTERACTIVE WATER PLAY VENUES with no standing water, and
2. THERAPY POOLS.

4.7.3.3.1.3 **Other Aquatic Venues** Optional SECONDARY DISINFECTION SYSTEMS may be installed on other AQUATIC VENUES not specified in MAHC 4.7.3.3.1.2.

4.7.3.3.1.4 **Labeled** If installed and labeled as SECONDARY DISINFECTION SYSTEMS, then they shall conform to all requirements specified under MAHC 4.7.3.3.

4.7.3.3.1.5 **Conform** If not labeled as SECONDARY DISINFECTION SYSTEMS, then they shall be labeled as SUPPLEMENTAL TREATMENT SYSTEMS and conform to requirements listed under MAHC 4.7.3.4.

4.7.3.3.2[A] ***Log Inactivation and Oocyst Reduction***

4.7.3.3.2.1[A] **Log Inactivation** SECONDARY DISINFECTION SYSTEMS shall be designed to achieve a minimum 3-log *(99.9%)* reduction in the number of infective *Cryptosporidium parvum* OOCYSTS per pass through the SECONDARY DISINFECTION SYSTEM for INTERACTIVE WATER PLAY AQUATIC VENUES and a minimum 2-log (99%) reduction per pass for all other AQUATIC VENUES.

4.7.3.3.2.2[A] ***Installation*** The SECONDARY DISINFECTION SYSTEM shall be located in the treatment loop *(post filtration)* and treat a portion *(up to 100%)* of the filtration flow prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE.

4.7.3.3.2.3 **Manufacturer's Instructions** The SECONDARY DISINFECTION SYSTEM shall be installed according to the manufacturer's directions.

4.7.3.3.2.4[A] **Minimum Flow Rate Calculation** The flow rate *(Q)* through the SECONDARY DISINFECTION SYSTEM shall be determined based upon the total volume of the AQUATIC VENUE or AQUATIC FEATURE *(V)* and a prescribed dilution time *(T)* for theoretically reducing the number of assumed infective *Cryptosporidium* OOCYSTS from an initial total number of 100 million *(10^8)* OOCYSTS to a concentration of one OOCYST/100 mL.

4.7.3.3.2.5[A] **Equation** Accounting for a 3-log *(99.9%)* or 2-log (99%) reduction of infective *Cryptosporidium* OOCYSTS through the SECONDARY DISINFECTION SYSTEM with each pass, the SECONDARY DISINFECTION SYSTEM flow rate *(Q)* shall be:

1) Q = V x {[14.8 – ln (V)] / (r x 60 x T)}, where:
   - Q = SECONDARY DISINFECTION SYSTEM flow rate *(gpm)*
   - V = Total water volume of the AQUATIC VENUE or AQUATIC FEATURE, including surge tanks, piping, equipment, etc. *(gals)*
   - r = Efficiency of the system (r = 0.999 for 3-log reduction, r = 0.99 for 2-log reduction)
   - T = Dilution time *(hrs.)*

4.7.3.3.2.6 **Time for Dilution Reduction** The dilution time shall be the lesser of 9 hours or 75% of the uninterrupted time an AQUATIC VENUE is closed in a 24 hour period.

4.7.3.3.2.7[A] **Flow Rate Measurements** Where a SECONDARY DISINFECTION SYSTEM is installed, a means shall be installed to confirm the required flow rate to maintain a minimum required log inactivation of infective *Cryptosporidium* OOCYSTS at the minimum flow rate.

4.7.3.3.2.7.1 **Flow Rate Defined** The minimum required flow rate through the SECONDARY DISINFECTION SYSTEM shall be as defined in MAHC 4.7.3.3.2.5.

4.7.3.3.3[A] ***Ultraviolet Light Systems*** To prevent mercury exposure, UV systems shall be installed to avoid lamp breakage according to the guidelines in EPA 815-R-06-007 Appendix E.

4.7.3.3.3.1[A] **Third Party Validation** UV equipment shall be third party validated in accordance with the practices outlined in the *EPA Ultraviolet Disinfectant Guidance Manual* dated November, 2006, publication number EPA 815-R-06-007.

4.7.3.3.3.1.1[A] **Validation Standard** The *EPA Ultraviolet Disinfectant Guidance Manual* shall be considered a recognized national STANDARD in the MAHC.

4.7.3.3.3.2 **Suitable for Intended Use** UV systems and all materials used therein shall be suitable for their intended use and be installed:

1) In accordance with the MAHC,
2) As CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization, and
3) As specified by the manufacturer.

4.7.3.3.3.3 **Installation** The UV equipment shall be installed after the filtration and before addition of primary DISINFECTANT.

4.7.3.3.3.3.1 **Labeled** UV equipment shall be labeled with the following design specifications: maximum flow rate, minimum transmissivity, minimum intensity, and minimum dosage.

4.7.3.3.3.3.2 **Strainer Installation** An inline strainer shall be installed after the UV unit to capture broken lamp glass or sleeves.

4.7.3.3.3.4 **Electrically Interlocked** The equipment shall be electrically interlocked with feature pump*(s)* or automated feature supply valves, such that when the UV equipment fails to produce the required dosage as measured by automated sensor, the water features do not operate.

4.7.3.3.3.4.1[A] **Alarm/Interlock Setpoint** The UV alarm/interlock setpoint shall be such that it ensures that the minimum required dose is delivered under all possible conditions of water UV transmittance and lamp output at the actual flow rate.

4.7.3.3.3.4.2 **Operation** UV systems shall not operate if the RECIRCULATION SYSTEM is not operating.

4.7.3.3.3.5 **Calibrated UV Sensors** The UV equipment shall be complete with calibrated UV sensors, which record the output of all the UV lamps installed in a system.

4.7.3.3.3.5.1 **Multiple Lamps** Where multiple lamps are fitted, sufficient sensors shall be provided to measure each lamp.

4.7.3.3.3.5.2 **Fewer Sensors** If the design utilizes fewer sensors than lamps, the location of lamps and sensors shall be such that the output of all lamps is adequately measured.

4.7.3.3.3.6 **Automated Shut Down** The automated shut down of the UV equipment for any reason shall initiate a visual alarm or other indication which will alert staff on-site or remotely.

4.7.3.3.3.6.1 **Signage** Signage instructing staff or PATRONS to notify facility management shall be posted adjacent to the visual indication.

4.7.3.3.3.6.2 **Not Staffed** If the AQUATIC FACILITY is not staffed, the sign shall include a means to contact management whenever the AQUATIC FACILITY is in use.

4.7.3.3.3.7 **Reports and Documentation** The UV equipment shall be supplied with the appropriate validation reports and documentation for that equipment model.

4.7.3.3.3.8 **Manufacturer Log Inactivation Chart** This documentation will include a graph or chart indicating the dose at which the required log inactivation is guaranteed for the system in question.

4.7.3.3.3.8.1 **Reduction Equivalent Dose Bias** This dose shall be inclusive of validation factors and RED BIAS.

4.7.3.3.3.8.2 **System Performance Curves** System performance curves that do not include such factors are not considered validated systems.

4.7.3.3.3.9[A] **Minimum RED** Validation records shall include the graph indicating the minimum intensity reading required at the operational flow for the minimum RED required to achieve the required log reduction.

4.7.3.3.3.9.1 **Minimum Intensity Shown** Where systems are validated to a specific dose, the graph shall show the minimum intensity reading required at the operational flow for that dose.

4.7.3.3.3.10 **Recommended Validation Protocol** Based on the recommended validation protocol presented in the EPA Disinfection Guidance Manual, UV reactors certified by ÖNORM and DVGW for a *Bacillus subtilis* RED of 40mJ/cm^2 shall be granted 3-log *Cryptosporidium* and 3-log *Giardia* inactivation credit as required in this CODE.

4.7.3.3.4 Ozone Disinfection

4.7.3.3.4.1[A] **Log Inactivation** SECONDARY DISINFECTION SYSTEMS using ozone shall provide the required inactivation of *Cryptosporidium* in the full flow of the SECONDARY DISINFECTION SYSTEM after any side-stream has remixed into the full flow of the SECONDARY DISINFECTION SYSTEM.

4.7.3.3.4.2[A] **Third Party Validation** Ozone systems shall be validated by an ANSI-accredited third party testing and certification organization to confirm that they provide the required log inactivation of *Cryptosporidium* in the full SECONDARY DISINFECTION SYSTEM flow after any side-stream has remixed into the full SECONDARY DISINFECTION SYSTEM flow and prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE recirculation treatment loop.

4.7.3.3.4.3[A] **Suitable for Use** Ozone systems and all materials used therein shall be suitable for their intended use and be installed:

1) In accordance with all applicable requirements,
2) As CERTIFIED, LISTED, AND LABELED to a specific STANDARD by an ANSI-accredited certification organization, and
3) As specified by the manufacturer.

4.7.3.3.4.4 **Ozone System Components** An ozone system shall be a complete system consisting of the following *(either skid-mounted or components)*:

1) Ozone generator,
2) Injector / injector manifold,
3) Reaction tank *(contact tank)* / mixing tank / degas tower,
4) Degas valve *(if applicable, to vent un-dissolved gaseous ozone)*,
5) Ozone destruct *(to destroy un-dissolved gaseous ozone)*,
6) ORP MONITOR / controller,
7) Ambient ozone MONITOR / controller,
8) Air flow meter / controller, and
9) Water BACKFLOW prevention device in gas delivery system.

4.7.3.3.4.5 **Appropriate Installation** These components *(or skid)* shall be installed as specified by the manufacturer to maintain the required system validation as noted above.

4.7.3.3.4.6 **ORP Monitor** The ozone generating equipment shall be designed, sized, and controlled utilizing an ORP MONITOR / controller *(independent of and in addition to any halogen ORP MONITOR/controller)*.

4.7.3.3.4.6.1 **Placed Downstream** The device shall be placed in the AQUATIC VENUE and AQUATIC FEATURE recirculation water downstream of the ozone side-stream loop and before the halogen feed

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10389

90

Date Submitted	02/14/2022	**Section**	454	**Proponent**	Michael Weinbaum
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

SW10237

Summary of Modification

NSF 50 used to always test filters to 5 passes of the water volume. As of 2022 they recognize that some filters can sufficiently clean water in fewer than 5 passes, and publish this. Filters like this should get "credit" in the building code, allowing energy savings.

Rationale

The purpose of filtration is to reduce turbidity which increases the effectiveness of disinfecting chemicals. A filter that can do in 1 or 2 passes what other filters need 5 passes to accomplish should not be required to do as many passes per day.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This creates a new category of filters for code enforcement officials to consider.

Impact to building and property owners relative to cost of compliance with code

This creates an opportunity for some owners to reduce their energy costs by half.

Impact to industry relative to the cost of compliance with code

Industry is already providing these enhanced filters.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Filtration is needed to reduce the number of particles that the disinfectant will try to attack.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This allows new and better products to get credit for how much better they are.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

There is no discrimination. All manufacturers are able to recommend a reduced number of turnovers for their filter and see if they can still pass the turbidity reduction test.

Does not degrade the effectiveness of the code

The code remains effective.

1st Comment Period History

SW10389-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:06:55 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

1st Comment Period History

SW10389-G2

Proponent	bob vincent	Submitted	4/17/2022 7:28:51 PM	Attachments	Yes

Comment:

Florida Department of Health is not in favor of this mod. It should remain code and protocol to use the ANSI-certified filter evaluation test found in the FBC code referenced NSF/ANSI Standard 50. Tests and subsequent certification for filters are listed at manufacturer specified flow rates. Their flow rate and other criteria are listed in the certification. Should they be more efficient, that would be reflected in their increased flow rate. The flow rate is related to the turnover time. The NSF Std Normative Annex 2 from the attached Std is the testing criteria for filters, and their listed certifications are granted and posted by the ANSI-certified testing lab.

454.1.6.5.2 Volume. The recirculation system shall be designed to provide a minimum of four turnovers of the pool volume per day. Pools that are less than 1,000 square feet (93 m^2) at health clubs shall be required to provide eight turnovers per day.

454.1.6.5.2.1 Reduction in minimum turnover rate. Any pool regulated under 454.1.7, 454.1.8, or 454.1.9 may have the minimum turnover rate assigned in those sections reduced by half if the provided filter or filters have passed the NSF 50 turbidity reduction test in one or two passes.However, the reduced rate must be equal to or greater than the rate assigned by 454.1.6.5.2.

NSF International Standard /
American National Standard /
National Standard of Canada

NSF/ANSI/CAN 50 - 2020

Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs, and Other Recreational Water Facilities

NSF International, an independent, not-for-profit, nongovernmental organization, is dedicated to being the leading global provider of public health and safety-based risk management solutions while serving the interests of all stakeholders.

This Standard is subject to revision.
Contact NSF to confirm this revision is current.

Users of this Standard may request clarifications and interpretations, or propose revisions by contacting:

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NSF International Standard /
American National Standard /
National Standard of Canada
for Recreational Water Facilities–

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Preference is given to the use of performance criteria measurable by examination or testing in NSF Standards development when such performance criteria may reasonably be used in lieu of design, materials, or construction criteria.

The illustrations, if provided, are intended to assist in understanding their adjacent standard requirements. However, the illustrations may not include all requirements for a specific product or unit, nor do they show the only method of fabricating such arrangements. Such partial drawings shall not be used to justify improper or incomplete design and construction.

At the time of this publication, examples of programs and processes were provided for general guidance. This information is given for the convenience of users of this standard and does not constitute an endorsement by NSF International. Equivalent programs and processes may be used.

Unless otherwise referenced, the annexes are not considered an integral part of NSF Standards. The annexes are provided as general guidelines to the manufacturer, regulatory agency, user, or certifying organization.

[1] The information contained in this Disclaimer is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Disclaimer may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

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Contents

Foreword[2]

The purpose of this Standard is to establish minimum materials, design and construction, and performance requirements for components, products, equipment and systems, related to public and residential recreational water facility operation.

If a value for measurement is followed by a value in other units in parenthesis, the second value may be only approximate. The first stated value is the requirement.

All references to gallons (gal) are in US gallons.

This Standard is designated as a National Standard of Canada (NSC) in compliance with requirements and guidance set out by the Standards Council of Canada (SCC).

This edition of the Standard contains the following revisions:

Issue 139

This revision updates language related to turbidity reduction testing in Section N-2.5. It also added a definition for "*high capacity cartridge filter*."

Issue 141

This revision modifies language relating to low pressure UV lamp testing in Section 15.8.1.

Issue 160

This revision updates language relating to pump flow rate outputs in Section 7.

Issue 163

This revision adds language regarding crypto reduction claims for filters in Sections 6.1 and N-2.9.

Issue 164

This revision clarifies the scope for pool chemical evaluation in the newly created Section 27.

Issue 165

This revision moves language from Annex N-12 to the newly created Section 27.

Issue 167

This revision updates language regarding piping materials in Section 4.5.

Issue 174

This revision corrects typos from a previous ballot in the chemical evaluation tables in the newly created Section 27.

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This Standard was developed by the NSF Joint Committee on Recreational Water Facilities using the consensus process described by the American National Standards Institute's *Essential Requirements* and the Standards Council of Canada's *Requirements and Guidance*. At the time of approval, the Joint Committees consisted of 10 public health / regulatory, 10 industry, and 10 user representatives.

The Standard and the accompanying text are intended for voluntary use by certifying organizations, regulatory agencies, and/or manufacturers as a basis of providing assurances that adequate health protection exists for covered products.

Suggestions for improvement of this Standard are welcome. This Standard is maintained on a continuous maintenance schedule and can be opened for comment at any time. Comments should be sent to: Chair, Joint Committee on Recreational Water Facilities at standards@nsf.org, or c/o NSF International, Standards Department, PO Box 130140, Ann Arbor, Michigan 48113-0140, USA.

SCC Foreword[3]

A National Standard of Canada is a standard developed by a Standards Council of Canada (SCC) accredited standards development organization, in compliance with requirements and guidance set out by the SCC. More information on National Standards of Canada can be found at <www.scc.ca>.

SCC is a Crown corporation within the portfolio of Innovation, Science and Economic Development (ISED) Canada. With the goal of enhancing Canada's economic competitiveness and social well-being, SCC leads and facilitates the development and use of national and international standards. SCC also coordinates Canadian participation in standards development, and identifies strategies to advance Canadian standardization efforts.

Accreditation services are provided by SCC to various customers, including product certifiers, testing laboratories, and standards development organizations. A list of SCC programs and accredited bodies is publicly available at <www.scc.ca>.

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NSF/ANSI/CAN Standard
for Recreational Water Facilities –

Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs, and other Recreational Water Facilities

Evaluation criteria for materials, components, products, equipment, and systems for use at recreational water facilities

1 General

1.1 Scope

This Standard covers materials, chemicals, components, products, equipment and systems related to public and residential recreational water facility operation.

1.2 Variations in design and operation

A component varying in design or operation may qualify under this Standard. Appropriate tests and investigations shall indicate that the component performs as well as components conforming to this Standard. Such components shall meet the requirements for materials, finishes, and construction in this Standard.

1.3 Alternate materials

If specific materials are mentioned, other materials equally satisfactory from the standpoint of public health may be permitted.

1.4 Standard review

A complete review of this Standard shall be conducted at least every five years. These reviews shall be conducted by representatives from the industry, public health, and user groups, or agencies of the NSF Joint Committee on Recreational Water Facilities.

2 Normative references

The following documents contain provisions that, through reference in this text, constitute provisions of this Standard. At the time of publication, the indicated editions were valid. All standards are subject to revision and parties are encouraged to investigate the possibility of applying the recent editions of the standards indicated below. The most recent published edition of the document shall be used for undated references.

21 CFR Chapter 1, *Code of Federal Regulations*[4]

21 CFR Part 58, Subchapter A, *Code of Federal Regulations*[4]

[4] US Government Publishing Office. 732 North Capitol Street NW, Washington, DC 20401. <www.govinfo.gov/app/collection/cfr>

40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants*[4]

40 CFR Part 141, *National Primary Drinking Water Regulations*[4]

40 CFR Part 143, *National Secondary Drinking Water Regulations*[4]

ANSI/APSP/ICC-11, *Standard for Water Quality in Public Pools and Spas*[5]

ANSI/APSP-16 – 2011, *Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs*[5]

ANSI/ASME A112.3.1 – 2007, *Stainless Steel Drainage Systems for Sanitary DWV, Storm, and Vacuum Applications Above and Below Ground*[6]

ANSI/ASME A112.6.3 – 2016 (R2007), *Floor and Trench Drains*[6]

ANSI/ASME A112.6.4 – 2003 (R2012), *Roof, Deck and Balcony Drains*[6]

ANSI/ASME A112.19.17 – 2010, *Safety Vacuum Release Systems (SVRS) for Residential & Commercial Swimming Pool, Spa, Hot Tub, Wading Pool Suction System*[6]

ANSI/ASME B40.100 – 2005, *Pressure Gauge and Gauge Attachments*[6]

APHA/AWWA/WEF, *Standard Methods for the Examination of Water and Wastewater*, 23rd edition (hereinafter referred to as *Standard Methods*)[7]

AS 4586 – 2013, *Slip resistance classification of new pedestrian surface material*[8]

ASME Boiler and Pressure Vessel Code, 2017[6]

ASTM C136/C136M – 2014, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, 2004*[9]

ASTM D1894 – 2014, *Standard Test Method for Static and Kinetic Coefficients of Plastic Film and Sheeting*[9]

ASTM D2464 – 2013, *Standard Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*[9]

ASTM D2466 – 2015, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*[9]

ASTM D2467 – 2006, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*[9]

ASTM, D3739 – 2010, *Standard Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis*[9]

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[5] Pool & Hot Tub Alliance (formerly the Association of Pool & Spa Professionals / National Swimming Pool Foundation). 2111 Eisenhower Avenue, Suite 500, Alexandria, VA 22314. <www.phta.org>

[6] The American Society of Mechanical Engineers. Two Park Avenue, New York, NY 10016. <www.asme.org>

[7] American Public Health Association, American Water Works Association, and Water Environment Federation. *Standard Methods for the Examination of Water and Wastewater*. <www.standardmethods.org>

[8] Standards Australia. Level 10, The Exchange Centre, 20 Bridge Street, Sydney NSW 2000, Australia. <www.standards.org.au>

[9] ASTM International. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. <www.astm.org>

ASTM E11 – 2009, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, 2009*[9]

ASTM E1153 – 2014, *Standard Test Method For Efficacy Of Sanitizers Recommended For Inanimate, Hard, Nonporous, Non-Food Contact Surfaces*[9]

ASTM F1346-91 – 2003, *Standard Performance Specification for Safety Covers and Labeling Requirements for All Covers for Swimming Pools, Spas and Hot Tubs*[9]

ASTM F2049-11 (2017), *Standard Safety Performance Specification for Fences/Barriers for Public, Commercial, and Multi-Family Residential Use Outdoor Play Areas*[9]

ASTM F2208 – 2014, *Standard Safety Specification for Residential Pool Alarms*[9]

ASTM F2387 – 2004, *Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas and Hot Tub*[9]

ASTM F2409-10 (2016), *Standard Guide for Fences for Non-Residential Outdoor Swimming Pools, Hot Tubs, and Spas*[9]

ASTM F2699-08 (2013), *Standard Guide for Fences for Commercial and Public Outdoor Water Spray/Play Areas*[9]

ASTM G154, *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*[9]

CEC-400-2016-002 Title 20, *California Energy Commission 2009 Appliance Efficiency Regulations*[10]

CSA B45.5/IAPMO Z124.1.2 – 2005 2011, Plastic Bathtub and Shower Units[11]

DIN EN-1177, *Impact attenuating playground surfacing – Methods of test for determination of impact attenuation*[12]

DVGW 2006, *UV disinfection devices for drinking water supply – requirements and testing*[13]

DVGW W294-1, -2, and -3[13]

IAPMO/ANSI Z124.7-2013, *Prefabricated Plastic Spa Shells*[14]

IAPMO/ANSI Z124.1.2-2005, *Plastic Bathtub and Shower Units*[14]

IAPMO/ANSI Z1033-2013c, *Flexible PVC Hose for Pools, Hot Tubs, Spa, and Jetted Bathtubs*[14]

IAPMO/ANSI Z1033-2015, *Flexible PVC Hoses and Tubing for Pools, Hot Tubs, Spas, and Jetted Bathtubs*[14]

[10] California Energy Commission. 1516 Ninth Street, Sacramento, CA 95814. <www.energy.ca.gov>

[11] CSA Group. 178 Rexdale Boulevard, Toronto, ON M9W 1R3, Canada. <www.csa.ca>

[12] European Standards. Krimicka 134, 318 13 Pilsen, Czech Republic. <www.en-standard.eu>

[13] Deutscher Verein des Gas- und Wasserfaches. Josef-Wirmer-Straße 1-3, 53123 Bonn, Germany. <www.dvgw.de>

[14] International Association of Plumbing and Mechanical Officials. 4755 E Philadelphia St., Ontario, CA 91761. <www.iapmo.org>

ISO/TS 15883-5, *Washer-disinfectors – Part 5: Test soils and methods for demonstrating cleaning efficacy Annex H*[15]

Model Aquatic Health Code 2018[16]

NFPA 70, Article 30 – 2017, *National Electrical Code* (NEC)[17]

NSF/ANSI 14, *Plastics Piping System Components and Related Materials*

NSF/ANSI 42, *Drinking Water Treatment Units – Aesthetic Effects*

NSF/ANSI 51, *Food Equipment Materials*

NSF/ANSI/CAN 60, *Drinking Water Treatment Chemicals – Health Effects*

NSF/ANSI/CAN 61, *Drinking Water System Components – Health Effects*

NSF/EPA ETV, *Generic Protocol for Development of Test / Quality Assurance Plans for Ultraviolet (UV) Reactors*

ÖNORM M 5873-1, *Plants for the disinfection of water using ultraviolet radiation - Requirements and testing – Low pressure mercury lamp plants*, 2001[8]

SAE Steel Numbering System[18]

UL 1081-2016, 7th edition, *Standard for Swimming Pool Pumps, Filters, and Chlorinators*[19]

UL 1261-2016, 6th edition, *Standard for Electric Water Heaters for Pools and Tubs*[19]

UL 1563-2009, *Standard for Electric Spas, Equipment Assemblies, and Associated Equipment*[19]

UL 2017-2011, *Standard for General-Purpose Signaling Devices and Systems*[19]

US EPA, *Methods for the Determination of Inorganic Substances in Environmental Samples*, 1993[20]

US EPA, *Methods for the Determination of Organic Compounds in Drinking Water Supplement*, 1990[20]

US EPA-600/4-79-020, *Methods for the Chemical Analysis of Water and Wastes*, March 1983[20]

US EPA *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*, November 2006[20]

[15] International Organization for Standardization. Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland. <www.iso.org>

[16] Centers for Disease Control and Prevention, 2500 Century Parkway, Mailstop E-78, Atlanta, GA 30333. <www.cdc.gov>

[17] National Fire Protection Association. 1 Batterymarch Park, Quincy, MA 02169-7471. <www.nfpa.org>

[18] SAE International. 400 Commonwealth Drive, Warrendale, PA 15096. <www.sae.org>

[19] UL LLC. 33 Pfingsten Road, Northbrook, IL 60062. <www.ul.com>

[20] Superintendent of Documents, US Government Printing Office. Washington, DC 20402<www.gpo.gov>

3 Definitions

3.1 accessible: Fabricated to be exposed for cleaning and inspection using simple tools (screwdriver, pliers, open-end wrench, etc.).

3.2 accuracy: The nearness of a measurement to the accepted or true value.[21] The accuracy is expressed as a range, about the true value, in which a measurement occurs (i.e., ± 0.5 ppm). It can also be expressed as the percent recovery of a known amount of analyte in a determination of the analyte (i.e., 103.5%).

3.3 agitation: Mechanical or manual movement to dislodge filter aid and dirt from the filter element.

3.4 air assist backwash: A compression of air in the filter effluent chamber using an air compressor or water pressure from the recirculating pump. When released, it rapidly decompresses and forces water in the filter tank through the elements in reverse direction to dislodge the filter aid and accumulated dirt and carry them to waste.

3.5 alternate sand-type media: Granular material(s) specified to be used instead of sand in a sand-type filter.

3.6 amps: The current, in amperes, under the motor data plate horsepower at rated volts.

3.7 analyte: Parameter that is a subject of the water analysis, such as pH or free chlorine.

3.8 automated controller: A system of at least one chemical probe, a controller, and auxiliary or integrated component, that senses the level of one or more swimming pool or spa / hot tub water parameters and provides a signal to other equipment to maintain the parameter(s) within a user-established range.

3.9 backwash: Flow of water through filter element(s) or media in a reverse direction to dislodge accumulated dirt or filter aid and remove them from the filter tank.

3.10 backwash cycle: Time required to thoroughly backwash the filter system.

3.11 backwash rate: Rate of application of water through a filter during backwash expressed in gal/min/ft^2 (L/min/m^2) of effective filter area.

3.12 body feed: Continuous addition of controlled amounts of filter aid during operation of a diatomite-type filter to maintain a permeable filter cake. If added as a slurry, this may be referred to as slurry feed.

3.13 bromine: A chemical that works as a sanitizer or disinfectant to kill bacteria and algae in pool and spa water.

3.14 cartridge: A depth- or surface-type filter component with fixed dimensions and designed to remove suspended particles from water flowing through the unit.

3.15 chemical feed rate indicator: Mechanism that produces reproducible results expressed in units of weight or volume of chemical per unit of time or per unit of volume of water. The mechanism may be a direct reading instrument or may require the use of a reference chart.

3.16 chemical feeder output rate: Weight or volume of active ingredients delivered by a chemical feeder, expressed in units of time.

3.17 chemical probe (sensor): Component of an automated controller that monitors a given control parameter (pH, ORP, free Cl_2, etc.).

[21] Skoog D.A., West D.M., *Fundamentals of Analytical Chemistry, 2nd* ed., Holt Rinehart and Winston, Inc. 1969, p.26

3.18 chlorine: A chemical that works as a sanitizer or disinfectant in pool and spa water to kill bacteria and algae and oxidizes ammonia and nitrogen compounds that can enter the pool / spa from swimmer body wastes and other sources.

3.19 cleaning: Physical removal of soiling materials.

3.20 combined chlorine: Chlorine that has combined with ammonia, nitrogen, or other organic compounds.

3.21 comply (complies, compliance): Meeting the requirements of the standard, which includes standards incorporated by reference in the text.

3.22 contaminant: Undesirable organic and inorganic, soluble and insoluble substances in water including microbiological organisms.

3.23 controller: Component of an automated controller that receives signals from chemical probes or sensors and sends an output signal to actuate equipment.

3.24 coolant flow rate: The flow rate of the coolant used to remove heat from the reaction chamber(s) of the ozone generator.

NOTE — The critical factor for heat removal is the mass flow rate (kg/h) of the coolant. The mass flow rate of the coolant is equal to the volumetric flow rate (m^3/h, ft^3/h) of the coolant times the density (kg/m^3, lb/ft^3) of the coolant.

For liquid cooled systems the density of the coolant (liquid) is virtually independent of temperature and pressure and can be specified as the volumetric flow rate of the cooling liquid (m^3/h, ft^3/h, GPM, LPM).

For gas cooled systems the density (and therefore the mass flow rate) of the coolant gas is dependent on temperature and pressure. For this Standard, the pressure and temperature ranges are small. The volumetric flow rate (m^3/h, ft^3/h, LPM, ft^3/m, CFM) of the coolant shall be specified. As a practical approximation of the mass flow rate.

3.25 corrosion resistant: Capable of maintaining original surface characteristics under prolonged contact with the use environment.

3.26 cover mounting ring: Fitting containing a recess located in the deck to receive the cover of a surface skimmer.

3.27 dead weight: Mass expressed typically in pounds (kilograms) per square foot (meter) to assist in assessment of use relative to floor strength and loading requirements. The intrinsic, invariable weight of a structure such as a spa, including the water and bather weight.

3.28 depth-type cartridge: Filter cartridge with media relying on penetration of particles into the media for removal and providing adequate holding capacity of such particles.

3.29 dew point (dew-point temperature): The temperature saturation (assuming air pressure and moisture content are constant). For corona discharge ozone generation greater than 2 g/h, the minimum dew point is -76 °F (-60 °C). For systems less than 2 g/h, the minimum dew point is -40 °F (-40 °C).

NOTE — For systems less than 2 g/h, the amount of nitric acid produced is negligible.

3.30 diatomite filter element: Device in a filter tank to trap solids and convey water to a manifold, collection header, pipe, or similar conduit. Filter elements usually consist of a septum and septum support.

3.31 disinfection: Killing of pathogenic agents by chemical or physical means directly applied.

3.32 easily cleanable: Manufactured so that dirt and debris and other soiling material may be removed by manual cleaning methods.

3.33 effective size: The size opening that will just pass 10% (by dry weight) of a representative sample of the filter material

3.34 effluent: The treated stream emerging from a unit, system, or process.

3.35 electronic water quality test device: A device that requires power supply (such as line current or a battery) to yield a result.

3.36 electrolytic chlorinator: A device that converts dissolved chloride salt (sodium chloride) into chlorine and its reaction products.

3.37 equalizer line: An automatically operating line from below the pool surface to the body of a skimmer, designed to prevent air being drawn into the filter when the water level drops below the skimmer inlet.

3.38 feed gas: The gas (ambient air, dry air, or oxygen) delivered to the inlet side of the ozone generator. The required quality and feed gas flow rate is determined by the manufacturer.

3.39 feed gas flow rate: The flow rate of the feed gas through the reaction chamber(s) of the ozone generator.

> NOTE — The critical factor for the reaction is the mass flow rate (kg/h) of the feed gas. The mass flow rate is the volumetric flow rate (m^3/h, ft^3/h) of the feed gas times the density (kg/m^3, lb/ft^3) of the feed gas.
>
> The density of a gas is dependent on the temperature and pressure. Because of the continuous variability of the parameters affecting density and volumetric flow rate in an ozone generator, there is no practical method to determine the true mass flow rate of the feed gas. For this Standard, due to the small range of pressure and temperature, the volumetric flow rate is specified as an approximation of the mass flow rate.
>
> For pressurized systems, the manufacturer specifies the volumetric flow rate and the gauge pressure of the feed gas at the inlet to the ozone generator.

3.40 filled weight: Mass expressed typically in pounds (kilograms) to explain the total weight of a product when operating at capacity. Filled weight of a product or structure such as a spa, including the water and bather weight.

3.41 filter aid: Finely divided medium (diatomaceous earth, processed perlite, etc.) used to coat a septum of a diatomite-type filter.

3.42 filter design flow rate: Flow rate of a filter determined by multiplying the total effective filter area by the allowable filtration rate, expressed in GPM (LPM).

3.43 filter media: The material that separates particulate matter from the water passing through.

3.44 filtration cycle (filter run): Operating time between filter cleanings.

3.45 filter, cartridge-type: A pressure or vacuum-type device designed to filter water through one or more cartridges.

3.46 filter, diatomite-type: A pressure or vacuum-type device designed to filter water through a thin layer of filter aid.

3.47 filter, high permeability-type: A pressure- or vacuum-type device designed to filter water through a high permeability element.

3.48 filter, sand-type: A device designed to filter water through sand or an alternate sand-type media. The filtration process may be done under pressure, under vacuum, or by gravity.

3.49 filtration rate: Flow rate of water through a filter expressed in gal/min/ft^2 (L/min/m^2) of effective filter area.

3.50 fitting: A piping component used to join, terminate, or provide changes of direction in a piping system (NSF/ANSI 14). These include, but are not limited to, these types: water inlet, water return, surface, deck drain, overflow, perimeter grating, water circulation, and treatment.

3.51 flow balance valve: Device to regulate effluent from the skimmer housing of each of two or more surface skimmers.

3.52 flow cell: A closed container with ports for the installation of one or more chemical probes, inlet and outlet ports for water and typically a sample port. A flow cell provides for offline installation of the chemical probes and a consistent flow of the water to be sampled.

3.53 flow meter (flow metering device): A device that measures the rate of flow of a substance through a conduit.

3.54 freeboard: Clear vertical distance in a sand-type filter between top of filter media and lowest outlet of upper distribution system.

3.55 free bromine: Bromine that has not combined with ammonia, nitrogen, or other organic compounds.

3.56 free chlorine: Chlorine that has not combined with ammonia, nitrogen, or other organic compounds.

3.57 friction loss: Pressure drop, expressed in feet (meters) of water or psi (kPa), caused by liquid flowing through the piping and fittings. (Friction loss tables may be used to estimate the actual friction loss in a system.)

3.58 head loss: Total pressure drop in psi (kPa) or feet (meters) of water (head) between inlet and outlet of a component.

3.59 high capacity cartridge filter: A cartridge-type filter designed for use at filtration rates ≤ 0.375 gpm/ft^2.

3.60 high permeability element: Mechanically interlocked, nonwoven filter material designed to remove suspended solids.

3.61 high rate: Design filtration rate greater than 5 gal/min/ft^2 (203 L/min/m^2) for public and residential pools, spas, or hot tubs.

3.62 hydrogen peroxide: A compound consisting of two atoms of hydrogen and two atoms of oxygen (H_2O_2) usually supplied in an aqueous solution.

3.63 indoor use: A product that is not designed, tested or certified for use outside or to be exposed to the elements and weather.

3.64 influent: The water stream entering a unit, system, or process.

3.65 integral: Part of the device that cannot be removed without compromising the device's function or destroying the physical integrity of the unit.

3.66 interactive waterplay venue: Any indoor or outdoor recreational water facility that includes sprayed, jetted, or other water sources contacting bathers and not necessarily incorporating standing or captured water as part of the bather activity area. These aquatic venues are also known as, but not limited to, splash pads, spray pads, wet decks.

3.67 Level 1 (L1): The highest accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy testing.

3.68 Level 2 (L2): The intermediate accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy Testing.

3.69 Level 3 (L3): The lowest accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy Testing.

3.70 manufactured manifold: Any combination of pipe and fittings provided by the valve manufacturer to form valve assembly using two or more valves.

3.71 maximum design head loss (filters): The maximum head loss recommended by the manufacturer for a clean filter at a specific flow rate.

3.72 maximum load amps: The maximum current, in amperes, under the service factor horsepower at -10% of the rated voltage.

3.73 mg/L or ppm: An abbreviation for milligrams per liter or parts per million, which is a concentration measurement for sanitizers and other chemical parameters such as alkalinity, calcium hardness, iron, copper, etc.

3.74 multiport valve: A device used to direct flow to, through, and from a swimming pool, spa, or hot tub filter, and usually replaces conventional valves and face piping on a filter.

3.75 net positive suction head (NPSH): The head available at the entrance or eye of an impeller to move and accelerate water entering the eye. This is the gauge pressure at the suction flange of pump plus velocity head.[22]

3.76 non-self-contained spa (hot tub / swim spa / therapy spa / resistance system): A factory-built spa in which the water heating and circulating equipment is not an integral part of the product. Non-self-contained spas may employ separate components such as individual filter, pump, heater and controls, or they may employ assembled combinations of various components.

3.77 nonelectric water quality test device: A device that does not require a power supply (such as line current or a battery) to yield a result.

3.78 NPSH available (NPSHA): Function of the system in which the pump operates. Available NPSH shall be at least equal to the required NPSH at the desired flow rate.

3.79 NPSH required (NPSHR): Value supplied by the pump manufacturer, based on the pump design.

3.80 operating range: The range for a parameter within which a water quality testing device (WQTD) provides acceptable accuracy as specified by the manufacturer. The operating range determines the test solutions used to evaluate the WQTD. Examples of operating ranges typical for WQTD's are water temperature 70 to 102 °F (20 to 50 °C), pH 6.8 to 8.2, free and combined chlorine 0 to 5 ppm or 0 to 10 ppm.

[22] See Section 7.6 for pump performance curve requirements.

3.81 operating water level: Level at which the water shall be maintained to enable proper water circulation and skimming.

3.82 outside use: A product that is designed, tested or certified for use outside or to be exposed to the elements and weather.

3.83 oxidation reduction potential (ORP): The potential in millivolts required to transfer electrons from the oxidant to the reductant, used as a qualitative measure of the state of oxidation in water treatment. The more positive the value, the more oxidizing the solution. ORP provides a qualitative indication of the activity of the sanitizer but is not a measure of disinfectant concentration.

3.84 ozone: A gas consisting of three atoms of oxygen (O_3).

3.85 ozone concentration: The amount of ozone in the gas stream leaving the generator. Concentration may be reported by any of the following: weight percent, g/m^3, volume percent, ppm by weight, ppm by volume, and the milligrams of ozone per liter of gas produced. Under this Standard, concentration will be reported by weight percent and g/m^3.

3.86 ozone generator: A device that when supplied with an oxygen containing gas and power, produces an ozone-containing gas. Said ozone generator includes any controls, transformers and frequency generators required to convert a standard electrical supply (as specified) to the electrical characteristics required to operate the generator cell properly.

3.87 ozone generator cell pressure: The gauge pressure of the feed gas in the reaction chamber(s).

3.88 ozone output rate: The mass of ozone produced by an ozone generator in weight per unit time (g/h, lb/h). Output rate is the mass of ozone per volume of product gas (g/m^3, lb/ft^3) multiplied by the feed gas flow rate (m^3/h, LPM, ft^3/h, CFM).

3.89 ozone short cycle or batch system: Systems that are not designed to operate for more than 5 min at a time.

3.90 packaged ozone system: An ozone generator packaged with a gas preparation system, typically on a single skid or otherwise a single unit.

3.91 pH: A numerical value expressing acidity or alkalinity, where 7 is neutral, higher values are more alkaline (basic) and lower values are more acidic. The numerical value is the negative base 10 log of the hydrogen ion concentration.

3.92 pool water: Water with a specific conductivity as shown below:

— Type 1 has a conductivity less than or equal to an aqueous sodium chloride solution of 1,500 ppm;

— Type 2 has a conductivity greater than Type 1 and less than or equal to an aqueous sodium chloride solution of 6000 ppm; and

— Type 3 water has a conductivity greater than Type 2.

NOTE — TDS are to include any total dissolved solids that exist within makeup up or initial fill water supply.

3.93 positive displacement: Mechanical displacement of fluid.

3.94 power: Brake horsepower input required to operate pumps.

3.95 precision: The numerical agreement between two or more measurements using the same test equipment.[23] The precision can be reported as the range for a measurement (difference between the minimum and maximum results). It can also be reported as the standard deviation or the relative standard deviation. It is a measure of how close together the measurements are, not how close they are to the correct or true value.

3.96 precoat: Layer of filter aid on septum of a diatomite-type filter at beginning of a filter cycle.

3.97 process equipment: Equipment used for on-site generation or application of ozone, ultraviolet light / hydrogen peroxide, copper and silver ions, or chlorine.

3.98 public spa (hot tub / swim spa / therapy spa resistance system): A spa other than a permanent residential spa or portable residential spa which is intended to be used for bathing and is operated by an owner, licensee, concessionaire, regardless of whether a fee is charged for use.

3.99 pump discharge pressure: Actual gauge reading taken at the discharge of a pump, expressed in kPa (psi).

3.100 reagent: A solid or liquid component of a water quality testing device (WQTD) that is used to condition a sample or that reacts with a test parameter as part of a test procedure.

3.101 reagent grade: A "laboratory" or highly purified grade of chemical.

3.102 readily accessible: Fabricated to be exposed for cleaning and inspection without using tools.

3.103 readily removable: Capable of being taken away from the main unit without using tools.

3.104 relative humidity: The ratio, in percent, of the actual amount of water vapor in a body of air in relation to the maximum amount that the body can hold at a given temperature. Relative humidity varies with temperature for a given amount of water vapor.

3.105 removable: Capable of being taken away from the main unit using only simple tools (screwdriver, pliers, open-end wrench, etc.).

3.106 repeatability: The within-run precision.[24]

3.107 reproducibility: The between-run precision.[24]

3.108 resolution: The smallest discernible difference between any two measurements that can be made.[24] For meters, this is usually how many decimal places and significant figures are displayed (i.e., 0.01). For titrations and various comparators, it is the smallest interval the device is calibrated or marked to (i.e., 1 drop = 10 ppm, 0.2 ppm for a direct read titration (DRT), or plus or minus half a unit difference for a color comparator or color chart).

3.109 run: A run is a single data set, from set up to clean up. Generally, one run occurs on one day. However, for meter calibrations, a single calibration is considered a single run or data set, even though it may take two or three days.

3.110 safety surfacing system: products intended to cover the floor of a recreational water venue that also comply with the requirements of this Standard, including the impact attenuation and slip resistance requirements.

[23] Jeffery G. H., Basset J., Mendham J., Denney R.C., *Vogel's Textbook of Quantitative Chemical Analysis*, 5th ed., Longman Scientific & Technical, 1989, p. 130.

[24] Statistics in Analytical Chemistry: Part 7 – A Review, D. Coleman and L Vanatta, American Laboratory, Sept 2003, p. 34.

3.111 sand-type filter, lower distribution system (underdrain [effluent]): Devices in the bottom of a sand-type filter to collect water uniformly during filtering and to uniformly distribute the backwash water.

3.112 sand-type filter, upper distribution system (influent): Devices to distribute water entering a sand-type filter to prevent movement or migration of the filter media. This system also collects water during filter backwashing unless other means are provided.

3.113 sealed: Fabricated without openings to prevent entry of liquid.

3.114 secondary disinfection: Units that demonstrate a 3 log (99.9%) or greater reduction or inactivation of *Cryptosporidium parvum* in a single pass when tested in accordance to Section 14.18.2.

3.115 self-contained spa (hot tub / swim spa / therapy spa / resistant system): A factory-built spa in which all control, water heating, and water-circulating equipment is an integral part of the product. Self-contained spas may be permanently wired or cord connected.

3.116 self-priming centrifugal pump: Pump (after initial filling with water) capable of priming and repriming a dry suction line (up to 10 ft [3 m] vertical lift) without using foot or check valves or adding water.

3.117 septum: Part of a diatomite-type filter element consisting of cloth, wire screen, or other porous material on which filter aid is deposited.

3.118 service factor amps: The current, in amperes, under the service factor horsepower at rated volts.

3.119 service factor horsepower: The motor data plate horsepower multiplied by the data plate service factor.

3.120 set point: The user established target level of a parameter (pH, ORP, etc.) to be maintained by an automated controller.

3.121 skid pack: A separate collection of components that are not an integral part of a pool, spa, or hot tub such as, but not limited to, filters, pumps, heaters, controls, fittings, pipes, and skimmers that are to be installed in accordance with the manufacturer's specifications.

3.122 skimmer cover: Device or lid to close deck opening to the skimmer housing.

3.123 skimmer equalizer pipe: Connection from skimmer housing to the pool, spa, or hot tub below the weir and sized to satisfy pump demand and prevent air lock.

3.124 skimmer equalizer valve: Device on the equalizer line that opens when water level inside skimmer tank drops below operating level and remains closed during normal skimming.

3.125 skimmer housing: Structure that attaches to or contains skimmer weir, strainer basket, and other devices used in the skimming operation.

3.126 skimmer weir assembly: Floating device over which water from the pool, spa, or hot tub passes during skimming, along with its means of guiding or attachment to, the skimmer.

3.127 slurry feed: Refer to body feed definition (see Section 2.12).

3.128 spa / hot tub (exercise spa, swim spa, therapy spa, resistance system): A unit, which is not usually drained, cleaned, or refilled for each individual. It may include, but is not limited to, hydro-jet circulation, hot water or cold water mineral baths, air induction bubbles, or any combination thereof. A portable or nonportable water basin intended for the total or partial submersion of persons in temperature-controlled water circulated in a closed system, and not intended to be drained and filled with each use. It is manufactured to factory specifications using specific design, plumbing, components, and suppliers such that the water is circulated, treated, and filtered via a closed-loop system. This may include certain systems or components integral to the spa, including but limited to, tub or shell structure and support system, steps and seats, hand hold(s) and rail(s), filter(s), pump(s), suction fitting(s) or drain(s), water return fittings, skimmers, piping, tubing hose, other air or water distributing fitting(s), resistance exercise equipment, heater(s) (solar, electric, or gas), chemical treatment system(s), control system, jets, lighting, blowers, A/V equipment or as part of a separate manufacturer specified assembly skid-pack. A water basin may contain specific features and equipment to produce a water flow intended to allow physical activity, but not limited to, exercising or swimming in place, hydro-therapy, resistance exercise or flotation and it is designed to allow for an unobstructed volume of water large enough to allow these activities.

3.129 spray rinse, manual: Spray system used manually for washing filter aid or accumulated dirt from filter surface either in place or after removal from filter tank (usually by a hose and nozzle).

3.130 spray rinse, mechanical: Fixed or mechanically movable spray system that directs a stream of water against filter surface and causes the filter aid or accumulated dirt to dislodge.

3.131 standard rate (rapid rate): Design filtration rate is not greater than 3 gal/min/ft^2 (122 L/min/m^2) for public pools, spas, or hot tubs, and not greater than 5 gal/min/ft^2 (203 L/min/m^2) for residential pools, spas, or hot tubs.

3.132 static suction lift: Vertical distance in meters (feet) from center line of the pump impeller to pool water level.

3.133 strainer basket: Readily removable, perforated, or otherwise porous container to catch coarse material.

3.134 supplemental disinfection: Units that demonstrate a 3 log (99.9%) or greater reduction of *Pseudomonas aeruginosa* and *Enterococcus faecium* when tested according to Section N-8.1.

3.135 supporting material: Material to support filter media in a sand-type filter.

3.136 surface-type cartridge: Filter cartridge with media relying on retention of particles on the surface of the cartridge for removal.

3.137 test solution: The liquid used to conduct a particular test or challenge.

3.138 total bromine: the sum of all active bromine compounds.

3.139 total chlorine: The sum of free and combined chlorine compounds.

3.140 total dynamic head: Arithmetic difference between total discharge head and suction head. (A vacuum reading is considered a negative pressure.) This value is used in developing the performance curve.

3.141 total discharge head: The static discharge head, plus the discharge velocity head, plus the friction head in the discharge line.

3.142 total suction head[22]: The static suction head minus the friction head in the suction line.

3.143 total dynamic suction lift (TDSL): Arithmetic total of static suction lift, friction head loss, and velocity head loss on suction side of pump.

3.144 toxic: Having an adverse physiological effect on humans.

3.145 trimmer valve: Flow adjusting device used to proportion flow between the skimming weir and main suction line, from the main outlet, or from the vacuum cleaning line.

3.146 turbidity: A measurement of suspended particulate matter in water expressed as nephelometric turbidity units (NTU).

3.147 turnover rate: The time required to recirculate the entire volume of water in a swimming pool, spa, or hot tub.

3.148 ultraviolet (UV) light: The segment of the light spectrum between 100 to 300 nm.

3.149 ultraviolet (UV) unit: A device that produces ultraviolet light between 250 to 280 nm for the purpose of inactivation of microorganisms by UV radiation.

3.150 uniformity coefficient: A ratio calculated as the size opening that will just pass 60% (by dry weight) of a representative sample of the filter material divided by the size opening that will just pass 10% (by dry weight) of the same sample.

3.151 user: Any person using a pool, spa, or hot tub, and adjoining deck area for the purpose of water sports, recreation, or related activities.

3.152 vacuum: Pressure lower than atmospheric pressure.

3.153 vacuum cleaner connection: Connection to attach a hose for cleaning.

3.154 water conditioning device: A device intended to treat swimming pool water and improve water quality without the introduction of additional chemicals.

3.155 waterline: Top of the overflow outlet of the spa.

3.156 water quality testing device (WQTD): A product designed to measure the level of a water quality parameter. A WQTD includes a device or method to provide a visual indication of a water quality parameter level and may include one or more reagents and accessory items.

3.156.1 WQTD accuracy: Accuracy is defined as how close the WQTD result is to the reference value.

3.156.2 WQTD precision: Precision is defined as how close replicates of a single value are to each other.

3.157 working pressure: Maximum operating pressure recommended by manufacturer.

3.158 zeolite: Hydrated aluminosilicates that contain sodium, potassium, magnesium, and calcium.

4 Swimming pool water contact materials

4.1 Materials

Materials shall not sustain permanent damage or deformation when subject to repeated handling associated with the routine operation and maintenance of the equipment.

Materials intended to be in contact with swimming pool or spa / hot tub water shall not impart undesirable levels of contaminants or color to the water, as determined in accordance with Annex N-1. The following items are exempt from the material review procedures described in Annex N-1:

— swimming pool and spa / hot tub components with a surface area less than 100 in^2 (650 cm^2) in direct contact with water;

— swimming pool components with a mass less than 1.4 oz (40 g);

— spa / hot tub components with a mass less than 0.07 oz (2 g);

— components made entirely from materials acceptable for use as a direct or indirect food additive in accordance with 21 CFR 170-199[4] (Food and Drugs);

— glass (virgin, not recycled);

— series AISI 300 stainless steel;

— titanium alloy grade 1 and 2; and

— coatings and components made from materials acceptable for use in contact with potable water in accordance with NSF/ANSI 14 (potable water material requirements), NSF/ANSI 42, NSF/ANSI 51, or NSF/ANSI/CAN 61. In order to be qualified under NSF/ANSI 14, NSF/ANSI 42, or NSF/ANSI/CAN 61, the surface area to water volume ratio of the intended use conditions shall meet the requirements of NSF/ANSI/CAN 61 when evaluated to the total allowable concentration (TAC) requirements of the Standard.

Materials listed under the United States Code of Federal Regulations, Title 21 (Food and Drugs) Part 189 *Substances prohibited for use in human food*, shall not be permitted as ingredients within material contacting pool, spa, or hot tub water. This includes arsenic, beryllium, cadmium, mercury, or thallium. Lead shall also not be used as an international ingredient in any water contact material except for products meeting the US Safe Drinking Water Act definition of lead free (≤ 0.25% weighted average lead content).

4.2 Corrosion resistance

Material intended to be in contact with swimming pool or spa / hot tub water shall be corrosion-resistant under use conditions or shall be rendered corrosion-resistant by a protective coating. Cathodic protection may be used to improve the corrosion resistance of a material. High-speed parts requiring close tolerances are not required to be corrosion resistant.

The following materials are considered to have acceptable corrosion resistance for general swimming pool and spa / hot tub equipment applications and are not required to have a protective coating:

— nonferrous alloys containing not less than 58% copper;
— nickel-copper alloy – Monel 400 (UNS N04400);
— SAE 300 series stainless steel;[18]
— thermoplastics and thermoset plastics; and
— concrete.

When used in pumps and strainers, cast iron is not required to have a protective coating.

4.3 Dissimilar metals

Dissimilar metals not normally compatible on the electromotive scale shall not be in direct contact with one another (except for sacrificial anode service).

4.4 Insulating fittings

Insulating fittings shall be provided when piping material is not compatible (on the electromotive scale) with adjoining fittings or parts of the circulation system. Such fittings shall be electrically nonconductive and shall conform to the applicable requirements of Sections 4.1 and 4.2.

4.5 Piping materials

4.5.1 Galvanized steel pipe and galvanized iron pipe with cast or malleable iron fittings and bronze or iron-bodied bronze fitted valves are acceptable for use without a protective coating. If such materials have a steel housing, then no insulating fittings are required. Otherwise, all metal pipe with a dissimilar metal housing shall have insulated fittings.

4.5.2 Piping intended for use in water applications with conductivity greater than or equal to 600 ppm aqueous solution of sodium chloride shall be made from one of the following materials:

— aluminum brass (UNS C68700);
— copper-nickel, 10% (UNS C70600);
— copper-nickel, 30% (UNS C71500);
— nickel-copper alloy – Monel 400 (UNS N04400);
— stainless steel Type 304 (passivated) (UNS S30400);
— stainless steel Type 316 (passivated) (UNS S 31600); or
— thermoplastics or thermoset pipes conforming to the applicable sections of NSF/ANSI 14.

5 Design and construction

This section contains general requirements that apply to all equipment covered under the scope of this Standard.

5.1 Installation of piping, valves, and fittings

If circulation system components are not supplied with the required piping, valves, and fittings installed, the manufacturer shall provide a piping diagram, a parts list, and installation procedures.

5.2 Assembly

Piping assemblies shall be capable of being disassembled for maintenance and repair.

5.3 Closing and sealing devices

Mechanical clamps, gaskets, and sealing devices shall not leak when subjected to the applicable pressure requirements.

5.4 Suction fittings

Suction fittings that are designed to be totally submerged for use in swimming pools and spa / hot tubs shall comply with ANSI/APSP–16[5] and the requirements of Section 4.

5.5 PVC hose

Helix or fabric reinforced flexible PVC hose, for use on circulation piping in pools, hot tubs, spas, and jetted bathtub units, shall comply with the following:

- — IAPMO/ANSI Z1033;[14]
- — the requirements of Section 4; and
- — Section N-2.1.5 after a 20,000-cycle strength test conducted in accordance with Section N-2.1.4.

5.6 Safety vacuum release systems (SVRS)

Manufactured SVRS shall comply with ASTM F2387[9] or ANSI/ASME A112.19.17[6] and the material requirements of Section 4.

5.7 Pool and spa covers

All pool or spa covers (safety or otherwise) shall be labeled in accordance with ASTM F1346[9] and shall conform to the requirements of Sections 4 and 5.

5.8 Pool alarms

Pool alarms shall comply with ASTM F2208,[9] as well as the requirements of Section 4.

5.9 Barriers and fencing

Fencing for use as a barrier around recreational water shall comply with one or more of the following Standards:

- — ASTM F1908;[9]
- — ASTM F2049;[9]
- — ASTM F2286;[9]
- — ASTM F2409;[9] or
- — ASTM F2699.[9]

NOTE — Check with the local authorities for residential and recreational water facility fencing requirements. The use of specific products, designs, installation requirements, and compliance with particular standards may be specified in local building codes or by the local public health official.

5.10 Vacuum port fitting cover

Vacuum port cover fittings shall comply with the requirements of IAPMO SPS 4[14] as well as the requirements of Section 4 of this Standard.

6 Filters

6.1 General

The requirements in this subsection apply to diatomite-type, sand-type, cartridge-type, and high-permeability-type filters.

6.1.1 Filter tanks (pressure service)

6.1.1.1 The working pressure of a pressure service filter shall be 50 psi (345 kPa) or greater. The design burst pressure of a pressure service filter tank shall be at least four times the working pressure (i.e., minimum safety factor = 4:1).

6.1.1.2 The filter tank and its integral components shall not rupture, leak, burst, or sustain permanent deformation when subject to the following conditions in accordance with Section N-2.1:

— a hydrostatic pressure equal to 1.5 times the working pressure for 300 s;
— 20,000 consecutive low-high pressure cycles; and
— a hydrostatic pressure equal to two times the working pressure.

NOTE — As noted in Annex N-2, leaking from integral components such as valves and fittings that may occur when the hydrostatic pressure is increased to two times the working pressure does not constitute nonconformance to this requirement.

Filter tanks designed, constructed, evaluated, and stamped with the appropriate Code Symbol Stamp, in accordance with the *ASME Boiler and Pressure Vessel Code*,[6] Section VIII or X, shall be exempt from this requirement.

6.1.2 Filter tanks (vacuum service)

6.1.2.1 The design collapse pressure of a vacuum service filter tank shall be at least 1.5 times the pressure developed by the weight of the water in the tank (i.e., minimum safety factor = 1.5).

6.1.2.2 Vacuum service filter tanks whose inlets may be closed during filter operation shall not rupture, leak, collapse, or sustain permanent deformation when subjected to a vacuum of 25 in Hg (85 kPa) for 300 s in accordance with Section N-2.2.

6.1.3 Internal components

6.1.3.1 Internal components of a pressure service filter shall not sustain damage or deformation that may affect water flow characteristics when the filter is operated in accordance with the manufacturer's instructions and when operated under the test conditions in Annex N-2.

6.1.3.2 Internal components of a vacuum service filter shall not sustain damage or deformation that may affect water flow characteristics when the filter is operated in accordance with the manufacturer's instructions and when operated under the test conditions in Annex N-2.

6.1.3.3 Filter element components of a filter designed for pressure backwashing shall not sustain damage or permanent deformation when exposed to the pressure differential developed during backwashing operations.

6.1.4 Initial head loss

The head loss through a filter operating at the design flow rate shall not exceed the manufacturer's maximum design head loss when determined in accordance with Section N-2.3.

6.1.5 Accessibility

Filter components requiring service shall be accessible for inspection and repair when installed in accordance with the manufacturer's instructions. Covers on openings required for access into the filter tank shall be removable.

6.1.6 Drains

A filter shall have a drain so that the filter tank may be drained in accordance with the manufacturer's winterizing instructions.

6.1.7 Air release

If the filter permits accumulation of air in the top of the filter tank, the filter tank shall have an automatic air release at the top of the tank. A manual air release valve shall also be provided.

6.1.8 Cleaning of filter media

The cleaning of filter media in accordance with the manufacturer's instructions shall render the filter media and elements free of visible dirt and debris. The head loss through the filter after cleaning the media shall not exceed 150% of the initial head loss through the filter. The head loss through the filter after cleaning shall not exceed the manufacturer's maximum design head loss. Testing shall be conducted in accordance with Section N-2.4.

6.1.9 Turbidity reduction

A filter shall reduce water turbidity by 70% or more when tested in accordance with Section N-2.5.

6.1.10 *Cryptosporidium parvum* oocyst reduction

6.1.10.1 A filter manufacturer may make a *C. parvum* log reduction claim up to a maximum of 1.0 log. A filter claimed by the manufacturer to reduce *C. parvum* shall be tested in accordance with Section N-2.9. The verified *C. parvum* log reduction determined in accordance with Section N-2.9 shall be noted on the data plate.

6.1.10.2 Polystyrene latex microspheres, as referenced in the test method for bag and cartridge filter systems in NSF/ANSI 419: *Public Drinking Water Equipment Performance – Filtration*, shall be an acceptable surrogate for live *C. parvum* oocyst.

6.1.10.3 The polystyrene latex microspheres shall have 95% of particles in the range of 3.00 ± 0.15 µm. The size variation of the polystyrene microspheres shall be confirmed by electron microscopy. The spheres shall have a surface charge content of less than 2 µeq/g. The microspheres shall contain a fluorescein isothiocyanate (FITC) dye or equivalent.

6.1.10.4 The maximum feed concentration shall be 10,000/L, to prevent overseeding that will lead to artificially high log removals performance.

6.1.10.5 Detection and enumeration of polystyrene microspheres shall be done in accordance with Annex A of NSF/ANSI 419.

6.1.10.6 If a filter has been validated for a reduction of *C. parvum* in accordance with Section 6.1.10 and Section N-2.9, the installation and operating instructions shall contain the following information:

— the validated log reduction, shall be indicated via the following statement:

> *"This filter has demonstrated the ability to provide a 1.0 log reduction of Cryptosporidium parvum at a flow rate of XXX gpm when tested with 3-µm polystyrene microspheres."*

— cleaning instructions, including but not limited to any backwash, rinse, filter to drain, or auxiliary recirculation steps. Minimum and maximum flow rates and times shall be included for each step;

— remediation instructions specific to the handling of waste, rinse, and/or backwash water that may contain *C. parvum*. These instructions must include a statement that all waste, rinse and backwash water generated by this filter must be directed to a sanitary sewer; and

— the allowable range of pressure drop through the filter, what pressure drop, or flow reduction indicates cleaning is required, and the terminal pressure drop requiring changeout of the media.

6.1.10.7 If a filter has been validated for a reduction of *C. parvum* in accordance with Section 6.1.9.2 and Section N-2.9, the data plate shall contain the following information:

— the validated log reduction shall be indicated on the data plate via the following statement:

> *"This filter has demonstrated the ability to provide a 1.0 log reduction of Cryptosporidium parvum when tested with 3-µm polystyrene microspheres."*

— name and grade of media used during the validation testing of *C. parvum* reduction and a statement that use of any other media invalidates the *C. parvum* reduction claim of the filter; and

— the data plate shall also include the following statement:

> *"Follow the cleaning and remediation instructions provided in the operating manual for safe handling of filter cleaning and wastewater. All waste, rinse, and/or backwash water generated by this filter must be directed to a sanitary sewer."*

6.2 Precoat media-type filters

The requirements in this subsection apply only to precoat media-type filters utilizing diatomite or other precoat filter media (that conforms to Section 13) and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.2.1 Filtration area

6.2.1.1 The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate.

6.2.1.1.1 For leaf or disc-type precoat media-type filters, the effective filtration area is equal to the total surface area of all septa minus the combined area of all septum support members wider than 0.25 in (6.4 mm) in contact with the septum during filtration.

6.2.1.1.2 For tube-type precoat media-type filters, the effective filtration area is equal to the total surface area of the precoat filter media-coated tubes minus the combined area of all septum support members wider than 0.25 in (6.4 mm) in contact with the septum during filtration. The effective filtration area shall be no more than 1.5 times the total surface area of the uncoated tubes.

6.2.1.2 For wire wound and similar-type elements, the width of septum support members shall not exceed 0.25 in (6.4 mm). The distance between adjacent septum members and the distance between adjacent openings shall not exceed 0.005 in (0.127 mm).

6.2.1.3 Septa shall be maintained in such a position as to preclude surface contacts that reduce effective filtration area.

6.2.2 Turbidity limits, precoat operation

During the precoat operation, the average turbidity of the filter effluent returning to the pool or spa / hot tub shall not exceed 10 nephelometric turbidity units (NTU) over the first 60 s of flow, as determined in accordance with Section N-2.6, except filters designed to refilter the effluent during the precoat operation or discharge it to waste without returning it to the pool or spa / hot tub are exempt from this requirement.

6.2.3 Spacing of elements

6.2.3.1 Filters shall be designed to provide a minimum clearance between adjacent filter elements equal to the thickness or diameter of the element or 1 in (25 mm), whichever is less.

6.2.3.2 The clearance between filter elements shall be sufficient to prevent contact between the septa during backwashing operations.

6.2.4 Baffles

A precoat media-type filter shall have a baffle, or other water-deflecting device, that prevents incoming water from eroding the filter aid during filtration.

6.2.5 Removal of waste from filter tank

A precoat media-type filter shall be designed so that wash water, dislodged filter aid, and dirt may be removed from the filter tank.

6.2.6 Installation and operating instructions

The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, cleaning instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance of the filter. The manual shall also specify the recommended amount, type, and grade of filter aid.

6.2.7 Data plate

6.2.7.1 A precoat media-type filter shall have a data plate that is permanent, easy to read, and securely attached to the filter housing at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— working pressure, if applicable; and
— steps of operation.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications shall be exempt from this requirement.

6.2.7.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.2.8 Filtration rate

The design filtration rate of precoat media-type filters shall not exceed the values specified in Table 6.1.

Table 6.1
Maximum design filtration rates for precoat media-type filters

Filter design	Intended application	Maximum design filtration rate
slurry feed	residential pool or spa / hot tub	3 gal/min/ft^2 (122 L/min/m^2)
slurry feed	public pool or spa / hot tub	2.5 gal/min/ft^2 (102 L/min/m^2)
no slurry feed	residential pool or spa / hot tub	2.5 gal/min/ft^2 (102 L/min/m^2)
no slurry feed	public pool or spa / hot tub	2 gal/min/ft^2 (81 L/min/m^2)

6.2.9 Precoat filter media

Precoat media shall conform to the requirements of Section 4, Materials.

6.2.9.1 Precoat media other than diatomaceous earth (DE)

Precoat media other than DE shall also conform to the requirements of Sections N-2.3 through N-2.7.

6.2.9.2 Precoat media labeling requirements

Precoat media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type and trade name);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling, storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

6.3 Sand-type filters

The requirements in this subsection apply only to sand-type filters and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.3.1 Upper distribution system (influent)

Components of the influent distribution system shall be designed so that they do not become clogged during filtration. The system shall distribute incoming water during the filter cycle to prevent appreciable movement or migration of filtering media at the design flow rate.

6.3.2 Lower distribution system (effluent)

Components of the effluent distribution system shall be designed so that they do not become clogged during filtration. The system shall provide adequate flow and distribution to expand the filtering bed uniformly during backwashing.

6.3.3 Accessibility of internal components

Internal filter components shall be accessible through an access opening in the filter tank. Filters having dome-type or similar underdrains with openings at least 0.189 in (4.8 mm) wide are exempt from this requirement.

6.3.4 Filter media

6.3.4.1 Filter sand shall be hard, silica-like material that is free of carbonates, clay, and other foreign material. The effective particle size shall be between 0.016 in (0.40 mm) and 0.022 in (0.55 mm), and the uniformity coefficient shall not exceed 1.75. Filters intended for use with an alternate media that does not conform to these requirements shall specify the alternate media on the data plate. The filter and the alternate media shall conform to the other applicable requirements of this Standard.

6.3.4.2 If a different media is used to support the filter media, it shall be rounded material that is free of limestone and clay and installed according to the manufacturer's instructions. When the support media and the filter media are installed in accordance with the manufacturer's recommendations, the filter media shall not intermix with the support media when operated and backwashed at least three cycles in accordance with Section N-2.4.

6.3.4.3 Alternate sand-type media

A material that is marketed or claimed to replace sand directly as a filter media in a sand-type filter shall conform to Sections 4.2, 6.1.8, 6.1.9, 6.3.4.3, and 5.3.5 when tested in a representative sand-type filter in accordance with Sections N-2.3 through N-2.5.

6.3.4.3.1 The manufacturer of an alternate sand-type media shall specify the particle size and uniformity coefficient for the media. Particle size and uniformity coefficient shall be confirmed in accordance with ASTM C136[9] with sieves conforming to ASTM E11.[9]

6.3.4.3.2 The filtration rate and backwash rate for an alternate sand-type media shall be as specified in Section 6.3.9.

6.3.4.3.3 Sand-type media labeling requirements

Sand-type media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type and trade name);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling, storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

6.3.5 Filter media behavior

6.3.5.1 Filter media shall not be removed during backwashing at a rate of 15 gal/min/ft^2 (610 L/min/m^2) or the manufacturer's recommended backwash rate.

6.3.5.2 Media shall be capable of being thoroughly cleaned when backwashed following the manufacturer's recommendations.

6.3.5.3 Filter media and supporting material shall not migrate during the filtration cycle. The filter bed shall remain level during the filtration cycle when operated at the design flow rate. The maximum difference between the highest and lowest elevations on the surface of the filter bed shall not exceed the values shown in Table 6.2.

Table 6.2
Maximum difference in media surface elevations on a sand type filter

Filter diameter (D)[1]	Maximum elevation difference
< 36 in (0.9 m)	3 in (76 mm)
36 to 63 in (0.9 to 1.6 m)	0.083 × D
> 63 in (1.6 m)	5.25 in (135 mm)

[1] For filters with noncircular surface geometry, D shall equal the maximum horizontal dimension on the media surface.

6.3.5.4 Filter media and supporting material shall not impart color to the water during filter operation.

6.3.5.5 The filter bed of a pressure service filter shall not break down or channel when subjected to a pressure differential of 15 psi (103 kPa) or the maximum recommended by the manufacturer, whichever is greater. The filter bed of a vacuum service filter shall not break down or channel when subjected to a pressure differential of 16 in Hg (54 kPa) or the maximum recommended by the manufacturer, whichever is greater.

6.3.6 Installation and operating instructions

6.3.6.1 The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, installation instructions, cleaning instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance.

6.3.6.2 The manufacturer of an alternate sand-type media shall provide written instructions for the installation of the media in a filter, including requirements for a different support media; for any specific preparation of the media for operation; and for the operation of filter with the alternate sand-type media.

6.3.7 Data plate

6.3.7.1 A sand-type filter shall have a data plate that is permanent, easy to read, and securely attached to the filter tank at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number or date code;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— design backwash flow rate in LPM or GPM;
— working pressure, or design collapse pressure for vacuum filter tanks;
— suitability for buried installation;
— steps of operation;
— filtration rate in gal/min/ft^2 or L/min/m^2; and
— special media specifications, if any, as required in Section 6.3.4.1.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications is exempt from this requirement.

6.3.7.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.3.8 Effective filtration area

The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate.

The actual filtration area is equal to the total area of the filter media bed minus the combined area of any obstructions (e.g., pipes, headers, air lines) wider than 0.25 in (6.4 mm) passing through the surface of the filter media bed.

6.3.9 Filtration and backwash rates

6.3.9.1 The design filtration rate of sand-type filters shall conform to the limits specified in Table 6.3.

Table 6.3
Design filtration rates for sand type filters

Filter design	Intended application	Design filtration rate
rapid rate	residential pool or spa / hot tub	max: 5 gal/min/ft^2 (204 L/min/m^2)
rapid rate	public pool or spa / hot tub	max: 3 gal/min/ft^2 (122 L/min/m^2)
high rate	residential pool or spa / hot tub	min: 5 gal/min/ft^2 (204 L/min/m^2) max: 20 gal/min/ft^2 (813 L/min/m^2)
high rate	public pool or spa / hot tub	min: 5 gal/min/ft^2 (204 L/min/m^2) max: 20 gal/min/ft^2 (813 L/min/m^2)

6.3.9.2 The design backwash rate shall be a minimum of 15 gal/min/ft^2 (610 L/min/m^2).

6.4 Cartridge-type and high-permeability-type filters

The requirements in this subsection apply only to cartridge-type and high-permeability-type filters and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.4.1 Clearance

The clearance between the filter tank and cartridge(s) or high-permeability element(s) shall be at least 0.25 in (6.4 mm). The clearance between adjacent cartridges shall be at least 0.25 in (6.4 mm).

6.4.2 Baffles

A filter shall have a baffle or other flow-deflecting device that prevents influent water from flowing directly against the effective filter area during filtration.

6.4.3 Trash screen (vacuum service cartridge filters)

Vacuum service cartridge filters shall have a trash screen at the filter inlet to remove large debris such as leaves and paper from the influent water before it reaches the filter cartridges.

6.4.4 Cartridge alignment (stacked multi-cartridge filters)

Stacked cartridges shall be securely fastened to one another. They shall be aligned to ensure a proper seal and to maintain the required clearance between adjacent cartridges. Devices used to align cartridges shall not obstruct the filtration area.

6.4.5 Removal of waste from filter tank

A filter shall be designed so that wash water and dislodged dirt may be removed from the filter tank.

6.4.6 Removal of cartridges

Cartridges shall be readily removable. If cartridge stacks are so long that lower cartridges cannot be removed by hand, the manufacturer shall provide a device for lifting them out of the filter tank.

6.4.7 Installation and operating instructions

The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, cleaning instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance. The manual shall also include the recommended size, number, and type of cartridges or high-permeability elements. If the reuse or replacement of cartridges or high-permeability element is recommended, the manufacturer shall provide printed removal and cleaning instructions.

6.4.8 Data plate

6.4.8.1 A filter shall have a data plate that is permanent, easy to read, and securely attached to the filter housing at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— working pressure;
— steps of operation; and
— recommended replacement cartridge or high-permeability element.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications is exempt from this requirement.

6.4.8.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.4.9 Filtration area

The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate. The actual filtration area is equal to the total surface area of the cartridge or element material minus the combined area of any obstructions wider than 0.25 in (6.4 mm) in direct contact with the cartridge / element material during filtration.

6.4.10 Filtration rates

The design filtration rate of a cartridge-type filter shall not exceed the maximum values specified in Table 6.4.

Table 6.4
Maximum design filtration rates for cartridge-type filters

Filter design	Intended application	Maximum design filtration rate
depth-type	residential pool or spa / hot tub	8 gal/min/ft^2 (325 L/min/m^2)
depth-type	public pool or spa / hot tub	3 gal/min/ft^2 (122 L/min/m^2)
surface-type	residential pool or spa / hot tub	1 gal/min/ft^2 (41 L/min/m^2)
surface-type	public pool or spa / hot tub	0.375 gal/min/ft^2 (15 L/min/m^2)

The design filtration rate of a high-permeability-type filter intended for use with a residential pool or spa / hot tub shall not exceed 10 gal/min/ft^2 (407 L/min/m^2).

7 Centrifugal pumps

This section contains requirements for centrifugal pumps used to circulate swimming pool or spa / hot tub water in commercial and residential applications. The requirements for strainers shall apply to strainers that are integral with the pump and to strainers supplied as separate equipment for use in conjunction with a centrifugal pump.

7.1 General

7.1.1 Pumps shall operate with minimum adjustment. Required adjustments to the power supply shall be acceptable.

7.1.2 Sections of the pump that require inspection or service shall be accessible.

7.1.3 Moving parts shall be covered.

7.1.4 Replacement parts shall fit the pump without a need to re-drill or otherwise alter the pump or replacement part.

7.2 Hydrostatic pressure test

Part of a pump that contains water under pressure shall be capable of withstanding a hydrostatic pressure test at 150% of the working pressure.

7.3 Strainers

7.3.1 Strainers shall be designed so that solids will not bypass the strainer basket during normal operation nor drop into the strainer pot when the strainer basket is removed for cleaning.

7.3.2 Strainer baskets shall be readily removable and easily cleanable.

7.3.3 Openings in the strainer basket shall not exceed 0.05 in^2 (0.3 cm^2) in area.

7.3.4 The ratio of the open area in the strainer basket to the cross-sectional area of the strainer inlet connection shall be 4:1 or greater. The open area in the strainer basket shall be no less than 10 in^2 (65 cm^2).

7.3.5 Strainers with an inlet connection with a nominal pipe size of 1.5 in (38 mm) or less shall have a strainer basket with a minimum internal volume of 25 in^3 (410 cm^3). Strainers with an inlet connection with a nominal pipe size of 2 in (51 mm) or greater shall have a strainer basket with a minimum internal volume of 90 in^3 (1475 cm^3).

7.3.6 Strainer covers shall be designed to be opened manually and shall have a gasket that creates a tight seal when tightened by hand.

7.3.7 A nonintegral strainer shall meet the requirements of Section 8.

7.4 Drain plugs

A pump shall have sufficient drain holes with plugs to drain the pump housing and strainer body (if applicable) without disconnection of the pump or its parts.

7.5 Shaft seals

The pump shaft shall be sealed by packing or a mechanical seal. If packing is used, there shall be a means for its periodic lubrication. Instructions on maintenance and lubrication shall be provided.

7.6 Pump performance curve

7.6.1 For each pump model or model series, the manufacturer shall provide a pump performance curve that plots the pump's total dynamic head versus the discharge flow rate. The manufacturer shall also have a curve available that plots the net positive suction head (NPSH) or total dynamic suction lift (TDSL), brake horsepower, and pump efficiency in relation to the performance curve. Pumps with a rating of 5 HP (3.7 kW) or less are not required to have a NPSH curve.

For pumps utilizing motors rated for multiple voltages, if the pump performance curve varies between rated voltages, such as may occur between 230 V and 208 V, the manufacturer shall provide a pump performance curve for each rated motor voltage.

7.6.2 The actual pump curve, as determined in accordance with Section N-3.1, shall be within a range of - 3% to + 5% of the total dynamic head or - 5% to + 5% of the flow, whichever is greater, indicated by the performance curve. Data taken above 90% full flow shall not be judged to the acceptance criteria.

Pumps with more than one operating speed shall be tested as documented below:

— fixed multispeed pump or motor assemblies, test at each speed; or
— variable speed pump or motor assemblies, test at 100%, 50%, and the lowest speed.

7.6.3 For pumps that provide a flow rate output (such as a visual flow rate in LPM/GPM or other manner), the pump may be tested in accordance with the following flow meter requirements of Section 24 of this standard:

— Section 24.8: Flow rate measurement accuracy;
— Section 24.9: Flow metering device testing and accuracy levels; and
— Section 24.12: Life testing.

7.7 Operation and installation instructions

7.7.1 The manufacturer shall provide a manual with each pump. The manual shall include written instructions for the proper installation, operation, and maintenance of the pump. Instructions shall include a parts list and diagrams to facilitate the identification and ordering of replacement parts. If the parts list does not uniquely identify each part for ordering, the manufacturer shall also supply the appropriate specification numbers and serial numbers, and the impeller diameter.

7.7.2 A pump manufactured without an integral strainer shall state in its installation instructions, on a data plate, or on an attached label that the pump is to be installed with a strainer conforming to the requirements in this Standard.

7.7.3 For pumps that provide a flow rate output, the instruction manual shall either state the accuracy level of flow metering performance, (e.g., Level 1 or L1) or shall include the statement:

"Displayed flow rate has not been evaluated to the flow meter requirements of NSF/ANSI/CAN 50."

7.8 Self-priming pumps

A pump designated as self-priming shall be capable of repriming itself when operated under a suction lift without the addition of more liquid. Self-priming capability shall be verified in accordance with Section N-3.3.

7.9 Data plate

7.9.1 A pump shall have a data plate that is permanent; easy to read; and securely attached, cast, or stamped into the pump at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— pump model number;

— pump serial number, date code, or specification number;

— whether the unit has been evaluated for swimming pools or spas / hot tubs, if not evaluated for both applications;

— designation as a self-priming or non-self-priming pump. If the pump is self-priming, the maximum vertical lift height shall be specified; and

— if applicable, accuracy level of flow metering performance, (e.g., Level 1 or L1).

7.9.2 The proper direction of impeller rotation shall be clearly indicated by an arrow on the data plate, on a separate plate, or cast onto the pump.

7.10 Motors

7.10.1 Motors shall be open-drip-proof or totally enclosed. They shall be constructed electrically and mechanically to perform satisfactorily under the end use conditions.

7.10.2 Motors shall be capable of operating a pump under full load with a voltage variation of ± 10% from data plate rating.

7.10.3 Single-phase motors with a power rating less than 3 HP (2.24 kW) shall have built-in thermal overloads to provide locked rotor and running protection. All other motors shall have:

— built-in thermal overload protection;

— magnetic line starters with overload relays; or

— installation instructions specifying that magnetic line starters with overload relays shall be provided upon installation.

7.10.4 Each motor shall have a permanent data plate that contains the following information:

— motor manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number;

— power rating (kilowatt or horsepower, or both);

— speed;

— voltage;

— frequency;

— phase;

— service factor;

— maximum load amps or full load amps (service factor amps);

— serial number or date code or both;

— frame size;

— rated temperature rise or the insulation system class and ambient temperature rating;

— time rating or duty rating; and

— statement of thermal protection.

8 Nonintegral strainers

This section contains requirements for nonintegral strainers for pumps used to circulate swimming pool or spa / hot tub water in commercial and residential applications. The requirements for integral strainers are specified in Section 7.3.

8.1 Nonintegral strainer basket

8.1.1 Nonintegral strainers shall be designed so that solids will not bypass the strainer basket during normal operation nor drop into the strainer pot when the strainer basket is removed for cleaning.

8.1.2 Nonintegral strainer baskets shall be readily removable and easily cleanable.

8.1.3 Openings in the nonintegral strainer basket shall not exceed 0.05 in^2 (0.3 cm^2) in area.

8.1.4 The ratio of the open area in the nonintegral strainer basket to the cross-sectional area of the strainer inlet connection shall be 4:1 or greater. The open area in the nonintegral strainer basket shall be no less than 10 in^2 (65 cm^2).

8.1.5 Nonintegral strainers with an inlet connection with a nominal pipe size of 1.5 in (38 mm) or less shall have a nonintegral strainer basket with a minimum internal volume of 25 in^3 (410 cm^3). Nonintegral strainers with an inlet connection with a nominal pipe size of 2 in (51 mm) or greater shall have a nonintegral strainer basket with a minimum internal volume of 90 in^3 (1475 cm^3).

8.2 Nonintegral strainer cover

Nonintegral strainer covers shall be designed to be opened manually and shall have a gasket that creates a tight seal when tightened by hand.

8.3 Drain plug

A nonintegral strainer shall have sufficient drain holes with plugs to drain the strainer body without disconnecting the strainer.

8.4 Head loss

The manufacturer of a nonintegral strainer shall specify the maximum flow rate for which the strainer is intended and shall provide a curve showing the head losses in the intended range of flow rates.

NOTE — This information is necessary to facilitate the proper matching of a pump and nonintegral strainer.

8.5 Hydrostatic pressure test

The nonintegral strainer shall be capable of withstanding a hydrostatic pressure testing of 150% of the maximum rated pressure (see Section N-4.1).

8.6 Operation and installation instructions

The manufacturer shall provide a manual with each nonintegral strainer. The manual shall include written instructions for the proper installation, operation, and maintenance of the nonintegral strainer. Instructions shall include a parts list and diagrams to facilitate the identification and ordering of replacement parts. If the parts list does not uniquely identify each part for ordering, the manufacturer shall also supply the appropriate specification numbers and serial numbers.

8.7 Data plate

A nonintegral strainer shall have a data plate that is permanent; easy to read; and securely attached, cast, or stamped into the strainer at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier;

— nonintegral strainer model number;

— nonintegral strainer serial number, date code, or specification number;

— whether the unit has been evaluated for swimming pools or spas / hot tubs, if not evaluated for both applications; and

— rated working pressure (i.e., 50 psi).

9 Valves

This section contains requirements for valves used on filters in public and residential swimming pools and spas / hot tubs. The requirements apply to the housing, valve, handle, and other components that are integral parts of the multiport valve.

9.1 General

9.1.1 Valves and component parts that may require inspection and service shall be accessible.

9.1.2 Valves shall be marked or keyed for proper assembly and operation.

9.1.3 Valves shall be designed so that parts may be replaced without drilling or otherwise altering the multiport valve or replacement part.

9.2 Positive indexing

9.2.1 Valves shall be marked so that the position of the operating handle clearly indicates each operation.

9.2.2 Valves shall be designed so that the position of the operating handle can only be changed intentionally.

9.2.3 Valves shall be designed so that the operating handle, if removed, may only be properly realigned.

9.3 Design pressure

The working pressure of a pressure service valve or manufactured manifold or operational system associated with single or multiple tank filter system shall be 50 psi (344 kPa) or greater. The design burst pressure of a pressure service valve or operational system associated with single or multiple tank filter system shall be designed to have a burst pressure of at least four times the working pressure (i.e., minimum safety factor = 4:1).

9.4 Pressure service

The valve or manufactured manifold and its integral components shall not rupture, leak, burst, or sustain permanent deformation when subject to the following conditions in accordance with the following: (Annex N-4):

— a hydrostatic pressure equal to 1.5 times the working pressure for 300 s;
— 20,000 consecutive pressure cycles per Section N-2.1.4.d; and
— a hydrostatic pressure equal to two times the working pressure per Section N-2.1.4.e.

9.5 Valve leakage

Filter system valves and manufactured manifolds, when operating at the test pressure and maximum design flow rate, shall not leak in excess of 3 mL from the waste port and 30mL from the return-to-pool port in the 5 min test.

9.6 Head loss curve

9.6.1 The manufacturer shall make available a head loss curve for both the filter and backwash positions.

9.6.2 The actual head loss across a multiport valve shall not exceed the head loss indicated by the manufacturer's head loss curve by more than 5% (see Section N-4.4).

9.6.3 The head loss curve for manufactured manifolds may be calculated using a standard friction loss table and actual valve head loss data.

9.7 Waste port seal

The filter system valve or manufactured manifold shall not leak more than 3 mL in a 5 min test through the waste port when the valve is set in the position and a static pressure of 0 to 10 psi (70 kPa) is applied to the return port (Section N-4.5).

9.8 Vacuum service

9.8.1 The design collapse pressure of a vacuum service valve shall be at least 1.5 times the pressure developed by the weight of the water in the tank (i.e., minimum safety factor = 1.5).

9.8.2 Vacuum service valves shall not rupture, leak, collapse, or sustain permanent deformation when subjected to a vacuum of 25 in Hg (85 kPa) for 300 s in accordance with Section N-2.2.

9.8.3 Vacuum service valves are exempt from port leakage testing.

9.9 Installation and operating instructions

The manufacturer shall provide a manual with each valve or manufactured manifold. The manual shall include operating instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance.

9.10 Identification

The multiport valve shall be clearly and permanently marked or labeled with the following:

— manufacturer name and contact information (address, phone number, website, or prime supplier);

— model number;

— working pressure;

— vacuum pressure, if applicable;

— operating setting; and

— special requirements for switching between settings (e.g., the pump shall be shut off prior to switching the valve position).

10 Recessed automatic surface skimmers

This section contains requirements for recessed automatic surface skimmers used for public and residential pools and spas / hot tubs. The requirements apply to the basic components of a surface skimmer, including the skimmer housing; strainer basket; weir; cover and mounting ring; equalizer valve or air lock protector; trimmer valve and flow balancing valves for multiple skimmer installation; and vacuum cleaner connections. Recommended procedures for the installation and operation of skimmers on public and residential pools and spas / hot tubs are provided in Annex I-2.

10.1 Housing

10.1.1 Skimmer housings whose inlets may be closed during part of operating cycle shall not sustain damage or permanent deformation when exposed to a negative pressure of 25 in Hg (85 kPa).

10.1.2 The housing design shall allow for a smooth flow over the effective weir length.

10.1.3 On swimming pool and spa / hot tub skimmers, the housing opening at the entrance throat shall be at least 4 in (102 mm) wide. If a circular weir is used, there shall be a clearance of at least 2 in (51 mm) between the weir lip and the side of the skimmer housing.

10.2 Weir

10.2.1 A skimmer shall have a weir that operates freely with continuous action and adjusts automatically to variations in water level over a minimum range of 4 in (102 mm), or 3 in (76 mm) if an auto-fill pool water level control device is used when operated at the minimum design flow rate (see Section N-5.2).

10.2.2 Flap-type weirs on swimming pool and spa / hot tub skimmers shall have a minimum unobstructed width of 3.75 in (95 mm) over the full operating range. Flap-type weirs shall be buoyant and designed to develop an even flow over their full width. The clearance between the weir and the housing side shall not exceed 0.125 in (3 mm) at any point. Hinge construction shall preclude leakage. The weir shall be firmly attached to the housing and shall be accessible for cleaning and replacement in the field.

10.2.3 Circular weirs shall have a minimum diameter of 4 in (102 mm). They shall be buoyant and designed to develop an even flow on the water surface around the circumference. The radial clearance between the weir float and the weir housing shall not exceed 0.079 in (2 mm). The float or basket housing shall have devices to eliminate binding. The weir shall be accessible for replacement in the field.

10.3 Strainer basket

10.3.1 A skimmer shall have a strainer basket to trap suspended and floating material in the overflow water passing through the skimmer. Spa / hot tub skimmers that have self-contained filters are exempt from this requirement.

10.3.2 Strainer baskets shall be readily removable and easily cleanable.

10.3.3 The area of each opening in the strainer basket shall not exceed 0.05 in^2 (0.3 cm^2).

10.3.4 For swimming pool skimmers, the total open area in the strainer basket shall be 30 in^2 (194 cm^2) or greater. For spa / hot tub skimmers, the total open area in the strainer basket shall be 11 in^2 (71 cm^2) or greater.

10.3.5 For swimming pool skimmers, the internal volume of the strainer basket shall be 160 in^3 (2,620 cm^3) or greater. For spa / hot tub skimmers, the internal volume in the strainer basket shall be 44 in^3 (720 cm^3) or greater.

10.4 Equalizer line

10.4.1 A skimmer design may have an equalizer line that prevents air from becoming entrained in the suction line.

10.4.2 Consult local codes to determine if skimmer installation requires an equalizer line. If an equalizer line is required for skimmer installation, any submerged suction equalizer outlet shall be covered by an appropriately certified and sized suction fitting (cover, sump, and fasteners) that is certified in accordance with ANSI/APSP-16.[5] It is the responsibility of installers, service technicians and facility operators to comply with local codes and regulations. If it is acceptable to disable the equalizer line during installation / service, such work shall be conducted in accordance with the skimmer manufacturer's instructions.

For skimmer designs that incorporate an equalizer line, one of the following shall occur:

— if the skimmer manufacturer does supply a suction fitting (along with the skimmer), the skimmer manufacturer shall specify the minimum flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer. The skimmer manufacturer shall mandate installation of the skimmer with the provided suction fitting which shall be certified to ANSI/APSP-16[5] with a flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer; or

— if the skimmer manufacturer doesn't supply a suction fitting (along with the skimmer), the skimmer manufacturer shall specify the minimum flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer. The skimmer manufacturer shall mandate the installation of a suction fitting that is certified to ANSI/APSP-16[5] with a flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer.

10.4.3 When the skimmer is operating at the maximum design flow rate and the water level is lowered to 2 in (51 mm) below the lowest overflow level of the weir (see Section N-5.2.4), the equalizer line (if provided) shall prevent air from being entrained in the pump suction line (see Section N-5.4).

10.4.4 When the skimmer is operating normally at the maximum design flow rate and up to 75% of the open area in the strainer basket is blocked, the flow rate (leakage) past the equalizer line (if provided) shall not exceed 10% of the total flow rate through the skimmer (see Section N-5.3).

10.5 Cover and mounting ring

10.5.1 A skimmer shall have a removable cover with a mounting ring. The cover and ring shall be free of sharp edges. The exposed surface of the cover shall be free of projections and have a permanent skid-resistant finish. A means of securing the cover in place shall be provided so that the cover cannot be dislodged, unintentionally removed, or otherwise become unstable during use.

10.5.2 Each type and model of polymer skimmer cover shall meet the UV exposure and structural integrity requirements in Sections 10.5.2.1 and 10.5.2.2. Type and model differences that require separate testing include shape, structure, material, color, plating, and finish. Skimmer covers that are too large to fit in the UV exposure chamber may have material bar samples molded, exposed, and tested in a manner consistent with methods developed for ANSI/APSP–16[5] suction fittings.

10.5.2.1 The cover shall be exposed to ultraviolet light and water spray in accordance with ASTM G154,[9] using the common exposure condition, Cycle 3 found in Table X2.1 of ASTM G154[9] for a period of 750 h (see Section N-5.5.2). The sample shall experience no crazing, cracking or geometrical deformation.

10.5.2.2 Skimmer covers that pass the UV exposure test shall be tested for structural integrity in accordance with Section N-5.5.3. A skimmer cover shall not deflect more than 0.35 in (9.0 mm), permanently deform, crack, or lose material exclusive of plating or finish when subjected to a point load of 300 lb ± 5 lb (136 kg ± 2.2 kg).

10.5.2.3 Requirement for evaluation of exposed ridges

After all structural testing is completed, the covers shall be evaluated for exposed ridges. Ridges shall be considered exposed when open to the atmosphere. Exposed ridges shall conform to Section 10.5.3.

10.5.3 Skimmer cleanability

10.5.3.1 The cover shall be designed to be easily cleanable. Covers with interior exposed structural ridges shall conform to the following. Nonexposed structural ridges are exempt from Sections 10.5.3.1.1, through 10.5.3.1.3.

10.5.3.1.1 Ridges with a height of less than $^1/_4$ in (0.25 in, 6.4 mm) are exempt from radius or fillet requirements.

10.5.3.1.2 Ridges with a height greater than or equal to $^1/_4$ in shall have a minimum radius of $^1/_4$ in (0.25 in, 6.4 mm) or provide a 135°, $^1/_4$ in (0.25 in, 6.4 mm) fillet at the base of the ridges (See Figure 2).

10.5.3.1.3 Ridges forming an open box, triangle, or any shape shall not have a depth greater than the internal width of the shape.

10.6 Trimmer valves

Trimmer valves shall not interfere with the performance of the skimmer.

10.7 Vacuum cleaner connections

Vacuum cleaner connections shall be in a convenient location for use and shall not interfere with normal operation of the skimmer.

10.8 Head loss

The actual head loss of a skimmer in normal operation shall not exceed the head loss indicated by the manufacturer's head loss claim by more than 5% or 0.25 psi, whichever is greater (see Section N-5.4). If a trimmer valve is present, the head loss shall be measured with the trimmer both 100% open, and again with the trimmer valve 50% open.

If a skimmer is equipped with an equalizer line, the actual head loss of a skimmer in equalizer operation shall not exceed the head loss indicated by the manufacturer's head loss claim by more than 5% or 0.25 psi, whichever is greater (see Section N-5.4)

10.9 Operation and installation instructions

10.9.1 The manufacturer shall provide written operation and installation instructions with each unit. The instructions shall include drawings, charts, head loss curves, and parts lists necessary for the proper installation, operation, and maintenance of the skimmer.

10.9.2 A skimmer equipped with an equalizer shall have, in its operation and installation instructions:

— a warning that the skimmer is to be installed with an equalizer wall or drain fitting certified to ANSI/APSP-16[5] to prevent hair or body entrapment at the skimmer equalizer;

— the skimmer manufacturer shall specify the minimum flow rating of the suction fitting (which meets or exceeds the maximum flow rating of the skimmer suction line); and

— to address jurisdictions that do not allow skimmers to be installed with equalizer lines, the skimmer manufacturer shall provide instructions for disabling (i.e., installation of the skimmer without the equalizer line) the equalizer line.

The skimmer manufacturer may or may not supply the suction fitting with the skimmer.

10.9.3 A skimmer's flow ratings (GPM, LPM) shall be specified by the manufacturer and conform to Sections 10.3.3.1 through 10.9.3.3, when applicable. When skimmers include water level based, maximum flow rating marks inside the housing, instructions shall indicate they are to be observed by users when the skimmer is off (i.e., no flow).

10.9.3.1 The minimum flow rating shall develop an even flow over the full width of the weir when tested at the skimmer's lowest operating water level (see Section N-5.2).

10.9.3.2 The maximum flow rating for each indicated operating water level shall not exceed the nominal pipe sizes specified by the manufacturer or entrain air in the suction line (see Section N-5.2). The maximum velocity for any nominal pipe size specified shall not exceed 6 FPS (1.83 MPS). Velocity calculations shall be based on the nominal inside diameter for ASTM D1785[9] schedule 40 PVC pipe.

10.9.3.3 The manufacturer may optionally specify water level based, maximum flow ratings within the operating range of the weir (e.g., the normal, mid-point operating level) that are higher than the maximum flow rating achieved when tested at the lowest operating water level of the weir (see Section N-5.2). When multiple water-level based flow ratings are used, each shall be indicated on a data plate inside the skimmer housing that is permanent, easy to read, and securely attached, cast or stamped at the appropriate water elevation. The elevation of these markings shall be set and observed when the pump is off.

10.10 Data plate

A skimmer shall have a data plate that is permanent, easy to read, and securely attached, cast or stamped into the cover or skimmer housing at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— skimmer model number;

— minimum design flow rate in GPM (LPM);

— maximum design flow rate in GPM (LPM); and

— multiple water level based maximum design flow rates in GPM (LPM) that refer to or are located adjacent water level marks located inside the skimmer housing, if applicable.

11 Mechanical chemical feeding equipment

This section contains requirements for mechanical chemical feeders that are used to dispense solutions, slurries, or solids in public or residential pools and spas / hot tubs. Components of mechanical feeding equipment, such as strainers, tubing connectors, and injection fittings supplied by the manufacturer as part of the chemical feed system, are also covered under this section. This section applies to fixed rate or single rate mechanical feeding equipment (for use with automatic control systems) and mechanical feeding equipment with adjustable output rates. This section does not contain requirements for chemical feeding equipment that relies on the flow rate of water in the recirculation system.

11.1 General

11.1.1 Mechanical chemical feeder parts that require cleaning and maintenance shall be accessible.

11.1.2 The mechanical chemical feeder shall be equipped to prevent unintended siphonage or other unintended discharge of chemicals and air into a swimming pool or spa / hot tub or piping systems.

11.2 Erosion resistance

11.2.1 Slurry feeders

When tested in accordance with the erosion resistance test described in Section N-6.2, a slurry feeder operating at the maximum output setting shall feed an agitated suspension of diatomaceous earth 5% (± 0.5%) by volume continuously for 2500 h at 20 ± 0.5 psi (138 ± 3 kPa) back pressure and shall have an output rate that is no less than 80% and no more than 120% of the manufacturer's maximum rated output. At the end of testing, the slurry feeder shall show no signs of erosion that could adversely affect proper operation.

11.2.2 Dry chemical feeders

When tested in accordance with the erosion resistance test described in Section N-6.2, a dry chemical feeder operating at the maximum output setting shall feed an applicable dry chemical continuously for 2,500 h at atmospheric pressure and shall have an output rate that is no less than 80% and no more than 120% of the manufacturer's maximum rated output. At the end of testing, the dry chemical feeder shall show no signs of erosion that could adversely affect proper operation.

11.3 Chemical resistance

11.3.1 When tested in accordance with the chemical resistance test described in Section N-6.3, mechanical chemical feeders exposed to the maximum in-use concentration of the applicable chemical(s) specified for the feeder, for a test period of 100 d, shall show no signs of erosion or structural deformation.

11.3.2 Following the 100-d chemical exposure specified in Section 11.3.1 and 24 h of operation at 100% output rate, mechanical chemical feeders shall conform to the uniformity of output requirements in Section 11.4.2. Fixed or single rate feeders for use with automatic controllers shall conform to Section 11.4.3.

11.4 Output rate

11.4.1 Mechanical chemical feeders shall have an output rate control mechanism that is adjustable in at least four increments over the full operating range. The mechanism for regulating the output rate shall be readily accessible when the feeder is installed in accordance with the manufacturer's instructions.

11.4.2 Mechanical chemical feeders shall deliver chemicals in slurries, solutions, or solids, at an output rate that is within ± 10% of feed rate indicator setting, over deliveries from 25% to 100% of the rated capacity when operated at the maximum back pressure recommended by the manufacturer (see Section N-6.5).

11.4.3 Fixed or single rate mechanical chemical feeders shall deliver chemicals in slurries, solutions, or solids, at an output rate that is within ± 10% of feed rate at 100% of the rated capacity when operated at the maximum back pressure recommended by the manufacturer (see Section N-6.5).

11.5 Hydrostatic pressure

Components of a mechanical chemical feeder that normally operates under pressure shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum operating pressure (see Section N-6.1).

11.6 Life test

When tested in accordance with the life test described in Section N-6.4, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units shall perform as intended by the manufacturer and shall continue to conform to the uniformity of output, suction lift, and pressure requirements of this section.

11.7 Shielding

Moving parts of the feeder shall be covered so that no openings are exposed.

11.8 Motors

11.8.1 Motors shall be continuous duty and shall conform to the requirements of Article 430 of NFPA 70, (NEC).[17]

11.8.2 Motors shall use standard voltages and cycles.

11.9 Suction lift

Positive displacement pump mechanical feeders operating with a suction lift of 4 ft (1.2 m) of water, at 80% back pressure and 100% of their rated capacity, shall deliver an output rate that is within ± 10% of the delivery specified by the manufacturer (see Section N-6.6).

11.10 Protection against overdosing

The manufacturer shall provide printed materials warning the user of the potential for elevated chemical concentrations and hazardous gas introduction into the pool or spa. At a minimum, the printed materials shall describe the potentially hazardous conditions, such as backwash and periods of no flow in the recirculation system. The steps to be taken during installation and operation to prevent such conditions shall be included. Feeders designed to be self-draining shall be exempt from this requirement.

11.11 Operation and installation instructions

The manufacturer shall supply operation and installation instructions with each mechanical chemical feeder. These instructions shall include the following:

— diagrams and a parts list to facilitate the identification and ordering of replacement parts;

— installation, operation, and maintenance instructions;

— reference to flooded suction installation and prevention of cross connections;

— reference to recommended use chemicals and maximum use concentrations;

— caution statement to address potentially hazardous conditions due to chemical overdosing (see Section 11.10);

— reference to one or more methods to stop chemical feed automatically when no return flow to the swimming pool or hot tub exists;

— model number of the unit; and

— applicable caution statements (prominently displayed).

11.12 Data plate

The data plate on mechanical chemical feeders shall be permanent; easy to read; and securely attached, cast, or stamped onto the feeder at a location readily accessible after normal installation. Data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— feeder model or serial number;

— maximum operating pressure rating in psi (kPa);

— reference to installation instructions for swimming pool and hot tub/spa applications for protection against overdosing during backwash and no-flow conditions;

— maximum output rating (volume of liquid or weight, or volume of solid chemicals, 24 h/d); and

— if the unit is a fixed rate or single rate mechanical chemical feeder include the following:

"Fixed / single rate feeder for use only with certified automatic controller."

The data plate shall indicate whether the mechanical chemical feeder is designed for swimming pool applications only or spa / hot tub applications only. A mechanical chemical feeder that is designed for both applications is exempt from this requirement.

12 Flow-through chemical feeding equipment

This section contains requirements for adjustable output rate flow-through chemical feeders and auxiliary components used for dispensing chemicals by a flow-through process in public and residential swimming pools or spas / hot tubs. Flow-through chemical feeders without adjustable output rates and gaseous feeding equipment are not covered under this section.

12.1 General

Parts of the feeder requiring cleaning and maintenance shall be accessible.

12.2 Chemical resistance

Flow-through chemical feeders exposed to the applicable chemicals per Section N-7.1 for a test period of 100 d shall show no signs of erosion or structural deformation.

12.3 Hydrostatic pressure

Flow-through chemical feeders shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum pressure rating (see Section N-7.2). The unit tested shall be one that has been exposed in accordance with the chemical resistance test per Section N-7.1 for a test period of 100 d.

12.4 Motors

Motors, if provided, shall be continuous duty and shall conform to the requirements of Article 430 of NFPA 70 (NEC).[17]

12.5 Output rate

12.5.1 The flow-through chemical feeder shall have an output rate control mechanism that is adjustable in at least four increments over the full operating range. The mechanism for regulating the output rate shall be readily accessible when the feeder is installed in accordance with the manufacturer's instructions.

Chemical feeders designed for one output rate or intended for use with a separate automated controller shall be exempt from this requirement.

12.5.2 The uniformity of output for a flow-through chemical feeder shall be tested and evaluated at settings of the output rate control mechanism equivalent to 50% and 100% of the rate of maximum chemical output recommended by the manufacturer. Chemical feeders designed for one output rate shall be evaluated at 100% of the maximum chemical output. The output of a flow-through chemical feeder shall be within ± 20% of the output specified by the manufacturer at each test setting of the output rate control mechanism. For each test setting, the output of the flow-through chemical feeder shall be repeatable within ± 10% when tested in accordance with Section N-7.3.

12.6 Protection against overdosing

The manufacturer shall provide printed materials warning the user of the potential for elevated chemical concentrations and hazardous gas introduction into the pool or spa. At a minimum, the printed materials shall describe the conditions that may result in such potentially hazardous conditions, such as backwash and periods of no flow in the recirculation system. The steps to be taken during installation or operation to prevent such conditions shall be included. Feeders designed to be self-draining shall be exempt from this requirement.

12.7 Flow-indicating device

12.7.1 Flow-through chemical feeders shall be provided with a flow-indicating device on the unit, or the installation instructions shall provide for the installation of a flow-indicating device for the full range of flow rates. Flow-through chemical feeders operated by an automated controller shall be exempt from this requirement.

12.7.2 When the chemical output of a flow-through chemical feeder is specified relative to the flow rate of water through the feeder (i.e., *X* gal/min [m^3/h] through the feeder = *Y* lb/d [kg/d] chemical output), the chemical feeder shall be supplied with a flow-indicating device (or instructions for installing such a device) for the full range of flow rates specified by the manufacturer.

12.7.3 Head loss

The manufacturer shall make available a head loss claim at the maximum and minimum settings for systems installed in the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

12.8 Operation and installation instructions

The manufacturer shall supply the following operation and installation instructions with each flow-through chemical feeder:

— diagrams and a parts list to facilitate the identification and ordering of replacement parts;

— installation, operation, and maintenance instructions;

— model number of the unit;

— caution statement to address potentially hazardous conditions due to chemical overdosing (see Section 12.6); and

— caution statements regarding the recommended use chemicals (prominently displayed).

12.9 Data plate

The data plate on flow-through chemical feeders shall be permanent; easy to read; and securely attached, cast, or stamped onto the feeder at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— feeder model (serial number optional);

— maximum output rate;

— recommended use chemical(s); and

— a caution statement indicating that the use of chemicals other than those recommended by the manufacturer may be hazardous.

The data plate shall indicate whether a flow-through chemical feeder is designed for swimming pool applications only or spa / hot tub applications only. A flow-through chemical feeder that is designed for both applications is exempt from this requirement.

13 Filtration media

This section contains requirements for filtration media for use in commercial and residential filters.

13.1 Precoat filter media

Precoat media shall conform to the requirements of Section 4.

13.1.1 Precoat filter media

Precoat media shall meet the applicable requirements of Sections N-2.3 through N-2.8.

13.1.2 The manufacturer of precoat media shall provide written instructions for the installation of the media in a filter; for any specific preparation of the media for operation; and for the operation of filter with the media.

13.1.3 Precoat filter media labeling requirements

Precoat media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type, and tradename);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

13.2 Sand and alternate sand-type filter media

13.2.1 Sand and alternate sand-type filter media shall conform to the requirements of Section 4.

13.2.2 Sand filter media

13.2.2.1 Filter sand shall be hard, silica-like material that is free of carbonates, clay, and other foreign material. The effective particle size shall be between 0.016 in (0.40 mm) and 0.022 in (0.55 mm), and the uniformity coefficient shall not exceed 1.75. Filters intended for use with an alternate media that does not conform to these requirements shall specify the alternate media on the data plate. The filter and the alternate media shall conform to the other applicable requirements of this Standard.

13.2.2.2 If a different media is used to support the filter media, it shall be rounded material that is free of limestone and clay and installed according to the manufacturer's instructions. When the support media and the filter media are installed in accordance with the manufacturer's recommendations, the filter media shall not intermix with the support media when operated and backwashed at least three cycles in accordance with Section N-2.4.

13.2.3 Sand and alternate sand-type filter media

Filter media in a sand-type filter shall conform to Sections 4.2, 6.1.8, 6.1.9, 6.3.5, and 13.3 when tested in a representative sand-type filter in accordance with Sections N-2.3 through N-2.5.

13.2.3.1 The manufacturer of sand and an alternate sand-type filter media shall specify the effective size and uniformity coefficient for the media. Effective size and uniformity coefficient evaluation shall be performed in accordance with ASTM C136[9] with sieves conforming to ASTM E11.[9] A minimum of five data points shall be measured for sizing. The particle size data shall be plotted as a smooth curve, which shall be used to read the sieve opening sizes at which 60% and 10% of particles can pass. The uniformity coefficient and effective size measured shall be ± 10% of the claimed uniformity coefficient and effective size or shall be within the claimed range of uniformity coefficient and effective size, whichever is larger.

13.2.3.2 The filtration rate and backwash rate for sand and alternate sand-type filter media shall be as specified in Section 6.3.9.

13.2.4 Installation and operating instructions

The manufacturer of sand and alternate sand-type media shall provide written instructions for the installation of the media in a filter, including requirements for a different support media; for any specific preparation of the media for operation; and for the operation of filter with the media.

13.2.5 Sand and alternate sand-type media labeling requirements

Sand and alternate sand-type filter media shall contain the following information on the product packaging or documentation shipped with the product:

- manufacturer's name and contact information (address, phone number, website, or prime supplier);
- product identification (product type, and tradename);
- net weight or net volume;
- when applicable, mesh or sieve size;
- uniformity coefficient for particle size;
- lot number or other production identifier such as a date code;
- when appropriate, special handling, storage and use instructions; and
- the specific certification mark of the certifying organization for certified products.

14 Ozone generation process equipment

14.1 General

Ozone generation process equipment covered by this section is intended for the secondary and supplemental disinfection of the water in the circulation system of public and residential recreational water facilities, including but are not limited to: pools, and spas / hot tubs, therapy pools, and interactive aquatic play features. Since these products are not intended to produce residual levels of disinfectant within the body of water, an EPA registered disinfecting chemical shall be added to impart a measurable residual. The measurable residual disinfecting chemical shall be easily and accurately measured by a water quality device certified to Section 20.

14.2 Ozone components

Ozone generation systems shall include but are not limited to the following components:

- ozone generator;
- ozone venturi injector;
- reaction / degas system;
- gaseous ozone destruct;
- ORP monitor / controller; and
- ambient ozone monitor / controller.

Smaller (residential) type ozone generators are not required to include all components of a commercial system.

14.3 Ozone generator

The ozone generator shall be designed to maintain ozone under vacuum from generation to the point of injection in the water stream. Automatic feed-gas flow control shall be incorporated to maintain a vacuum set-point and correct for variations in suction. Minimum protection (e.g., vacuum switch transducer, etc. to shut down the ozone power) against vacuum loss shall be included; and water backflow protection devices shall be included in the ozone gas delivery line.

14.4 Injection methods

Injection methods shall be designed to prevent off gassing in excess of the Occupational Safety and Health Administration (OSHA) standards for in-air ozone concentration. Ozone levels exceeding 0.1 ppm (0.2 mg/m^3) shall not be acceptable in the pool, spa / hot tub water when tested in accordance with Section N-8.2.

For companies under jurisdiction other than US regulation for ozone off gassing, those jurisdictions' regulations are the default.

14.5 Gas flow meter

Ozone generation systems shall be equipped with a gas flow meter.

14.6 Valve and component identification

All valves and performance devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

14.7 Cleanability

Parts of ozone generation systems requiring cleaning and maintenance shall be accessible.

14.8 Ozone resistant materials

Materials in direct contact with ozone gas shall be resistant to degradation by ozone at the ozone concentration specified by the manufacturer.

14.9 Compatible materials for operation

14.9.1 For use of alternate materials, at a minimum the supplier shall confirm compatibility with end use. Other materials may be used for construction of ozone generators if proper material compatibility is demonstrated. Acceptable documentation shall include component material manufacturer's compatibility charts or written warranty statement.

Tables 14.1 and 14.2 provide examples of ozone-resistant materials that are commercially available. These materials are recommended for use with dry gas with a maximum temperature of 104 °F (40 °C). Alternate materials may be used for ozone generators if material compatibility is demonstrated (see Section 14.18 Life test). The material supplier shall provide documentation of compatibility including component material manufacturer's compatibility charts or written warranty statement. Ozone resistant materials not in Table 14.1 and 14.2 shall be tested in accordance with Section N-7.1.

14.9.2 Components and piping

Table 14.1
Components and piping

	Ozone gas < 2500 ppm	Ozone gas > 2500 ppm
glass	X	X
ceramics	X	X
PVC	X	NR
CPVC	X	NR
UPVC (unplasticized)	X	NR
aluminum	X	X (4% wt max)
304 L stainless steel	X	X
316 L stainless steel	X	X
superalloys such as Inconel[1] and Hastelloy-C[2]	X	X
titanium	X	X
perfluoroalkoxy resin (PFA) such as Teflon®[3] or equivalent	X	X
fluorinated ethylene propylene (FEP) such as Teflon®[3] or equivalent	X	X
polytetrafluoroethylene (PTFE) such as Teflon®[3] or equivalent	X	X
ethylene tetrafluoroethylene (ETFE) such as Tefzel®[3] or equivalent	X	X
ethylene chlorotrifluoroethylene (ECTFE) such as Halar®[4] or equivalent	X	X
Neoprene® or equivalent	X	NR
polyvinylidene fluoride (PVDF) such as Kynar®[5] or equivalent	X	X
p-chlorotrifluoroethylene P-CTFE such as Kel-F®[6] 2800 and Neoflon®[7] or equivalent	X	X

[1] Special Metals Corporation

[2] Haynes International, Inc.

[3] Dupont

[4] Ausimont USA, Inc.

[5] Elf Atochem North America

[6] 3M Company

[7] Daikin Industries

NR – not recommended

NOTE — Abbreviations for components, piping, gasket and seals are in accordance with ASTM D4000.

14.9.3 Gaskets and seals

Table 14.2
Gaskets and seals

	Ozone gas < 2500 ppm	Ozone gas > 2500 ppm
p-chlorotrifluoroethylene (P-CTFE) such as Kel-F®[1] or equivalent	X	X
perfluorelastomer such as Kalrez®[2] or equivalent	X	X
perfluorinated copolymer such as Chem-Rez®[3] or equivalent	X	X
Gortex® or equivalent	X	X
PTFE tape	X	X
chlorosulfonated polyethylene such as Hypalon®[2] or equivalent	X	NR
vinylidene fluoride such as Viton®[2] or equivalent	X	X (4% wt max)
polydimethyl siloxane (silicone)	X	X (4% wt max)
ethylene propylene diene monomer (EPDM)	X	NR

[1] 3M Company
[2] Dupont
[3] Green, Tweed and Company
NR – not recommended

14.10 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

14.11 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10% (when tested in accordance with Section N-2.3).

14.12 Water flow meter

If the performance of a unit is dependent on a specified water flow rate, a means to monitor and control the flow shall be provided.

14.13 Oxidation-reduction potential (ORP) monitoring

Ozone systems shall be equipped with ORP monitoring equipment. The ORP monitoring equipment shall comply with the applicable requirements of Section 19.

14.14 Warning devices

The ozone generation system shall have a visual or audible alarm to alert facility staff of the ORP reading for the ozone system when it reaches below 650 mV.

14.15 Operational protection

Ozone generation systems shall have an automatic mechanism for ceasing ozone production whenever one or more of the following conditions exist:

— door open or cover panel removed from the generator cabinet;
— low feed-gas supply;
— loss of vacuum;
— high temperature of the ozone generator module;
— high temperature of the high voltage transformer;
— loss of water flow (including during backwash cycle); and
— high dew point in the ambient feed air (not necessary if oxygen is used).

NOTE — High dew point results in nitric acid production which can severely damage ozone generators and contaminate the water.

14.16 Ozone destruct

The injection and mass transfer components of an ozone generation system shall be equipped with a method of collecting undissolved gaseous ozone and destroying it before it is vented to atmosphere. The gaseous ozone concentration at the outlet of the ozone destruct system vent shall be 0 mg/m^3 (0.07 ppm).

14.17 Ozone output

Ozone generation systems shall be tested for ozone concentration and output rate in accordance with Section N-8.2.

14.18 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the output, pressure, and disinfection efficacy requirements of this section.

14.19 Disinfection efficacy

Process equipment designed for supplemental disinfection such as ion generators, ozone and ultraviolet light equipment shall demonstrate a 3 log (99.9%) or greater inactivation of influent bacteria when tested according to Section N-8.1.

Process equipment designed for secondary disinfection such as ion generators, ozone and ultraviolet light equipment shall demonstrate a 3 log (99.9%) or greater reduction of *C. parvum* when tested and evaluated according to Section 14.20.

Ozone equipment shall carry the following information in the installation and use instructions:

— Level 1 (L1): NSF/ANSI/CAN 50, Section 14.19, disinfection efficacy testing for 3 log (99.9%) or greater of <name organisms>, NSF/ANSI/CAN 50, Section 14.20 *Cryptosporidium parvum reduction* for a 3 log (99.9%) or greater in a single pass. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority.

— Level 2 (L2): NSF/ANSI/CAN 50, Section 13.19, disinfection efficacy testing for 3 log (99.9%) or greater of <name organisms>. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority.

14.20 *Cryptosporidium* reduction

Manufacturers of an ozone generation system with a claim of *C. parvum* reduction shall demonstrate a minimum of 3 log (99.9%) or greater reduction of *C. parvum* in a single pass when tested in accordance with Section N-8.4.

The ozone generation system shall reduce the number of live *C. parvum* oocysts from an influent challenge of at least 5000 (5×10^3) infectious oocysts per liter by at least 99.9% when tested in accordance with Section N-8.3. The *C. parvum* oocysts shall be from a calf source. The viability shall be greater than 50% determined by excystation.[25] The oocysts shall be stored with 1,000 IU/mL penicillin and 1,000 µg/mL streptomycin at 39 °F (4 °C) and shall be used within eight weeks of collection. The live *C. parvum* oocysts shall not be inactivated by any means including chemical or UV irradiation prior to passing through the ozone generation system.

> NOTE — It has been reported that the oocyst wall of viable oocysts may deform. Excystation is performed as an indication of the potential of the oocyst wall to deform and is not done to measure the infectivity of the organism. The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

14.21 Operation and installation instructions

— drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers;

— output rate (in pounds or kilograms per day or hour);

— maximum daily operation time (if not designed for continuous operation; and

— level of disinfection efficacy.

14.22 Information on ozone off-gassing and removal devices

Information shall be provided to the user concerning the potential for off-gassing of ozone and required ozone removal devices, if applicable.

[25] The in vitro excystation method is specified in *Development of a Test to Assess Cryptosporidium parvum Oocysts Viability: Correlation with Infectivity Potential,* American Water Works Association Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235 <www.waterresearchfoundation.org>.

14.23 Data plate

Data plate(s) shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain the following:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number;

— serial number or date of manufacture;

— certification mark of the ANSI-Accredited testing and certification organization;

— electrical requirements (volts, amps, Hertz) for operation;

— type of feed-gas;

— rated feed-gas flow rate (SCFH or LPM);

— rated ozone production (grams per hour [g/h] or pounds per day [lb/d]);

— method of cooling and coolant flow rates;

— level of disinfection certification (L1 or L2);

— maximum daily operation time (if not designed for continuous operation);

— caution statements (prominently displayed) including a statement that the unit should be used with an EPA registered disinfection chemical to impart a measurable residual concentration in the water; and

— a statement identifying if the unit is suitable for supplemental disinfection or for secondary disinfection.

15 Ultraviolet (UV) light process equipment

15.1 General

UV light process equipment covered by this section is intended for the secondary and supplemental treatment of public and residential swimming pools and spas / hot tubs. Since these products are not intended to produce residual levels of disinfectant within the body of the swimming pool or spa, these products are intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority. The residual chemical shall be easily and accurately measureable by a field test kit.

15.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

15.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

15.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

15.5 Performance indication

A supplemental UV system shall be provided with an effective means to alert the user when a component of this equipment is not operating.

A secondary UV system shall incorporate on the control panel a constantly visible readout of the actual flow (in US GPM), the actual calculated dose (in mJ/cm^2) and the actual lamp intensity (in w/m^2). It is acceptable for the display to constantly cycle through the parameters. The cycle duration shall not take more than 15 s.

15.6 Operation and installation instructions

15.6.1 Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— whether the system has a mechanical cleaning system or requires an external chemical cleaning system installed per Section 15.13.1;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— maximum daily operation time (if not designed for continuous operation); and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

15.6.2 UV systems claiming inactivation of cysts, the installation and operational instructions or product manual shall contain the following:

— reactor configuration type (U, S, etc.);

— number of lamps per reactor;

— lamp designation or model number;

— sensor designation or model number;

— UVT of water (minimum value or a range of UVTs under which validation was performed);

— organism used in testing;

— correlation between test organism and *C. parvum*;

— effective log inactivation of organism at maximum flow rate or validated flow rates;

— effective UV dose delivered at specified wavelength and flow rate; and

— whether the system has a mechanical cleaning system or requires an external chemical cleaning system installed per Section 15.13.1

15.7 Data plate

Data plate shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain the following:

— equipment name and function(s);

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number designation;

— electrical requirements for operational volts, amps, and Hertz of the unit;

— serial number or year of construction;

— maximum rated operating pressure in kPa (psi);

— prominently displayed caution statement:

"*UV light is harmful to eyes and exposed skin; turn off electrical supply before opening unit.*"

— caution statement that the unit should be used with registered or approved disinfection chemicals to impart required residual concentrations;

— model and number of UV lamp(s);

— maximum daily operation time (if not designed for continuous operation);

— maximum design flow rate in GPM (LPM); and

— a statement identifying if the unit is suitable for supplemental disinfection or for secondary disinfection.

15.8 Disinfection efficacy

Ultraviolet light process equipment designed for supplemental disinfection shall demonstrate a 3 log (99.9%) or greater inactivation of influent bacteria when tested according to Section N-8.1.

Ultraviolet light process equipment designed for secondary disinfection shall demonstrate a 3 log (99.9%) or greater inactivation of *C. parvum* when tested and evaluated according to Section 15.18 and is exempt from Section N-8.1 testing if during secondary validation the lamp intensity (per Section 15.5) is equal to or greater than the lamp intensity after the unit has completed life testing. Section N-8.1 shall be required if the dose is less.

Ultraviolet light process equipment designed for supplemental disinfection shall carry the following information in the installation and use instructions and be noted in the official certification listings:

> *"This unit has demonstrated an ability to provide three log inactivation of <name organisms>. This unit has not demonstrated an ability to provide three log kill or inactivation of <name organisms if applicable>. This product is designed for supplementary disinfection and is intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority."*

Ultraviolet light process equipment designed for secondary disinfection shall carry the following information in the installation and use instructions and be noted in the official certification listings:

> *"This unit has been tested to confirm a minimum inactivation equivalent of 3 log (99.9%) C. parvum in accordance with NSF/ANSI/CAN 50 and the US EPA UV DGM. This product has met the requirements of NSF/ANSI/CAN 50, Section N-8.1: Disinfection Efficacy, for the ≥ minimum of a 3 log (99.9%) reduction of Enterococcus faecium [ATCC #6569] and Pseudomonas aeruginosa [ATCC #27313]. This product is intended for secondary disinfection and is intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority."*

15.9 Valve and component identification

All valves and performance indication devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

15.10 Operating temperatures

The unit and all its components shall be designed to withstand a maximum operating temperature of 102 ± 5 °F (39 ± 3 °C).

15.11 Operational protection

Units shall be equipped with an automatic mechanism for shutting off the power to the UV light source whenever the cover is removed.

15.12 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the operational protection, pressure, and disinfection efficacy requirements of this Section.

Life testing shall be conducted within the operating temperatures of its intended end use; swimming pool 75 ± 10 °F (24 ± 6 °C) or spas and hot tubs, 65 to 104 °F (18 to 40 °C).

Life testing is not required on UV units being tested for *Cryptosporidium* inactivation (Section 15.18) because the NSF ETV UV Protocol and US EPA UV DGM[20] requires a 100-h burn in for the lamp prior to testing.

15.13 Cleaning

15.13.1 For systems utilizing quartz sleeves to separate the water passing through the chamber from the UV source, the system shall be designed to permit cleaning of the lamp jackets and the sensor window or lens without mechanical disassembly. All piping for in-place cleaning purposes shall be entirely independent of the water piping system in and out of the unit, and a drain shall be provided. The chamber shall be designed so that at least one end can be dismantled for general and physical cleaning.

15.13.2 For systems utilizing polytetra-fluoroethylene (PTFE) surface materials to separate the water passing through the UV chamber from the UV lamps, the unit shall be designed to be readily accessible to the interior and exterior of the PTFE. The unit shall be designed to permit use of either physical or chemical cleaning methods.

15.14 Ultraviolet (UV) lamps

UV lamps shall be readily accessible for replacement, and instructions for replacement shall be provided.

15.15 Chemical resistant materials

Internal surfaces exposed to direct ultraviolet light shall be resistant to use application conditions.

15.16 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

15.17 Hydrostatic pressure requirements

UV light process equipment that normally operates under pressure shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum operating pressure (see Section N-6.4).

15.18 UV *Cryptosporidium* inactivation and dose determination

Manufacturers of UV systems with a claim to inactivate cysts (such as *Cryptosporidium*, *Giardia*, etc.) shall demonstrate a minimum 3 log (99.9%) or greater inactivation of *C. parvum* in a single pass.

NOTE — Operators of spray parks, spray pads, or interactive water features with no standing water should consider greater inactivation performance of 4 log (99.99%). The local public health authority may select different levels of log inactivation or power delivery for different applications such as competition lap pools, spas, wave pools, wading pools, etc.

15.18.1 Sample selection

When validating a range of aquatic or recreational water use UV systems for inactivation of cysts such as *C. parvum*, each of the following variables shall be used to determine which UV reactor / systems and components shall be tested within the range of product. Select at least two worst-case models from the range of products based upon all of the following variables.

— test the unit representative of the worst-case reactor hydraulics and UV dose delivery as determined by computational fluid dynamics modeling, including intensity and flow modeling;

— test the unit with the lowest power to highest flow rate;

— test one unit of each configuration (if family range contains U and S reactors, test each);

— test one unit of each UV lamp type (if alternate lamp types or suppliers, test each);

— in the case where the UV system utilizes low pressure (LP) lamps, it is sufficient to provide a data sheet of the lamp that includes the expected lamp life. In addition, the following characteristics of the lamp must be the same:

  — lamp length, the length of the lamp from base face to base face, ± 0.5 in;
  — the arc length, the lit length, ± 0.5 in;

  - — the diameter, ± 10%;
  - — the quartz material, fused silica, synthetic quartz, deep UV blocking;
  - — electrode current, ± 0.2 A;
  - — lamp wattage, ± 5 W;
  - — output, 185/254 nm or 254 nm;
  - — mercury source, elemental, spot amalgam, pocket amalgam; and
  - — connections, single ended, double ended.

- — test one unit of each UV sensor type (if alternate UV sensor types or suppliers, test each).

NOTE — The above variables require that multiple UV systems are tested in order to validate a range of products.

15.18.2 Testing

Products shall be tested to confirm single pass inactivation equivalent to 3 log (99.9%) or greater of *C. parvum* in accordance with NSF/EPA ETV – *Generic Protocol for Development of Test / Quality Assurance Plans for Ultraviolet (UV) Reactors*.[20] Only full stream testing shall be acceptable, there shall be no partial or side stream treatment testing.

The manufacturer of a reactor validated for performance under one of the following protocols shall submit details of the testing for evaluation and validation:

- — US EPA UV DGM;[20]
- — DVGW, W-294 Parts 1-3;[13] or
- — ÖNORM, 5873 1 and 2.[8]

Validation of a range of reactors with pre-existing test data shall include testing of at least one (1) unit at one (1) set point to evaluate for potential changes in design, suppliers and corroborate previous data.

16 In-line electrolytic chlorinator or brominator process equipment

16.1 General

In-line electrolytic chlorinator or brominator process equipment covered by this section is intended for use in circulation systems of public and residential swimming pools and spas / hot tubs. Equipment shall produce a quantity of sodium hypochlorite or hydrobromous acid as stated by the manufacturer.

16.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

16.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

16.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

16.5 Performance indication

The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

16.6 Operation and installation instructions

Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— output rate (in lb or kg per day or hour);

— maximum daily operation time (if not designed for continuous operation; and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

16.7 Data plate

Data plate shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain at least the following:

— equipment name;
— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— model number;
— electrical requirements – volts, amps and hertz;
— serial number or date of manufacture;
— caution statements (prominently displayed);
— output rate in pounds or kilograms per day per hour);
— maximum daily operation time (if not designed for continuous operation); and
— salt concentration range.

16.8 Valve and component identification

All valves and performance indication devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

16.9 Operating temperatures and pressures

If installed within the recirculating piping system, in-line electrolytic chlorinator or brominator process equipment shall be designed to withstand a maximum operating temperature of 102 ± 5 °F (39 ± 3 °C) and a minimum rated pressure of 50 psig (345 kPa).

16.10 Operational protection

Systems shall have an automatic mechanism for shutting off the electric power to the electrolytic cell whenever one or more of the following conditions exist:

— loss of electric power to the recirculation pump; or
— interruption of water flow through the electrolytic cell.

16.11 Warning devices

A visual or audible alarm shall be provided to warn the user when the cell voltages are not within the manufacturer's recommended range, or when the salt concentration falls below the manufacturer's recommended minimum level.

16.12 Chemical-resistant materials

Equipment parts shall incorporate materials that are resistant to the environment to which the parts will be subjected.

16.13 Output rate

16.13.1 The output rate shall be adjustable in at least four increments over the full operating range. Means for regulating shall be conveniently located when mounted according to the manufacturer's instructions.

16.13.2 Delivery

Units shall deliver chemicals at an output rate shown by the feed rate indicator ± 10% of the setting, over deliveries from 25% to 100% rated capacity.

16.14 Pressure requirements

Units shall meet a hydrostatic pressure of 1.5 times the manufacturer's maximum pressure rating applied to all parts of the feeder subject to pressure during operation when tested at 102 ± 5 °F (39 ± 3 °C).

16.15 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the delivery, pressure and operational protection requirements of this section.

16.16 Salt level

In-line electrolytic chlorinator or brominators shall be designed to operate satisfactorily on the dissolved salt concentration range specified by the manufacturer.

16.17 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

17 Brine (batch) type electrolytic chlorine or bromine generators

17.1 General

Batch and process type electrolytic brine chlorine or bromine generators covered by this section are intended for use in circulation systems of public and residential swimming pools and spa / hot tubs.

17.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

17.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

17.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

17.5 Performance indication

The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

17.6 Operation and installation instructions

Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— output rate (in pounds or kilograms per day or hour);

— maximum daily operation time (if not designed for continuous operation); and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10438

91

Date Submitted	02/15/2022	**Section**	454.2.17.1.15	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

R4501.17.1.15

Summary of Modification

Streamlines the mesh barrier provisions by removing listed requirements found in the ASTM F2286 Standard and simply requiring compliance with that Standard, which is what manufacturers of these types of barriers design to and comply with - no technical changes are being made.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). The manufacturers of these types of barriers design and fabricate to ASTM F2286. The installation instructions for the product reflects the requirements of the standard. There isn’t any reason for the Florida Code to have the detailed information in it as the installation instructions for the product has to reflect the requirements of the standard. Referring to the standard streamlines and simplifies the code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No impact, if anything easier to just note compliance with the listed standard.

Impact to building and property owners relative to cost of compliance with code

No impact, if anything easier to just note compliance with the listed standard.

Impact to industry relative to the cost of compliance with code

No impact, if anything easier to just note compliance with the listed standard.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This section of code provides for pool safety requirements and specifically mesh barriers. Streamlining the code to require compliance with a longstanding industry standard that manufacturers use today in Florida, supports public safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by streamlining and making it simpler by deleting the standard requirements laid out and referencing the standard.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10438-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:07:52 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.2.17.1.15

A mesh safety barrier meeting the requirements of Section 454.2.17, installed in accordance with the manufacturer's instructions and complying with ASTM F2286, ~~and the following minimum requirements~~ shall be considered a barrier as defined in this section. Where a hinged gate is used with a mesh fence, the gate shall comply with Section 454.2.17.1.8. Mesh fences shall not be installed on top of above-ground/on-ground private swimming pools.~~:~~

1. ~~Individual component vertical support posts shall be capable of resisting a minimum of 52 pounds (24 kg) of horizontal force prior to breakage when measured at a 36 inch (914 mm) height above grade. Vertical posts of the child safety barrier shall extend a minimum of 3 inches (76 mm) below deck level and shall be spaced no greater than 36 inches (914 mm) apart.~~
2. ~~The mesh utilized in the barrier shall have a minimum tensile strength according to ASTM D 5034 of 100 lbf, and a minimum ball burst strength according to ASTM D 3787 of 150 lbf. The mesh shall not be capable of deformation such that a 1/4-inch (6.4 mm) round object could not pass through the mesh. The mesh shall receive a descriptive performance rating of no less than "trace discoloration" or "slight discoloration" when tested according to ASTM G 53, Weatherability, 1,200 hours.~~
3. ~~When using a molding strip to attach the mesh to the vertical posts, this strip shall contain, at a minimum, #8 by ½ inch (12.7 mm) screws with a minimum of two screws at the top and two at the bottom with the remaining screws spaced a maximum of 6 inches (152 mm) apart on center.~~
4. ~~Patio deck sleeves (vertical post receptacles) placed inside the patio surface shall be of a nonconductive material.~~
5. ~~A latching device shall attach each barrier section at a height no lower than 45 inches (1143 mm) above grade. Common latching devices that include, but are not limited to, devices that provide the security equal to or greater than that of a hook-and-eye-type latch incorporating a spring actuated retaining lever (commonly referred to as a safety gate hook).~~
6. ~~The bottom of the mesh safety barrier shall not be more than 1 inch (25 mm) above the deck or installed surface (grade).~~

Add new standard under the ASTM Standards listed in Chapter 35 as follows:

ASTM F2286-16 Standard Design and Performance Specification for Removable Mesh Fencing for Swimming Pools, Hot Tubs, and Spas **454.2.17.1.15**

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10441

92

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Chapter 4, Section 454.2.1, and R4501.2, on elevated pools

Summary of Modification

This proposal adds a definition for "elevated pool" and requires these type of pools to be designed and constructed in accordance with ANSI/PHTA/ICC 10 - 2021.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). This proposal seeks to recognize elevated pools and spas in the Florida Building Code with a reference to the ANSI/PHTA/ICC 10 -2021 Standard. There is currently no code guidance on this type of structure. The reasoning for the creation of an ANSI/PHTA/ICC Standard on elevated pools and spas stems from multiple sources. Jurisdictions and regulators seek guidance on this issue as the number of elevated pools and spas constructed and installed has increased greatly in recent years. Various issues including leaking and other consumer issues has led to litigation. The specialized construction of an elevated pool or spa including materials, piping, values, waterproof systems, and leak detection equipment should be addressed. Design and construction guidelines in this Standard - and those already in the Florida Building Code - seeks to diminish these issues.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

May have a minimal cost related to time spent on learning these new requirements.

Impact to building and property owners relative to cost of compliance with code

Could increase costs but while ensuring proper construction and safety guidelines are met for these type of pools.

Impact to industry relative to the cost of compliance with code

May have a minimal cost related to time spent on learning these new requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this code change ensures elevated pools and spas are required to meet an ANSI approved standard that ensures proper construction guidelines are met, including aspects that protect the general public related to safety and welfare.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This change strengthens and improves the code by providing for a standard laying out what is required of these types of pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

No, rather it improves it.

Alternate Language

1st Comment Period History

SW10441-A1

Proponent Dallas Thiesen **Submitted** 4/15/2022 11:20:06 AM **Attachments** Yes

Rationale:

Defining "Elevated Pool" is needed for clarity in the code but need more specificity. ANSI/PHTA/ICC 10-2021 should not be incorporated in to the Florida Building Code. Proposed Modifications SW10323 and SW10324 adequately address leaking issues presented by elevated swimming pools and provides a path to adequately dampproof existing elevated pools in Florida when undertaking resurfacing projects.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Deals with safety of elevated swimming pools.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Adds clarity to the code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials, products, or methods.

Does not degrade the effectiveness of the code

Adds clarity to the code

1st Comment Period History

SW10441-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:19:12 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes the adoption of ANSI/PHTA-10 2022 in the Florida Building Code. Proposed Modifications SW10323 and SW10324 adequately address leaking issues presented by elevated swimming pools and provides a path to adequately dampproof existing elevated pools in Florida when undertaking resurfacing projects.

454.1 Definitions

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water **integrated in to a building or structure** that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

~~454.1.12 Elevated Pools.~~

~~Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.~~

-

~~Add new standard under the APSP (PHTA) Standards listed in Chapter 35 as follows:~~

-

~~ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure 454.1.12~~

454.1 Definitions *(add new as follows)*

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

Add new section as follows:

454.1.12 Elevated Pools.
Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.

Add new standard under the APSP (PHTA) Standards listed in Chapter 35 as follows:

ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure 454.1.12

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

93

SW10442

Date Submitted	02/15/2022	**Section**	454.2.1	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

454.1 and R4501.2, on elevated pools

Summary of Modification

This proposal adds a definition for "elevated pool" and requires these type of pools to be designed and constructed in accordance with ANSI/PHTA/ICC 10 - 2021.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). This proposal seeks to recognize elevated pools and spas in the Florida Building Code with a reference to the ANSI/PHTA/ICC 10 -2021 Standard. There is currently no code guidance on this type of structure. The reasoning for the creation of an ANSI/PHTA/ICC Standard on elevated pools and spas stems from multiple sources. Jurisdictions and regulators seek guidance on this issue as the number of elevated pools and spas constructed and installed has increased greatly in recent years. Various issues including leaking and other consumer issues has led to litigation. The specialized construction of an elevated pool or spa including materials, piping, values, waterproof systems, and leak detection equipment should be addressed. Design and construction guidelines in this Standard - and those already in the Florida Building Code - seeks to diminish these issues.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

May have a minimal cost related to time spent on learning these new requirements.

Impact to building and property owners relative to cost of compliance with code

Could increase costs but while ensuring proper construction and safety guidelines are met for these type of pools.

Impact to industry relative to the cost of compliance with code

May have a minimal cost related to time spent on learning these new requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this code change ensures elevated pools and spas are required to meet an ANSI approved standard that ensures proper construction guidelines are met, including aspects that protect the general public related to safety and welfare.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This change strengthens and improves the code by providing for a standard laying out what is required of these types of pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

No, rather it improves it.

Alternate Language

1st Comment Period History

SW10442-A1

Proponent Dallas Thiesen **Submitted** 4/15/2022 11:23:05 AM **Attachments** Yes

Rationale:

Defining "Elevated Pool" is needed for clarity in the code but needs more specificity. ANSI/PHTA/ICC 10-2021 should not be incorporated in to the Florida Building Code

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Deals with safety of elevated swimming pools.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Adds clarity to the code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials, products, or methods.

Does not degrade the effectiveness of the code

Adds clarity to the code

1st Comment Period History

SW10442-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:19:40 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes the adoption of ANSI/PHTA-10 2022 in the Florida Building Code.

454.2.1 Definitions

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water **integrated in to a building or structure** that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

~~**454.2.24 Elevated Pools.**~~

~~Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.~~

-

~~*Add new standard under the APSP (PHTA) Standards listed in Chapter 35 as follows:*~~

-

~~ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure 454.2.24~~

454.2.1 Definitions *(add new as follows)*

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

Add new section as follows:

454.2.24 Elevated Pools.
Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.

Add new standard under the APSP (PHTA) Standards listed in Chapter 35 as follows:

ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure 454.2.24

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10455

94

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

May need to change cited reference national standards in FBC references chapter.

Summary of Modification

Changes and updates code referenced national standards to more current date.

Rationale

The referenced national standards have been updated since these dates were placed into FBC 454.1, and the updates reflect the modern expert improvements to these standards.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None to Nominal

Impact to industry relative to the cost of compliance with code

None to Nominal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Firmly connected with health and safety

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves and provides equivalent of better products

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade

Alternate Language

1st Comment Period History

SW10455-A1

Proponent bob vincent **Submitted** 4/17/2022 10:34:06 AM **Attachments** Yes

Rationale:

Previously posted standards were not the most current.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
none to nominal

Impact to building and property owners relative to cost of compliance with code
none to nominal

Impact to industry relative to the cost of compliance with code
none to nominal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Yes, updated standards have this connection

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Yes, updated standards do this

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
Does not discriminate

Does not degrade the effectiveness of the code
Does not degrade effectiveness

1st Comment Period History

SW10455-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:20:45 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

Corrected updated copyright-protected NSF/ANSI standards for the: definition of Precoat pot, and sections 454.1.6.5.1, 454.1.6.5.16.5.2, 454.1.9.2.5.2, & 454.1.11.3

Only the following sections have dated standards:

454.1.6.5.1 Recirculation and treatment equipment such as filters, recessed automatic surface skimmers, ionizers, ozone generators, disinfection feeders and chlorine generators shall be tested and approved using the certified by an ANSI-accredited certification body to NSF/ANSI/CAN Standard 50-2020, Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities, October 21, 2020 NSF/ANSI Standard 50, Circulation System Components and Related Materials for Swimming Pool, Spas/Hot Tubs, dated April 2007, which is incorporated by reference, which has been deemed copyright protected, and is available for review at the Department of State, R.A. Gray Building, 500 South Bronough Street, Tallahassee, FL 32399-0250.

.

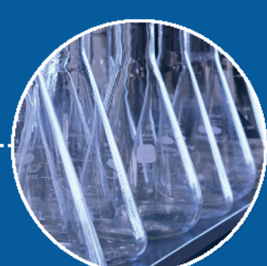
454.1.11.3 Construction standards for artificial lagoons.
If an artificial liner is utilized as a containment system, the artificial liner used to contain the water shall consist of a material tested and certified by an ANSI-accredited certification body to under NSF/ANSI/CAN Standard 61-2021, Drinking Water System Components--Health Effects, April 14, 2021 NSF/ANSI Standard 61-2017, Drinking Water System Components - Health Effects, dated March 13, 2017, hereby incorporated by reference, which has been deemed copyright protected, and is available for review at the Department of State, R.A. Gray Building, 500 South Bronough Street, Tallahassee, FL 32399-0250.

"Precoat pot" means a container with a valved connection to the suction side of the recirculation pump of a pressure diatomaceous earth (D.E.) type filter system used for coating the filter with D. E. powder or NSF/ANSI/CAN Standard 50-2007 tested/certified and manufacturer approved substitute filter aid.

NSF International Standard /
American National Standard /
National Standard of Canada

NSF/ANSI/CAN 61 - 2021

Drinking Water System Components - Health Effects



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This Standard is subject to revision.
Contact NSF to confirm this revision is current.

Users of this Standard may request clarifications and interpretations, or propose revisions by contacting:

Chair, Joint Committee on Drinking Water Additives – System Components
c/o NSF International
789 North Dixboro Road, PO Box 130140
Ann Arbor, Michigan 48113-0140 USA
Phone: (734) 769-8010   Fax: (734) 769-0109
Email: info@nsf.org
Web: <www.nsf.org>

NSF International Standard /
American National Standard /
National Standard of Canada
for Drinking Water Additives –

Drinking Water System Components – Health Effects

Standard Developer
NSF International

ICS 13.060.20

Designated as an ANSI Standard
April 14, 2021
American National Standards Institute

Designated as a National Standard of Canada
April 14, 2021 **Standards Council of Canada**

Prepared by
The NSF Joint Committee on Drinking Water Additives

Recommended for adoption by
The NSF Council of Public Health Consultants

Adopted by
NSF International
June 1988

Revised October 1988	Revised May 1990	Revised May 1991
Revised May 1992	Revised September 1994	Revised January 1995
Revised July 1996	Revised September 1996	Revised November 1996
Revised January 1997	Revised March 1997	Revised July 1997
Revised November 1998	Revised January 1999	Revised November 1999
Revised September 2000	Revised February 2001	Addendum September 2001
Revised July 2002	Addendum August 2002	Editorial revision October 2003
Revised November 2004	Addendum March 2005	Revised October 2005
Revised March 2007	Revised July 2007	Addendum October 2007
Revised December 2008	Revised August 2009	Revised February 2010
Revised October 2010	Revised June 2001	Addendum March 2012
Revised July 2012	Addendum March 2013	Revised January 2014
Revised September 2014	Revised February 2015	Revised October 2015
Revised July 2016	Addendum January 2017	Revised October 2017
Revised February 2019	Revised October 2019	Revised July 2020
Revised November 2021		

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For ordering copies or for making inquiries with regard to this Standard, please reference the designation "NSF/ANSI/CAN 61 – 2021."

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Printed in the United States of America.

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The illustrations, if provided, are intended to assist in understanding their adjacent standard requirements. However, the illustrations may not include all requirements for a specific product or unit, nor do they show the only method of fabricating such arrangements. Such partial drawings shall not be used to justify improper or incomplete design and construction.

At the time of this publication, examples of programs and processes were provided for general guidance. This information is given for the convenience of users of this standard and does not constitute an endorsement by NSF International. Equivalent programs and processes may be used.

Unless otherwise referenced, the annexes are not considered an integral part of NSF Standards. The annexes are provided as general guidelines to the manufacturer, regulatory agency, user, or certifying organization.

[1] The information contained in this Disclaimer is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Disclaimer may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

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Contents

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Foreword[2]

In response to a competitive request for proposals from the US Environmental Protection Agency (US EPA), a Consortium led by NSF International (NSF) agreed to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the Consortium include the American Water Works Association Research Foundation (WRF), the Association of State Drinking Water Administrators (ASDWA), the Conference of State Health and Environmental Managers (COSHEM), and the American Water Works Association (AWWA). (COSHEM has since become inactive as an organization.) Each organization was represented on a steering committee with oversight responsibility for the administration of the cooperative agreement. The Steering Committee provides guidance on overall administration and management of the cooperative agreement. Currently, the member organizations remain active in an oversight role.

Two Standards for additives products have been adopted. NSF/ANSI/CAN 60: *Drinking Water Treatment Chemicals — Health Effects* covers many of the water treatment chemicals, also known as direct additives. This Standard, NSF/ANSI/CAN 61, covers all indirect additives products and materials. Testing to determine the potential of a product to impart taste and/or odor to drinking water is not included in this Standard.

NSF/ANSI/CAN 61, and subsequent product certification against it, has replaced the US EPA Additives Advisory Program for drinking water system components. US EPA terminated its advisory role in April 1990. For more information with regard to US EPA's actions, refer to the July 7, 1988 *Federal Register* (53FR25586).

NSF/ANSI/CAN 61 was developed to establish minimum requirements for the control of potential adverse human health effects from products that contact drinking water. It does not attempt to include product performance requirements that are currently addressed in other voluntary consensus standards established by such organizations as the AWWA, ASTM International, and the American National Standards Institute (ANSI). Because this Standard complements the performance standards of these organizations, it is recommended that products also meet the appropriate performance requirements specified in the standards of such organizations.

Water age can be a major factor in the deterioration of water quality within plumbing systems affecting issues of both public health and aesthetic concerns. With increased water age is an increased potential for the formation of disinfection by-products, increased corrosion, and an increased potential for microbial regrowth. It can also lead to a loss in the effectiveness of corrosion control measures and an increased potential for nitrification of the water.

Within NSF/ANSI/CAN 61, most extraction protocols result in exposure periods between 12 to 24 hours. While these are appropriate for typical drinking water system use, they can be significantly less than in others. Examples of where high water age can occur include:

— water storage tanks in rain water catchment systems where the duration may be weeks or months;

— plumbing system designs in green buildings which result of overall reduction in water usage without a change in piping design to minimize stagnation;

— buildings where stagnant periods occur due to nonuse such as schools between semesters, vacation homes, or seasonal buildings; and

— products on isolated lines with either long or oversized piping resulting low water turnover.

[2] The information contained in this Disclaimer is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Disclaimer may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

NSF/ANSI/CAN 61 compliant products are often specified in these applications yet the potential accumulation of leachates over extended periods of exposure may or may not be addressed though this Standard. It is important that the design of drinking water plumbing systems take into account potentials for extended aging of water. This may include the flushing of the water piping system after extended periods of nonuse. It is also important for managers of the drinking systems in buildings be aware of the potential for high water age and proactively manage the system to minimize it.

This Standard and the accompanying text are intended for voluntary use by certifying organizations, utilities, regulatory agencies, and/or manufacturers as a basis of providing assurances that adequate health protection exists for covered products. Product certification issues, including frequency of testing and requirements for follow-up testing, evaluation, enforcement, and other policy issues, are not addressed by this Standard.

In 2020, the Joint Committee developed proposed changes designed to increase the public health protection of this Standard relative to the evaluation of lead leaching from endpoint devices. Due to the significant impact of these changes, the Joint Committee has established an extended effective date for the requirement to become mandatory on January 1, 2024. This effective date was selected to provide manufacturers a reasonable time to reengineer products to meet the new requirements, to have them tested, and to make them available in the marketplace. This date is based on the date of product manufacture. Manufacturers and certifiers are encouraged to actively pursue conformance to the new requirement prior to January 1, 2024. For clarity, the Joint Committee has placed the pending requirements in an informative annex.

All references to gallons (gal) are in US gallons.

This Standard is designated as a National Standard of Canada (NSC) in compliance with requirements and guidance set out by the Standards Council of Canada (SCC).

This edition of the Standard contains the following revisions:

Issue 157

This revision removes Table N-1.3a, adds the pH 5 extraction water test to brass / bronze surfaces in Table N-1.3 (formerly Table N-1.3 b), and adds the requirement of a use limitation statement on product literature and certification listings for those products that fail for copper at pH 5.

Issue 158

This revision adds units of in^2/L to the DSA-to-volume ratio numbers in the first bullet under Section 3.3.2.

Issue 159

This revision includes several corrections and clarifications, including:

— additional guidance in Table 4.2 (Single time point exposure schedule) to be consistent with other exposure sequence tables in the standard;

— correction of reference to exposure protocol from Sections N-1.4.4.2 to N-1.4.4.4 for other mechanical devices. Section N-1.4.4.2 is for POE systems and system components requiring exposure under pressure for a 16-hr exposure time. Section N-1.4.4.4 redirects to Table N-1.9 which specifies an exposure time of 24 hr for other mechanical devices, aligning with guidance in Section 8.3.2;

— guidance for reverse osmosis systems in Table N-1.7 (product exposure) to indicate that typical exposure conditions occur within the product itself; and

— additional guidance on decanting and refilling of samples for in-line and other mechanical devices that was previously included in Section N-1.4.4.1 to be consistent with other exposure sequence tables in the standard.

The Interpretations Annex contains responses to interpretation requests. The responses will be published in each version of the Standard until such time that the interpretation response is no longer applicable.

This Standard was developed by the NSF Joint Committee on Drinking Water Additives – System Components using the consensus process described by the American National Standards Institute and the Standards Council of Canada's *Requirements and Guidance*. At the time of approval, the Joint Committee consisted of 9 public health / regulatory, 9 industry, 6 product certifier / testing lab, and 8 user representatives.

Suggestions for improvement of this Standard are welcome. This Standard is maintained on a Continuous Maintenance schedule and can be opened for comment at any time. Comments should be sent to: Chair, Joint Committee on Drinking Water Additives – System Components at standards@nsf.org, or c/o NSF International, Standards Department, PO Box 130140, Ann Arbor, Michigan 48113-0140, USA.

SCC Foreword

A National Standard of Canada is a standard developed by a Standards Council of Canada (SCC) accredited standards development organization, in compliance with requirements and guidance set out by the SCC. More information on National Standards of Canada can be found at <www.scc.ca>.

SCC is a Crown corporation within the portfolio of Innovation, Science and Economic Development (ISED) Canada. With the goal of enhancing Canada's economic competitiveness and social well-being, SCC leads and facilitates the development and use of national and international standards. SCC also coordinates Canadian participation in standards development, and identifies strategies to advance Canadian standardization efforts.

Accreditation services are provided by SCC to various customers, including product certifiers, testing laboratories, and standards development organizations. A list of SCC programs and accredited bodies is publicly available at <www.scc.ca>.

Consortium Organizations

NSF International

Popularly referred to as NSF, NSF International is a noncommercial agency. It is incorporated under the laws of Michigan as a not-for-profit organization devoted to research, education, and service. It seeks to solve problems involving man and his environment. It wishes to promote health and enrich the quality of life through conserving and improving that environment. Its fundamental principle of operation is to serve as a neutral medium in which business and industry, official regulatory agencies, and the public come together to deal with problems involving products, equipment, procedures, and services related to health and the environment. It is conceived and administered as a public service organization.

NSF is perhaps best known for its role in developing Standards and Criteria for equipment, products, and services that bear upon health. NSF was the lead organization in the Consortium responsible for developing this Standard. NSF conducts research; tests and evaluates equipment, products, and services for compliance with standards and criteria; and grants and controls the use of NSF registered Marks.

NSF offers product certification (listing services) for all products covered by its Standards. Each program has established policies governing the associated product evaluation, Listing Services, follow-up, and enforcement activities. The NSF Listing Mark is widely recognized as a sign that the product or service to which it relates complies with the applicable NSF Standard(s).

Water Research Foundation

The mission of the American Water Works Association Research Foundation (now the Water Research Foundation), is to sponsor practical, applied research on behalf of the drinking water industry of North America. The scope of the research program embraces all aspects of water supply operation, from development and maintenance of water resources to treatment technologies and water quality issues, from storage and distribution system operations to health effects studies and utility planning and management activities. Water Research Foundation (WRF) serves as the centralized industry institution for planning, managing, and funding cooperative research and development in drinking water, including the subsequent transfer of technology and results for practical application by the water utility community.

WRF's purpose in this cooperative program is to provide a communication link with the water utilities throughout North America and serve as the focal point for identification of research needs of the water supply industry with respect to the additives program.

The Association of State Drinking Water Administrators

The Association of State Drinking Water Administrators (ASDWA) is a nonprofit organization whose eligible membership is comprised of drinking water program administrators in each of the 50 states and seven US territories. Through the organization, representatives speak with a collective voice to Congressional committees, the United States Environmental Protection Agency (EPA), professional and trade associations, water utilities, and the general public on issues related to state drinking water programs. With its mission of protecting the public health through assurance of high-quality drinking water, and promoting responsible, reasonable, and feasible drinking water programs at the state and federal levels, the Association is a valued contributor to the consortium, and to the program. It provides the link between the additives program and the state drinking water programs.

The Conference of State Health and Environmental Managers

The Conference of State Health and Environmental Managers (COSHEM), known formerly as the Conference of State Sanitary Engineers (CSSE), is currently inactive as an organization. It brought to the consortium expertise and involvement of state health and environmental program managers. The Conference was the focal point for health concerns of all state environmental programs, including drinking water, wastewater, air, solid and hazardous wastes, radiology, occupational health, and food. A standing committee on water supply focused on drinking water issues and kept the membership informed. The Conference played an important role early in the program through two-way communication with state health and environmental program decision makers.

American Water Works Association

The purpose of the American Water Works Association (AWWA) is to promote public health, safety, and welfare by improving the quality and increasing the quantity of water delivered to the public, and to developing and furthering an understanding of the problems relating thereto by:

— advancing the knowledge of the design, construction, operation, water treatment, and management of water utilities;

— developing standards for procedures, equipment, and materials used by public water supply systems;

— advancing the knowledge of problems involved in the development of resources, production, and distribution of safe and adequate water supplies;

— educating the public on the problems of water supply and promoting a spirit of cooperation between consumers and suppliers in solving these problems; and

— conducting research to determine the causes of problems with providing a safe and adequate water supply, and proposing solutions thereto in an effort to improve the quality and quantity of the water supply provided to the public.

AWWA brings to the Consortium its established position as the largest public drinking water association in North America, with a broad membership that includes utilities, consultants, manufacturers / distributors / agents, contractors, and other organizations with a direct interest in drinking water.

NSF/ANSI/CAN Standard
for Drinking Water Additives –

Drinking Water System Components – Health Effects

1 General

1.1 Purpose

This Standard establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted to drinking water from products, components, and materials used in drinking water systems. This Standard does not establish performance, taste and odor, or microbial growth support requirements for drinking water system products, components, or materials.

1.2 Scope

1.2.1 This Standard is intended to cover specific materials or products that come into contact with: drinking water, drinking water treatment chemicals, or both. The focus of the Standard is evaluation of contaminants or impurities imparted indirectly to drinking water. The products and materials covered include, but are not limited to, process media (e.g., carbon, sand), protective materials (e.g., coatings, linings, liners), joining and sealing materials (e.g., solvent cements, welding materials, gaskets), pipes and related products (e.g., pipes, tanks, fittings), mechanical devices used in treatment / transmission / distribution systems (e.g., valves, chlorinators, separation membranes, point-of-entry (POE) drinking water treatment systems), and mechanical plumbing devices (e.g., faucets, endpoint control valves).

1.2.2 Point-of-use (POU) drinking water treatment devices are not covered by the scope of this Standard.

1.3 Normative references

The following documents contain requirements that, by reference in this text, constitute requirements of this Standard. At the time this Standard was balloted, the editions listed below were valid. All documents are subject to revision, and parties are encouraged to investigate the possibility of applying the recent editions of the documents indicated below. The most recent published edition of the document shall be used for undated references.

21 CFR Part 58, *Good Laboratory Practice for Nonclinical Laboratory Studies*[3]

40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants*[3]

40 CFR Part 141, *National Primary Drinking Water Regulations*[3]

40 CFR Part 160, *Good Laboratory Practice Standards*[3]

[3] National Archives and Records Administration, Office of the Federal Register. 7 G Street NW, Suite A-734, Washington, DC 20401. <www.ecfr.gov>

40 CFR Part 798, *Health Effects Testing Guidelines*[3]

APHA/AWWA/WEF, *Standard Methods for the Examination of Water and Wastewater*, twenty-second edition[4]

ASTM A240/A240M-05, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*[5]

ASTM A269-04, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*[5]

ASTM A312/A312M-05, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*[5]

ASTM A789/A789M-05, *Standard Specification for Seamless and Welded Ferritic / Austenitic Stainless Steel Tubing for General Service*[5]

ASTM A790/A790M-05, *Standard Specification for Seamless and Welded Ferritic / Austenitic Stainless Steel Pipe*[5]

ASTM A815/A815M-04, *Standard Specification for Wrought Ferritic, Ferritic / Austenitic, and Martensitic Stainless Steel Piping Fittings*[5]

ASTM C31/C31M-00e1, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*[5]

ASTM C109/C109M-99, *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars*[5]

ASTM C 183-02, *Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement*[5]

ASTM C192/C192M-00, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*[5]

ASTM C511-98, *Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes*[5]

ASTM C778-00, *Standard Specification for Standard Sand*[5]

ASTM D2855-96, *Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings*[5]

ASTM D3182-89 (1994), *Standard Practice for Rubber – Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets*[5]

ASTM E29-02, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*[5]

ASTM F493-97, *Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings*[5]

ANSI/AWWA B100-96, *AWWA Standard for Filtering Material*[6]

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[4] American Public Health Association, American Water Works Association, and Water Environment Federation. <www.standardmethods.org>

[5] ASTM International. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. <www.astm.org>

[6] American Water Works Association. 6666 W Quincy Avenue, Denver, CO 80235. <www.awwa.org>

ANSI/AWWA C652-92, *AWWA Standard for Disinfection of Water-Storage Facilities*[6]

NSF/ANSI/CAN 60, *Drinking Water Treatment Chemicals – Health Effects*

NSF/ANSI/CAN 372, *Drinking Water System Components – Lead Content*

NSF/ANSI/CAN 600, *Health Effects Evaluation and Criteria for Chemicals in Drinking Water*

OECD, *OECD Guidelines for the Testing of Chemicals*, May 1996[7]

SSPC-PA2– 2004, *Steel Structures Painting Manual Volume 2. Paint Application Specification*[8]

The Society for Protective Coatings, *Steel Structures Painting Manual*. Volume 2. Reference Paint Application Specification No. 2 (SSPC-PA2)[8]

US EPA-570-9-82-002, *Manual for the Certification of Laboratories Analyzing Drinking Water*, October 1982[9]

US EPA-600/4-79-020, *Methods for the Chemical Analysis of Water and Wastes*, March 1983[9]

US EPA-600/4-80-032, *Prescribed Procedures for Measurement of Radioactivity in Drinking Water*[9]

US EPA-600/4-84-053, *Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater*, June 1984[9]

US EPA-600/R-05/054, *Determination of Nitrosamines in Drinking Water By Solid Phase Extraction and Capillary Column Gas Chromatography With Large Volume Injection and Chemical Ionization Tandem Mass Spectrometry (MS/MS)*, September 2004[9]

US FDA, *Toxicological Principles for the Safety Assessment of Direct Food Additives and Color Additives in Food*[10]

1.4 Limitations

The requirements of this Standard are limited to addressing potential health effects, except where specific application and performance standards are referenced. This Standard does not establish taste and odor requirements for drinking water system products and materials. The criteria set forth in this Standard cover products created by good manufacturing practices (GMP) and generally recognized manufacturing processes. As the presence of unusual or unexpected impurities is frequently dependent upon the method of manufacture and the quality of raw material used, products prepared by other than recognized methods of manufacture or with unusual raw materials shall be fully evaluated in accordance with Section 3 of this Standard (General requirements). Products that have been evaluated and found to meet other NSF standards having health requirements equivalent to this Standard as indicated in each section shall be acceptable for drinking water applications without separate evaluation under this Standard.[11]

[7] Organization for Economic Cooperation and Development. 2 Rue Andre-Pascal, 75775 Paris Cedex 16, France. <www.oecd.org>

[8] Association for Materials Protection and Performance. 15835 Park Ten Place. Houston, TX 77084. <www.ampp.org>

[9] US Environmental Protection Agency. 1200 Pennsylvania Avenue NW, Washington, DC 20004. <www.epa.gov>

[10] US Department of Health and Human Services, Public Health Service, Food and Drug Administration. 10903 New Hampshire Ave, Silver Spring, MD 20993. <www.fda.gov>

[11] Final acceptance of a product for drinking water application is the responsibility of the appropriate federal, state, or local regulatory agent.

1.5 Alternate products or materials

While specific materials are stipulated in this Standard, drinking water system products or components that incorporate alternate materials shall be acceptable when it is verified that the product or component meets the applicable requirements of the Standard based on its end use.

1.6 Significant figures and rounding

For determining conformance with the specifications in this Standard, the Absolute Method in ASTM E29[5] *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications* shall be used. When rounding data, the rounding procedure in Section 6.4 of ASTM E29[5] shall be used.

2 Definitions

Terms used in this Standard that have a specific technical meaning are defined here.

2.1 analytical summary: A list of the analytes and analytical procedures, both chemical and microbiological, that are selected to determine whether a product is conformant to the requirements of the Standard; analytes may be either product-specific or formulation-dependent.

2.2 at the tap: Referring to the point of delivery or point of use for drinking water.

2.3 cold water application: A product application that is not intended to result in exposure for extended periods to water in excess of ambient water temperature.

2.4 contaminant: A physical, chemical, biological, or radiological substance or matter in water.

NOTE — Consistent with the definition in the US Federal Safe Drinking Water Act, a contaminant can have either a beneficial or detrimental effect on the potability of water.

2.5 diluted surface area (DSA): The surface area / volume ratio of a product, component, or material calculated using its actual wetted surface area, the field static and/or field flow volumes directed by the standard for the end use for which the product is being evaluated. The calculation shall use the normalization equation specific to that end use. The values for lab surface area and lab volume in the normalization equation shall be entered as 1 for the purposes of this determination causing the DSA ratio to equal the calculated NF factor. The volume of chemical generated or water treated shall be for a 24-h period.

Example calculation: For a component of a chemical generator that has an actual surface area of 5 in^2 and the unit treats a minimum daily water volume of 500,000 L/d (refer to Annex N-1 for definition of normalization terms):

$$\text{DSA}\left(\frac{\text{in}^2}{\text{L}}\right) = \text{NF} = \text{N1} \times \text{N2} \times \text{N4} = \frac{SA_F}{SA_L} \times \frac{V_L}{V_{F(static)}} \times \frac{V_{F(static)}}{V_{F(flowing)}} \times \frac{V_{TC}}{V_{WT}} = \frac{5}{1} \times \frac{1}{500{,}000} = 0.00001\ \frac{\text{in}^2}{\text{L}}$$

Where:

SA_F = surface area exposed in the field

SA_L = 1 (per DSA definition)

V_L = 1 (per DSA definition)

$V_{F(static)}$ = cancels out of the equation for this example

$V_{F(flowing)}$ = V_{TC} and the two cancel out of the equation in this example (i.e., the volume of solution leaving the chemical generator [$V_{F(flowing)}$] is the same as that being used to treat the water [V_{TC}])

V_{WT} = volume of raw water treated with the concentrated chemical when dosed at the prescribed feed rate during a 24-h period.

2.6 direct additives: A treatment chemical and its contaminants directly added to water during the production of drinking water.

2.7 distribution system: The system of conduits or the network of pipelines (located primarily in the streets) through which a primary domestic water supply is distributed to consumers. In plumbing codes, this term is applied to all the hot and cold water piping installed in buildings.

2.8 drinking water: Water intended for human consumption.

2.9 drinking water treatment unit system: A complete water treatment device, including all components needed to connect the device to a potable water supply.

2.10 free available chlorine: The sum of hypochlorous acid and hypochlorite ions.

2.11 good manufacturing practices (GMP): The practice of maximizing the purity of products and materials by maintaining and practicing appropriate quality control (QC) and quality assurance (QA) procedures.

2.12 hot water application: A product application that is intended to result in exposure for extended periods to water that has been raised from ambient temperature.

2.13 indirect additives: Contaminants that are extracted into drinking water through contact with the surfaces of materials, components, or products used for its treatment, storage, transmission, or distribution.

2.14 manufacturer: A corporation, company, or individual that produces, formulates, packages, or repackages products, components, and materials that are intended to be in contact with drinking water.

2.15 maximum contaminant level (MCL): The maximum concentration of a regulated contaminant that is permitted in a public drinking water supply, as defined under the US Federal Safe Drinking Water Act.

NOTE — If the manufacturer requests review to relevant alternate regulatory requirements, the certifying agency can consider alternative regulatory levels, e.g., Canadian maximum acceptable concentrations (MACs).

2.16 normalization: The process of adjusting laboratory extraction results by accounting for differences between laboratory and field surface area-to-volume ratios to reflect the contaminant concentration at the tap.

2.17 normalized concentration: A value for a contaminant concentration from a laboratory extraction test that has been adjusted to reflect the potential contaminant concentration at the tap.

2.18 point-of-entry (POE) system: A system with a minimum initial clean-system flow rate of no less than 15 L/min at 103 kPa pressure drop and 18 ± 5 °C water temperature (not less than 4 gal/min at 15 psig pressure drop and 65 ± 10 °F water temperature) used to treat the water supply at a building or facility for drinking, washing, and flushing or for other nonconsumption water supply purposes.

2.19 point-of-use (POU) system: A plumbed-in or faucet-mounted system used to treat the drinking and/or cooking water at a single tap or multiple taps but not used to treat the majority of water used for washing and flushing or other nonconsumption purposes at a building or facility. Any batch system or device not connected to the plumbing system is considered a POU system.

2.20 short-term exposure level (STEL): A maximum concentration of a contaminant that is permitted in drinking water for an acute exposure calculated in accordance with NSF/ANSI/CAN 600 (previously Annex A).

2.21 single product allowable concentration (SPAC): The maximum concentration of a contaminant in drinking water that a single product is allowed to contribute as defined by NSF/ANSI/CAN 600 (previously Annex A).

2.22 total allowable concentration (TAC): The maximum concentration of a nonregulated contaminant allowed in a public drinking water supply as defined by NSF/ANSI/CAN 600 (previously Annex A).

2.23 transmission system: A system of conduits through which a primary water supply is transmitted to the distribution system.

2.24 unit void volume (UVV): Total water-holding volume with the medium (media) and internal components in place.

3 General requirements

3.1 General

3.1.1 Product and material information described in Section 3.2 shall be used to determine the specific section (4 through 9) under which a product or material shall be evaluated.

3.1.2 Products or materials whose intended uses fall under more than one section of this Standard shall be evaluated under the section with the most rigorous evaluation conditions.

3.1.3 Within the applicable section of this Standard, products shall be evaluated under the most rigorous conditions unless results from a less rigourous test can be mathematically extrapolated to ensure compliance with the most rigorous condition.

3.1.4 The most rigorous condition is associated with the shortest conditioning period, longest exposure period, highest surface area to volume ratio, and highest exposure temperature, unless demonstrated otherwise with emperical data.

3.2 Information and formulation requirements

The following information shall be obtained and reviewed for all materials with a water contact surface to determine the appropriate analytical testing and to ensure that the potential health effects of products and materials are accurately and adequately identified:

— the product section(s) under which the product, component, or material is covered and the intended function or end use of the product or the material;

— for assemblies, subassemblies, products or components, a list of all materials and their corresponding surface areas that come into direct contact with water;

— when appropriate, the total volume of water that the product can hold when filled to capacity;

— the anticipated minimum, maximum, and average volumes of water that come into contact with the product, component, or material during a 24 h period;

— complete formulation information (equal to 100.0%) for each water contact material. This shall include:

— a complete formulation shall result in the identity by CAS number or chemical name of each component of the formulation including but not limited to the activators, antioxidants, antimicrobials, cosolvents, fillers, initiators, peroxides, pigments, plasticizers, process aids, solvents, stabilizer, surfactants and terminators; and

— percent or parts by weight for each chemical in the formulation or reference to a national or international standardized material specification for metallic materials (e.g., UNS copper alloy specifications).

NOTE 1 — The complete formulation information may be omitted for a component material if:

— the generic material type is contained in Table 3.1 and its DSA in the application is ≤ 0.001 in^2/L or 0.0001 in^2/L for static or flowing conditions respectively; or

— the generic material type is contained in Table 3.1 and if the material is in a high flow device and used exclusively at public water treatment facilities. For the purposes of this section, high flow devices are limited to chemical feeders, disinfectant generators (e.g., chlorine dioxide, hypochlorite, ozone and ultraviolet), electrodialysis technologies, microfiltration technologies, nanofiltration technologies, reverse osmosis and ultrafiltration technologies; or

— the generic material type is contained in Table 3.1 and if *(1)* used in a mechanical device or mechanical plumbing device, and *(2)* the material is not a coating, and *(3)* the component is not a process media; or

— if *(1)* the material is not listed in Table 3.1, and *(2)* it is used in a mechanical device or mechanical plumbing device, and *(3)* the material is not a coating, and *(4)* the component is not a process media, and *(5)* the material is tested to the requirements of Table 3.2.

If the product is to be considered compliant to a lead content standard, the lead content (percent by weight) and wetted surface area of each component that comes into contact with the direct flow of water under the normal operation of the product is required. Complete documentation shall be submitted in accordance with NSF/ANSI/CAN 372.

NOTE 2 — A material is defined as a combination of ingredients used to manufacture (mold, extrude, stamp, cast, machine, mix, etc.) a part or component used in the assembly of a device. To include, but not be limited to, plastics, elastomers, metallic components, media, lubricants, adhesives, process aid, preservatives, coatings, and surface treatments.

— when the chemical composition of an ingredient or component cannot be determined based on the information submitted by the material supplier, the information shall be obtained by the certifier from the ingredient supplier prior to determining all formulation dependant analytes;

— the composition of the materials ingredients and their components shall be known to determine the identity of formulation specific analytes;

— the maximum temperature to which the product, component, or material is exposed during its intended end use;

— a description / classification of the manner in which the product or material is manufactured (including any process parameters that affect product surface areas in direct contact with water), handled, and packaged. The manufacturing process variability shall be verified by the manufacturer as to its effect on contaminant leachate levels, and the manufacturer shall establish and demonstrate appropriate ongoing process controls to ensure ongoing product conformance with this Standard;

NOTE — The methods used to alter the water contact surfaces of product components during manufacturing, either mechanically (e.g., metal cutting, molding, stamping) or chemically (e.g., washing, coating, plating, brite-dip cleaning), may have a significant effect upon contaminant leachate performance.

— when available, a list of the known or suspected impurities within the product or material and the maximum percent or parts by weight of each impurity;

— when available, the solubility, hydrolysis products, and extraction rates of chemicals within the product or material; and

— when available, a list of published and unpublished toxicological studies relevant to the chemicals and impurities present in the product, component, or material.

3.2.1 Information and formulation requirements for regenerated / reactivated media

In addition to the information formulation requirements of Section 3.2, the following information is required for the formulation review and preparation of the analytical summary for regenerated and reactivated media:

— a description of the regeneration / reactivation process and process controls, such as time, temperature, chemical regenerants, and any quality control (QC) tests associated with the regeneration / reactivation process to ensure contaminants are removed from the spent media so that it complies with the requirements of this Standard;

— a copy of the procedure detailing the evaluation, and conclusion associated with the review of data from spent media sources identifying all regulated contaminants, or other contaminants of concern that are removed from water and any contaminant spills or unusual water conditions; and

— a copy of the data, and a copy of the documentation associated with the evaluation of the data from the spent media source(s) associated with a specific lot of reactivated or regenerated media for which a retained sample is available for testing.

3.2.1.1 Incoming shipments of media to be regenerated / reactivated

The following information shall be provided by the water system and maintained by the processing plant for each shipment of spent media received for regeneration / reactivation:

— identification of the type of the spent media, spent media source, and application of use (e.g., production of drinking water);

— identification of the original media, including manufacturer or previous regeneration / reactivation facility, trade designation, mesh size and compliance with this Standard for each spent media source;

— regulated contaminants or other contaminants of concern removed from water, including any contaminant spills or unusual water quality conditions;

— statement as to whether the spent media has been knowingly exposed to:

— activated carbon: polychlorinated biphenyls (PCBs), or dioxins; or
— other media: herbicides, pesticides, PCBs, dioxins or 1,2 dibromo-3chloropropane (DBCP).

— statement to verify that the spent media source is from a public water system (publicly or privately owned) as defined by US EPA regulations (40 CFR § 141.2),[3] or equivalent regulations in Canada and other countries, where applicable.

3.3 Identification of analytes

For all products and materials, the formulation information required in Section 3.2 shall be reviewed for completeness (e.g., all formulations total 100.0%), and to determine whether a minimum test battery has been established for each water contact material (see Table 3.1). In addition to selecting the minimum testing parameters decribed in Table 3.1, a formulation review to identify any formulation-dependent analytes shall be performed for all water contact materials (see Section 3.3.1).

In instances where the complete formulation has not been obtained for a material that is used in a component of a mechanical device or mechanical plumbing device as allowed through Note 1 of Section 3.2, testing shall include the material-specific analyses in Table 3.1, or as directed in Table 3.2.

3.3.1 Formulation-dependent analysis selection

For all water contact materials, the formulation information described in Section 3.2 shall be reviewed, and formulation-dependent analytes shall be identified for each water contact material. The criteria for selection of a formulation-dependent analyte shall include, but not be limited to, the following:

— known or suspected toxicity of the substance or its byproduct(s);

— high water solubility of the substance;

— monomer(s) of polymeric ingredients;

— solvents and cosolvents used in the polymerization process or those used in the material formulation;

— antioxidants, antimicrobials, curing agents, initiators, peroxides, pigments, plasticizers, process aids, stabilizer and terminators and their impurities, degradation and hydrolysis products;

— high probability of extraction of a substance or its byproduct(s) at toxicologically significant concentrations; and

— extraction or migration information for the substance provided by the manufacturer or that present in the public literature.

3.3.2 Established minimum test batteries

The materials listed in Table 3.1 or Table 3.2 shall be tested for the indicated analyses and any formulation-dependent analyses identified during the formulation-dependent analyte selection. Products, components, or materials made exclusively from materials in Table 3.1 shall not require testing if:

— their DSA-to-volume ratio in the application is ≤ 0.001 in^2/L or 0.0001 in^2/L for static or flowing conditions respectively, or

— the material is uncoated concrete for use in a water storage structure of 1.33×10^6 L (0.35×10^6 gal) or greater and any admixtures used have been evaluated to this Standard and found compliant within the use levels in the concrete, or

— the material is uncoated concrete or for use in applications with a DSA-to-volume ratio less than or equal to 0.8 in^2/L or 0.08 in^2/L for static or flowing conditions respectively, and any admixtures used have been evaluated to this Standard and found compliant within the use levels in the concrete; or

NOTE — The addition of the criteria for concrete water storage structures is in recognition of the diminishing value of investigations on those with high volumes (low surface area-to-volume ratios) where admixtures have seprately been verified as compliant with this Standard and the water storage structure is seperately monitored for regulated contamaminants including radionuclides.

— the material is in a high flow device and used exclusively at public water treatment facilities. For the purposes of this section, high flow devices are limited to chemical feeders, disinfection generators (e.g., chlorine dioxide, hypochlorite, ozone and ultraviolet), electrodialysis technologies, microfiltration technologies, nanofiltration technologies, reverse osmosis and ultrafiltration technologies.

3.4 Products manufactured from Annex N-2 acceptable materials

Products manufactured entirely from Annex N-2 materials shall not be required to undergo extraction testing for material-specific analytes of interest. However, extraction testing for contaminants contributed by processes specific to a production site shall be considered formulation-dependent analytes. Annex N-2 contains the evaluation requirements for qualification as an acceptable material.

Table 3.1
Material-specific analyses

Material type	Required analyses
pipe / fitting / device materials	
aluminum	regulated metals,[1] aluminum
aluminum oxide ceramics	regulated metals,[1] aluminum
asphaltic-coated ductile iron	GC/MS,[2] VOCs, regulated metals,[1] polynuclear aromatic hydrocarbons (PNAs), molybdenum, vanadium, manganese
brass	regulated metals,[1] zinc, nickel, bismuth[3]
carbon graphite nonimpregnated	GC/MS,[2] VOCs, polynuclear hydrocarbons (PNAs), regulated metals[1]
carbon graphite (phenol formaldehyde impregnated)	GC/MS,[2] VOCs, polynuclear hydrocarbons (PNAs), formaldehyde, regulated metals[1]
carbon steel	regulated metals[1]
cast iron	regulated metals[1]
chrome / nickel plating	regulated metals,[1] nickel
concrete[4]	regulated metals[1]
concrete aggregate[4]	regulated metals,[1] radionuclides
copper	regulated metals[1]
ductile iron	regulated metals[1]
galvanized steel	regulated metals,[1] zinc, nickel
magnets	regulated metals,[1] metals[3,5]
nickel based alloys	regulated metals,[1] nickel
platinum	regulated metals,[1] platinum
quartz	regulated metals[1]
ruby or sapphire (natural and synthetic aluminum oxide gemstones)	regulated metals,[1] aluminum
silicon carbide ceramics	regulated metals,[1] silicon
silver	regulated metals,[1] silver

Table 3.1
Material-specific analyses

Material type	Required analyses
stainless steel	regulated metals,[1] nickel
titanium	regulated metals,[1] titanium
tungsten carbide	regulated metals,[1] tungsten
zirconium oxide ceramics	regulated metals,[1] zirconium
plastic materials	
acetal (AC) / polyoxymethylene (POM)	GC/MS,[2] VOCs, regulated metals,[1,3] formaldehyde
acrylonitrile-butadiene-styrene (ABS), acrylonitrile-styrene (SAN)	GC/MS,[2] VOCs, regulated metals,[1,3] acrylonitrile, 1,3-butadiene, styrene
cross-linked polyethylene (PEX)	GC/MS,[2] VOCs, regulated metals,[1,3] methanol, *tert*-butyl alcohol[6]
nylon 6	GC/MS,[2] VOCs, regulated metals,[1,3] caprolactam
other nylons	GC/MS,[2] VOCs, regulated metals,[1,3] nylon monomers
polybutylene (PB)	GC/MS,[2] VOCs, regulated metals[1,3]
polycarbonate (PC)	GC/MS,[2] bisphenol A, VOCs, regulated metals[1,3]
polyethylene (PE)	GC/MS,[2] VOCs, regulated metals[1,3]
polyphenylene oxide (PPO)	GC/MS,[2] dimethyl phenol, VOCs, regulated metals[1,3]
polyphthalamide (PPA)	GC/MS,[2] VOCs, regulated metals,[1,3] hexamethylene diamine, terephthalic acid, isophthalic acid
polypropylene (PP)	GC/MS,[2] VOCs, regulated metals[1,3]
polystyrene	styrene, GC/MS,[2] VOCs, regulated metals,[1] phenolics (by GC/MS base/acid scan)[2]
polysulphone including poly[phenylene sulphone] (PPSU)	GC/MS,[2] VOCs, regulated metals,[1,3] sulphone monomer
polyurethane (PUR)	GC/MS,[2] VOCs, regulated metals[1,3]
polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC)	regulated metals,[1,3] phenolics,[2] VOCs, tin,[7] lead, antimony,[8] residual vinyl chloride monomer (RVCM)[9]
PVC (flexible)	GC/MS,[2] VOCs, regulated metals,[1,3] lead, phthalates,[10] RVCM,[9] tin,[7] zinc[11]
joining and sealing materials	
chloroprene	GC/MS,[2] VOCs, and 2-chloro-1,3-butadiene, phthalates,[10] PNAs,[2] nitrosoamines[12]
ethylene-propylene-diene monomer (EPDM)	GC/MS,[2] VOCs, phthalates,[10] PNAs,[2] nitrosoamines[12]
ethylene tetrafluoroethylene (ETFE)	GC/MS,[2] VOCs, perfluorooctanoic acid
flux	GC/MS,[2,3] VOCs, regulated metals,[1,3] PNAs[2,3]
fluoroelastomer	GC/MS,[2] VOCs, perfluorooctanoic acid
isoprene	GC/MS,[2] VOCs, phthalates,[10] PNAs,[2] isoprene monomer, nitrosoamines[12]
nitrile-butadiene rubber (NBR, BUNA-N, HNBR)	GC/MS,[2] VOCs, phthalates,[10] PNAs,[2] 1,3-butadiene, acrylonitrile, nitrosoamines[12]

Table 3.1
Material-specific analyses

Material type	Required analyses
PTFE	GC/MS,[2] VOCs, perfluorooctanoic acid
PVDF	GC/MS,[2] VOCs, vinylidene fluoride, hexafluoropropene
silicone	GC/MS,[2] VOCs, 2,4-dichlorobenzoic acid
solder	regulated metals,[1] aluminum, bismuth, nickel, silver, strontium, zinc
solvent cements	GC/MS,[2] VOCs,[3] acetone, tetrahydrofuran, cyclohexanone, methyl ethyl ketone, dimethylformamide, methyl isobutyl ketone
styrene-butadiene rubber (SBR)	GC/MS,[2] VOCs, phthalates,[10] PNAs,[2] 1,3-butadiene, styrene, nitrosoamines[12]
barrier materials	
asphaltic coatings	GC/MS,[2] VOCs, regulated metals,[1] molybdenum, vanadium, manganese, PNAs[2]
epoxy coatings (liquid and powder)	GC/MS,[2] VOCs, bisphenol A,[3] bisphenol A-diglycidyl ether,[13] bisphenol A-diglycideryl ether,[13] bisphenol A-propoxylate,[3,13] epichlorohydrin,[3] bisphenol F,[3] bisphenol F-diglycidyl ether,[3,13] bisphenol F-diglycideryl ether,[3,13] bisphenol F-propoxylate,[3,13] solvent and reactive diluent additives[3,14]
polyester coatings	GC/MS,[2] VOCs, residual monomers[15]
polyurethane coatings	GC/MS,[2] VOCs
portland and hydraulic cements[4]	GC/MS,[2] regulated metals,[1] dioxins and furans, radionuclides, glycols and ethanolamines[16]

[1] Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, thallium. Chromium shall be evaluated against the pass/fail criteria of chromium VI as a screening level. If the normalized result exceeds this criteria, the sample shall be tested according to the method described in Section N-1.7.3 and shall be evaluated against the pass/fail criteria listed in Table 4.1 of NSF/ANSI/CAN 600 (previously Table D.1) for the tested product. Regardless of chromium species, the total chromium pass/fail criteria shall not be exceeded.

[2] See Section N-1.7

[3] The testing may be waived for a this specific analyte where formulation information indicates that it is not present. In instances where the complete formulation has not been obtained for the material as allowed through Note 1 of 3.2, testing shall include this analyte.

[4] Concrete aggregate sampling is required only if the method for testing for individual concrete components is used. Aggregate sampling is not required if concrete cylinders are tested for the constituents in portland and hydraulic cements.

[5] Aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, cerium, cobalt, chromium, cesium, copper, dysprosium, erbium, europium, gallium, gadolinium, germanium, hafnium, indium, lanthanum, lead, lithium, lutetium, manganese, mercury, molybdenum, niobium, neodymium, nickel, palladium, praseodymium, platinum, rubidium, rhenium, rhodium, ruthenium, samarium, selenium, silver, strontium, tantalum, tellurium, thallium, tin, titanium, tungsten, uranium, vanadium, tungsten, ytterbium, zinc, zirconium. Chromium shall be evaluated against the pass/fail criteria of chromium VI as a screening level. If the normalized result exceeds this criteria, the sample shall be tested according to the method described in Section N-1.7.3 and shall be evaluated against the pass/fail criteria listed in Table 4.1 of NSF/ANSI/CAN 600 (previously Table D.1) for the tested product. Regardless of chromium species, the total chromium pass/fail criteria shall not be exceeded.

[6] *tert*-Butyl alcohol analysis is required for PEX materials except those crosslinked via e-beam methodology.

[7] The analysis for tin is required when tin-based stabilizers are used.

[8] The analysis for antimony is required when antimony-based stabilizers are used.

[9] The level of RVCM within the walls of PVC or CPVC products and materials shall be directly determined (Section N-1.7).

Table 3.1
Material-specific analyses

Material type	Required analyses
[10] The analysis for phthalates is required when phthalate ester plasticizers are used. Analysis shall be for the specific phthalate ester(s) used in the formulation.	
[11] The analysis for zinc is required when zinc-based stablilizers are used.	
[12] Analysis for n-nitrosodimethylamine, n-nitrosomethylethylamine, n-nitrosodiethylamine, n-nitrosodi-n-propylamine, n-nitrosopyrrolidine, n-nitrosomorpholine, n-nitrosopiperidine, n-nitrosodi-n-butylamine and n-nitrosodiphenylamine are required when material is sulfur cured.	
[13] Analysis shall be performed using liquid chromatography with ultraviolet detection (LC/UV).	
[14] Analysis shall be performed for the specific solvent and reactive diluent additives used in the individual product formulation, such as benzyl alcohol.	
[15] Analysis shall be performed for residual concentrations of the specific ester monomers used in the individual product formulation.	
[16] Glycol and ethanolamine analyses shall be performed on cements containing these compounds as grinding aids.	

Table 3.2
Material specific analyses not listed in Table 3.1 or materials without formulation information (excluding coatings and process media)

Material type	Material specific analyses[1]	Suggested Method[2]
metallic materials not listed in Table 3.1	aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, cerium, cobalt, chromium, hexavalent chromium, cesium, copper, dysprosium, erbium, europium, gallium, gadolinium, germanium, hafnium, indium, lanthanum, lead, lithium, lutetium, manganese, mercury, molybdenum, niobium, neodymium, nickel, palladium, praseodymium, platinum, rubidium, rhenium, rhodium, ruthenium, samarium, selenium, silicon, silver, strontium, tantalum, tellurium, thallium, tin, titanium, tungsten, uranium, vanadium, tungsten, ytterbium, zinc, zirconium Chromium shall be evaluated against the pass/fail criteria of chromium VI as a screening level. If the normalized result exceeds this criteria, the sample shall be tested according to the method described in Section N-1.7.3 and shall be evaluated against the pass/fail criteria listed in NSF/ANSI/CAN 600 Table 4.1 for the tested product. Regardless of chromium species, the total chromium pass/fail criteria shall not be exceeded.	EPA 200.8
plastic materials not listed in Table 3.1	bisphenol A, caprolactam, dimethyl phenol, terephthalic acid, isophthalic acid, hexamethylene diamine, acrylic acid, methacrylic acid, bisphenol A-propylene oxide adducts, hydroquinone, phthalic acid, 1,4-butanediol, p-phenylenediamine, o-phenylenediamine, 1,6-hexanediol, m-phenylenediamine, melamine, triethylene diamine, trimethylolpropane	LC/UV
	nylon monomers = 11-aminoundecanoic acid, 1,10-diaminodecane, laurolactam, adipic acid, 2-methyl-1,5-pentanediamine	LC/UV
	sulphone monomer, 4,4'-dichlorodiphenyl sulfone, and diphenyl sulfone	LC/UV
	formaldehyde	EPA 8315A
	RVCM, 1,2-dichloro-3-propanol, 1,3-dichloro-2-propanol, methyl butenol isomers, methylene bis-cyclohexylamine 4,4'-, cyclohexanamine methylenebis methyl propyl, methylenedianiline, methanol	GC/FID
	dimethylphthalate, diethylphthalate, bis(2-ethylhexyl)phthalate (DEHP), di-n-butylphthalate	EPA525.2
	1,3-butadiene, styrene, *tert*-butyl alcohol, VOCs, epichlorohydrin, methyl-*tert*-butyl ether (MTBE), vinylidene fluoride, hexafluoropropylene, acrylonitrile	EPA 524.2
	antimony, arsenic, barium, beryllium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, selenium, thallium, tin Chromium shall be evaluated against the pass/fail criteria of chromium VI as a screening level. If the normalized result exceeds this criteria, the sample shall be tested according to the method described in Section N-1.7.3 and shall be evaluated against the pass/fail criteria listed in NSF/ANSI/CAN 600 Table 4.1 for the tested product. Regardless of chromium species, the total chromium pass/fail criteria shall not be exceeded.	EPA 200.8
	phenolics, acetal oligomers, dimethyl terephthalate, diethylphthalate, diisobutylphthalate, di-n-butylphthalate, butylbenzylphthalate, di-n-octylphthalate	EPA 625 BNA
	perfluorooctanoic acid	LC/MS ES

Table 3.2
Material specific analyses not listed in Table 3.1 or materials without formulation information (excluding coatings and process media)

Material type	Material specific analyses[1]	Suggested Method[2]
elastomer materials not listed in Table 3.1	phenolics (by GC/MS base/acid scan), PNAs, semivolatile compounds, bisphenol F, bisphenol F – propylene oxide adducts, diisobutylphthalate diethylphthalate, dimethyl terephthalate, butylbenzylphthalate, di-n-butylphthalate, butylbenzylphthalate, di-n-octylphthalate	EPA 625 BNA
	VOCs, and 2-chloro-1,3-butadiene, isoprene monomer, chloroprene, 1,3-butadiene, acrylonitrile, vinylidene fluoride, hexafluoropropene, 2,4-dichlorobenzoic acid, alpha-methyl styrene, styrene, isobutylene	EPA524.2
	aniline	GC/ECD
	perfluorooctanoic acid	LC/MS ES
	dimethylphthalate, diethylphthalate, di-n-butylphthalate, diphenylamine, bis(2-ethylhexyl)phthalate (DEHP), p-phenylenediamine, o-toluidine, o-phenylenediamine, m-phenylenediamine	EPA 525.2
	n-nitrosodimethylamine, n-nitrosomethylethylamine, n-nitrosopiperidine, n-nitrosodiethylamine, n-nitrosodi-n-propylamine, n-nitrosopyrrolidine, n-nitrosomorpholine, n-nitrosodi-n-butylamine, n-nitrosodiphenylamine	EPA 521
	metals	EPA 200.8
adhesives	tetraethylene glycol, ethylene glycol, 2-ethyl-1,3-hexanediol	LC/MS
	m-phenylene diamine, methacrylic acid, bisphenol A, bisphenol A - propylene oxide adducts, melamine, maleic acid, hydroquinone, acrylic acid, ethyl-2-cyanoacrylate	LC/UV
	acetates and acrylates, 1,3-butylene glycol dimethacrylate, semivolatile compounds	EPA 625
	formaldehyde	EPA 8315A
	epichlorohydrin, 1,3-butadiene, acrylonitrile	EPA 524.2
	1,3-dichloro-2-propanol in water, methylenedianiline micro / derivatization, 1,3-dichloro-2-propanol, micro / derivatization, 1,2-dichloro-3-propanol, aniline	GC/FID
	*1,4- butanediol, cyanoacetic acid, benzyl alcohol	LC/MS
lubricants	phenolics	EPA 625
	2,4-dichlorobenzoic acid, acrylic acid	LC/UV
	perfluorooctanoic acid	LCMS/ES-
	propylene glycol; ethylene glycol	LC/MS
other materials not listed in Table 3.1 without formulation information (excluding coatings and process media)	chlorobenzenediamine, and dichlorobenzenediamine isomers	derivatization GC/ECD
	volatile organic compounds including 2-methylpropene (isobutylene), tetrahydrofuran, cyclohexanone, acetone, 1,3-butadiene, 2-chloro-1,3-butadiene (chloroprene), epichlorohydrin, methyl ethyl ketone, 2-methyl-1,3-butadiene (isoprene), divinyl benzene (vinyl styrene), 2,4-dichlorobenzoic acid, 2-methylpropene (isobutylene) methyl-tert-butyl ether (MTBE), alpha-methyl styrene, hexafluoropropylene, vinylidene fluoride, hydroquinone monomethyl ether, acrylonitrile	EPA 524.2
	semivolatile compounds, PNAs, acetates and acrylates, ethyl acetate, vinyl acetate, 1,4-dioxane, ethylhexyl acrylate, dimethyl terephthalate, diethylphthalate, diisobutylphthalate, di-n-butylphthalate, di-n-octylphthalate, butylbenzylphthalate	EPA 625 BNA
	gross alpha and beta radioactivity in drinking water	EPA 900.0

Table 3.2
Material specific analyses not listed in Table 3.1 or materials without formulation information (excluding coatings and process media)

Material type	Material specific analyses[1]	Suggested Method[2]
	acrylamide by derivitization, captan, methylenedianiline aniline, micro / derivatization, methylene bis-cyclohexylamine 4,4'-, microextraction	GC/ECD
other materials not listed in Table 3.1 without formulation information (excluding coatings and process media)	methyl-2-propanol, 2-, (t-butylalcohol), methanol, n-butanol, *sec*-butyl alcohol, methyl butenol isomers, 1,2-dichloro-3-propanol, 1,3-dichloro-2-propanol in water, 1-propanol, 2-propanol	GC/FID
	aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, cerium, cobalt, chromium, hexavalent chromium, cesium, copper, dysprosium, erbium, europium, gallium, gadolinium, germanium, hafnium, indium, lanthanum, lead, lithium, lutetium, manganese, mercury, molybdenum, niobium, neodymium, nickel, palladium, praseodymium, platinum, rubidium, rhenium, rhodium, ruthenium, samarium, selenium, silicon, silver, strontium, tantalum, tellurium, thallium, tin, titanium, tungsten, uranium, vanadium, ytterbium, zinc, zirconium Chromium shall be evaluated against the pass/fail criteria of chromium VI as a screening level. If the normalized result exceeds this criteria, the sample shall be tested according to the method described in Section N-1.7.3 and shall be evaluated against the pass/fail criteria listed in NSF/ANSI/CAN 600 Table 4.1 for the tested product. Regardless of chromium species, the total chromium pass/fail criteria shall not be exceeded.	EPA 200.8
	triethylene diamine, 1,6-hexanediol, 2-ethyl-1,3-hexanediol, trimethylolpropane, propylene glycol, perfluorooctanoic acid, diethylene glycol, ethylene glycol, hexalene glycol, tetraethylene glycol, triethylene glycol, dipropylene glycol	LC/MS
other materials not listed in Table 3.1 without formulation information (excluding coatings and process media)	benzyl alcohol, bisphenol A , bisphenol A - propylene oxide adducts, bisphenol F, diphenyl sulfone, 4,4'-dichlorodiphenyl sulfone, dimethylformamide, n,n-dimethylacetamide, diphenylamine, di-t-butyl-4-alkyl phenols, ethylenethiourea (2-imidazolidinethione), hydroquinone, methyl-2-pyrrolidinone, n,n-diethyl-p-toluidene, isomers of phenylene diamine, toluenediamine, 2,4-, toluenediamine, 2,6-, tetramethyl thiuram monosulfide, diethylene triamine, ethylene diamine, 2-methyl-1,5-pentanediamine, ethyl-2-cyanoacrylate, laurolactam, 1,3-butylene glycol dimethacrylate, caprolactam, acrylic acid, adipic acid11-aminoundecanoic acid, hexamethylene diamine, maleic acid, methacrylic acid, melamine trimellitic acid, cyanoacetic acid	LC/UV
	n-nitrosodimethylamine, n-nitrosomethylethylamine, n-nitrosodiethylamine, n-nitrosodi-n-propylamine, n-nitrosopyrrolidine, n-nitrosomorpholine, n-nitrosopiperidine, n-nitrosodi-n-butylamine, n-nitrosodiphenylamine	EPA 521
	1,4-butanediol	LC/MS
	formaldehyde	EPA 8315A
	4,4'-methylenebis[N-(1 -methylpropyl)- cyclohexanamine, 2-methylimidazole	LC/MS
	isophthalic acid, phthalic acid, terephthalic acid, o-toluidine, n,n-diethyl-p-toluidene, dimethylphthalate, diethylphthalate, di-n-butylphthalate, bis(2-ethylhexyl)phthalate (DEHP)	EPA 525.2

[1] The testing may be waived for a specific analyte when partial information indicates that it is not present.

[2] Refer to Section N-1.7 for analytical methods. Alternate methods that have been validated may be used.

3.5 Restriction on use of lead containing materials

There shall be no lead added as an intentional ingredient in any product, component, or material submitted for evaluation to this Standard, with the following exceptions:

— brass or bronze used in products meeting the definition of "lead free" under the specific provisions of the Safe Drinking Water Act of the United States;

— solders and flux meeting the definition of "lead free" under the specific provisions of the Safe Drinking Water Act of the United States;

— brass or bronze used in products specifically identified as exemptions within Section (a)(4)(B) of the Safe Drinking Water Act of the United States;

— fire sprinklers (head);

— trace amounts required for operation of products used to monitor the characteristics of drinking water, such as the glass membranes used with some selective ion or pH electrodes; and

— materials or components exempted from formulation information requirements as allowed per Section 3.2, Note 1.

> NOTE — To the maximum extent possible, lead should not be added as an intentional ingredient in any product covered by the scope of this Standard. The exception above relative to materials and components exempt from formulation information requirements has only been included in recognition that the use of lead as an intentional additive is unable to be identified in cases where formulation information is not obtained.

3.6 Lead content of products

With the exception of those exempted in the Safe Drinking Water Act of the United States, the wetted surfaces of products shall have a weighted average lead content ≤ 0.25% when evaluated in accordance with NSF/ANSI/CAN 372. For the purpose of this section, product shall refer to anything individually evaluated for compliance under the standard, including materials and components. Solders and fluxes shall have a lead content no more than 0.2%.

4 Pipes and related products

4.1 Scope

4.1.1 The requirements in this section apply to pipes and pipe-related products and the water contact materials associated with these products. Pipe-related products include, but are not limited to, the following items: fittings, couplings, mini-manifolds, flexible and rigid tubing, riser tubing, dip tubes, hoses, well casings, drop pipes and well screens.

4.1.2 Coatings and other barrier materials requested to be evaluated on their own that are intended for application to pipes or pipe-related products shall be evaluated under Section 5.

> NOTE — Coatings and other barrier materials, which meet the requirements of Section 5 at a specific surface area-to-volume ratio, shall be considered to meet the requirements of a pipe or pipe-related product application for a surface area-to-volume ratio less than or equal to the ratio accepted under the Section 5 evaluation.

4.1.3 Individual ingredients of cement-based pipes and related products (including portland and blended hydraulic cement and admixtures) are evaluated under Section 5.

4.1.4 Products and materials intended to join or seal pipes or pipe-related products are evaluated under Section 6.

4.2 Definitions

4.2.1 cold water application: A product application that is intended to result in continuous exposure to water of ambient temperature. Products are tested for an end use temperature of 23 ± 2 °C (73 ± 4 °F).

4.2.2 commercial hot water application: A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end use temperature of 82 ± 2 °C (180 ± 4 °F).

4.2.3 domestic hot water application: A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end use temperature of 60 ± 2 °C (140 ± 4 °F).

4.2.4 fire sprinkler: A fast response fire suppression device for dwelling units that automatically opens when heat activated, allowing the discharge of water onto a fire.

4.2.5 nominal diameter: A designation system used to specify a pipe size, where the designation for a specific size is approximately equal to the average inside diameter of the pipe.

4.2.6 mini-manifold: A device with an inlet and less than four other openings used to connect tubing within a residence or building. This device shall be evaluated as a fitting under Section 4.

4.3 General requirements

4.3.1 The product size with the most conservative normalization condition shall be evaluated. Successful evaluation of such a product shall qualify all products of less conservative normalization conditions, provided that the materials of construction are identical as specified in Section 4.4.1.

> NOTE — For products of 1.3- to 10-cm (0.5- to 4-in) nominal diameter and products of 10-cm (4-in) diameter and greater, the most stringent normalization condition is typically the smallest inner diameter product within the nominal diameter range. Products of less than 1.3-cm (0.5-in) nominal diameter are assumed to have limited exposure in the distribution system (see assumptions in Tables 4.4 and 4.5). Successful qualification of products of less than 1.3-cm (0.5-in) nominal diameter may not demonstrate the acceptability of all products 1.3-cm (0.5-in) nominal diameter and greater.

4.3.2 Residual vinyl chloride evaluation

Polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC) products and materials shall be evaluated for the level of residual vinyl chloride monomer (RVCM) in the product wall or in the material according to Section N-1.7.

4.4 Sample requirements

4.4.1 General

A sample can represent a product line of various sizes when:

— materials are of the same alloy, composition, or formulation;
— materials have undergone the same manufacturing process (e.g., casting or extrusion);
— designs and manufacturing processes are analogous; and/or
— it has the most stringent normalization requirements (see Section 4.3.1).

4.4.2 Materials

When a material is proposed for evaluation, a representative sample of the material shall be used. Material test samples (e.g., plaque or sheet) shall be used only if no chemical or physical difference exists between the material sample and the material as it is used in applications covered by Section 4. A material intended to be processed by more than one method (e.g., injection molding, extrusion, or stamping) shall be tested in each of its processed forms.

4.4.3 Finished products

When a finished product (e.g., pipe or fitting) is proposed for evaluation, a sample of the finished product shall be used for testing except in the following specific instances:

— concrete cylinders, cubes, or other concrete surrogate samples can be evaluated on behalf of concrete-lined pipes and other concrete-based products;

— coatings, applied to the appropriate substrate, can be evaluated on behalf of products whose entire water contact surface is covered by the coating; or

— finished products shall be permitted to be evaluated using material samples if a finished product evaluation is impractical for one or more of the following reasons:

  — an internal volume > 20 L (5.3 gal);
  — a weight > 34 kg (75 lb); or
  — *in situ* manufacture of the finished product.

Material samples shall be permitted to be evaluated on behalf of a finished product if the first and second criteria listed under Section 4.4.1 are satisfied.

4.5 Extraction procedures

4.5.1 Analytical summary

An analytical summary shall be prepared for each product or material. The analytical summary shall consist of the formulation-dependent analytes identified in Section 3.2 and the applicable material-specific analytes listed in Table 3.1.

4.5.2 Preparation of test samples

4.5.2.1 To the extent possible, test samples shall be prepared so that the laboratory surface area-to-volume ratio is equal to or greater than the surface area-to-volume ratio at which the product is intended to be used in the field. When the use of test assemblies is required, they shall be constructed in a manner as to not cover an otherwise wetted surface. Test assembly end closures that marginally increase the volume of the test assembly beyond the volume at which the product is intended to be used in the field may be used. Components and materials added to the test sample to form the test assembly shall be present in the control sample.

4.5.2.1.1 For the evaluation of metal and metal containing product samples that are connected to pipe or tubing products under normal installation conditions (e.g., fittings), the samples shall be attached to lengths of pipe or tubing of the appropriate nominal diameter. The exposed surface area-to-volume ratio of the fitting test sample shall represent a percentage of the total exposed surface area (test sample plus the attached pipe or tubing) that is equal to the percentage specified in the Table 4.5 normalization assumptions (± 5%) (e.g., 94.2 to 189.0 cm^2/L [55.3 to 110.9 in^2/gal] for nominal $^1/_2$-in pipe which is part of a flexible or rigid piping system respectively).

Assemblies should be made of relatively inert materials and designed in a manner which eliminates or minimizes the occurence of the same contaminant being present in the control and the test sample whenever possible. The control shall be made of the same material and exposed at the same surface area to volume ratio as the test sample.

Threaded products shall be assembled by threading a pipe material which has been cut to an appropriate length equal to the $V_{F(static)}$. For products being tested which are less than a liter, the attached pipe volume combined with the product volume shall be equal to 1 L (± 5%) for the test sample. When preparing a product which has a soldered joint, the control shall be prepared using the same solder and extension material as the test sample. Products with quick connect fitting ends are most easily assembled by attaching polyethylene tubing, cut to the appropriate length and diameter using the same polyethylene tubing for the control.

Nonmetal and copper (C12200) product samples that are connected to pipe or tubing products under normal installation conditions (e.g., fittings) may be prepared as described for metal and metal containing product samples. Nonmetal containing products and copper (C12200) may also be prepared so that the laboratory surface area-to-volume ratio is equal to or greater than the surface area-to-volume ratio at which the product is intended to be used in the field.

Components (e.g., gaskets or O-rings) of a fitting that are wetted under normal operating pressures but are not wetted under the conditions of a static exposure shall be tested separately from the assembly in an “in vessel” exposure. The laboratory surface area for the “in vessel” exposure shall be a minimum of ten-fold greater than the wetted surface area of the product to ensure that the reporting level of the analysis, when normalized, is equal to or less than the pass/fail criteria for all contaminants. The result of the “in vessel” exposure shall then be normalized to the applicable surface area of the product.

4.5.2.2 Unless the manufacturer’s instructions direct otherwise, test samples shall be rinsed in cold tap water until any extraneous debris or contamination that occurred during shipping and handling is removed. The samples shall then be rinsed in reagent water that meets the requirements of Section N-1.9.2.1.

4.5.2.3 If the exterior surface of a product is to be exposed, all markings that are not integral to the product (e.g., ink markings) shall be removed.

4.5.2.4 When the test sample contains internal threaded outlets, 75% of the threaded surface area shall be covered by insertion of a threaded component of the appropriate diameter to produce a watertight seal.

4.5.3 Exposure water

4.5.3.1 General

Exposure water selection shall be determined by the analytes of interest identified on the analytical summary (see Section 4.5.1). Exposure water(s) shall be selected in accordance with Section N-1.2.5.

4.5.3.2 Copper (C12200) pipe, tubing and fittings

Copper (C12200) pipe, tubing and fittings evaluated under Section 4 of this Standard shall not require analysis for regulated metals release under the pH 5 test condition provided the following use limitation statement is included in the manufacturer’s use instructions or product literature that references this Standard:

> “*Use of this material may not be appropriate in all water chemistries. Copper [tube, pipe, or fitting] may require corrosion control to limit the leaching of copper into drinking water under certain water chemistries. Refer to Informative Annex I-6.1 of NSF/ANSI/CAN 61 for the water quality considerations to be used before installing this product.*”

4.5.3.3 Copper and copper alloys other than C12200

Copper and copper alloy pipe and tubing comprised of alloys other than C12200 shall be exposed in either the pH 5 (Section N-1.9.3) or the pH 6.5 (Section N-1.9.4) exposure waters (at the discretion of the manufacturer) and in the pH 8 (Section N-1.9.7) exposure waters as described in Section N-1.9. Copper and copper alloy fittings comprised of alloys other than C12200 intended to be used with copper and copper alloy pipe and tubing shall be exposed in either the pH 5 (Section N-1.9.3) or the pH 6.5 (Section N-1.9.4) exposure waters (at the discretion of the manufacturer) and in the pH 8 (Section N-1.9.7) exposure water, as described in Section N-1.9. For all copper and copper alloy pipes, tubing, and fittings tested using the pH 6.5 exposure water, the manufacturer's literature shall indicate this use limitation by inclusion of the following statement in the use instructions or product literature that references this Standard:

> "*Use of this material may not be appropriate in all water chemistries. Copper [tube, pipe, or fitting] may require corrosion control to limit the leaching of copper into drinking water under certain water chemistries. Refer to Informative Annex I-6.1 of NSF/ANSI/CAN 61 for the water quality considerations to be used before installing this product.*"

4.5.3.4 Brass and bronze materials

Brass and bronze materials shall be exposed in the pH 5 (Section N-1.9.3) and in the pH 8 (Section N-1.9.8) exposure waters as described in N-1.9. Normalized copper concentrations observed using the pH 5 test waters that exceed the TAC for the static condition or the SPAC for the flowing conditions at pH 5 may be waived when the product contains brass or bronze materials and when the manufacturer's literature includes the use limitations for these materials with certain water characteristics by inclusion of the following statement in the use instructions or product literature that references this Standard:

> "*Use of this material may not be appropriate in all water chemistries. Products containing brass/bronze materials may require corrosion control to limit the leaching of copper into drinking water under certain water chemistries. Refer to Informative Annex I-6.1 of NSF/ANSI/CAN 61 for the water quality considerations to be used before installing this product.*"

4.5.4 Conditioning and exposure options

4.5.4.1 In-product conditioning and exposure

During in-product conditioning and exposure, the test sample shall be filled completely with exposure water. The product having the greatest surface area-to-volume ratio (typically the smallest diameter) shall be preferentially used. When necessary to prevent the loss of exposure water, samples shall be capped with inert materials (e.g., glass).

4.5.4.2 In-vessel conditioning and exposure

During in-vessel conditioning and exposure, samples shall be placed in containers composed of and covered with a material that is inert to the exposure water. The exposure water shall completely immerse the sample. All samples shall be exposed at a surface area-to-volume ratio that is equal to or greater than that of the intended end use. The actual wetted surface area-to-volume ratio achieved during the exposure shall be recorded.

NOTE — The stated duration of the conditioning period at the hot temperature does not include any time needed to elevate the product sample or exposure vessel to the required exposure temperature.

4.5.4.3 Multiple time point protocol

When the normalized concentration of a contaminant exceeds, or is expected to exceed, its acceptable level when evaluated as a single time point exposure, determination of the contaminant leaching rate using a multiple time point exposure shall be considered. For the purpose of contaminant concentration evaluation, Day 1 shall be defined as the time point at which extractant water is collected for analysis under the single time point exposure protocol. Day 90 shall be defined as 90 d after this time point. When over time data are used, the Day 1 concentration for the contaminant of concern shall meet the short term exposure level and Day 90 concentration shall meet the total allowable concentration (TAC) / single product allowable concentration (SPAC) respectively. When extrapolation is used, the relationship between contaminant concentration and time shall be determined and plotted using a minimum of five data points.

When a multiple time point protocol is employed in the evaluation of a contaminant, consideration shall be given to the availability of appropriate toxicity data to define an acute exposure limit for the contaminant, as required in NSF/ANSI/CAN 600, Section 3.3 (previously Annex A, Section A.5). Consideration shall also be given to the leaching characteristics of the contaminant. Multiple time point analysis shall not be used for lead or any other metal contaminant listed as a regulated contaminant by US EPA or Health Canada.

4.5.5 Single time point conditioning protocols

A separate sample shall be conditioned for each type of exposure water selected in Section 4.5.3.

4.5.5.1 Single time point conditioning – Cold and intermittent hot applications

Products that are intended to be in contact with cold water or intermittent hot water shall be conditioned in the exposure water(s) selected in Section 4.5.3 at 23 ± 2 °C (73 ± 4 °F) for 14 d. During the 14-d period, the exposure water shall be changed at least 10 times with a minimum period of 24 ± 1 h between water changes. The free available chlorine concentration during the conditioning period shall be 2 mg/L. After the 14-d conditioning period, the exposure water in the product or in the vessel shall be decanted and discarded. Shortened conditioning periods shall be used at the request of the manufacturer. Exposure of the sample according to Section 4.5.6 shall immediately follow conditioning.

NOTE — Table 4.1 provides an example single time point conditioning protocol. Alternate protocols shall be permitted as long as the requirements of Section 4.5.5.1 are met.

4.5.5.2 Single time point conditioning – Continuous hot applications

Products that are intended to be in continuous contact with hot water shall be conditioned in the exposure water(s) selected in Section 4.5.3 at either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F) for 14 d. During the 14-d period, the exposure water shall be changed at least 10 times with a minimum period of 24 ± 1 h between water changes. The free available chlorine concentration during the conditioning period shall be 2 mg/L. After the 14-d conditioning period, the exposure water in the product or in the vessel shall be decanted and discarded. Shortened conditioning periods shall be permitted at the request of the manufacturer. Exposure of the sample according to Section 4.5.6 shall immediately follow conditioning.

NOTE — Table 4.1 provides an example single time point conditioning protocol. Alternate protocols shall be permitted as long as the requirements of Section 4.5.5.2 are met.

4.5.6 Single time point exposure protocols

Products to be evaluated at a single time point shall be exposed according to the schedule in Table 4.2. The first two 24-h exposure periods shall be optional at the discretion of the manufacturer. A separate sample shall be exposed for each type of exposure water selected in Section 4.5.3. For each sample, the exposure water shall be of the same pH as the water used for conditioning of the sample.

4.5.6.1 Single time point exposure – Cold application

Immediately after conditioning, the product shall be exposed at 23 ± 2 °C (73 ± 4 °F) according to the schedule in Table 4.2.

4.5.6.2 Single time point exposure – Hot applications

4.5.6.2.1 Intermittent hot water exposure

Immediately after conditioning, the product shall undergo exposure according to the schedule in Table 4.2. Prior to each exposure, the product shall be exposed at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F), for 30 ± 5 min. The product shall then be exposed at 23 ± 2 °C (73 ± 4 °F) for the duration of the exposure period.

4.5.6.2.2 Continuous hot water exposure

Immediately after conditioning, the product (in-product exposures) or the exposure vessel (in-vessel exposures) shall be filled with fresh exposure water of the applicable pH (see Section 4.5.3). The product shall then be exposed at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F), according to the schedule in Table 4.2.

4.5.7 Multiple time point conditioning / exposure protocols

For the purpose of determining a contaminant leaching rate as a function of time, extractant water samples shall be collected during the conditioning period of products for which multiple time point exposure has been elected, according to the protocols in Sections 4.5.7.1 and 4.5.7.2. A separate sample shall be conditioned and exposed for each type of exposure water selected in Section 4.5.3.

4.5.7.1 Cold application

Products that are intended to be in contact with only cold water shall be maintained at 23 ± 2 °C (73 ± 4 °F) for 19 d. During the 19 d period, the exposure water shall be changed at least 12 times, with a minimum period of 24 ± 1 h between water changes. At five of these water changes, extraction water shall be collected for analysis after a 24 h exposure. For extrapolation and normalization purposes, the number of hours elapsed since the most recent water change (or sample collection) and the number of days elapsed since the initiation of the exposure shall be recorded at the time of each extraction water collection.

NOTE — Table 4.3 provides an example multiple time point conditioning / exposure protocol. Alternate protocols shall be permitted as long as the requirements of Section 4.5.7.1 are met.

At the discretion of the manufacturer, direct measurement of a Day 90 extraction shall be permitted. The products shall be maintained at 23 ± 2 °C (73 ± 4 °F). Extraction water shall be collected for analysis at a minimum of two time points: after Day 1 (representing 14 d of conditioning and 1 d of acute exposure), and after the final exposure terminating on Day 90 (representing 14 d of conditioning, 1 d of acute exposure, and 90 d of chronic exposure). The exposure water shall be changed at least weekly during the interval between the initial and final exposures and on at least four days during the final week of exposure.

4.5.7.2 Hot applications

4.5.7.2.1 Intermittent hot water exposure

Products that are intended to be in intermittent contact with hot water shall undergo the cold application exposure according to Section 4.5.7.1. At the initiation of each exposure that will be collected for analysis, the product shall be exposed at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F), for 30 ± 5 min. The product shall then be exposed at 23 ± 2 °C (73 ± 4 °F) for the duration of the exposure period. The exposure water shall not be decanted prior to the completion of the exposure period.

NOTE 1 — Table 4.3 provides an example multiple time point conditioning / exposure protocol. Alternate protocols shall be permitted as long as the requirements of Section 4.5.7.2.1 are met.

NOTE 2 — The stated duration of the conditioning period at the hot temperature does not include any time needed to elevate the product sample or exposure vessel to the required exposure temperature.

At the discretion of the manufacturer, direct measurement of a Day 90 extraction shall be permitted. At the initiation of each exposure that will be collected for analysis, the products shall be exposed at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F), for 30 ± 5 min. The product shall then be exposed at 23 ± 2 °C (73 ± 4 °F) for the duration of the exposure period. The exposure water shall not be decanted prior to the completion of the exposure period. Extraction water shall be collected for analysis at a minimum of two time points: after Day 1 (representing 14 d of conditioning and 1 d of acute exposure), and after the final exposure terminating on Day 90 (representing 14 d of conditioning, 1 d of acute exposure, and 90 d of chronic exposure). The exposure water shall be changed at least weekly during the interval between the initial and final exposure and on at least 4 d during the final week of exposure.

4.5.7.2.2 Continuous hot water exposure

Products that are intended to be in continuous contact with hot water shall be maintained at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F) for 19 d. During the 19-d period, the exposure water shall be changed at least 12 times with a minimum period of 24 ± 1 h between water changes. At five of these water changes, extraction water shall be collected for analysis after a 24-h exposure. For extrapolation and normalization purposes, the number of hours elapsed since the most recent water change (or sample collection) and the number of days elapsed since the initiation of the exposure shall be recorded at the time of each extraction water collection.

NOTE — Table 4.3 provides an example multiple time point conditioning / exposure protocol. Alternate protocols shall be permitted as long as the requirements of Section 4.5.7.2.2 are met.

At the discretion of the manufacturer, direct measurement of a Day 90 extraction shall be permitted. The products shall be maintained at the selected elevated temperature, either 60 ± 2 °C (140 ± 4 °F) or 82 ± 2 °C (180 ± 4 °F). Extraction water shall be collected for analysis at at least two time points: after Day 1 (representing 14 d of conditioning and 1 d of acute exposure), and after the final exposure terminating on Day 90 (representing 14 d of conditioning, 1 d of acute exposure, and 90 d of chronic exposure). The exposure water shall be changed at least weekly during the interval between the initial and final exposure and on at least 4 d during the final week of exposure.

4.5.8 Collection and preservation of extraction water

Immediately after exposure, extraction waters collected for analysis shall be poured into previously prepared sample containers for storage until analysis, as specified in Section N-1.6.

4.6 Analysis

4.6.1 Extraction waters shall be analyzed with the methods listed in Section N-1.7.

4.6.2 Samples requiring analysis for RVCM shall be evaluated according to the method in Section N-1.7.

4.7 Normalization of contaminant concentrations

4.7.1 General

The concentration of analytes detected in the extraction water shall be multiplied by a calculated normalization factor (*NF*) to account for differences between laboratory and field surface area-to-volume ratios. The normalization factor shall be based on calculations and assumptions relevant to the end use of the product.

The general formula for the derivation of the normalization factor is described in the following equations:

$$NF = N1 \times N2$$

$$N1 = \frac{SA_F}{SA_L} \times \frac{V_L}{V_{F(static)}}$$

$$N2 = \frac{V_{F(static)}}{V_{F(flowing)}}$$

Where:

SA_F = surface area exposed in the field

SA_L = surface area exposed in the laboratory

V_L = volume of extraction water used in the laboratory

$V_{F(static)}$ = volume of water to which the product is exposed under static conditions

$V_{F(flowing)}$ = volume of water to which the product is exposed under flowing conditions during a period of time equivalent to the laboratory test

When the length of the exposure being normalized is other than 16 h in length, the normalized value shall be adjusted to reflect a 16-h exposure (e.g., multiply the normalized value by 0.7 when a 24-h exposure was used). The nominal diameter of the product shall determine which assumptions are used for normalization (see Tables 4.4 and 4.5). The actual inner diameter of the product shall be used for the normalization calculations of surface area and volume.

NOTE — Adjustment of the normalized contaminant concentration for the duration of the exposure period shall consider the extraction kinetics of the contaminant under evaluation. For contaminants that do not exhibit linear extraction kinetics, adjustment for the duration of exposure shall be done in accordance with the demonstrated kinetics of the contaminant or shall not be applied if this information is not available.

4.7.2 Products other than pipe

4.7.2.1 Fire sprinklers for multipurpose plumbing systems

Fire sprinklers intended for use in multipurpose plumbing systems (serving both drinking water and fire protection needs) shall be evaluated for acceptance based upon a use assumption of one unit per 0.43 L. Fire sprinkler fittings shall be evaluated in accordance with Section 4.7.2.2.

NOTE 1 — The evaluation of fire sprinkler system components is only intended to apply to those used in "multipurpose plumbing systems". The evaluation of potential extractants from fire sprinkler components from nondrinking water systems is not addressed under this Standard.

NOTE 2 — Fire sprinkler use assumption based on system design requirements in NAPF 13 D[12] Criterion of one unit per 0.43 L based on use in a network of 1/2 in PEX piping and the volume of water contained in 12 ft of pipe. This assumes installation of fittings with three ports (minimum number) and 4 ft of pipe associated with each port (accounts for the one port on each side of an 8 ft pipe which is the minimum distance required between sprinklers).

4.7.2.2 Products other than fire sprinklers

The SA_F shall be calculated from the assumed length of pipe corresponding to the segment of the system in which the product is used (e.g., 100 ft of pipe in the service line or 280 ft of pipe in the residence). The $V_{F(static)}$ component of the N1 term shall be the volume of water contained within the assumed length of pipe.

[12] NFPA 13D. *Installation of Sprinkler Systems: One and Two Family Dwellings and Manufactured Homes, National Fire Protection Association, 2010.* <www.nfpa.org>

For fittings, the actual inner diameter of the pipe used with the fittings shall be used to calculate both SA_F and $V_{F(static)}$. PVC, CPVC and PP transition fittings with stainless steel or copper alloy inserts (except for stainless steel or copper alloy inserts intended for use with PEX tubing), unions and repair couplings are specfically excluded from this evaluation.

For PVC, CPVC and PP transition fittings with stainless steel or copper alloy inserts (except for stainless steel or copper alloy inserts intended for use with PEX tubing), unions and repair couplings, the SA_F shall be the wetted surface area of a single product. The $V_{F(static)}$ component of the N1 term shall be the volume of water a single product contains when filled to capacity, except that $V_{F(static)}$ shall equal 1 L (0.26 gal) for all products that contain less than 1 L (0.26 gal) of water when filled to capacity.

NOTE — These products shall be evaluated in this manner because the materials (stainless steel or copper alloy or repair coupling material) will not repeat within the piping system. When a material does repeat within the system, it shall be evaulated as a pipe or fitting, as appropriate. PVC, CPVC and PP transition fittings with a stainless steel or copper alloy insert intended for use with PEX tubing are excluded because the remainder of the PEX system may also be plumbed with stainless steel or copper alloy fittings. Thus, the stainless steel or copper alloy material would repeat throughout the PEX system.

4.7.3 Sample calculations for normalization of products in Section 4 are provided in Table 4.6.

4.7.4 Selection of normalization conditions

Pipe and fitting products with a nominal diameter greater than or equal to 10 cm (4 in) shall be normalized to the flowing condition. Pipe and fitting products with a nominal diameter of less than 10 cm (4 in) shall be normalized to the static condition when the value of N2 is ≤ 0.1. Pipe and fitting products with a nominal diameter of < 10 cm (4 in) shall be normalized to the flowing condition when the value of N2 is > 0.1.

4.7.5 Multiple time point exposure calculations

Laboratory values from each time point at which extractant water was collected (a minimum of five data points shall be required for extrapolation) shall be normalized as indicated in Section 4.7.1, depending on product end use. A decay curve of these normalized contaminant concentrations in relation to elapsed exposure time shall be plotted. Contaminant concentrations shall be determined for two time points as follows: at Day 1 (representing 14 d of conditioning and 1 d of acute exposure) and at Day 90 (representing 14 d of conditioning, 1 d of acute exposure, and 90 d of chronic exposure) shall be extrapolated from this curve (see Section 4.5.7).

If direct measurement of a Day 90 exposure has been performed, laboratory values from each time point at which extractant water was collected (a minimum of two time points as defined in Sections 4.5.7.1 and 4.5.7.2) shall be normalized as indicated in Section 4.7.1, depending on product end use.

4.8 Evaluation of contaminant concentrations

4.8.1 Contaminants measured in a single time point extraction

For pipe and fitting products, normalized static contaminant concentrations shall be no greater than their respective MCLs or TACs, and normalized flowing contaminant concentrations shall be no greater than their respective SPACs calculated in accordance with NSF/ANSI/CAN 600 (previously Annex A).

4.8.2 Contaminants measured in a multiple time point extraction

Normalized Day 1 contaminant concentrations shall not exceed the STEL as defined in NSF/ANSI/CAN 600 (previously Annex A, Section A.5).

Normalized extrapolated or directly measured Day 90 contaminant concentrations shall not exceed the limits defined in Section 4.8.1.

4.8.3 Residual vinyl chloride monomer (RVCM)

The average RVCM concentration shall be less than or equal to 3.2 mg/kg as evaluated in the product wall.

Table 4.1
Example single time point conditioning schedule

Conditioning time	Elapsed time	Comment
24 ± 1 h	1 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	2 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	3 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	4 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
72 ± 1 h	7 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	8 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	9 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	10 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	11 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
72 ± 1 h	14 d	Exposure water is decanted and discarded; conditioning is terminated.

Table 4.2
Single time point exposure schedule

Exposure time	Elapsed time[1]	Comment
24 ± 1 h (optional)	15 d (optional)	Extraction water is decanted and discarded; the exposure vessel or product is refilled with exposure water and exposure is continued.
24 ± 1 h (optional)	16 d (optional)	Extraction water is decanted and discarded; the exposure vessel or product is refilled with exposure water and exposure is continued.
16 h	17 d (15 d if the two optional exposure periods are not elected)	Extraction water is collected for analysis; the exposure is terminated.
[1] Elapsed time indicated includes the 14 d of conditioning preceding the exposure.		

Table 4.3
Example multiple time point conditioning / exposure schedule

Exposure time	Elapsed time	Sample collection
24 ± 1 h	1 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	2 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	3 d	Extraction water is decanted and discarded; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	4 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
72 ± 1 h	7 d	Extraction water is decanted and discarded; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	8 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	9 d	Extraction water is decanted and discarded; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	10 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
96 ± 1 h	14 d	Extraction water is decanted and discarded; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	15 d	Extraction water is collected for analysis at completion of the exposure period; the product or exposure vessel is refilled with exposure water and the exposure is continued.
72 ± 1 h	18 d	Extraction water is decanted and discarded; the product or exposure vessel is refilled with exposure water and the exposure is continued.
24 ± 1 h	19 d	Extraction water is collected for analysis at completion of the exposure period; the exposure is terminated.

Table 4.4
Pipes – Normalization factors and assumptions

<table>
<tr><th>Product nominal diameter</th><th>Assumptions</th><th>Exposure type</th><th>N1</th><th>N2 (flowing condition)</th></tr>
<tr><td rowspan="2">noncopper pipe nominal
≥ 10 cm (4 in)</td><td rowspan="2">— water is exposed to the same material from the treatment plant to the service line; and
— a 16-h exposure period is evaluated.</td><td>in-product</td><td>1</td><td>1</td></tr>
<tr><td>in-vessel</td><td>calculated according to Section 4.7.1</td><td>1</td></tr>
<tr><td rowspan="2">10 cm (4 in)
> nominal
≥ 1.3 cm (0.5 in)</td><td rowspan="2">— a 16-h exposure period is evaluated;
— residential water usage is 681 L (180 gal) per 24 h; and
— 100 ft of service line from water main to residence.</td><td>in-product</td><td>1</td><td>calculated according to Section 4.7.1</td></tr>
<tr><td>in-vessel</td><td>calculated according to Section 4.7.1</td><td>calculated according to Section 4.7.1</td></tr>
<tr><td rowspan="2">nominal
< 1.3 cm (0.5 in)</td><td>— a maximum run of 7.6 m (25 ft) of small diameter product is installed;</td><td>in-product</td><td>1</td><td>calculated according to Section 4.7.1</td></tr>
<tr><td>— for products with an internal volume less than 1 L (0.26 gal), $V_{F(static)}$ is set equal to 1 L;
— a 16-h exposure period is evaluated;
— residential water usage is 681 L (180 gal) per 24 h; and
— 280 ft per residence (140 ft each for hot and cold sides).</td><td>in-vessel</td><td>calculated according to Section 4.7.1</td><td>calculated according to Section 4.7.1</td></tr>
<tr><td rowspan="2">copper pipe
≥ 10 cm (4 in)</td><td rowspan="2">— utilized as main distribution lines within buildings;[1]
— a 16-h exposure period is evaluated.</td><td>in-product</td><td>1</td><td>0.55</td></tr>
<tr><td>in-vessel</td><td>calculated according to Section 4.7.1</td><td>0.55</td></tr>
<tr><td colspan="5">[1] The N2 value for copper products used as main distribution lines in buildings was calculated based on the static volume of a piping network of up to 20 mi and an average flow of 100 gpm.</td></tr>
</table>

Table 4.5
Fittings (installed at regular intervals) – Normalization factors and assumptions

Product nominal diameter	Assumptions	Exposure type	N1	N2 (flowing condition)
nominal ≥ 10 cm (4 in)	— water is exposed to the same material from the treatment plant to the service line; — fittings represent 2% of the distribution system surface area; and — a 16-h exposure period is evaluated.	in-product	0.02	1
		in-vessel	calculated according to Section 4.7.1 and multiplied by 0.02	1
10 cm (4 in) > nominal ≥ 1.3 cm (0.5 in)	— fittings represent 2% of the piping system for products 10 cm (4 in) > nominal ≥ 2.5 cm (1.0 in) (rigid and flexible systems); — fittings represent 6% of the piping system surface area for products 2.5 cm (1.0) in > nominal ≥ 1.3 cm (0.5 in) (rigid systems)[1]; — fittings represent 3% of the piping system surface area for products 2.5 cm (1.0) in > nominal ≥ 1.3 cm (0.5) in (flexible systems)[1]; — a 16-h exposure period is evaluated; — residential water usage is 681 L (180 gal) per 24 h; and — 100 ft of service line from water main to residence.	in-product	0.02, 0.06, or 0.03, depending on product diameter and end use (flexible or rigid system)	calculated according to Section 4.7.1
		in-vessel	calculated according to Section 4.7.1 and multiplied by 0.02, 0.06, or 0.03, depending on product diameter and end use (flexible or rigid system)	calculated according to Section 4.7.1
nominal < 1.3 cm (0.5 in)	— a maximum run of 7.6 m (25 ft) of small diameter product is installed; — fittings represent 6% of the residential system surface area for rigid piping systems;[1] — fittings represent 3% of the residential system surface area for flexible piping systems;[1] — a 16-h exposure period is evaluated; — residential water usage is 681 L (180 gal) per 24 h; and — 280 ft of pipe per residence (140 ft each for hot and cold sides).	in-product	0.06 or 0.03, depending on product end use (flexible or rigid system)	calculated according to Section 4.7.1
		in-vessel	calculated according to Section 4.7.1 and multiplied by 0.06 or 0.03, depending on product end use (flexible or rigid system)	calculated according to Section 4.7.1

[1] For products that may be used with either rigid or flexible systems, fittings shall be assumed to represent 6% of the piping system surface area.

Table 4.6
Example normalization calculations

Parameters	Calculation
In-product exposure of a 30.5 cm (1 ft) length of 15.2 cm (6 in) i.d. pipe	
SA_F = 1,459 cm² (226 in²) SA_L = 1,459 cm² (226 in²) $V_{F(static)}$ = 5.6 L (1.5 gal) V_L = 5.6 L (1.5 gal)	$\text{normalized flowing concentration} = \frac{226\ in^2}{226\ in^2} \times \frac{1.5\ gal}{1.5\ gal} \times 1 \times \text{laboratory concentration}$
In-vessel exposure of a 2.5 cm (1 in) i. d. pipe	
$SA_F / V_{F(static)}$ = 1,575 cm²/1 L (924 in²/1 gal) SA_L= 247 in² (1,594 cm²) V_L = 0.2 gal (0.8 L)	$\text{normalized static concentration} = \frac{924\ in^2}{247\ in^2} \times \frac{0.2\ gal}{1\ gal} \times \text{laboratory concentration}$
In-product exposure of a 63.5 cm (25 ft) length of 0.6 cm (0.25 in) i.d. pipe	
SA_F = 1,520 cm² (235.6 in²) SA_L = 1,520 cm² (235.6 in²) $V_{F(static)}$ = 0.24 L (0.064 gal) – default to 1 L (0.26 gal) V_L = 0.24 L (0.064 gal)	$\text{normalized static concentration} = \frac{235.6\ in^2}{235.6\ in^2} \times \frac{0.064\ gal}{0.26\ gal} \times \text{laboratory concentration}$
In-product exposure of a 25.4 (10 in) long 15.2 (6 in) i.d. fitting	
SA_F = 1,216.1 cm² (188.5 in²) SA_L = 1,216.1 cm² (188.5 in²) $V_{F(static)}$ = 4.6 L (1.2 gal) V_L = 4.6 L (1.2 gal)	$\text{normalized flowing concentration} = \frac{188.5\ in^2}{188.5\ in^2} \times \frac{1.2\ gal}{1.2\ gal} \times 1 \times 0.02 \times \text{laboratory concentration}$
In-vessel exposure of a 1.3 cm (0.5 in) i.d. fitting used with flexible piping systems	
$SA_F / V_{F(static)}$ = 3,040 cm²/1 L (1,885 in²/1 gal) SA_L = 1,594 cm² (247 in²) V_L = 0.8 L (0.2 gal)	$\text{normalized static concentration} = \frac{1885\ in^2}{247\ in^2} \times \frac{0.2\ gal}{1\ gal} \times 0.03 \times \text{laboratory concentration}$
In-vessel exposure of a 0.6 cm (0.25 in) i.d. fitting used with rigid piping systems	
$SA_F / V_{F(static)}$ = 908 in²/1 gal (1,523 cm²/1 L) SA_L = 865 in² (5,581cm²) $V_{F(static)}$ = 0.064 gal (0.24 L) – default to 0.26 gal (1 L) V_L = 0.4 gal (1.3 L)	$\text{normalized static concentration} = \frac{236\ in^2}{865\ in^2} \times \frac{0.4\ gal}{0.26\ gal} \times 0.06 \times \text{laboratory concentration}$
In-vessel exposure of a 1.3 cm (0.5 in) i.d. fitting used as a repair coupling	
$SA_F / V_{F(static)}$ = 3,040 cm²/1 L (1,885 in²/1 gal) $V_{F(static)}$ = 0.003 L (0.0009 gal) default to 1 L (0.26 gal) SA_L = 5,581cm² (865 in²) V_L = 1.3 L (0.4 gal)	$\text{normalized static concentration} = \frac{1.6\ in^2}{865\ in^2} \times \frac{0.4\ gal}{0.26\ gal} \times \text{laboratory concentration}$
NOTE — Definitions for SA_F, SA_L, $V_{F(static)}$, $V_{F(flowing)}$, and V_L are found in Section 4.7.1.	

5 Barrier materials

5.1 Scope

The requirements of this section apply to products and materials intended to form a barrier providing containment of drinking water or to prevent drinking water contact with another surface. The products and materials that are covered include, but are not limited to, coatings and paints applied to fittings, pipes, mechanical devices and nonresidential storage tanks including the interior surface of tank covers; linings, liners, bladders and diaphragms; and constituents of concrete and cement-mortar (e.g., portland and blended hydraulic cements, admixtures, sealers, and mold release agents). These products and materials can be field-applied, factory-applied, precast, or cast-in-place.

Concrete aggregate sampling is required only if the method for testing for individual concrete components is used. Aggregate sampling is not required if concrete cylinders are tested for the constituents in portland and hydraulic cements.

5.2 Definitions

5.2.1 admixture: A material other than water, aggregates, hydraulic cement, and fiber reinforcement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing.

5.2.2 aggregate: Granular material, such as sand, gravel, or crushed stone used with a cementing medium to form hydraulic-cement concrete or mortar.

5.2.3 barrier material: A material in contact with drinking water that serves a containment or separation purpose.

5.2.4 blended hydraulic cement: A hydraulic cement consisting of two or more inorganic constituents (at least one of which is not portland cement or portland cement clinker) that separately or in combination contribute to the strength-gaining properties of the cement.

5.2.5 coating / paint: A material applied to a surface where a direct bond to the substrate is formed.

5.2.6 concrete: A composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate; in hydraulic-cement concrete, the binder is formed from a mixture of hydraulic cement and water.

5.2.7 diaphragm / bladder: A flexible membrane that separates the surrounding media from the drinking water.

5.2.8 field applied paint / coating systems: A paint/coating applied to product after it is installed.

5.2.9 factory applied paint / coating systems: A paint/coating applied to to new product at a manufacturing site.

5.2.10 form / mold release agent: A material applied to the inside of a form or mold used to cast concrete or cement-mortar, which prevents adhesion of the concrete or cement-mortar to its surface.

5.2.11 hydraulic cement: A cement that sets and hardens by chemical interaction with water and that is capable of doing so under water.

5.2.12 immediate return to service paint / coating systems: immediate return to service paint / coating systems are intended to be applied to an existing pipe for rehabilitation purposes and intended to be returned to service 0 to 48 h following the final cure.

5.2.13 liners / linings: Prefabricated materials applied, bonded, or attached to a surface that is subject to direct / indirect contact with drinking water.

5.2.14 mortar: A mixture of water, cement, and sand.

5.2.15 portland cement: A hydraulic cement (usually containing calcium sulfate) produced by pulverizing portland cement clinker (a partially fused substance consisting primarily of hydraulic calcium silicates).

5.2.16 potable water contact area of tanks: The potable water contact areas of tanks shall include both the area normally submerged during use as well as the areas where water may condense and fall back into the tank such as ceilings.

5.2.17 sealer: A liquid that is applied as a coating to the surface of hardened concrete or cement-mortar, either to prevent or decrease the penetration of liquid or gaseous media during service exposure.

5.3 General requirements

5.3.1 Product labeling

Products or product containers shall be marked and include, at a minimum, product identification, batch number, or date of manufacture. When it is not feasible to mark the product or material, the manufacturer shall maintain identification records.

5.3.2 Paints and coatings

For all paints and coatings, the manufacturer shall submit detailed use instructions for the laboratory preparation and application that are representative of their published use instructions for factory or field applications. Use instructions shall specify the appropriate preparation and application procedures, including order of application for multiple layer systems, substrate preparation (including use of specific primer), subcomponent mixing ratio, induction time, thinning, application method, application thickness(es), curing schedule,and final cure time prior to water immersion. Coating systems that are composed of multiple products (e.g., primer, intermediate coat(s), and top coat, including any thinners) shall be evaluated as an applied system. Use instructions indicating the coating / paint will rehabilitate existing pipe and that the water system can be returned to service within 48 h following the final cure shall be evaluated as immediate return to service paint / coating systems.

Public listing for a coating / paint shall include application procedures including order of application for multiple layer systems, use of a specific primer if one is used, subcomponent mixing ratio, thinning, application method, application thickness(es), curing schedule and final cure time and temperature prior to water immersion. Paint / coating system intended to be applied to pipe shall be designated as “certified for use on new pipe” or “certified for use on pipe intended for immediate return to service”.

5.4 Sample requirements

When required for evaluation, a sample of the product or material equivalent to that used in field applications shall be obtained.

A single sample can represent a product line of similar formulations (e.g., different colors of the same coating product line) when:

— the sample selected for testing contains all of the formulation ingredients of toxicological concern (see Section 3.2) at concentrations equal to or greater than the products it is selected to represent;

— product application conditions for the sample selected for testing (e.g., application thickness(es), cure times, solvent concentrations) are equal to or more severe than the products it is selected to represent; and

— for multiple component formulations, the mixing ratio(s) of the selected sample is(are) identical to that of the products it represents.

5.4.1 Cement samples

Cement samples, weighing a minimum of 9 kg (20 lb), shall be collected in accordance with the applicable sections of ASTM C 183.[5] To minimize contamination, all sample collection tools shall be cleaned and wiped with isopropyl alcohol before use. Collected samples shall be placed in moisture-proof containers. To minimize organic contamination, sample containers shall not be filled near a running motor or any type of exhaust system.

5.4.2 Concrete cylinder samples

Concrete test cylinders for the evaluation of cast-in-place or precast concrete structures shall be submitted with specific information on the composition of the concrete mix design for the specific installation, including the specific sources of cement, aggregate, admixtures, and any other additives. Specific information on the tank dimensions and water storage capacity shall also be provided. Concrete batch tickets, collected at the site of production, shall serve as evidence of the concrete mix actually used in the structure being evaluated.

5.4.3 Other barrier materials

Samples of barrier materials shall be collected at the point of manufacture.

5.5 Extraction procedures

5.5.1 Analytical summary

An analytical summary shall be prepared for each product. The analytical summary shall consist of the formulation-dependent analytes identified through the formulation review (see Section 3.2) and the applicable product-specific analytes listed in Table 3.1.

5.5.2 Preparation of test samples

5.5.2.1 Test samples shall be prepared such that a minimum surface area-to-volume ratio of 50 cm^2/L (29 in^2/gal) is achieved during the exposure, and so that the entire surface to be exposed is covered by exposure water. For concrete aggregate evaluations, the media shall be tested at a laboratory evaluation ratio no less than the field use level calculated in accordance with Section 5.7.2. Samples shall be rinsed with cold tap water and then in reagent water, meeting the requirements of Section N-1.9.2.1 unless manufacturer's instructions direct otherwise.

5.5.2.2 Field-applied paint and coating systems

Field-applied paint and coating systems shall be applied in accordance with the detailed use instructions (see Section 5.3.2) under the supervision of the testing laboratory. Products shall be applied to a glass slide when appropriate. Products requiring a reactive substrate shall be applied to the appropriate alternate substrate. Coating products shall be applied using application conditions as specified by the manufacturer in the detailed use instructions, e.g., the highest recommended percentage of thinner, the shortest curing period between coats or layers, the maximum recommended film thickness per coat, and the shortest final curing period prior to immersion. Products shall be cured within ± 4 °C of the specified cure temperature. For exothermic coatings with a maximum field use thickness in excess of 120 mil (3.0 mm), an additional evaluation at the manufacturer's minimum recommended field use thickness shall be conducted. The maximum dry film thickness per coat attested to by the testing laboratory shall be based on the average per coat dry film thickness evaluated. When samples are prepared using an airless plural component system the system shall be operated at the midpoint of the coating manufacturer's recommended pressure and temperature range.

NOTE — The practical application of coatings may result in spots of coating thicknesses in excess of the maximum dry film thickness per coat attested to by the testing laboratory. Guidance on acceptable variations from the maximum dry film thicknesses is provided in The Society for Protective Coatings *Steel Structures Painting Manual Volume 2*. Reference *Paint Application Specification No. 2 (SSPC-PA2)*[8] where the average of spot measurements on each 10 m^2 (100 ft^2) area shall not exceed the specified maximum thickness, and no single spot measurement shall be more than 120% of it. In that document, spot measurements are defined as the average of at least three gauge readings within a 1.5-in (4-cm) diameter circle.

Multiple layer paint and coating systems that require the application of distinct coating product formulations in sequence shall be applied in a stepped manner so as to expose all layers. Multiple coats of the same product (of the same color) applied in sequence shall not constitute multiple layers and shall not be applied in a stepped manner. Multiple coats of the same product (of different colors) applied in sequence shall not constitute multiple layers and shall not be applied in a stepped manner, unless deemed necessary by the testing laboratory to address potential health effects concerns from the differences in color formulations. Stepped coating systems shall be applied per the dimensions in Table 5.1.

5.5.2.3 Factory-applied paint and coating systems

Paint and coating systems requiring factory application, factory curing, or both shall be prepared and applied in accordance with the detailed use instructions (see Section 5.3.2) under the supervision of the testing laboratory. Products shall be applied to a glass slide when appropriate. Products requiring a reactive substrate shall be applied to the appropriate alternate substrate. Coating products shall be applied using application conditions as specified by the manufacturer in the product use instructions, e.g., the highest recommended percentage of thinner, the shortest curing period between coats or layers, the maximum recommended film thickness per coat. Products shall be cured within ± 4 °C of the specified cure temperature, however temperature control is not required between the end of cure and immersion for factory applied coatings. For exothermic coatings with a maximum field use thickness in excess of 120 mil (3.0 mm), an additional evaluation at the manufacturer's minimum recommended field use thickness shall be conducted. The maximum dry film thickness per coat attested to by the testing laboratory shall be based on the average per coat dry film thickness evaluated.

NOTE — The practical application of coatings may result in spots of coating thicknesses in excess of the maximum dry film thickness per coat attested to by the testing laboratory. Guidance on acceptable variations from the maximum dry film thicknesses is provided in The Society for Protective Coatings *Steel Structures Painting Manual Volume 2*. Reference *Paint Application Specification No. 2 (SSPC-PA2)*[8] where the average of spot measurements on each 10 m^2 (100 ft^2) area shall not exceed the specified maximum thickness, and no single spot measurement shall be more than 120% of it. In that document, spot measurements are defined as the average of at least three gauge readings within a 1.5-in (4-cm) diameter circle.

Multiple layer paint and coating systems, which require the application of distinct coating product formulations in sequence, shall be applied in a stepped manner so as to expose all layers. Multiple coats of the same product (of the same color) applied in sequence shall not constitute multiple layers and shall not be applied in a stepped manner. Multiple coats of the same product (of different colors) applied in sequence shall not constitute multiple layers and shall not be applied in a stepped manner, unless deemed necessary by the testing laboratory to address potential health effects concerns from the differences in color formulations. Stepped coating systems shall be applied per the dimensions in Table 5.1.

NOTE — It is recognized that a coating system may be applied using a combination of factory and field application techniques. This is considered acceptable as long as the coating system is tested to the manufacturer's recommended application conditions, as specified in Sections 5.5.2.2 and 5.5.2.3.

5.5.2.4 Products requiring cement mortar cubes

Test sample mortar cubes shall be prepared in accordance to the applicable sections of ASTM C 109.[5] Mix water shall meet reagent water requirements (see Section N-1.9.2.1). Sand shall be washed in accordance with the procedures in ASTM C 778.[5] Mixing tools and other items coming into contact with the mortar shall be washed with soap and water, rinsed with tap water, rinsed with reagent water, and rinsed with isopropyl alcohol. The mortar shall be placed in polyethylene or polypropylene lined molds; no form release agents shall be used. Specimens shall be removed from the molds after 24 h and placed in glass or polyethylene beakers and covered with an inverted watch glass supported on glass Rebel hooks (or other devices to prevent air seal of the vessel) and placed for 28 d ± 12 h, or fewer as specified by the manufacturer, in a moist cabinet meeting the requirements of ASTM C 511.[5] The specimens shall be removed from the moist cabinet and air dried at 23 ± 2 °C (73 ± 4 °F) and 50 ± 5% relative humidity for 7 d.

5.5.2.4.1 Portland and hydraulic cements

Test cubes for portland and blended hydraulic cements shall be prepared in accordance with Section 5.5.2.4.

5.5.2.4.2 Admixtures

These products shall be added to the cement-mortar or concrete mixture using the manufacturer's highest recommended admixture dosage. The test samples shall be prepared as described in Section 5.5.2.4.

5.5.2.4.3 Sealers

These products shall be applied per manufacturer's recommendations to the test cubes prepared in accordance with Section 5.5.2.4. The coated cubes shall be allowed to cure for the manufacturer's recommended time period.

5.5.2.4.4 Form and mold release agents

These products shall be applied per manufacturer specifications to the mold used during the preparation of the test cubes (see Section 5.5.2.4).

5.5.2.5 Concrete water storage tanks

Concrete test cylinders (4 in × 8 in) shall be prepared according to ASTM C 31[5] or ASTM C 192,[5] and moist cured in an ASTM C 511[5] cabinet for a minimum of 3 d. Cylinder molds shall be manufactured of virgin materials free of detectable concentrations of any interfering contaminants.

5.5.3 Exposure water

Exposure water selection shall be determined by the analytes of interest identified on the analytical summary (see Section 5.5.1). Exposure water(s) shall be selected in accordance with Section N-1.2.5.

5.5.4 Conditioning (optional)

Test samples shall be conditioned immediately after curing. This conditioning procedure simulates the disinfection of water mains and storage tanks prior to placing into service, and is based on AWWA Standards C651-05 and C652-02.[6]

Coatings intended for pipes and fittings can be conditioned as follows:

a) Prepare 50 mg/L free available chlorine solution using sodium hypochlorite (NaClO – reagent grade or equivalent).

b) Using a spray bottle, spray the previously rinsed test samples, wetting all surfaces to be exposed.

c) Let the test samples stand for at least 3 h.

d) Place the test samples in racks, rinse with cold tap water, and rinse with reagent water, meeting the requirements of Section N-1.9.2.1.

Coatings intended for water storage tanks or multiple uses (tanks, pipes, other) may be conditioned as follows:

a) Prepare 200 mg/L free available chlorine solution using sodium hypochlorite (NaClO – reagent grade or equivalent).

b) Using a spray bottle, spray the previously rinsed test samples, wetting all surfaces to be exposed.

c) Let the test samples stand for at least 30 min.

d) Place the test samples in racks, rinse with cold tap water, and rinse with reagent water, meeting the requirements of Section N-1.9.2.1.

Products may also be disinfected per manufacturer's use instructions.

5.5.5 Exposure protocols

For all test samples, exposure shall commence immediately following the conditioning step. If immediate exposure is not possible, the test samples shall be dried in a laminar flow hood and exposed within 4 h. Successful evaluation at an elevated exposure temperature shall preclude testing at a lower exposure temperature. A separate sample shall be exposed for each type of exposure water selected in Section 5.5.3.

The exact surface area-to-volume ratio achieved during the exposure shall be recorded.

5.5.5.1 Cold application

Cold application product samples, as designated by the manufacturer, shall be placed in an exposure vessel and completely covered with exposure water of the applicable pH (see Section 5.5.3). The exposure vessel shall be placed in a 23 ± 2 °C (73 ± 4 °F) environment for the duration of the exposure period.

5.5.5.2 Domestic hot application

Products that are intended for domestic hot applications as designated by the manufacturer (e.g., for use in single-family dwellings) shall be placed in an exposure vessel and completely covered with exposure water of the applicable pH (see Section 5.5.3). The exposure vessel shall be placed in a 60 ± 2 °C (140 ± 4 °F) environment for the duration of the exposure period.

5.5.5.3 Commercial hot application

Products that are intended for commercial hot applications, as designated by the manufacturer, (e.g., for use in multiple-family dwellings, restaurants, hospitals) shall be placed in an exposure vessel and completely covered with exposure water of the applicable pH (see Section 5.5.3). The exposure vessel shall be placed in an 82 ± 2 °C (180 ± 4 °F) environment for the duration of the exposure period.

5.5.5.4 Single time point exposure protocol

When normalized contaminant concentrations from the product are expected to be less than their acceptable concentrations (see NSF/ANSI/CAN 600, Section 3 [previously Annex A of this Standard]) when tested at a single time point (e.g., flexible membrane liners), the product shall be exposed according to the single time point exposure protocols in Table 5.2, (tanks), and Tables 5.3 and 5.4 (pipes). Coatings intended for mulitple uses for tank, pipe or other applications shall be exposed per Table 5.2. Extraction water samples shall be collected at the conclusion of the final exposure period. For paint / coating systems intended for immediate return to service, the first four days of the exposure for tanks and the first two days of the exposure for pipes will be eliminated and the water samples shall be collected at the conclusion of the first 24-h period for tanks, and the first 16 h period for pipes.

5.5.5.5 Multiple time point exposure protocol

When the normalized concentration of a contaminant exceeds, or is expected to exceed, its acceptable concentration (see NSF/ANSI/CAN 600, Section 3 [previously Annex A of this Standard]) when evaluated as a single time point (see Section 5.5.5.4), determination of the contaminant leaching rate as a function of time shall be considered. The relationship between contaminant concentration(s) and time shall be determined and plotted using a minimum of five data points. Table 5.5 summarizes the multiple time point exposure sequence. For contaminants of interest that do not require over time testing, extraction water shall be collected following the third exposure period (elapsed time 5 d). For paint / coating systems intended for immediate return to service, the first four days of the exposure will be eliminated and the water samples shall be collected at the conclusion of the first 24-h period following conditioning.

At the discretion of the manufacturer, direct measurement of a Day 90 extraction shall be permitted. The products shall be exposed at the selected application temperature (e.g., 23 ± 2 °C; 60 ± 2 °C; 82 ± 2 °C) for the full duration of the exposure. Extraction water shall be collected for analysis at a minimum of two time points: after Day 1 and after the final exposure terminating on Day 90. The exposure water shall be changed at least weekly during the interval between the initial and final exposure and on at least 4 d during the final week of exposure.

> NOTE — Day 1 is defined as the time point at which extractant water for all contaminants is collected for analysis (5 d of elapsed time). Day 90 is defined as 90 d following this time point (95 d of elapsed time).

5.5.6 Collection and preservation of extraction water

Immediately following the exposure period, the extraction water shall be poured into previously prepared sample containers for storage as detailed in Section N-1.6, until analysis. Extraction water for solvent analysis shall be collected in a sample bottle containing sodium thiosulfate in a quantity sufficient to neutralize any residual chlorine, if applicable.

5.6 Analysis of extraction water

Extraction waters shall be analyzed with the methods listed in Section N-1.8.

5.7 Normalization

5.7.1 Normalization for tanks / storage vessels

5.7.1.1 The following equation shall be used to calculate the normalized concentration of each contaminant for tanks or other storage vessels:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{SA_F}{V_F} \times \frac{V_L}{SA_L} \times \frac{24\text{ h}}{\text{hours of exposure}}$$

Where:

$\frac{SA_F}{V_F}$ = surface area to volume ratio for the specified tank capacity, as defined in Table 5.6

SA_L = surface area exposed in the laboratory

V_L = volume of extraction water used in the laboratory

When the length of the exposure being normalized is other than 24 h in length, the normalized value shall be adjusted to reflect a 24-h exposure.

Products used as barriers for tanks or storage vessels shall use the surface area-to-volume ratios shown in Table 5.6. Surface area-to-volume ratios for products used as barriers in tanks or storage vessels with a capacity other than those shown in Table 5.6 shall be determined on a case-by-case basis, as described in Section 5.7.1.2.

NOTE — Due to the potential for condensation to form on the interior surfaces of water storage tank and reservoir covers, which may leach contaminants and then drip into the water tank or reservoir, the interior surface of these covers shall be considered water contact materials. Table 5.6 and Section 5.7.1.2 thus include the surface area of the roof (ceiling) in the calculation of the water contact surface area to volume ratio of the tank or storage vessel.

5.7.1.2 Calculation of the surface area-to-volume ratio for tanks or storage vessels

The following assumptions shall be used in determining the surface area-to-volume ratio for each nominal tank capacity:

— the tank has a smooth interior surface;
— the tank is cylindrical in shape;
— the tank is installed in a vertical position; and
— the roof (ceiling) of the tank is in contact with drinking water.

The following equation shall be used to calculate the surface area-to-volume ratio for tanks or storage vessels of capacities that do not appear in Table 5.6:

Volume in gallons:

$$\text{surface area-to-volume ratio } \left(\text{in}^2/\text{L}\right) = 119.5 \times \frac{\left(0.1702 \times \frac{Y}{X}\right)^{0.66} \times \left(X + \frac{1}{2}\right)}{Y}$$

Where:

X = the height / diameter ratio of the tank or storage vessel
Y = the volume (in gallons) of the tank or storage vessel

5.7.2 Normalization for concrete aggregate

The following equation shall be used to calculate the normalized concentration of each contaminant for concrete aggregate evaluations. Table 5.8 provides examples of calculated aggregate field use assmptions for several reservoir capacities.

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{\text{aggregate field use assumption (g/L)}}{\text{laboratory evaluation ratio (g/L)}}$$

Where:

aggregate field use assumption (g/L)	=	ratio of concrete structure's wetted surface area to structure's volume (in^2/L)	x	correlation of concrete volume to evaluated concrete surface area (in^3/in^2)	x	aggregate mass per volume of concrete (g/in^3)

— ratio of concrete structure's wetted surface area to structure's volume: The surface area-to-volume ratios shown in Table 5.6 shall be used. Surface area-to-volume ratios for products used as barriers in tanks or storage vessels with a capacity other than those shown in Table 5.6 shall be determined on a case-by-case basis, as described in Secion 5.7.1.2;

— correlation of concrete volume to evaluated concrete surface area: 0.1 (in^3/in^2);

NOTE — The 0.1 in^3/in^2 value accounts for 100% of the aggregate exposed within the top 0.1 in of concrete.

— aggregate mass per volume of concrete (g/in^3): Concrete mix design specific value:

$$NF = N1 \times N2$$

$$N1 = \frac{SA_F}{SA_L} \times \frac{V_L}{V_{F(static)}}$$

$$N2 = \frac{V_{F(static)}}{V_{F(flowing)}}$$

Where:

SA_F = surface area exposed in the field

SA_L = surface area exposed in the laboratory

V_L = volume of extraction water used in the laboratory

$V_{F(static)}$ = volume of water to which the product is exposed under static conditions

$V_{F(flowing)}$ = volume of water to which the product is exposed under flowing conditions during a period of time equivalent to the laboratory test

When the length of the exposure being normalized is other than 24 h in length, the normalized value shall be adjusted to reflect a 24-h exposure (e.g., multiply the normalized value by $^{24}/_{72}$ when a 3-d exposure was used). Products used as barriers for pipes shall use the surface area-to-volume ratios shown in Table 5.7.

Pipe and fitting coatings with a nominal diameter ≥ 10 cm (4 in) shall be normalized to the flowing condition. Pipe and fitting coatings with a nominal diameter of < 10 cm (4 in) shall be normalized to the static condition when the value of N2 is ≤ 0.1. Pipe and fitting coatings with a nominal diameter of < 10 cm (4 in) shall be normalized to the flowing condition when the value of N2 is > 0.1.

5.7.3 Over time exposure calculations

Laboratory values from each time point for which extractant water was collected (minimum of five data points required) shall be normalized as indicated in Sections 5.7.1 or 5.7.2, depending on product end use.

A decay curve of these normalized contaminant concentrations in relation to elapsed exposure time shall be plotted. A contaminant concentration at Day 90 of exposure shall be extrapolated from this data.

NOTE — Day 1 is defined as the time point at which extractant water for all contaminants is collected for analysis (5 d of elapsed time). Day 90 is defined as 90 d following this time point (95 d of elapsed time).

5.8 Evaluation of contaminant concentrations

5.8.1 Contaminants measured at a single time point

Normalized contaminant concentrations for tanks shall be no greater than their respective SPACs determined in accordance with NSF/ANSI/CAN 600 (previously Annex A). For pipe and fitting products, normalized static contaminant concentrations shall be no greater than their respective MCLs, or TACs, and normalized flowing contaminant concentrations shall be no greater than their respective SPACs calculated in accordance with NSF/ANSI/CAN 600 (previously Annex A).

5.8.2 Contaminants measured over time

Normalized Day 1 contaminant concentrations shall not exceed the STEL as defined in NSF/ANSI/CAN 600, Section 3.3 (previously Annex A, Section A.5). Extrapolated Day 90 contaminant concentrations shall not exceed their respective SPACs for tank products determined in accordance with NSF/ANSI/CAN 600 (previously Annex A). For pipe and fitting products extrapolated Day 90 normalized static contaminant concentrations shall not exceed their respective MCLs, or TACs, and normalized flowing contaminant concentrations shall not exceed their respective SPACs determined in accordance with NSF/ANSI/CAN 600 (previously Annex A).

Table 5.1
Paint and coating system sample preparation

Number of layers in system	Layer	Panel surface area exposed for each layer
one layer	—	entire panel
two layer	primer layer	$^1/_3$
	top layer	$^2/_3$
three layer	primer layer	$^1/_6$
	intermediate layer	$^1/_3$
	top layer	$^1/_2$
four layer	primer layer	$^1/_{12}$
	first intermediate layer	$^1/_6$
	second intermediate layer	$^1/_4$
	top layer	$^1/_2$
NOTE — A layer is one or more coats of the same coating material.		

Table 5.2
Single time point exposure sequence for tank products

Length of exposure	Elapsed time	Sample collection
24 ± 1 h	1 d	discard extractant water and refill
24 ± 1 h	2 d	discard extractant water and refill
48 ± 4 h	4 d	discard extractant water and refill
24 ± 1 h	5 d	extractant water collected for analysis at conclusion of exposure period

NOTE 1 — Sample exposures are sequential: decant and discard extraction water, refill container, and continue exposure.

NOTE 2 — For paint / coating systems intended for immediate return to service, the first four days of the exposure will be eliminated and the water samples shall be collected at the conclusion of the first 24-h period following conditioning.

Table 5.3
Example single time point conditioning schedule for pipes and related product coatings

Condtioning time	Elaspsed time	Comment
24 ± 1 h	1 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	2 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	3 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	4 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
72 ± 1 h	7 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	8 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	9 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	10 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
24 ± 1 h	11 d	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and conditioning is continued.
72 ± 1 h	14 d	Exposure water is decanted and discarded, and conditioning is terminated.

NOTE — For paint / coating systems intended for immediate return to service, the conditioning time is eliminated.

Table 5.4
Single time point exposure protocol for pipe and related product coatings

Exposure time	Comment
24 ± 1h	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and the exposure is continued.
24 ± 1h	Exposure water is decanted and discarded; the exposure vessel or product is refilled with exposure water and the exposure is continued.
16 ± 1h	Exposure water is collected for analysis.
NOTE — For paint / coating systems intended for immediate return to service, the first two days of exposure are eliminated	

Table 5.5
Multiple time point exposure sequence

Length of exposure	Elapsed time	Sample collection
24 ± 1 h	1 d	extractant water collected for analysis
24 ± 1 h	2 d	extractant water collected for analysis
48 ± 4 h	4 d	discard extractant water and refill
24 ± 1 h	5 d	extractant water collected for analysis
6 ± 1 d	11 d	discard extractant water and refill
24 ± 1 h	12 d	extractant water collected for analysis
6 ± 1 d	18 d	discard extractant water and refill
24 ± 1 h	19 d	extractant water collected for analysis
6 ± 1 d	25 d	discard extractant water and refill
24 ± 1 h	26 d	extractant water collected for analysis
6 ± 1 d	32 d	discard extractant water and refill
24 ± 1 h	33 d	extractant water collected for analysis
NOTE — Sample exposures are sequential: decant required volume for analysis when indicated, discard any remaining extraction water, refill container, and continue exposure.		

Table 5.6
Surface area-to-volume ratios for tanks or storage vessels

Nominal capacity (gal)[1]	Surface area (ft^2)[2]	Length / diameter ratio	Surface area-to-volume ratio (in^2/1 L)
5	5.3	5.0	40.4
10	8.4	5.0	32.0
25	15.5	5.0	23.6
50	22.0	3.0	16.8
75	28.9	3.0	14.6
100	35.0	3.0	13.3
200	55.1	2.9	10.5
300	71.3	2.7	9.0
400	85.8	2.6	8.2

Table 5.6
Surface area-to-volume ratios for tanks or storage vessels

Nominal capacity (gal)[1]	Surface area (ft^2)[2]	Length / diameter ratio	Surface area-to-volume ratio (in^2/1 L)
500	99.0	2.5	7.5
600	110	2.3	7.0
700	121	2.2	6.6
800	132	2.1	6.3
900	141	1.9	5.9
1,000	150	1.8	5.7
1,500	196	1.8	5.0
2,000	238	1.8	4.5
3,000	312	1.8	4.0
4,000	378	1.8	3.6
5,000	438	1.8	3.3
6,000	495	1.8	3.1
7,000	548	1.8	3.0
8,000	600	1.8	2.9
9,000	648	1.8	2.7
10,000	696	1.8	2.6
20,000	1,104	1.8	2.1
30,000	1,447	1.8	1.8
40,000	1,753	1.8	1.7
50,000	2,034	1.8	1.6
60,000	2,297	1.8	1.5
70,000	2,545	1.8	1.4
80,000	2,782	1.8	1.32
90,000	3,010	1.8	1.27
100,000	3,228	1.8	1.23
200,000	5,125	1.8	0.97
250,000	5,946	1.8	0.90
500,000	9,439	1.8	0.72
750,000	12,370	1.8	0.63
1,000,000	14,980	1.8	0.57
1,500,000	19,630	1.8	0.50
2,000,000	23,780	1.8	0.45
5,000,000	43,810	1.8	0.33
7,500,000	57,400	1.8	0.29
10,000,000	69,530	1.8	0.26

[1] US gallons.

[2] Surface area calculations include the sides, floor, and roof (ceiling) of a tank.

Table 5.7
Surface area-to-volume ratios for pipe

Nominal pipe diameter (inches)	Surface area-to-volume ratio (in²/1 L)
0.5	488
0.75	326
1	244
1.25	195
1.5	163
1.75	140
2	122
2.25	109
2.5	97.6
2.75	88.8
3	81.4
3.5	69.7
4	61.0
4.5	54.2
5	48.8
5.5	44.4
6	40.7
6.5	37.6
7	34.9
8	30.5
9	27.1
10	24.4
11	22.2
12	20.3
13	18.8
14	17.4
15	16.3
16	15.3
17	14.4
18	13.6
19	12.8
20	12.2
21	11.6
22	11.1
23	10.6
24	10.2
25	9.8
36	6.8
48	5.1

Table 5.7
Surface area-to-volume ratios for pipe

Nominal pipe diameter (inches)	Surface area-to-volume ratio (in^2/1 L)
60	4.1
72	3.4
84	2.9
97	2.5
108	2.3
120	2.0

Table 5.8
Example aggregate field use assumptions

Nominal reservoir capacity (gallons)	NSF/ANSI/CAN 61, Table 5.6 surface area-to-volume ratio (in^2/L)	Calculated field use[1] assumption for mass aggregate per reservoir volume (g/L)
1,000	5.7	18
10,000	2.6	8.2
100,000	1.23	3.9
250,000	0.90	2.8

[1] Based on example concrete with a designed weight of 150 lb/ft^3 and an aggregate content representing 80% of that weight.

6 Joining and sealing materials

6.1 Coverage

This section covers materials that join or seal pipes and related products (e.g., tanks); protective (barrier) materials; and mechanical devices that contact drinking water.

6.2 Definitions

6.2.1 flux: A formulation intended to remove traces of surface oxides, to promote wetting, and to protect surfaces to be soldered or brazed from oxidation during heating.

6.2.2 gaskets and sealing materials: Materials used to fill a hole or joint to prevent leakage.

6.2.3 joining materials: Materials that form a bond when used to put parts together.

6.2.4 lubricant: A substance interposed between two surfaces for the purpose of reducing the friction or wear between them.

6.3 Material and extraction testing requirements

Samples for testing shall be prepared as specified by the manufacturer's written instructions, and exposed as outlined in Annex N-1. Any contaminants extracted shall have normalized concentrations no greater than the limits specified in NSF/ANSI/CAN 600 (previously Annex A).

6.4 Items of special significance

The manufacturer shall supply written information relative to the product's intended end uses and applications.

7 Process media

7.1 Scope

The requirements in this section apply to process media products intended for the reduction of dissolved or suspended materials present in drinking water. The products that are covered include, but are not limited to, process media used in the following processes: ion exchange, adsorption, oxidation, aeration, and filtration.

Requirements in this section for regenerated / reactivated media are intended to apply to regeneration / reactivation companies that provide services for water systems, and are not intended to apply to water systems that produce potable water, regenerate or reactivate their own media, and do not sell, barter, trade or pass their media to another water system. Products and facilities that are specifically covered by the requirements for regenerated / reactivated media include:

— off-site regeneration / reactivation facilities that are independent from the water utility; and
— on-site regeneration facilities that are not owned and controlled by the water utility.

Products and facilities that are specifically exempt from these requirements for regenerated / reactivated media include:

— off-site and on-site regeneration / reactivation facilities that are owned by the water utility and is processing media for only that water utility's use; and

— on-site regeneration by any party where the media is not removed from its original vessel, and the equipment is dedicated and the utility assumes responsibility for the maintenance of all supplies and equipment.

7.2 Definitions

7.2.1 adsorption: The retention of a gas, liquid, solid, or dissolved material onto the surface of a solid.

7.2.2 adsorption media: A process media material upon which a gas, liquid, solid, or dissolved material will be retained.

7.2.3 aeration: The process of bringing water into contact with air in order to expedite the transfer of gas between the two phases.

7.2.4 aeration packing media: Media used in aerators to increase the surface area of the liquid being processed, resulting in increased liquid-to-air contact and improved gas transfer.

7.2.5 commingled media: A mixture of spent media from different spent media sources. Reactivated / regenerated media from a single source that is mixed with virgin media is not considered to be commingled.

7.2.6 filtration: The process of passing a dilute liquid suspension through filter media to reduce the concentration of suspended or colloidal matter.

7.2.7 filtration media: Process media through which a liquid is passed for the purpose of filtration.

7.2.8 ion exchange: A chemical process in which ions are reversibly interchanged between a liquid and a solid.

7.2.9 ion exchange resins: Process media consisting of insoluble polymers having functional groups capable of exchanging ions.

7.2.10 low-density process media: Process media such as diatomaceous earth, perlite, or other media, which have a bulk density of < 500 g/L and are used for filtration purposes.

7.2.11 oxidative media: Process media that chemically facilitate oxidation on the media surface and thereby enhance removal of ions from water.

7.2.12 potable / food grade reactivation / regeneration facility: A reactivation / regeneration facility where all process equipment in contact with spent media is used exclusively to handle media used to treat products designated for human consumption, which does not include pharmaceutical related applications. If the facility is part of a larger media facility that handles nonpotable / nonfood grade media, the potable / food grade reactivation facility shall have separate entry and shall not allow transport between the facility and the nonpotable / nonfood grade portion. Any media classified as hazardous under the Resource Conservation and Recovery Act (RCRA) or by US state or Canadian provincial, or territorial regulations is excluded from reactivation / regeneration in a potable/food grade reactivation facility.

7.2.13 process media: Water insoluble material used to reduce the concentration of dissolved or suspended substances in water through such operations as ion exchange, aeration, adsorption, oxidation, and filtration.

7.2.14 reductive media: Process media that chemically facilitate reduction on the media surface and thereby enhance removal of ions from water.

7.2.15 reactivation: A controlled thermal process operating at a temperature and gas environment sufficient to pyrolyze adsorbates from spent activated carbon and restore adsorption capacity.

7.2.16 regeneration: The periodic restoration of an adsorptive media (excluding activated carbon) back to useable form by employing a chemical regenerant to displace contaminants removed during the treatment process.

7.2.17 spent media: Media that has been in service and is no longer able to produce a desired effluent quality.

7.3 General requirements

7.3.1 Manufacturer use instructions

Media that require conditioning, dosing, use of filtration aids or specific recommended use concentrations, shall contain manufacturer use instructions on the product packaging or other technical literature. For process media products that are dosed (e.g., powdered activated carbon [PAC]), use instructions shall include the maximum dose at which the product can be acceptably used (as determined by evaluation to the requirements of this section).

7.3.2 Product labeling

Process media product containers shall facilitate traceability to the production location and shall, at a minimum, contain the following information:

— manufacturer's name and address;
— production location identifier;
— product identification (product type and, when applicable, trade name);

— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number; and
— when appropriate, special handling, storage, and use instructions.

7.3.2.1 Additional labeling and literature requirements for reactivated / regenerated media

Product packaging, literature shipped with the product, and certification listings for reactivated / regenerated media shall explicitly identify the product as reactivated or regenerated. Labeling of media from commingled sources shall identify the product as commingled.

7.3.3 Additional requirements for reactivated / regenerated media

Only reactivation / regeneration facilities and equipment used to handle spent and reactivated / regenerated media, classified as potable and/or food grade, shall be used. Transportation containers, including storage vessels on vehicles, transfer hoses and other equipment in contact with the media, shall be suitably protected from environmental contamination and suitably cleaned, by evidence of wash-out tickets that are presented to the purchaser or certifying agency on demand.

Samples from each reactivated / regenerated batch of media shall be retained at the facility for a period of at least 2 yr, and be made available for analysis by the purchaser or a certification organization. Retained samples shall contain at least twice the weight in Table 7.2.

Commingled spent media shall be of comparable type and function.

Reactivation / regeneration facilities shall have written verification from each water system on a standardized form provided by the facility that each shipment of spent media to be processed meets the following criteria:

— the spent media shall have been used only for drinking water applications;

— the spent media supplier is a public water system as defined by US EPA regulations (40 CFR § 141.2),[3] or equivalent regulations in Canada or other countries where applicable;

— the spent media shall not be a RCRA hazardous waste as defined by 40 CFR Part 261;[3]

— the spent media is not classified as a hazardous waste in the facility's state, province, or territory; and

— the spent media shall not have knowingly been exposed to:

— activated carbon: polychlorinated biphenyls (PCBs) or dioxins;[13] or

— other media: herbicides, pesticides, polychlorinated biphenyls (PCBs), dioxins or 1,2 dibromo-3 chloropropane (DBCP).

The form shall also contain:

— the name and address of the water system supplying the spent media;

— the identification of the type of media;

— manufacturer or previous regeneration / reactivation facility of the original media;

[13] Criteria are derived from AWWA B605: *Reactivation of Granular Activated Carbon.*

— trade designation of the original media;

— mesh size;

— compliance of the original media with this Standard;

— characterization of all regulated contaminants and other contaminants of concern that the media was exposed to; and

— a signed statement of attestation of the above.

7.3.4 Product line evaluation

When a line of products is manufactured to the same material formulation and contains identical ingredients, product evaluation shall be preferentially conducted on the product form that has the highest surface area-to-volume ratio (smallest particle size). Products of a lower surface area-to-volume ratio (larger particle size) shall be considered to have met the requirements of this section when a higher surface area-to-volume ratio product, belonging to the same line of products and having an identical use, has been demonstrated to meet the requirements of this section.

7.4 Sample requirements

A representative sample of the media shall be reduced to three test samples, each of a sufficient quantity for the extraction procedures described in Section 7.5. The three test samples shall be placed and stored in airtight, moisture-proof, sealed glass containers. If a glass container is inappropriate, containers made from some other inert material recommended by the manufacturer shall be used. Each container shall be clearly labeled with product name, type of sample, manufacturer name, sampling data, production location, lot number, and the name of the individual who collected the sample. One sample shall be used for exposure and analysis; the remaining two samples shall be retained for re-evaluation purposes.

7.5 Extraction procedures

7.5.1 Analytical summary

An analytical summary shall be prepared for each product. The analytical summary shall consist of the formulation-dependent analytes identified in accordance with Section 3.3 and the applicable product-specific minimum test batteries listed in Table 7.1.

7.5.2 Wetting

POE system media receive wetting as specified in Section 7.5.5.4.

Process media that receive conditioning shall be immersed completely (wetted) in reagent water prior to conditioning and exposure. The weight of the sample to be wetted shall be at least equal to the amount of media required to perform the exposure at the specified weight-to-volume ratio (see Tables 7.2 and 7.3).

> NOTE — For example, a media for which 2 L (0.53 gal) of extractant water is required to perform the selected analyses, and the media is exposed at 25 g/L, a minimum of 50 g of media is wetted.

For low-density process media, 0.5 L (0.13 gal) of the process media shall be wetted; the weight of this volume of media shall be measured and recorded prior to wetting.

Following the specified wetting period, the sample shall be completely drained and the water discarded.

7.5.2.1 Granular activated carbon (GAC)

GAC test samples shall be wetted for 16 ± 1 h.

7.5.2.2 Other process media products

All other process media that receive conditioning shall be wetted for 60 ± 10 min.

7.5.3 Conditioning (backwashing)

POE system media receive conditioning as specified in Section 7.5.5.4.

7.5.3.1 Filtration and adsorption media

Wetted filtration or adsorption media (excluding diatomaceous earth, perlite, and PAC products, and other media of < 0.25 mm diameter) shall be placed in a conditioning chamber (a glass column with a minimum inner diameter of 2 in). The amount of media conditioned shall be sufficient to meet or exceed its specific weight per volume ratio (see Table 7.2) and to generate sufficient exposure water to complete the selected analyses. Reagent water shall be directed slowly upward through the conditioning system until the entire amount of media is flooded. The media shall then be backwashed at a flow rate that fluidizes the media or attains sufficient transport velocities to remove extraneous particulate matter; the maximum wetted media expansion rates for various process media products are indicated in Table 7.3. Filtration and adsorption media shall be subjected to the prescribed backwash for 30 ± 2 min.

7.5.3.2 Diatomaceous earth, perlite, PAC, and other process media

Diatomaceous earth, perlite, PAC, and all other process media with functions other than filtration or adsorption shall not be conditioned unless the manufacturer's use instructions stipulate a specific conditioning protocol.

7.5.3.3 Special postconditioning procedures for sand and anthracite products

Upon completion of the backwash, 1% to 1.5% of the sand or anthracite column (by height) shall be scraped away and discarded.

7.5.4 Exposure water

All exposure water that is being used to determine compliance to this Standard shall be prepared fresh daily and stored in a closed container.

7.5.4.1 Adsorption media

Adsorption media shall be exposed in a pH 5 sodium dihydrogen phosphate buffer, prepared by mixing 0.1 M NaH_2PO_4, 0.04 M $MgCl_2$, and reagent water that meets the requirements of Section N-1.9.2.1, at a ratio of 1:1:18, respectively.

7.5.4.2 Nonadsorptive media used in POE devices

Media used in POE devices shall be exposed, based on a formulation review and determination of the most severe condition(s), to one or more appropriate extraction waters as detailed in Section N-1.9 and Table N-1.3 for all other wetted materials.

7.5.4.3 All other process media

All other process media shall be exposed in reagent water, meeting the requirements of Section N-1.9.2.1.

7.5.5 Exposure protocols

Table 7.2 contains the weight per volume ratios for exposure of process media.

7.5.5.1 Adsorption media

7.5.5.1.1 Media of < 0.25 mm in diameter

Immediately after completion of wetting, the media sample shall be exposed in an appropriately sized vessel. The amount of media exposed per volume of exposure water (see Section 7.5.4.1) shall be sufficient to meet or exceed its specific weight per volume ratio according to Table 7.2, and to generate sufficient exposure water to complete the selected analyses. The vessel shall be covered and placed on a magnetic stirrer for 60 ± 5 min. Immediately after the exposure period, the liquid portion of the exposure shall be passed through a Whatman[14] #41 filter and a 0.45 μ filter, and the resulting filtrate shall be collected. The solid portion of the exposed sample remaining on the filter shall be dried and weighed, and used to calculate the evaluation dose.

7.5.5.1.2 Media of ≥ 0.25 mm in diameter

Immediately after completion of conditioning, the media sample shall be exposed in an appropriately sized vessel. The amount of media exposed per volume of exposure water (see Section 7.5.4.1) shall be sufficient to meet or exceed its specific weight per volume ratio in Table 7.2 and to generate sufficient exposure water to complete the selected analyses. The contents of the vessel shall be mixed to ensure that the entire sample is in contact with the exposure water. The vessel shall be sealed with polytetrafluoroethylene (PTFE), and the sample shall be exposed according to the schedule outlined in Table 7.4. The weight-to-volume ratio shall be recorded at the time of exposure and shall represent the evaluation dose.

7.5.5.2 Filtration media, ion exchange resins, synthetic media, and all other process media

Immediately after completion of wetting, or conditioning if applicable, the media sample shall be exposed in an appropriately sized vessel. The amount of media exposed per volume of exposure water (see Section 7.5.4) shall be sufficient to meet or exceed its specific weight per volume ratio in Table 7.2 and to generate sufficient exposure water to complete the selected analyses. The contents of the vessel shall be mixed to ensure that the entire sample is in contact with the exposure water. The vessel shall be sealed with PTFE, and the sample shall be exposed according to the schedule outlined in Table 7.4. The weight-to-volume ratio shall be recorded at the time of exposure and shall represent the evaluation dose.

7.5.5.3 Aeration packing media

Aeration packing media shall be exposed in appropriately sized vessels at a surface area-to-volume ratio greater than or equal to its manufacturer's recommended field surface area-to-volume ratio and in a volume of exposure water sufficient to complete the selected analyses. The vessel shall be sealed with PTFE, and the sample shall be exposed according to the schedule outlined in Table 7.4.

> NOTE — The volume of extraction water can be proportionately increased if an additional amount of media was prepared in order to complete the selected analyses.

7.5.5.4 POE system media

POE system media shall be exposed at a weight to volume ratio greater than or equal to the maximum value recommended by the manufacturer for the ratio of the weight of media (as shipped) per unit void volume (UVV) of a POE system.

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[14] Whatman PLC. 27 Great West Road, Brentford, Middlesex TW8 9BW, UK. <www.whatman.com>

7.5.5.4.1 POE system media shall be placed in a suitable exposure vessel and shall be installed, flushed, and conditioned in accordance with the manufacturer's instructions using the exposure water specified in Section 7.5.4 at an initial inlet static pressure of 340 kPa (50 psig).

7.5.5.4.2 After media are flushed and conditioned in accordance with Section 7.5.5.4.1, the exposure vessel shall be refilled with the exposure water specified in Section 7.5.4 and maintained for 24 h at a temperature of 23 ± 2 °C (73 ± 4 °F). The exposure vessel shall then be flushed with 5 unit volumes, refilled, and maintained for a second 24 h at an ambient temperature of 23 ± 2 °C (73 ± 4 °F). The exposure vessel shall again be flushed with 5 unit volumes, refilled, and maintained for a third period of 24 h at a temperature of 23 ± 2 °C (73 ± 4 °F). At the end of the third 24-h exposure, the extraction water sample shall be collected in accordance with Section 7.5.6. The volume collected from an exposure vessel shall be the UVV of the vessel. If a larger volume is required for analysis, multiple exposure vessels shall be used.

7.5.6 Collection and preservation of extraction water

Immediately after exposure, extraction waters shall be poured into previously prepared sample containers for storage until analysis, as specified in Section N-1.6.

7.6 Analysis

Extraction waters including exposure water samples and exposure water controls and reagent water used for wetting and conditioning shall be analyzed with the methods listed in Section N-1.7.

7.7 Normalization

The concentration of analytes present in the extraction water shall be multiplied by calculated normalization factors to account for differences between the actual laboratory evaluation ratio and the weight per volume ratio in Table 7.2.

7.7.1 Process media with manufacturer's recommended use concentration

The concentration reported by the laboratory shall be normalized with the following equation:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{\text{manufacturer's use concentration(mg/L)}}{\text{laboratory evaluation ratio (mg/L)}}$$

This equation shall be used to normalize media that is sold with use specifications indicating a maximum use concentration (MUC) which can be calculated as follows:

$$\text{MUC} = \frac{\left[\left(1\text{ft}^2\right) \times (\text{bed depth ft}) \times \left(\text{density g/cm}^3\right) \times \left(28{,}320\text{ cm}^3/\text{ft}^3\right) \times (1{,}000\text{ mg/g})\right]}{\left[(\text{minimum flow rate gal/min})(60\text{ min/hr})(1\text{ h})\right]}$$

7.7.2 Process media except for activated carbon media and aeration packing media (without manufacturer's use concentration)

The concentration reported by the laboratory shall be normalized with the following equation:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{\text{weight per volume ratio (mg/L)}}{\text{laboratory evaluation ratio (mg/L)}}$$

This equation shall be used to normalize filtration media, ion exchange resins, synthetic media, and other media to the weight per volume ratios listed in Table 7.2.

7.7.3 Activated carbon media for non-POE system applications (without manufacturer's use concentration)

The concentration reported by the laboratory shall be normalized with the following equation:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{250 \text{ mg/L}}{\text{laboratory evaluation ratio (mg/L)}}$$

Equation 2 shall be used to normalize activated carbon media (granular or powdered) to a weight per volume ratio of 250 mg/L.

7.7.4 Filter precoat media (e.g., perlite, diatomaceous earth) for non-POE system applications

The concentration reported by the laboratory shall be normalized with the following equation:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{\text{manufacturer's use concentration(mg/L)}}{\text{laboratory evaluation ratio (mg/L)}}$$

Equation 3 shall be used to normalize dosed media (except PAC) to the manufacturer's recommended MUC.

7.7.5 Aeration packing media

The concentration reported by the laboratory shall be normalized with the following equation (Equation 4):

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{SA_F}{SA_L} \times \frac{V_F}{V_{F(flowing)}}$$

Where:

SA_L = surface area attained during laboratory exposures;

V_L = volume of exposure water used during laboratory exposures;

SA_F = surface area of the product under field conditions; and

$V_{F(flowing)}$= minimum volume of water to which the product is exposed in the field under flowing conditions during a period of time equivalent to the laboratory evaluation.

NOTE — When manufacturer use instructions indicate that the aeration product can be subjected to static conditions in the field, normalized concentrations shall be modified to reflect the static condition. For the static condition, the $V_{F(flowing)}$ parameter shall be substituted with $V_{F(static)}$, which is equal to the volume of water contacting the media under static conditions in the field.

7.7.6 Process media for POE systems

The concentration reported by the laboratory shall be normalized with the following equation:

$$\text{normalized contaminant concentration} = \text{laboratory contaminant concentration} \times \frac{\text{manufacturer's recommended use concentration (mg/L)}}{\text{laboratory evaluation ratio (mg/L)}}$$

The concentration of contaminants known to be associated with any nonmedia materials or ingredients that could not be dissociated from the media, or materials that would have been released into the effluent of the system in the absence of the physical barrier provided by the media (e.g., the binder used to produce carbon blocks), shall require additional normalization to account for differences between laboratory exposed surface areas and those normally wetted under normal use conditions. This normalization adjustment shall be performed in accordance with Section N-1.8.

NOTE — For instance, carbon block end caps may have more wetted surface area exposed without the carbon block attached to normal system components.

7.8 Evaluation of contaminant concentrations

7.8.1 For process media, normalized contaminant concentrations shall be no greater than their respective SPACs, determined in accordance with NSF/ANSI/CAN 600 (previously Annex A).

7.8.2 For aeration packing media and POE media that require evaluation to the static condition, the normalized static contaminant concentrations shall be no greater than their respective MCLs or TACs, determined in accordance with NSF/ANSI/CAN 600 (previously Annex A).

Table 7.1
Product-specific minimum test batteries for process media products

Product	Primary use	Analytes for virgin media	Analytes for regenerated / reactivated media
activated alumina	adsorption	metals,[1] nickel, and aluminum	see footnote 2
aluminum silicates (e.g., zeolites)	filtration	metals,[1] GC/MS (base neutral acid scans), and radionuclides	see footnote 2
impregnated aluminum silicates	adsorption	metals,[1] GC/MS (base neutral acid scans), and radionuclides	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides
anthracite	filtration	metals,[1] GC/MS (base neutral acid scans)	see footnote 2
diatomaceous earth	filtration	metals[1] and radionuclides	see footnote 2
garnet	filtration	metals,[1] GC/MS (base neutral acid scans)	see footnote 2
granular activated carbon (GAC)	adsorption	metals,[1] GC/MS[4] (base neutral acid scans)	metals,[3] GC/MS[4] (base neutral acid scans), and radionuclides
gravel	filtration	metals,[1] GC/MS (base neutral acid scans)	see footnote 2
ilmenite	filtration	metals,[1] GC/MS (base neutral acid scans), and radionuclides	see footnote 2
ilmenite	adsorption	metals,[1] GC/MS (base neutral acid scans), and radionuclides	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides
ion exchange resins	ion exchange	residual monomer, other formulation dependent	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides, other formulation dependent

Table 7.1
Product-specific minimum test batteries for process media products

impregnated ion exchange resins	adsorption	metals,[1] GC/MS (base neutral acid scans), and radionuclides, residual monomer, other formulation dependent	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides, other formulation dependent
oxidative media (e.g., manganese green sand)	oxidation	metals,[1] GC/MS (base neutral acid scans)	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides
perlite	filtration	metals,[1] GC/MS (base neutral acid scans), and radionuclides	see footnote 2
powdered activated carbon (PAC)	adsorption	metals,[1] GC/MS (base neutral acid scans)	see footnote 2
metal-based media (e.g., granular iron, iron oxide, titanium dioxide, etc.)	adsorption	metals,[1] GC/MS (base neutral acid scans), and radionuclides	metals,[3] GC/MS (base neutral acid scans), VOCs and radionuclides
sand	filtration	metals,[1] GC/MS (base neutral acid scans)	see footnote 2
synthetic media	aeration, filtration	formulation dependent	see footnote 2

[1] Metals: antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, thallium.

[2] These products are not typically regenerated or reactivated at remote locations. Therefore a minimum test battery has not been established. A full formulation review would be required for these products if they are evaluated under this Standard.

[3] Metals (for reactivated and regenerated media): antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, thallium, aluminum, manganese, nickel, silver, tin, vanadium, zinc.

[4] GC/MS (base neutral acid scans) required if documentation identifying process controls intended to ensure complete activation/reactivation is not available.

Table 7.2
Process media exposure weight per volume ratios

Media type	Weight per volume[1]
media with manufacturer's use instructions	≥ manufacturer's recommended use concentration[2]
adsorption media:	—
activated alumina	625 ± 25 g/L
GAC and PAC	25 ± 5 g/L
anthracite and gravel:[3]	—
≤ 3/8-in diameter particles	625 ± 25 g/L
> 3/8-in diameter particles	1250 ± 25 g/L
filter precoat media (e.g., perlite, diatomaceous earth)	10 times the manufacturer's recommended use concentration
filtration media other than anthracite or gravel	625 ± 25 g/L
ion exchange resins	625 ± 25 g/L
synthetic media	625 ± 25 g/L
point-of-entry (POE) system media	manufacturer's recommended use concentration[4]

[1] Weight per volume of the product on an "as shipped" basis.

[2] Media with manufacturer's recommended use concentration shall be exposed at this use concentration or higher.

[3] For the size range specified, not more than 8% by weight shall be either finer than or coarser than the designated size limit (AWWA B100-96).

[4] For POE application media, this shall be the maximum value recommended by the manufacturer of the ratio of the weight of media[1] per 'unit void volume' of a POE system.

Table 7.3
Maximum conditioning expansion rates for filtration and adsorption media

Media type	Maximum laboratory expansion rate of wetted media (by height) (%)
activated alumina	25 ± 5%
aluminum silicates (zeolites)	25 ± 5%
anthracite	25 ± 5%
garnet	30 ± 5%
granular activated carbon (GAC)	30 ± 5%
gravel	10 ± 5%
ilmenite	30 ± 5%
manganese greensand	30 ± 5%
sands	20 ± 5%

Table 7.4
Exposure schedule for process media of ≥ 0.25 mm in diameter

Time	Temperature	Comment
60 ± 5 min	23 ± 2 °C (73 ± 4 °F)	Exposure water is drained / decanted and discarded; the exposure vessel is refilled and exposure is continued.
60 ± 5 min	23 ± 2 °C (73 ± 4 °F)	Exposure water is drained / decanted and discarded; the exposure vessel is refilled and exposure is continued.
60 ± 5 min	23 ± 2 °C (73 ± 4 °F)	Exposure water is collected and filtered for analyses.

8 Mechanical devices

8.1 Coverage

This section covers devices, components, and materials used therein, that are used in treatment / transmission / distribution systems, and are in contact with drinking water intended for human ingestion, drinking water treatment chemicals, or both. Examples are listed in Table 8.1. POU drinking water treatment devices are not covered by the requirements in this section.

8.2 Definitions

8.2.1 cold water application: A product application that is intended to result in continuous exposure to water of ambient temperature. Products are tested for an end use temperature of 23 ± 2 °C (73 ± 4 °F).

8.2.2 commercial hot water application: A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end use temperature of 82 ± 2 °C (180 ± 4 °F).

8.2.3 domestic hot water application: A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end use temperature of 60 ± 2 °C (140 ± 4 °F).

8.2.4 in-line device: A device (used to measure or control the flow of water) installed on a service line or building distribution system downstream of the water main and upstream of endpoint devices.

8.2.5 manifold: A device with an inlet and four or more outlets used to direct water to multiple fixtures or end use devices within a residence. Manifolds are characterized by the number of ports, which are outlets perpendicular to the manifold trunk or body.

8.2.6 building distribution system: A continuous system of piping and related fittings, beginning at the tap on the main, that is intended to convey potable water to points of usage.

8.3 Device, component, or material requirements

8.3.1 General

Devices, components, or materials shall be considered to have met the requirements of this section if at least one of the following conditions is met:

— the devices, components, or materials covered under this section are tested and evaluated according to the procedures specified in Sections N-1.4 and N-1.8; or

— the devices, components, or materials meet the requirements of Section 8.3.2.

When all components or materials, or both, of a device meet the requirements of this section, the device shall also meet the requirements of this section. When all materials of a component meet the requirements of this section, the component shall also meet the requirements of this section.

8.3.2 Evaluation of devices, components, or materials tested to other sections of this Standard

Devices, components, or materials that have been tested to other sections of the Standard shall meet the following criteria:

— they shall be made of the same alloy(s), composition(s), or formula(s);

— they shall have undergone analogous manufacturing processes;

— they shall have been tested at a temperature that meets or exceeds the required exposure temperature in Section N-1.4;

— they shall have been conditioned for a period of time not more than 14 d, and exposed for a period of time not less than 12 h for in-line devices or 24 h for other mechanical devices; and

— the concentration(s) of the extracted contaminant(s) shall be normalized to the requirements of Section N-1.8.

8.3.3 Metallic contaminants

When a device or component is qualified through the separate testing of two or more components, the normalized concentrations for each specific metallic contaminant from individual components shall be summed. The total of the normalized metallic contaminant concentrations shall meet the requirements of Section N-1.8.

8.4 In-line devices, components, and materials

Samples for the testing of in-line devices, components, and materials (see Section 8.1) shall be selected according to the requirements of Sections N-1.2.3 and N-1.4.1. Extraction waters shall be selected according to Section N-1.2.5. In-line product samples shall be conditioned as indicated in Section N-1.4.3. After conditioning, the samples shall be exposed as indicated in Section N-1.4.4.1 and Table N-1.8. Normalization shall be as specified in Sections N-1.8.3 and N-1.8.4, as applicable.

8.4.1 Brass or bronze containing in-line devices

The evaluation of brass or bronze containing in-line devices for contaminants other than lead shall require exposure of at least one sample in accordance with Section 8.4.

The evaluation of brass or bronze containing in-line devices for lead under the pH 8 conditions shall be exposed in at least triplicate (more if specified by the manufacturer) if the test representative holds ≤ 2 L and has a dry weight ≤ 15 kg (33 lb). If specified by the manufacturer, the test representative that holds more than 2 L, or has a dry weight in excess of 15 kg (33 lb) may also be exposed in a quantity greater than 1.

The extraction waters from triplicate exposures shall be either combined to one sample for all contaminant analysis or shall be analyzed individually and results averaged. If more than three samples are exposed, the waters from each sample shall be analyzed individually for lead and results averaged. Averaging of results shall be performed prior to normalization. When one or more of the individual results is found to be nondetectable, the reporting limit shall be used to represent the unit results when averaging.

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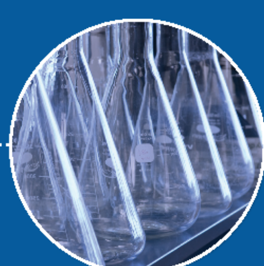
Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs, and Other Recreational Water Facilities



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At the time of this publication, examples of programs and processes were provided for general guidance. This information is given for the convenience of users of this standard and does not constitute an endorsement by NSF International. Equivalent programs and processes may be used.

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[1] The information contained in this Disclaimer is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Disclaimer may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

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Contents

Foreword[2]

The purpose of this Standard is to establish minimum materials, design and construction, and performance requirements for components, products, equipment and systems, related to public and residential recreational water facility operation.

If a value for measurement is followed by a value in other units in parenthesis, the second value may be only approximate. The first stated value is the requirement.

All references to gallons (gal) are in US gallons.

This Standard is designated as a National Standard of Canada (NSC) in compliance with requirements and guidance set out by the Standards Council of Canada (SCC).

This edition of the Standard contains the following revisions:

Issue 139

This revision updates language related to turbidity reduction testing in Section N-2.5. It also added a definition for "*high capacity cartridge filter.*"

Issue 141

This revision modifies language relating to low pressure UV lamp testing in Section 15.8.1.

Issue 160

This revision updates language relating to pump flow rate outputs in Section 7.

Issue 163

This revision adds language regarding crypto reduction claims for filters in Sections 6.1 and N-2.9.

Issue 164

This revision clarifies the scope for pool chemical evaluation in the newly created Section 27.

Issue 165

This revision moves language from Annex N-12 to the newly created Section 27.

Issue 167

This revision updates language regarding piping materials in Section 4.5.

Issue 174

This revision corrects typos from a previous ballot in the chemical evaluation tables in the newly created Section 27.

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This Standard was developed by the NSF Joint Committee on Recreational Water Facilities using the consensus process described by the American National Standards Institute's *Essential Requirements* and the Standards Council of Canada's *Requirements and Guidance*. At the time of approval, the Joint Committees consisted of 10 public health / regulatory, 10 industry, and 10 user representatives.

The Standard and the accompanying text are intended for voluntary use by certifying organizations, regulatory agencies, and/or manufacturers as a basis of providing assurances that adequate health protection exists for covered products.

Suggestions for improvement of this Standard are welcome. This Standard is maintained on a continuous maintenance schedule and can be opened for comment at any time. Comments should be sent to: Chair, Joint Committee on Recreational Water Facilities at standards@nsf.org, or c/o NSF International, Standards Department, PO Box 130140, Ann Arbor, Michigan 48113-0140, USA.

SCC Foreword[3]

A National Standard of Canada is a standard developed by a Standards Council of Canada (SCC) accredited standards development organization, in compliance with requirements and guidance set out by the SCC. More information on National Standards of Canada can be found at <www.scc.ca>.

SCC is a Crown corporation within the portfolio of Innovation, Science and Economic Development (ISED) Canada. With the goal of enhancing Canada's economic competitiveness and social well-being, SCC leads and facilitates the development and use of national and international standards. SCC also coordinates Canadian participation in standards development, and identifies strategies to advance Canadian standardization efforts.

Accreditation services are provided by SCC to various customers, including product certifiers, testing laboratories, and standards development organizations. A list of SCC programs and accredited bodies is publicly available at <www.scc.ca>.

[3] The information contained in this Disclaimer is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Disclaimer may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

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NSF/ANSI/CAN Standard
for Recreational Water Facilities –

Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs, and other Recreational Water Facilities

Evaluation criteria for materials, components, products, equipment, and systems for use at recreational water facilities

1 General

1.1 Scope

This Standard covers materials, chemicals, components, products, equipment and systems related to public and residential recreational water facility operation.

1.2 Variations in design and operation

A component varying in design or operation may qualify under this Standard. Appropriate tests and investigations shall indicate that the component performs as well as components conforming to this Standard. Such components shall meet the requirements for materials, finishes, and construction in this Standard.

1.3 Alternate materials

If specific materials are mentioned, other materials equally satisfactory from the standpoint of public health may be permitted.

1.4 Standard review

A complete review of this Standard shall be conducted at least every five years. These reviews shall be conducted by representatives from the industry, public health, and user groups, or agencies of the NSF Joint Committee on Recreational Water Facilities.

2 Normative references

The following documents contain provisions that, through reference in this text, constitute provisions of this Standard. At the time of publication, the indicated editions were valid. All standards are subject to revision and parties are encouraged to investigate the possibility of applying the recent editions of the standards indicated below. The most recent published edition of the document shall be used for undated references.

21 CFR Chapter 1, *Code of Federal Regulations*[4]

21 CFR Part 58, Subchapter A, *Code of Federal Regulations*[4]

[4] US Government Publishing Office. 732 North Capitol Street NW, Washington, DC 20401. <www.govinfo.gov/app/collection/cfr>

40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants*[4]

40 CFR Part 141, *National Primary Drinking Water Regulations*[4]

40 CFR Part 143, *National Secondary Drinking Water Regulations*[4]

ANSI/APSP/ICC-11, *Standard for Water Quality in Public Pools and Spas*[5]

ANSI/APSP-16 – 2011, *Standard Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs*[5]

ANSI/ASME A112.3.1 – 2007, *Stainless Steel Drainage Systems for Sanitary DWV, Storm, and Vacuum Applications Above and Below Ground*[6]

ANSI/ASME A112.6.3 – 2016 (R2007), *Floor and Trench Drains*[6]

ANSI/ASME A112.6.4 – 2003 (R2012), *Roof, Deck and Balcony Drains*[6]

ANSI/ASME A112.19.17 – 2010, *Safety Vacuum Release Systems (SVRS) for Residential & Commercial Swimming Pool, Spa, Hot Tub, Wading Pool Suction System*[6]

ANSI/ASME B40.100 – 2005, *Pressure Gauge and Gauge Attachments*[6]

APHA/AWWA/WEF, *Standard Methods for the Examination of Water and Wastewater*, 23rd edition (hereinafter referred to as *Standard Methods*)[7]

AS 4586 – 2013, *Slip resistance classification of new pedestrian surface material*[8]

ASME Boiler and Pressure Vessel Code, 2017[6]

ASTM C136/C136M – 2014, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, 2004*[9]

ASTM D1894 – 2014, *Standard Test Method for Static and Kinetic Coefficients of Plastic Film and Sheeting*[9]

ASTM D2464 – 2013, *Standard Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*[9]

ASTM D2466 – 2015, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40*[9]

ASTM D2467 – 2006, *Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80*[9]

ASTM, D3739 – 2010, *Standard Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis*[9]

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[5] Pool & Hot Tub Alliance (formerly the Association of Pool & Spa Professionals / National Swimming Pool Foundation). 2111 Eisenhower Avenue, Suite 500, Alexandria, VA 22314. <www.phta.org>

[6] The American Society of Mechanical Engineers. Two Park Avenue, New York, NY 10016. <www.asme.org>

[7] American Public Health Association, American Water Works Association, and Water Environment Federation. *Standard Methods for the Examination of Water and Wastewater*. <www.standardmethods.org>

[8] Standards Australia. Level 10, The Exchange Centre, 20 Bridge Street, Sydney NSW 2000, Australia. <www.standards.org.au>

[9] ASTM International. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. <www.astm.org>

ASTM E11 – 2009, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, 2009*[9]

ASTM E1153 – 2014, *Standard Test Method For Efficacy Of Sanitizers Recommended For Inanimate, Hard, Nonporous, Non-Food Contact Surfaces*[9]

ASTM F1346-91 – 2003, *Standard Performance Specification for Safety Covers and Labeling Requirements for All Covers for Swimming Pools, Spas and Hot Tubs*[9]

ASTM F2049-11 (2017), *Standard Safety Performance Specification for Fences/Barriers for Public, Commercial, and Multi-Family Residential Use Outdoor Play Areas*[9]

ASTM F2208 – 2014, *Standard Safety Specification for Residential Pool Alarms*[9]

ASTM F2387 – 2004, *Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS) for Swimming Pools, Spas and Hot Tub*[9]

ASTM F2409-10 (2016), *Standard Guide for Fences for Non-Residential Outdoor Swimming Pools, Hot Tubs, and Spas*[9]

ASTM F2699-08 (2013), *Standard Guide for Fences for Commercial and Public Outdoor Water Spray/Play Areas*[9]

ASTM G154, *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*[9]

CEC-400-2016-002 Title 20, *California Energy Commission 2009 Appliance Efficiency Regulations*[10]

CSA B45.5/IAPMO Z124.1.2 – 2005 2011, Plastic Bathtub and Shower Units[11]

DIN EN-1177, *Impact attenuating playground surfacing – Methods of test for determination of impact attenuation*[12]

DVGW 2006, *UV disinfection devices for drinking water supply – requirements and testing*[13]

DVGW W294-1, -2, and -3[13]

IAPMO/ANSI Z124.7-2013, *Prefabricated Plastic Spa Shells*[14]

IAPMO/ANSI Z124.1.2-2005, *Plastic Bathtub and Shower Units*[14]

IAPMO/ANSI Z1033-2013c, *Flexible PVC Hose for Pools, Hot Tubs, Spa, and Jetted Bathtubs*[14]

IAPMO/ANSI Z1033-2015, *Flexible PVC Hoses and Tubing for Pools, Hot Tubs, Spas, and Jetted Bathtubs*[14]

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[10] California Energy Commission. 1516 Ninth Street, Sacramento, CA 95814. <www.energy.ca.gov>

[11] CSA Group. 178 Rexdale Boulevard, Toronto, ON M9W 1R3, Canada. <www.csa.ca>

[12] European Standards. Krimicka 134, 318 13 Pilsen, Czech Republic. <www.en-standard.eu>

[13] Deutscher Verein des Gas- und Wasserfaches. Josef-Wirmer-Straße 1-3, 53123 Bonn, Germany. <www.dvgw.de>

[14] International Association of Plumbing and Mechanical Officials. 4755 E Philadelphia St., Ontario, CA 91761. <www.iapmo.org>

ISO/TS 15883-5, *Washer-disinfectors – Part 5: Test soils and methods for demonstrating cleaning efficacy Annex H*[15]

Model Aquatic Health Code 2018[16]

NFPA 70, Article 30 – 2017, *National Electrical Code* (NEC)[17]

NSF/ANSI 14, *Plastics Piping System Components and Related Materials*

NSF/ANSI 42, *Drinking Water Treatment Units – Aesthetic Effects*

NSF/ANSI 51, *Food Equipment Materials*

NSF/ANSI/CAN 60, *Drinking Water Treatment Chemicals – Health Effects*

NSF/ANSI/CAN 61, *Drinking Water System Components – Health Effects*

NSF/EPA ETV, *Generic Protocol for Development of Test / Quality Assurance Plans for Ultraviolet (UV) Reactors*

ÖNORM M 5873-1, *Plants for the disinfection of water using ultraviolet radiation - Requirements and testing – Low pressure mercury lamp plants*, 2001[8]

SAE Steel Numbering System[18]

UL 1081-2016, 7th edition, *Standard for Swimming Pool Pumps, Filters, and Chlorinators*[19]

UL 1261-2016, 6th edition, *Standard for Electric Water Heaters for Pools and Tubs*[19]

UL 1563-2009, *Standard for Electric Spas, Equipment Assemblies, and Associated Equipment*[19]

UL 2017-2011, *Standard for General-Purpose Signaling Devices and Systems*[19]

US EPA, *Methods for the Determination of Inorganic Substances in Environmental Samples*, 1993[20]

US EPA, *Methods for the Determination of Organic Compounds in Drinking Water Supplement*, 1990[20]

US EPA-600/4-79-020, *Methods for the Chemical Analysis of Water and Wastes*, March 1983[20]

US EPA *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*, November 2006[20]

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[15] International Organization for Standardization. Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland. <www.iso.org>

[16] Centers for Disease Control and Prevention, 2500 Century Parkway, Mailstop E-78, Atlanta, GA 30333. <www.cdc.gov>

[17] National Fire Protection Association. 1 Batterymarch Park, Quincy, MA 02169-7471. <www.nfpa.org>

[18] SAE International. 400 Commonwealth Drive, Warrendale, PA 15096. <www.sae.org>

[19] UL LLC. 33 Pfingsten Road, Northbrook, IL 60062. <www.ul.com>

[20] Superintendent of Documents, US Government Printing Office. Washington, DC 20402<www.gpo.gov>

3 Definitions

3.1 accessible: Fabricated to be exposed for cleaning and inspection using simple tools (screwdriver, pliers, open-end wrench, etc.).

3.2 accuracy: The nearness of a measurement to the accepted or true value.[21] The accuracy is expressed as a range, about the true value, in which a measurement occurs (i.e., ± 0.5 ppm). It can also be expressed as the percent recovery of a known amount of analyte in a determination of the analyte (i.e., 103.5%).

3.3 agitation: Mechanical or manual movement to dislodge filter aid and dirt from the filter element.

3.4 air assist backwash: A compression of air in the filter effluent chamber using an air compressor or water pressure from the recirculating pump. When released, it rapidly decompresses and forces water in the filter tank through the elements in reverse direction to dislodge the filter aid and accumulated dirt and carry them to waste.

3.5 alternate sand-type media: Granular material(s) specified to be used instead of sand in a sand-type filter.

3.6 amps: The current, in amperes, under the motor data plate horsepower at rated volts.

3.7 analyte: Parameter that is a subject of the water analysis, such as pH or free chlorine.

3.8 automated controller: A system of at least one chemical probe, a controller, and auxiliary or integrated component, that senses the level of one or more swimming pool or spa / hot tub water parameters and provides a signal to other equipment to maintain the parameter(s) within a user-established range.

3.9 backwash: Flow of water through filter element(s) or media in a reverse direction to dislodge accumulated dirt or filter aid and remove them from the filter tank.

3.10 backwash cycle: Time required to thoroughly backwash the filter system.

3.11 backwash rate: Rate of application of water through a filter during backwash expressed in gal/min/ft^2 (L/min/m^2) of effective filter area.

3.12 body feed: Continuous addition of controlled amounts of filter aid during operation of a diatomite-type filter to maintain a permeable filter cake. If added as a slurry, this may be referred to as slurry feed.

3.13 bromine: A chemical that works as a sanitizer or disinfectant to kill bacteria and algae in pool and spa water.

3.14 cartridge: A depth- or surface-type filter component with fixed dimensions and designed to remove suspended particles from water flowing through the unit.

3.15 chemical feed rate indicator: Mechanism that produces reproducible results expressed in units of weight or volume of chemical per unit of time or per unit of volume of water. The mechanism may be a direct reading instrument or may require the use of a reference chart.

3.16 chemical feeder output rate: Weight or volume of active ingredients delivered by a chemical feeder, expressed in units of time.

3.17 chemical probe (sensor): Component of an automated controller that monitors a given control parameter (pH, ORP, free Cl_2, etc.).

[21] Skoog D.A., West D.M., *Fundamentals of Analytical Chemistry, 2nd* ed., Holt Rinehart and Winston, Inc. 1969, p.26

3.18 chlorine: A chemical that works as a sanitizer or disinfectant in pool and spa water to kill bacteria and algae and oxidizes ammonia and nitrogen compounds that can enter the pool / spa from swimmer body wastes and other sources.

3.19 cleaning: Physical removal of soiling materials.

3.20 combined chlorine: Chlorine that has combined with ammonia, nitrogen, or other organic compounds.

3.21 comply (complies, compliance): Meeting the requirements of the standard, which includes standards incorporated by reference in the text.

3.22 contaminant: Undesirable organic and inorganic, soluble and insoluble substances in water including microbiological organisms.

3.23 controller: Component of an automated controller that receives signals from chemical probes or sensors and sends an output signal to actuate equipment.

3.24 coolant flow rate: The flow rate of the coolant used to remove heat from the reaction chamber(s) of the ozone generator.

NOTE — The critical factor for heat removal is the mass flow rate (kg/h) of the coolant. The mass flow rate of the coolant is equal to the volumetric flow rate (m^3/h, ft^3/h) of the coolant times the density (kg/m^3, lb/ft^3) of the coolant.

For liquid cooled systems the density of the coolant (liquid) is virtually independent of temperature and pressure and can be specified as the volumetric flow rate of the cooling liquid (m^3/h, ft^3/h, GPM, LPM).

For gas cooled systems the density (and therefore the mass flow rate) of the coolant gas is dependent on temperature and pressure. For this Standard, the pressure and temperature ranges are small. The volumetric flow rate (m^3/h, ft^3/h, LPM, ft^3/m, CFM) of the coolant shall be specified. As a practical approximation of the mass flow rate.

3.25 corrosion resistant: Capable of maintaining original surface characteristics under prolonged contact with the use environment.

3.26 cover mounting ring: Fitting containing a recess located in the deck to receive the cover of a surface skimmer.

3.27 dead weight: Mass expressed typically in pounds (kilograms) per square foot (meter) to assist in assessment of use relative to floor strength and loading requirements. The intrinsic, invariable weight of a structure such as a spa, including the water and bather weight.

3.28 depth-type cartridge: Filter cartridge with media relying on penetration of particles into the media for removal and providing adequate holding capacity of such particles.

3.29 dew point (dew-point temperature): The temperature saturation (assuming air pressure and moisture content are constant). For corona discharge ozone generation greater than 2 g/h, the minimum dew point is -76 °F (-60 °C). For systems less than 2 g/h, the minimum dew point is -40 °F (-40 °C).

NOTE — For systems less than 2 g/h, the amount of nitric acid produced is negligible.

3.30 diatomite filter element: Device in a filter tank to trap solids and convey water to a manifold, collection header, pipe, or similar conduit. Filter elements usually consist of a septum and septum support.

3.31 disinfection: Killing of pathogenic agents by chemical or physical means directly applied.

3.32 easily cleanable: Manufactured so that dirt and debris and other soiling material may be removed by manual cleaning methods.

3.33 effective size: The size opening that will just pass 10% (by dry weight) of a representative sample of the filter material

3.34 effluent: The treated stream emerging from a unit, system, or process.

3.35 electronic water quality test device: A device that requires power supply (such as line current or a battery) to yield a result.

3.36 electrolytic chlorinator: A device that converts dissolved chloride salt (sodium chloride) into chlorine and its reaction products.

3.37 equalizer line: An automatically operating line from below the pool surface to the body of a skimmer, designed to prevent air being drawn into the filter when the water level drops below the skimmer inlet.

3.38 feed gas: The gas (ambient air, dry air, or oxygen) delivered to the inlet side of the ozone generator. The required quality and feed gas flow rate is determined by the manufacturer.

3.39 feed gas flow rate: The flow rate of the feed gas through the reaction chamber(s) of the ozone generator.

NOTE — The critical factor for the reaction is the mass flow rate (kg/h) of the feed gas. The mass flow rate is the volumetric flow rate (m^3/h, ft^3/h) of the feed gas times the density (kg/m^3, lb/ft^3) of the feed gas.

The density of a gas is dependent on the temperature and pressure. Because of the continuous variability of the parameters affecting density and volumetric flow rate in an ozone generator, there is no practical method to determine the true mass flow rate of the feed gas. For this Standard, due to the small range of pressure and temperature, the volumetric flow rate is specified as an approximation of the mass flow rate.

For pressurized systems, the manufacturer specifies the volumetric flow rate and the gauge pressure of the feed gas at the inlet to the ozone generator.

3.40 filled weight: Mass expressed typically in pounds (kilograms) to explain the total weight of a product when operating at capacity. Filled weight of a product or structure such as a spa, including the water and bather weight.

3.41 filter aid: Finely divided medium (diatomaceous earth, processed perlite, etc.) used to coat a septum of a diatomite-type filter.

3.42 filter design flow rate: Flow rate of a filter determined by multiplying the total effective filter area by the allowable filtration rate, expressed in GPM (LPM).

3.43 filter media: The material that separates particulate matter from the water passing through.

3.44 filtration cycle (filter run): Operating time between filter cleanings.

3.45 filter, cartridge-type: A pressure or vacuum-type device designed to filter water through one or more cartridges.

3.46 filter, diatomite-type: A pressure or vacuum-type device designed to filter water through a thin layer of filter aid.

3.47 filter, high permeability-type: A pressure- or vacuum-type device designed to filter water through a high permeability element.

3.48 filter, sand-type: A device designed to filter water through sand or an alternate sand-type media. The filtration process may be done under pressure, under vacuum, or by gravity.

3.49 filtration rate: Flow rate of water through a filter expressed in gal/min/ft^2 (L/min/m^2) of effective filter area.

3.50 fitting: A piping component used to join, terminate, or provide changes of direction in a piping system (NSF/ANSI 14). These include, but are not limited to, these types: water inlet, water return, surface, deck drain, overflow, perimeter grating, water circulation, and treatment.

3.51 flow balance valve: Device to regulate effluent from the skimmer housing of each of two or more surface skimmers.

3.52 flow cell: A closed container with ports for the installation of one or more chemical probes, inlet and outlet ports for water and typically a sample port. A flow cell provides for offline installation of the chemical probes and a consistent flow of the water to be sampled.

3.53 flow meter (flow metering device): A device that measures the rate of flow of a substance through a conduit.

3.54 freeboard: Clear vertical distance in a sand-type filter between top of filter media and lowest outlet of upper distribution system.

3.55 free bromine: Bromine that has not combined with ammonia, nitrogen, or other organic compounds.

3.56 free chlorine: Chlorine that has not combined with ammonia, nitrogen, or other organic compounds.

3.57 friction loss: Pressure drop, expressed in feet (meters) of water or psi (kPa), caused by liquid flowing through the piping and fittings. (Friction loss tables may be used to estimate the actual friction loss in a system.)

3.58 head loss: Total pressure drop in psi (kPa) or feet (meters) of water (head) between inlet and outlet of a component.

3.59 high capacity cartridge filter: A cartridge-type filter designed for use at filtration rates ≤ 0.375 gpm/ft^2.

3.60 high permeability element: Mechanically interlocked, nonwoven filter material designed to remove suspended solids.

3.61 high rate: Design filtration rate greater than 5 gal/min/ft^2 (203 L/min/m^2) for public and residential pools, spas, or hot tubs.

3.62 hydrogen peroxide: A compound consisting of two atoms of hydrogen and two atoms of oxygen (H_2O_2) usually supplied in an aqueous solution.

3.63 indoor use: A product that is not designed, tested or certified for use outside or to be exposed to the elements and weather.

3.64 influent: The water stream entering a unit, system, or process.

3.65 integral: Part of the device that cannot be removed without compromising the device's function or destroying the physical integrity of the unit.

3.66 interactive waterplay venue: Any indoor or outdoor recreational water facility that includes sprayed, jetted, or other water sources contacting bathers and not necessarily incorporating standing or captured water as part of the bather activity area. These aquatic venues are also known as, but not limited to, splash pads, spray pads, wet decks.

3.67 Level 1 (L1): The highest accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy testing.

3.68 Level 2 (L2): The intermediate accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy Testing.

3.69 Level 3 (L3): The lowest accuracy and repeatability performance level of a water testing device. Refer to Section N-11.6 Accuracy Testing.

3.70 manufactured manifold: Any combination of pipe and fittings provided by the valve manufacturer to form valve assembly using two or more valves.

3.71 maximum design head loss (filters): The maximum head loss recommended by the manufacturer for a clean filter at a specific flow rate.

3.72 maximum load amps: The maximum current, in amperes, under the service factor horsepower at -10% of the rated voltage.

3.73 mg/L or ppm: An abbreviation for milligrams per liter or parts per million, which is a concentration measurement for sanitizers and other chemical parameters such as alkalinity, calcium hardness, iron, copper, etc.

3.74 multiport valve: A device used to direct flow to, through, and from a swimming pool, spa, or hot tub filter, and usually replaces conventional valves and face piping on a filter.

3.75 net positive suction head (NPSH): The head available at the entrance or eye of an impeller to move and accelerate water entering the eye. This is the gauge pressure at the suction flange of pump plus velocity head.[22]

3.76 non-self-contained spa (hot tub / swim spa / therapy spa / resistance system): A factory-built spa in which the water heating and circulating equipment is not an integral part of the product. Non-self-contained spas may employ separate components such as individual filter, pump, heater and controls, or they may employ assembled combinations of various components.

3.77 nonelectric water quality test device: A device that does not require a power supply (such as line current or a battery) to yield a result.

3.78 NPSH available (NPSHA): Function of the system in which the pump operates. Available NPSH shall be at least equal to the required NPSH at the desired flow rate.

3.79 NPSH required (NPSHR): Value supplied by the pump manufacturer, based on the pump design.

3.80 operating range: The range for a parameter within which a water quality testing device (WQTD) provides acceptable accuracy as specified by the manufacturer. The operating range determines the test solutions used to evaluate the WQTD. Examples of operating ranges typical for WQTD's are water temperature 70 to 102 °F (20 to 50 °C), pH 6.8 to 8.2, free and combined chlorine 0 to 5 ppm or 0 to 10 ppm.

[22] See Section 7.6 for pump performance curve requirements.

3.81 operating water level: Level at which the water shall be maintained to enable proper water circulation and skimming.

3.82 outside use: A product that is designed, tested or certified for use outside or to be exposed to the elements and weather.

3.83 oxidation reduction potential (ORP): The potential in millivolts required to transfer electrons from the oxidant to the reductant, used as a qualitative measure of the state of oxidation in water treatment. The more positive the value, the more oxidizing the solution. ORP provides a qualitative indication of the activity of the sanitizer but is not a measure of disinfectant concentration.

3.84 ozone: A gas consisting of three atoms of oxygen (O_3).

3.85 ozone concentration: The amount of ozone in the gas stream leaving the generator. Concentration may be reported by any of the following: weight percent, g/m^3, volume percent, ppm by weight, ppm by volume, and the milligrams of ozone per liter of gas produced. Under this Standard, concentration will be reported by weight percent and g/m^3.

3.86 ozone generator: A device that when supplied with an oxygen containing gas and power, produces an ozone-containing gas. Said ozone generator includes any controls, transformers and frequency generators required to convert a standard electrical supply (as specified) to the electrical characteristics required to operate the generator cell properly.

3.87 ozone generator cell pressure: The gauge pressure of the feed gas in the reaction chamber(s).

3.88 ozone output rate: The mass of ozone produced by an ozone generator in weight per unit time (g/h, lb/h). Output rate is the mass of ozone per volume of product gas (g/m^3, lb/ft^3) multiplied by the feed gas flow rate (m^3/h, LPM, ft^3/h, CFM).

3.89 ozone short cycle or batch system: Systems that are not designed to operate for more than 5 min at a time.

3.90 packaged ozone system: An ozone generator packaged with a gas preparation system, typically on a single skid or otherwise a single unit.

3.91 pH: A numerical value expressing acidity or alkalinity, where 7 is neutral, higher values are more alkaline (basic) and lower values are more acidic. The numerical value is the negative base 10 log of the hydrogen ion concentration.

3.92 pool water: Water with a specific conductivity as shown below:

— Type 1 has a conductivity less than or equal to an aqueous sodium chloride solution of 1,500 ppm;

— Type 2 has a conductivity greater than Type 1 and less than or equal to an aqueous sodium chloride solution of 6000 ppm; and

— Type 3 water has a conductivity greater than Type 2.

NOTE — TDS are to include any total dissolved solids that exist within makeup up or initial fill water supply.

3.93 positive displacement: Mechanical displacement of fluid.

3.94 power: Brake horsepower input required to operate pumps.

3.95 precision: The numerical agreement between two or more measurements using the same test equipment.[23] The precision can be reported as the range for a measurement (difference between the minimum and maximum results). It can also be reported as the standard deviation or the relative standard deviation. It is a measure of how close together the measurements are, not how close they are to the correct or true value.

3.96 precoat: Layer of filter aid on septum of a diatomite-type filter at beginning of a filter cycle.

3.97 process equipment: Equipment used for on-site generation or application of ozone, ultraviolet light / hydrogen peroxide, copper and silver ions, or chlorine.

3.98 public spa (hot tub / swim spa / therapy spa resistance system): A spa other than a permanent residential spa or portable residential spa which is intended to be used for bathing and is operated by an owner, licensee, concessionaire, regardless of whether a fee is charged for use.

3.99 pump discharge pressure: Actual gauge reading taken at the discharge of a pump, expressed in kPa (psi).

3.100 reagent: A solid or liquid component of a water quality testing device (WQTD) that is used to condition a sample or that reacts with a test parameter as part of a test procedure.

3.101 reagent grade: A "laboratory" or highly purified grade of chemical.

3.102 readily accessible: Fabricated to be exposed for cleaning and inspection without using tools.

3.103 readily removable: Capable of being taken away from the main unit without using tools.

3.104 relative humidity: The ratio, in percent, of the actual amount of water vapor in a body of air in relation to the maximum amount that the body can hold at a given temperature. Relative humidity varies with temperature for a given amount of water vapor.

3.105 removable: Capable of being taken away from the main unit using only simple tools (screwdriver, pliers, open-end wrench, etc.).

3.106 repeatability: The within-run precision.[24]

3.107 reproducibility: The between-run precision.[24]

3.108 resolution: The smallest discernible difference between any two measurements that can be made.[24] For meters, this is usually how many decimal places and significant figures are displayed (i.e., 0.01). For titrations and various comparators, it is the smallest interval the device is calibrated or marked to (i.e., 1 drop = 10 ppm, 0.2 ppm for a direct read titration (DRT), or plus or minus half a unit difference for a color comparator or color chart).

3.109 run: A run is a single data set, from set up to clean up. Generally, one run occurs on one day. However, for meter calibrations, a single calibration is considered a single run or data set, even though it may take two or three days.

3.110 safety surfacing system: products intended to cover the floor of a recreational water venue that also comply with the requirements of this Standard, including the impact attenuation and slip resistance requirements.

[23] Jeffery G. H., Basset J., Mendham J., Denney R.C., *Vogel's Textbook of Quantitative Chemical Analysis*, 5th ed., Longman Scientific & Technical, 1989, p. 130.

[24] Statistics in Analytical Chemistry: Part 7 – A Review, D. Coleman and L Vanatta, American Laboratory, Sept 2003, p. 34.

3.111 sand-type filter, lower distribution system (underdrain [effluent]): Devices in the bottom of a sand-type filter to collect water uniformly during filtering and to uniformly distribute the backwash water.

3.112 sand-type filter, upper distribution system (influent): Devices to distribute water entering a sand-type filter to prevent movement or migration of the filter media. This system also collects water during filter backwashing unless other means are provided.

3.113 sealed: Fabricated without openings to prevent entry of liquid.

3.114 secondary disinfection: Units that demonstrate a 3 log (99.9%) or greater reduction or inactivation of *Cryptosporidium parvum* in a single pass when tested in accordance to Section 14.18.2.

3.115 self-contained spa (hot tub / swim spa / therapy spa / resistant system): A factory-built spa in which all control, water heating, and water-circulating equipment is an integral part of the product. Self-contained spas may be permanently wired or cord connected.

3.116 self-priming centrifugal pump: Pump (after initial filling with water) capable of priming and repriming a dry suction line (up to 10 ft [3 m] vertical lift) without using foot or check valves or adding water.

3.117 septum: Part of a diatomite-type filter element consisting of cloth, wire screen, or other porous material on which filter aid is deposited.

3.118 service factor amps: The current, in amperes, under the service factor horsepower at rated volts.

3.119 service factor horsepower: The motor data plate horsepower multiplied by the data plate service factor.

3.120 set point: The user established target level of a parameter (pH, ORP, etc.) to be maintained by an automated controller.

3.121 skid pack: A separate collection of components that are not an integral part of a pool, spa, or hot tub such as, but not limited to, filters, pumps, heaters, controls, fittings, pipes, and skimmers that are to be installed in accordance with the manufacturer's specifications.

3.122 skimmer cover: Device or lid to close deck opening to the skimmer housing.

3.123 skimmer equalizer pipe: Connection from skimmer housing to the pool, spa, or hot tub below the weir and sized to satisfy pump demand and prevent air lock.

3.124 skimmer equalizer valve: Device on the equalizer line that opens when water level inside skimmer tank drops below operating level and remains closed during normal skimming.

3.125 skimmer housing: Structure that attaches to or contains skimmer weir, strainer basket, and other devices used in the skimming operation.

3.126 skimmer weir assembly: Floating device over which water from the pool, spa, or hot tub passes during skimming, along with its means of guiding or attachment to, the skimmer.

3.127 slurry feed: Refer to body feed definition (see Section 2.12).

3.128 spa / hot tub (exercise spa, swim spa, therapy spa, resistance system): A unit, which is not usually drained, cleaned, or refilled for each individual. It may include, but is not limited to, hydro-jet circulation, hot water or cold water mineral baths, air induction bubbles, or any combination thereof. A portable or nonportable water basin intended for the total or partial submersion of persons in temperature-controlled water circulated in a closed system, and not intended to be drained and filled with each use. It is manufactured to factory specifications using specific design, plumbing, components, and suppliers such that the water is circulated, treated, and filtered via a closed-loop system. This may include certain systems or components integral to the spa, including but limited to, tub or shell structure and support system, steps and seats, hand hold(s) and rail(s), filter(s), pump(s), suction fitting(s) or drain(s), water return fittings, skimmers, piping, tubing hose, other air or water distributing fitting(s), resistance exercise equipment, heater(s) (solar, electric, or gas), chemical treatment system(s), control system, jets, lighting, blowers, A/V equipment or as part of a separate manufacturer specified assembly skid-pack. A water basin may contain specific features and equipment to produce a water flow intended to allow physical activity, but not limited to, exercising or swimming in place, hydro-therapy, resistance exercise or flotation and it is designed to allow for an unobstructed volume of water large enough to allow these activities.

3.129 spray rinse, manual: Spray system used manually for washing filter aid or accumulated dirt from filter surface either in place or after removal from filter tank (usually by a hose and nozzle).

3.130 spray rinse, mechanical: Fixed or mechanically movable spray system that directs a stream of water against filter surface and causes the filter aid or accumulated dirt to dislodge.

3.131 standard rate (rapid rate): Design filtration rate is not greater than 3 gal/min/ft^2 (122 L/min/m^2) for public pools, spas, or hot tubs, and not greater than 5 gal/min/ft^2 (203 L/min/m^2) for residential pools, spas, or hot tubs.

3.132 static suction lift: Vertical distance in meters (feet) from center line of the pump impeller to pool water level.

3.133 strainer basket: Readily removable, perforated, or otherwise porous container to catch coarse material.

3.134 supplemental disinfection: Units that demonstrate a 3 log (99.9%) or greater reduction of *Pseudomonas aeruginosa* and *Enterococcus faecium* when tested according to Section N-8.1.

3.135 supporting material: Material to support filter media in a sand-type filter.

3.136 surface-type cartridge: Filter cartridge with media relying on retention of particles on the surface of the cartridge for removal.

3.137 test solution: The liquid used to conduct a particular test or challenge.

3.138 total bromine: the sum of all active bromine compounds.

3.139 total chlorine: The sum of free and combined chlorine compounds.

3.140 total dynamic head: Arithmetic difference between total discharge head and suction head. (A vacuum reading is considered a negative pressure.) This value is used in developing the performance curve.

3.141 total discharge head: The static discharge head, plus the discharge velocity head, plus the friction head in the discharge line.

3.142 total suction head[22]: The static suction head minus the friction head in the suction line.

3.143 total dynamic suction lift (TDSL): Arithmetic total of static suction lift, friction head loss, and velocity head loss on suction side of pump.

3.144 toxic: Having an adverse physiological effect on humans.

3.145 trimmer valve: Flow adjusting device used to proportion flow between the skimming weir and main suction line, from the main outlet, or from the vacuum cleaning line.

3.146 turbidity: A measurement of suspended particulate matter in water expressed as nephelometric turbidity units (NTU).

3.147 turnover rate: The time required to recirculate the entire volume of water in a swimming pool, spa, or hot tub.

3.148 ultraviolet (UV) light: The segment of the light spectrum between 100 to 300 nm.

3.149 ultraviolet (UV) unit: A device that produces ultraviolet light between 250 to 280 nm for the purpose of inactivation of microorganisms by UV radiation.

3.150 uniformity coefficient: A ratio calculated as the size opening that will just pass 60% (by dry weight) of a representative sample of the filter material divided by the size opening that will just pass 10% (by dry weight) of the same sample.

3.151 user: Any person using a pool, spa, or hot tub, and adjoining deck area for the purpose of water sports, recreation, or related activities.

3.152 vacuum: Pressure lower than atmospheric pressure.

3.153 vacuum cleaner connection: Connection to attach a hose for cleaning.

3.154 water conditioning device: A device intended to treat swimming pool water and improve water quality without the introduction of additional chemicals.

3.155 waterline: Top of the overflow outlet of the spa.

3.156 water quality testing device (WQTD): A product designed to measure the level of a water quality parameter. A WQTD includes a device or method to provide a visual indication of a water quality parameter level and may include one or more reagents and accessory items.

3.156.1 WQTD accuracy: Accuracy is defined as how close the WQTD result is to the reference value.

3.156.2 WQTD precision: Precision is defined as how close replicates of a single value are to each other.

3.157 working pressure: Maximum operating pressure recommended by manufacturer.

3.158 zeolite: Hydrated aluminosilicates that contain sodium, potassium, magnesium, and calcium.

4 Swimming pool water contact materials

4.1 Materials

Materials shall not sustain permanent damage or deformation when subject to repeated handling associated with the routine operation and maintenance of the equipment.

Materials intended to be in contact with swimming pool or spa / hot tub water shall not impart undesirable levels of contaminants or color to the water, as determined in accordance with Annex N-1. The following items are exempt from the material review procedures described in Annex N-1:

— swimming pool and spa / hot tub components with a surface area less than 100 in^2 (650 cm^2) in direct contact with water;

— swimming pool components with a mass less than 1.4 oz (40 g);

— spa / hot tub components with a mass less than 0.07 oz (2 g);

— components made entirely from materials acceptable for use as a direct or indirect food additive in accordance with 21 CFR 170-199[4] (Food and Drugs);

— glass (virgin, not recycled);

— series AISI 300 stainless steel;

— titanium alloy grade 1 and 2; and

— coatings and components made from materials acceptable for use in contact with potable water in accordance with NSF/ANSI 14 (potable water material requirements), NSF/ANSI 42, NSF/ANSI 51, or NSF/ANSI/CAN 61. In order to be qualified under NSF/ANSI 14, NSF/ANSI 42, or NSF/ANSI/CAN 61, the surface area to water volume ratio of the intended use conditions shall meet the requirements of NSF/ANSI/CAN 61 when evaluated to the total allowable concentration (TAC) requirements of the Standard.

Materials listed under the United States Code of Federal Regulations, Title 21 (Food and Drugs) Part 189 *Substances prohibited for use in human food*, shall not be permitted as ingredients within material contacting pool, spa, or hot tub water. This includes arsenic, beryllium, cadmium, mercury, or thallium. Lead shall also not be used as an international ingredient in any water contact material except for products meeting the US Safe Drinking Water Act definition of lead free (≤ 0.25% weighted average lead content).

4.2 Corrosion resistance

Material intended to be in contact with swimming pool or spa / hot tub water shall be corrosion-resistant under use conditions or shall be rendered corrosion-resistant by a protective coating. Cathodic protection may be used to improve the corrosion resistance of a material. High-speed parts requiring close tolerances are not required to be corrosion resistant.

The following materials are considered to have acceptable corrosion resistance for general swimming pool and spa / hot tub equipment applications and are not required to have a protective coating:

— nonferrous alloys containing not less than 58% copper;
— nickel-copper alloy – Monel 400 (UNS N04400);
— SAE 300 series stainless steel;[18]
— thermoplastics and thermoset plastics; and
— concrete.

When used in pumps and strainers, cast iron is not required to have a protective coating.

4.3 Dissimilar metals

Dissimilar metals not normally compatible on the electromotive scale shall not be in direct contact with one another (except for sacrificial anode service).

4.4 Insulating fittings

Insulating fittings shall be provided when piping material is not compatible (on the electromotive scale) with adjoining fittings or parts of the circulation system. Such fittings shall be electrically nonconductive and shall conform to the applicable requirements of Sections 4.1 and 4.2.

4.5 Piping materials

4.5.1 Galvanized steel pipe and galvanized iron pipe with cast or malleable iron fittings and bronze or iron-bodied bronze fitted valves are acceptable for use without a protective coating. If such materials have a steel housing, then no insulating fittings are required. Otherwise, all metal pipe with a dissimilar metal housing shall have insulated fittings.

4.5.2 Piping intended for use in water applications with conductivity greater than or equal to 600 ppm aqueous solution of sodium chloride shall be made from one of the following materials:

— aluminum brass (UNS C68700);
— copper-nickel, 10% (UNS C70600);
— copper-nickel, 30% (UNS C71500);
— nickel-copper alloy – Monel 400 (UNS N04400);
— stainless steel Type 304 (passivated) (UNS S30400);
— stainless steel Type 316 (passivated) (UNS S 31600); or
— thermoplastics or thermoset pipes conforming to the applicable sections of NSF/ANSI 14.

5 Design and construction

This section contains general requirements that apply to all equipment covered under the scope of this Standard.

5.1 Installation of piping, valves, and fittings

If circulation system components are not supplied with the required piping, valves, and fittings installed, the manufacturer shall provide a piping diagram, a parts list, and installation procedures.

5.2 Assembly

Piping assemblies shall be capable of being disassembled for maintenance and repair.

5.3 Closing and sealing devices

Mechanical clamps, gaskets, and sealing devices shall not leak when subjected to the applicable pressure requirements.

5.4 Suction fittings

Suction fittings that are designed to be totally submerged for use in swimming pools and spa / hot tubs shall comply with ANSI/APSP–16[5] and the requirements of Section 4.

5.5 PVC hose

Helix or fabric reinforced flexible PVC hose, for use on circulation piping in pools, hot tubs, spas, and jetted bathtub units, shall comply with the following:

— IAPMO/ANSI Z1033;[14]
— the requirements of Section 4; and
— Section N-2.1.5 after a 20,000-cycle strength test conducted in accordance with Section N-2.1.4.

5.6 Safety vacuum release systems (SVRS)

Manufactured SVRS shall comply with ASTM F2387[9] or ANSI/ASME A112.19.17[6] and the material requirements of Section 4.

5.7 Pool and spa covers

All pool or spa covers (safety or otherwise) shall be labeled in accordance with ASTM F1346[9] and shall conform to the requirements of Sections 4 and 5.

5.8 Pool alarms

Pool alarms shall comply with ASTM F2208,[9] as well as the requirements of Section 4.

5.9 Barriers and fencing

Fencing for use as a barrier around recreational water shall comply with one or more of the following Standards:

— ASTM F1908;[9]
— ASTM F2049;[9]
— ASTM F2286;[9]
— ASTM F2409;[9] or
— ASTM F2699.[9]

NOTE — Check with the local authorities for residential and recreational water facility fencing requirements. The use of specific products, designs, installation requirements, and compliance with particular standards may be specified in local building codes or by the local public health official.

5.10 Vacuum port fitting cover

Vacuum port cover fittings shall comply with the requirements of IAPMO SPS 4[14] as well as the requirements of Section 4 of this Standard.

6 Filters

6.1 General

The requirements in this subsection apply to diatomite-type, sand-type, cartridge-type, and high-permeability-type filters.

6.1.1 Filter tanks (pressure service)

6.1.1.1 The working pressure of a pressure service filter shall be 50 psi (345 kPa) or greater. The design burst pressure of a pressure service filter tank shall be at least four times the working pressure (i.e., minimum safety factor = 4:1).

6.1.1.2 The filter tank and its integral components shall not rupture, leak, burst, or sustain permanent deformation when subject to the following conditions in accordance with Section N-2.1:

— a hydrostatic pressure equal to 1.5 times the working pressure for 300 s;
— 20,000 consecutive low-high pressure cycles; and
— a hydrostatic pressure equal to two times the working pressure.

NOTE — As noted in Annex N-2, leaking from integral components such as valves and fittings that may occur when the hydrostatic pressure is increased to two times the working pressure does not constitute nonconformance to this requirement.

Filter tanks designed, constructed, evaluated, and stamped with the appropriate Code Symbol Stamp, in accordance with the *ASME Boiler and Pressure Vessel Code*,[6] Section VIII or X, shall be exempt from this requirement.

6.1.2 Filter tanks (vacuum service)

6.1.2.1 The design collapse pressure of a vacuum service filter tank shall be at least 1.5 times the pressure developed by the weight of the water in the tank (i.e., minimum safety factor = 1.5).

6.1.2.2 Vacuum service filter tanks whose inlets may be closed during filter operation shall not rupture, leak, collapse, or sustain permanent deformation when subjected to a vacuum of 25 in Hg (85 kPa) for 300 s in accordance with Section N-2.2.

6.1.3 Internal components

6.1.3.1 Internal components of a pressure service filter shall not sustain damage or deformation that may affect water flow characteristics when the filter is operated in accordance with the manufacturer's instructions and when operated under the test conditions in Annex N-2.

6.1.3.2 Internal components of a vacuum service filter shall not sustain damage or deformation that may affect water flow characteristics when the filter is operated in accordance with the manufacturer's instructions and when operated under the test conditions in Annex N-2.

6.1.3.3 Filter element components of a filter designed for pressure backwashing shall not sustain damage or permanent deformation when exposed to the pressure differential developed during backwashing operations.

6.1.4 Initial head loss

The head loss through a filter operating at the design flow rate shall not exceed the manufacturer's maximum design head loss when determined in accordance with Section N-2.3.

6.1.5 Accessibility

Filter components requiring service shall be accessible for inspection and repair when installed in accordance with the manufacturer's instructions. Covers on openings required for access into the filter tank shall be removable.

6.1.6 Drains

A filter shall have a drain so that the filter tank may be drained in accordance with the manufacturer's winterizing instructions.

6.1.7 Air release

If the filter permits accumulation of air in the top of the filter tank, the filter tank shall have an automatic air release at the top of the tank. A manual air release valve shall also be provided.

6.1.8 Cleaning of filter media

The cleaning of filter media in accordance with the manufacturer's instructions shall render the filter media and elements free of visible dirt and debris. The head loss through the filter after cleaning the media shall not exceed 150% of the initial head loss through the filter. The head loss through the filter after cleaning shall not exceed the manufacturer's maximum design head loss. Testing shall be conducted in accordance with Section N-2.4.

6.1.9 Turbidity reduction

A filter shall reduce water turbidity by 70% or more when tested in accordance with Section N-2.5.

6.1.10 *Cryptosporidium parvum* oocyst reduction

6.1.10.1 A filter manufacturer may make a *C. parvum* log reduction claim up to a maximum of 1.0 log. A filter claimed by the manufacturer to reduce *C. parvum* shall be tested in accordance with Section N-2.9. The verified *C. parvum* log reduction determined in accordance with Section N-2.9 shall be noted on the data plate.

6.1.10.2 Polystyrene latex microspheres, as referenced in the test method for bag and cartridge filter systems in NSF/ANSI 419: *Public Drinking Water Equipment Performance – Filtration*, shall be an acceptable surrogate for live *C. parvum* oocyst.

6.1.10.3 The polystyrene latex microspheres shall have 95% of particles in the range of 3.00 ± 0.15 µm. The size variation of the polystyrene microspheres shall be confirmed by electron microscopy. The spheres shall have a surface charge content of less than 2 µeq/g. The microspheres shall contain a fluorescein isothiocyanate (FITC) dye or equivalent.

6.1.10.4 The maximum feed concentration shall be 10,000/L, to prevent overseeding that will lead to artificially high log removals performance.

6.1.10.5 Detection and enumeration of polystyrene microspheres shall be done in accordance with Annex A of NSF/ANSI 419.

6.1.10.6 If a filter has been validated for a reduction of *C. parvum* in accordance with Section 6.1.10 and Section N-2.9, the installation and operating instructions shall contain the following information:

— the validated log reduction, shall be indicated via the following statement:

> *"This filter has demonstrated the ability to provide a 1.0 log reduction of Cryptosporidium parvum at a flow rate of XXX gpm when tested with 3-µm polystyrene microspheres."*

— cleaning instructions, including but not limited to any backwash, rinse, filter to drain, or auxiliary recirculation steps. Minimum and maximum flow rates and times shall be included for each step;

— remediation instructions specific to the handling of waste, rinse, and/or backwash water that may contain *C. parvum*. These instructions must include a statement that all waste, rinse and backwash water generated by this filter must be directed to a sanitary sewer; and

— the allowable range of pressure drop through the filter, what pressure drop, or flow reduction indicates cleaning is required, and the terminal pressure drop requiring changeout of the media.

6.1.10.7 If a filter has been validated for a reduction of *C. parvum* in accordance with Section 6.1.9.2 and Section N-2.9, the data plate shall contain the following information:

— the validated log reduction shall be indicated on the data plate via the following statement:

> *"This filter has demonstrated the ability to provide a 1.0 log reduction of Cryptosporidium parvum when tested with 3-µm polystyrene microspheres."*

— name and grade of media used during the validation testing of *C. parvum* reduction and a statement that use of any other media invalidates the *C. parvum* reduction claim of the filter; and

— the data plate shall also include the following statement:

> *"Follow the cleaning and remediation instructions provided in the operating manual for safe handling of filter cleaning and wastewater. All waste, rinse, and/or backwash water generated by this filter must be directed to a sanitary sewer."*

6.2 Precoat media-type filters

The requirements in this subsection apply only to precoat media-type filters utilizing diatomite or other precoat filter media (that conforms to Section 13) and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.2.1 Filtration area

6.2.1.1 The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate.

6.2.1.1.1 For leaf or disc-type precoat media-type filters, the effective filtration area is equal to the total surface area of all septa minus the combined area of all septum support members wider than 0.25 in (6.4 mm) in contact with the septum during filtration.

6.2.1.1.2 For tube-type precoat media-type filters, the effective filtration area is equal to the total surface area of the precoat filter media-coated tubes minus the combined area of all septum support members wider than 0.25 in (6.4 mm) in contact with the septum during filtration. The effective filtration area shall be no more than 1.5 times the total surface area of the uncoated tubes.

6.2.1.2 For wire wound and similar-type elements, the width of septum support members shall not exceed 0.25 in (6.4 mm). The distance between adjacent septum members and the distance between adjacent openings shall not exceed 0.005 in (0.127 mm).

6.2.1.3 Septa shall be maintained in such a position as to preclude surface contacts that reduce effective filtration area.

6.2.2 Turbidity limits, precoat operation

During the precoat operation, the average turbidity of the filter effluent returning to the pool or spa / hot tub shall not exceed 10 nephelometric turbidity units (NTU) over the first 60 s of flow, as determined in accordance with Section N-2.6, except filters designed to refilter the effluent during the precoat operation or discharge it to waste without returning it to the pool or spa / hot tub are exempt from this requirement.

6.2.3 Spacing of elements

6.2.3.1 Filters shall be designed to provide a minimum clearance between adjacent filter elements equal to the thickness or diameter of the element or 1 in (25 mm), whichever is less.

6.2.3.2 The clearance between filter elements shall be sufficient to prevent contact between the septa during backwashing operations.

6.2.4 Baffles

A precoat media-type filter shall have a baffle, or other water-deflecting device, that prevents incoming water from eroding the filter aid during filtration.

6.2.5 Removal of waste from filter tank

A precoat media-type filter shall be designed so that wash water, dislodged filter aid, and dirt may be removed from the filter tank.

6.2.6 Installation and operating instructions

The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, cleaning instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance of the filter. The manual shall also specify the recommended amount, type, and grade of filter aid.

6.2.7 Data plate

6.2.7.1 A precoat media-type filter shall have a data plate that is permanent, easy to read, and securely attached to the filter housing at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— working pressure, if applicable; and
— steps of operation.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications shall be exempt from this requirement.

6.2.7.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.2.8 Filtration rate

The design filtration rate of precoat media-type filters shall not exceed the values specified in Table 6.1.

Table 6.1
Maximum design filtration rates for precoat media-type filters

Filter design	Intended application	Maximum design filtration rate
slurry feed	residential pool or spa / hot tub	3 gal/min/ft^2 (122 L/min/m^2)
slurry feed	public pool or spa / hot tub	2.5 gal/min/ft^2 (102 L/min/m^2)
no slurry feed	residential pool or spa / hot tub	2.5 gal/min/ft^2 (102 L/min/m^2)
no slurry feed	public pool or spa / hot tub	2 gal/min/ft^2 (81 L/min/m^2)

6.2.9 Precoat filter media

Precoat media shall conform to the requirements of Section 4, Materials.

6.2.9.1 Precoat media other than diatomaceous earth (DE)

Precoat media other than DE shall also conform to the requirements of Sections N-2.3 through N-2.7.

6.2.9.2 Precoat media labeling requirements

Precoat media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type and trade name);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling, storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

6.3 Sand-type filters

The requirements in this subsection apply only to sand-type filters and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.3.1 Upper distribution system (influent)

Components of the influent distribution system shall be designed so that they do not become clogged during filtration. The system shall distribute incoming water during the filter cycle to prevent appreciable movement or migration of filtering media at the design flow rate.

6.3.2 Lower distribution system (effluent)

Components of the effluent distribution system shall be designed so that they do not become clogged during filtration. The system shall provide adequate flow and distribution to expand the filtering bed uniformly during backwashing.

6.3.3 Accessibility of internal components

Internal filter components shall be accessible through an access opening in the filter tank. Filters having dome-type or similar underdrains with openings at least 0.189 in (4.8 mm) wide are exempt from this requirement.

6.3.4 Filter media

6.3.4.1 Filter sand shall be hard, silica-like material that is free of carbonates, clay, and other foreign material. The effective particle size shall be between 0.016 in (0.40 mm) and 0.022 in (0.55 mm), and the uniformity coefficient shall not exceed 1.75. Filters intended for use with an alternate media that does not conform to these requirements shall specify the alternate media on the data plate. The filter and the alternate media shall conform to the other applicable requirements of this Standard.

6.3.4.2 If a different media is used to support the filter media, it shall be rounded material that is free of limestone and clay and installed according to the manufacturer's instructions. When the support media and the filter media are installed in accordance with the manufacturer's recommendations, the filter media shall not intermix with the support media when operated and backwashed at least three cycles in accordance with Section N-2.4.

6.3.4.3 Alternate sand-type media

A material that is marketed or claimed to replace sand directly as a filter media in a sand-type filter shall conform to Sections 4.2, 6.1.8, 6.1.9, 6.3.4.3, and 5.3.5 when tested in a representative sand-type filter in accordance with Sections N-2.3 through N-2.5.

6.3.4.3.1 The manufacturer of an alternate sand-type media shall specify the particle size and uniformity coefficient for the media. Particle size and uniformity coefficient shall be confirmed in accordance with ASTM C136[9] with sieves conforming to ASTM E11.[9]

6.3.4.3.2 The filtration rate and backwash rate for an alternate sand-type media shall be as specified in Section 6.3.9.

6.3.4.3.3 Sand-type media labeling requirements

Sand-type media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type and trade name);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling, storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

6.3.5 Filter media behavior

6.3.5.1 Filter media shall not be removed during backwashing at a rate of 15 gal/min/ft^2 (610 L/min/m^2) or the manufacturer's recommended backwash rate.

6.3.5.2 Media shall be capable of being thoroughly cleaned when backwashed following the manufacturer's recommendations.

6.3.5.3 Filter media and supporting material shall not migrate during the filtration cycle. The filter bed shall remain level during the filtration cycle when operated at the design flow rate. The maximum difference between the highest and lowest elevations on the surface of the filter bed shall not exceed the values shown in Table 6.2.

Table 6.2
Maximum difference in media surface elevations on a sand type filter

Filter diameter (D)[1]	Maximum elevation difference
< 36 in (0.9 m)	3 in (76 mm)
36 to 63 in (0.9 to 1.6 m)	0.083 × D
> 63 in (1.6 m)	5.25 in (135 mm)

[1] For filters with noncircular surface geometry, D shall equal the maximum horizontal dimension on the media surface.

6.3.5.4 Filter media and supporting material shall not impart color to the water during filter operation.

6.3.5.5 The filter bed of a pressure service filter shall not break down or channel when subjected to a pressure differential of 15 psi (103 kPa) or the maximum recommended by the manufacturer, whichever is greater. The filter bed of a vacuum service filter shall not break down or channel when subjected to a pressure differential of 16 in Hg (54 kPa) or the maximum recommended by the manufacturer, whichever is greater.

6.3.6 Installation and operating instructions

6.3.6.1 The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, installation instructions, cleaning instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance.

6.3.6.2 The manufacturer of an alternate sand-type media shall provide written instructions for the installation of the media in a filter, including requirements for a different support media; for any specific preparation of the media for operation; and for the operation of filter with the alternate sand-type media.

6.3.7 Data plate

6.3.7.1 A sand-type filter shall have a data plate that is permanent, easy to read, and securely attached to the filter tank at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number or date code;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— design backwash flow rate in LPM or GPM;
— working pressure, or design collapse pressure for vacuum filter tanks;
— suitability for buried installation;
— steps of operation;
— filtration rate in gal/min/ft^2 or L/min/m^2; and
— special media specifications, if any, as required in Section 6.3.4.1.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications is exempt from this requirement.

6.3.7.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.3.8 Effective filtration area

The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate.

The actual filtration area is equal to the total area of the filter media bed minus the combined area of any obstructions (e.g., pipes, headers, air lines) wider than 0.25 in (6.4 mm) passing through the surface of the filter media bed.

6.3.9 Filtration and backwash rates

6.3.9.1 The design filtration rate of sand-type filters shall conform to the limits specified in Table 6.3.

Table 6.3
Design filtration rates for sand type filters

Filter design	Intended application	Design filtration rate
rapid rate	residential pool or spa / hot tub	max: 5 gal/min/ft^2 (204 L/min/m^2)
rapid rate	public pool or spa / hot tub	max: 3 gal/min/ft^2 (122 L/min/m^2)
high rate	residential pool or spa / hot tub	min: 5 gal/min/ft^2 (204 L/min/m^2) max: 20 gal/min/ft^2 (813 L/min/m^2)
high rate	public pool or spa / hot tub	min: 5 gal/min/ft^2 (204 L/min/m^2) max: 20 gal/min/ft^2 (813 L/min/m^2)

6.3.9.2 The design backwash rate shall be a minimum of 15 gal/min/ft^2 (610 L/min/m^2).

6.4 Cartridge-type and high-permeability-type filters

The requirements in this subsection apply only to cartridge-type and high-permeability-type filters and their integral components designed for the filtration of swimming pool or spa / hot tub water.

6.4.1 Clearance

The clearance between the filter tank and cartridge(s) or high-permeability element(s) shall be at least 0.25 in (6.4 mm). The clearance between adjacent cartridges shall be at least 0.25 in (6.4 mm).

6.4.2 Baffles

A filter shall have a baffle or other flow-deflecting device that prevents influent water from flowing directly against the effective filter area during filtration.

6.4.3 Trash screen (vacuum service cartridge filters)

Vacuum service cartridge filters shall have a trash screen at the filter inlet to remove large debris such as leaves and paper from the influent water before it reaches the filter cartridges.

6.4.4 Cartridge alignment (stacked multi-cartridge filters)

Stacked cartridges shall be securely fastened to one another. They shall be aligned to ensure a proper seal and to maintain the required clearance between adjacent cartridges. Devices used to align cartridges shall not obstruct the filtration area.

6.4.5 Removal of waste from filter tank

A filter shall be designed so that wash water and dislodged dirt may be removed from the filter tank.

6.4.6 Removal of cartridges

Cartridges shall be readily removable. If cartridge stacks are so long that lower cartridges cannot be removed by hand, the manufacturer shall provide a device for lifting them out of the filter tank.

6.4.7 Installation and operating instructions

The manufacturer shall provide a manual with each filter. The manual shall include operating instructions, cleaning instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance. The manual shall also include the recommended size, number, and type of cartridges or high-permeability elements. If the reuse or replacement of cartridges or high-permeability element is recommended, the manufacturer shall provide printed removal and cleaning instructions.

6.4.8 Data plate

6.4.8.1 A filter shall have a data plate that is permanent, easy to read, and securely attached to the filter housing at a readily accessible location. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— filter model number;
— filter serial number;
— effective filtration area in square meters or square feet;
— required clearance (vertical and horizontal for service and maintenance);
— design flow rate in LPM or GPM;
— working pressure;
— steps of operation; and
— recommended replacement cartridge or high-permeability element.

The data plate shall indicate whether a filter is designed for swimming pool applications only or spa / hot tub applications only. A filter designed for both applications is exempt from this requirement.

6.4.8.2 If provided with the filter, each valve on the face piping of the filter shall have a permanent label or tag identifying its operation (e.g., influent, backwash, bypass).

6.4.9 Filtration area

The actual filtration area shall be within ± 5% of the effective filtration area specified on the filter data plate. The actual filtration area is equal to the total surface area of the cartridge or element material minus the combined area of any obstructions wider than 0.25 in (6.4 mm) in direct contact with the cartridge / element material during filtration.

6.4.10 Filtration rates

The design filtration rate of a cartridge-type filter shall not exceed the maximum values specified in Table 6.4.

Table 6.4
Maximum design filtration rates for cartridge-type filters

Filter design	Intended application	Maximum design filtration rate
depth-type	residential pool or spa / hot tub	8 gal/min/ft^2 (325 L/min/m^2)
depth-type	public pool or spa / hot tub	3 gal/min/ft^2 (122 L/min/m^2)
surface-type	residential pool or spa / hot tub	1 gal/min/ft^2 (41 L/min/m^2)
surface-type	public pool or spa / hot tub	0.375 gal/min/ft^2 (15 L/min/m^2)

The design filtration rate of a high-permeability-type filter intended for use with a residential pool or spa / hot tub shall not exceed 10 gal/min/ft^2 (407 L/min/m^2).

7 Centrifugal pumps

This section contains requirements for centrifugal pumps used to circulate swimming pool or spa / hot tub water in commercial and residential applications. The requirements for strainers shall apply to strainers that are integral with the pump and to strainers supplied as separate equipment for use in conjunction with a centrifugal pump.

7.1 General

7.1.1 Pumps shall operate with minimum adjustment. Required adjustments to the power supply shall be acceptable.

7.1.2 Sections of the pump that require inspection or service shall be accessible.

7.1.3 Moving parts shall be covered.

7.1.4 Replacement parts shall fit the pump without a need to re-drill or otherwise alter the pump or replacement part.

7.2 Hydrostatic pressure test

Part of a pump that contains water under pressure shall be capable of withstanding a hydrostatic pressure test at 150% of the working pressure.

7.3 Strainers

7.3.1 Strainers shall be designed so that solids will not bypass the strainer basket during normal operation nor drop into the strainer pot when the strainer basket is removed for cleaning.

7.3.2 Strainer baskets shall be readily removable and easily cleanable.

7.3.3 Openings in the strainer basket shall not exceed 0.05 in^2 (0.3 cm^2) in area.

7.3.4 The ratio of the open area in the strainer basket to the cross-sectional area of the strainer inlet connection shall be 4:1 or greater. The open area in the strainer basket shall be no less than 10 in^2 (65 cm^2).

7.3.5 Strainers with an inlet connection with a nominal pipe size of 1.5 in (38 mm) or less shall have a strainer basket with a minimum internal volume of 25 in^3 (410 cm^3). Strainers with an inlet connection with a nominal pipe size of 2 in (51 mm) or greater shall have a strainer basket with a minimum internal volume of 90 in^3 (1475 cm^3).

7.3.6 Strainer covers shall be designed to be opened manually and shall have a gasket that creates a tight seal when tightened by hand.

7.3.7 A nonintegral strainer shall meet the requirements of Section 8.

7.4 Drain plugs

A pump shall have sufficient drain holes with plugs to drain the pump housing and strainer body (if applicable) without disconnection of the pump or its parts.

7.5 Shaft seals

The pump shaft shall be sealed by packing or a mechanical seal. If packing is used, there shall be a means for its periodic lubrication. Instructions on maintenance and lubrication shall be provided.

7.6 Pump performance curve

7.6.1 For each pump model or model series, the manufacturer shall provide a pump performance curve that plots the pump's total dynamic head versus the discharge flow rate. The manufacturer shall also have a curve available that plots the net positive suction head (NPSH) or total dynamic suction lift (TDSL), brake horsepower, and pump efficiency in relation to the performance curve. Pumps with a rating of 5 HP (3.7 kW) or less are not required to have a NPSH curve.

For pumps utilizing motors rated for multiple voltages, if the pump performance curve varies between rated voltages, such as may occur between 230 V and 208 V, the manufacturer shall provide a pump performance curve for each rated motor voltage.

7.6.2 The actual pump curve, as determined in accordance with Section N-3.1, shall be within a range of - 3% to + 5% of the total dynamic head or - 5% to + 5% of the flow, whichever is greater, indicated by the performance curve. Data taken above 90% full flow shall not be judged to the acceptance criteria.

Pumps with more than one operating speed shall be tested as documented below:

— fixed multispeed pump or motor assemblies, test at each speed; or
— variable speed pump or motor assemblies, test at 100%, 50%, and the lowest speed.

7.6.3 For pumps that provide a flow rate output (such as a visual flow rate in LPM/GPM or other manner), the pump may be tested in accordance with the following flow meter requirements of Section 24 of this standard:

— Section 24.8: Flow rate measurement accuracy;
— Section 24.9: Flow metering device testing and accuracy levels; and
— Section 24.12: Life testing.

7.7 Operation and installation instructions

7.7.1 The manufacturer shall provide a manual with each pump. The manual shall include written instructions for the proper installation, operation, and maintenance of the pump. Instructions shall include a parts list and diagrams to facilitate the identification and ordering of replacement parts. If the parts list does not uniquely identify each part for ordering, the manufacturer shall also supply the appropriate specification numbers and serial numbers, and the impeller diameter.

7.7.2 A pump manufactured without an integral strainer shall state in its installation instructions, on a data plate, or on an attached label that the pump is to be installed with a strainer conforming to the requirements in this Standard.

7.7.3 For pumps that provide a flow rate output, the instruction manual shall either state the accuracy level of flow metering performance, (e.g., Level 1 or L1) or shall include the statement:

"Displayed flow rate has not been evaluated to the flow meter requirements of NSF/ANSI/CAN 50."

7.8 Self-priming pumps

A pump designated as self-priming shall be capable of repriming itself when operated under a suction lift without the addition of more liquid. Self-priming capability shall be verified in accordance with Section N-3.3.

7.9 Data plate

7.9.1 A pump shall have a data plate that is permanent; easy to read; and securely attached, cast, or stamped into the pump at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— pump model number;

— pump serial number, date code, or specification number;

— whether the unit has been evaluated for swimming pools or spas / hot tubs, if not evaluated for both applications;

— designation as a self-priming or non-self-priming pump. If the pump is self-priming, the maximum vertical lift height shall be specified; and

— if applicable, accuracy level of flow metering performance, (e.g., Level 1 or L1).

7.9.2 The proper direction of impeller rotation shall be clearly indicated by an arrow on the data plate, on a separate plate, or cast onto the pump.

7.10 Motors

7.10.1 Motors shall be open-drip-proof or totally enclosed. They shall be constructed electrically and mechanically to perform satisfactorily under the end use conditions.

7.10.2 Motors shall be capable of operating a pump under full load with a voltage variation of ± 10% from data plate rating.

7.10.3 Single-phase motors with a power rating less than 3 HP (2.24 kW) shall have built-in thermal overloads to provide locked rotor and running protection. All other motors shall have:

— built-in thermal overload protection;

— magnetic line starters with overload relays; or

— installation instructions specifying that magnetic line starters with overload relays shall be provided upon installation.

7.10.4 Each motor shall have a permanent data plate that contains the following information:

— motor manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number;

— power rating (kilowatt or horsepower, or both);

— speed;

— voltage;

— frequency;

— phase;

— service factor;

— maximum load amps or full load amps (service factor amps);

— serial number or date code or both;

— frame size;

— rated temperature rise or the insulation system class and ambient temperature rating;

— time rating or duty rating; and

— statement of thermal protection.

8 Nonintegral strainers

This section contains requirements for nonintegral strainers for pumps used to circulate swimming pool or spa / hot tub water in commercial and residential applications. The requirements for integral strainers are specified in Section 7.3.

8.1 Nonintegral strainer basket

8.1.1 Nonintegral strainers shall be designed so that solids will not bypass the strainer basket during normal operation nor drop into the strainer pot when the strainer basket is removed for cleaning.

8.1.2 Nonintegral strainer baskets shall be readily removable and easily cleanable.

8.1.3 Openings in the nonintegral strainer basket shall not exceed 0.05 in^2 (0.3 cm^2) in area.

8.1.4 The ratio of the open area in the nonintegral strainer basket to the cross-sectional area of the strainer inlet connection shall be 4:1 or greater. The open area in the nonintegral strainer basket shall be no less than 10 in^2 (65 cm^2).

8.1.5 Nonintegral strainers with an inlet connection with a nominal pipe size of 1.5 in (38 mm) or less shall have a nonintegral strainer basket with a minimum internal volume of 25 in^3 (410 cm^3). Nonintegral strainers with an inlet connection with a nominal pipe size of 2 in (51 mm) or greater shall have a nonintegral strainer basket with a minimum internal volume of 90 in^3 (1475 cm^3).

8.2 Nonintegral strainer cover

Nonintegral strainer covers shall be designed to be opened manually and shall have a gasket that creates a tight seal when tightened by hand.

8.3 Drain plug

A nonintegral strainer shall have sufficient drain holes with plugs to drain the strainer body without disconnecting the strainer.

8.4 Head loss

The manufacturer of a nonintegral strainer shall specify the maximum flow rate for which the strainer is intended and shall provide a curve showing the head losses in the intended range of flow rates.

NOTE — This information is necessary to facilitate the proper matching of a pump and nonintegral strainer.

8.5 Hydrostatic pressure test

The nonintegral strainer shall be capable of withstanding a hydrostatic pressure testing of 150% of the maximum rated pressure (see Section N-4.1).

8.6 Operation and installation instructions

The manufacturer shall provide a manual with each nonintegral strainer. The manual shall include written instructions for the proper installation, operation, and maintenance of the nonintegral strainer. Instructions shall include a parts list and diagrams to facilitate the identification and ordering of replacement parts. If the parts list does not uniquely identify each part for ordering, the manufacturer shall also supply the appropriate specification numbers and serial numbers.

8.7 Data plate

A nonintegral strainer shall have a data plate that is permanent; easy to read; and securely attached, cast, or stamped into the strainer at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier;

— nonintegral strainer model number;

— nonintegral strainer serial number, date code, or specification number;

— whether the unit has been evaluated for swimming pools or spas / hot tubs, if not evaluated for both applications; and

— rated working pressure (i.e., 50 psi).

9 Valves

This section contains requirements for valves used on filters in public and residential swimming pools and spas / hot tubs. The requirements apply to the housing, valve, handle, and other components that are integral parts of the multiport valve.

9.1 General

9.1.1 Valves and component parts that may require inspection and service shall be accessible.

9.1.2 Valves shall be marked or keyed for proper assembly and operation.

9.1.3 Valves shall be designed so that parts may be replaced without drilling or otherwise altering the multiport valve or replacement part.

9.2 Positive indexing

9.2.1 Valves shall be marked so that the position of the operating handle clearly indicates each operation.

9.2.2 Valves shall be designed so that the position of the operating handle can only be changed intentionally.

9.2.3 Valves shall be designed so that the operating handle, if removed, may only be properly realigned.

9.3 Design pressure

The working pressure of a pressure service valve or manufactured manifold or operational system associated with single or multiple tank filter system shall be 50 psi (344 kPa) or greater. The design burst pressure of a pressure service valve or operational system associated with single or multiple tank filter system shall be designed to have a burst pressure of at least four times the working pressure (i.e., minimum safety factor = 4:1).

9.4 Pressure service

The valve or manufactured manifold and its integral components shall not rupture, leak, burst, or sustain permanent deformation when subject to the following conditions in accordance with the following: (Annex N-4):

— a hydrostatic pressure equal to 1.5 times the working pressure for 300 s;
— 20,000 consecutive pressure cycles per Section N-2.1.4.d; and
— a hydrostatic pressure equal to two times the working pressure per Section N-2.1.4.e.

9.5 Valve leakage

Filter system valves and manufactured manifolds, when operating at the test pressure and maximum design flow rate, shall not leak in excess of 3 mL from the waste port and 30mL from the return-to-pool port in the 5 min test.

9.6 Head loss curve

9.6.1 The manufacturer shall make available a head loss curve for both the filter and backwash positions.

9.6.2 The actual head loss across a multiport valve shall not exceed the head loss indicated by the manufacturer's head loss curve by more than 5% (see Section N-4.4).

9.6.3 The head loss curve for manufactured manifolds may be calculated using a standard friction loss table and actual valve head loss data.

9.7 Waste port seal

The filter system valve or manufactured manifold shall not leak more than 3 mL in a 5 min test through the waste port when the valve is set in the position and a static pressure of 0 to 10 psi (70 kPa) is applied to the return port (Section N-4.5).

9.8 Vacuum service

9.8.1 The design collapse pressure of a vacuum service valve shall be at least 1.5 times the pressure developed by the weight of the water in the tank (i.e., minimum safety factor = 1.5).

9.8.2 Vacuum service valves shall not rupture, leak, collapse, or sustain permanent deformation when subjected to a vacuum of 25 in Hg (85 kPa) for 300 s in accordance with Section N-2.2.

9.8.3 Vacuum service valves are exempt from port leakage testing.

9.9 Installation and operating instructions

The manufacturer shall provide a manual with each valve or manufactured manifold. The manual shall include operating instructions, installation instructions, design head loss curve and parts lists, and any drawings or charts necessary to permit proper installation, operation, and maintenance.

9.10 Identification

The multiport valve shall be clearly and permanently marked or labeled with the following:

— manufacturer name and contact information (address, phone number, website, or prime supplier);

— model number;

— working pressure;

— vacuum pressure, if applicable;

— operating setting; and

— special requirements for switching between settings (e.g., the pump shall be shut off prior to switching the valve position).

10 Recessed automatic surface skimmers

This section contains requirements for recessed automatic surface skimmers used for public and residential pools and spas / hot tubs. The requirements apply to the basic components of a surface skimmer, including the skimmer housing; strainer basket; weir; cover and mounting ring; equalizer valve or air lock protector; trimmer valve and flow balancing valves for multiple skimmer installation; and vacuum cleaner connections. Recommended procedures for the installation and operation of skimmers on public and residential pools and spas / hot tubs are provided in Annex I-2.

10.1 Housing

10.1.1 Skimmer housings whose inlets may be closed during part of operating cycle shall not sustain damage or permanent deformation when exposed to a negative pressure of 25 in Hg (85 kPa).

10.1.2 The housing design shall allow for a smooth flow over the effective weir length.

10.1.3 On swimming pool and spa / hot tub skimmers, the housing opening at the entrance throat shall be at least 4 in (102 mm) wide. If a circular weir is used, there shall be a clearance of at least 2 in (51 mm) between the weir lip and the side of the skimmer housing.

10.2 Weir

10.2.1 A skimmer shall have a weir that operates freely with continuous action and adjusts automatically to variations in water level over a minimum range of 4 in (102 mm), or 3 in (76 mm) if an auto-fill pool water level control device is used when operated at the minimum design flow rate (see Section N-5.2).

10.2.2 Flap-type weirs on swimming pool and spa / hot tub skimmers shall have a minimum unobstructed width of 3.75 in (95 mm) over the full operating range. Flap-type weirs shall be buoyant and designed to develop an even flow over their full width. The clearance between the weir and the housing side shall not exceed 0.125 in (3 mm) at any point. Hinge construction shall preclude leakage. The weir shall be firmly attached to the housing and shall be accessible for cleaning and replacement in the field.

10.2.3 Circular weirs shall have a minimum diameter of 4 in (102 mm). They shall be buoyant and designed to develop an even flow on the water surface around the circumference. The radial clearance between the weir float and the weir housing shall not exceed 0.079 in (2 mm). The float or basket housing shall have devices to eliminate binding. The weir shall be accessible for replacement in the field.

10.3 Strainer basket

10.3.1 A skimmer shall have a strainer basket to trap suspended and floating material in the overflow water passing through the skimmer. Spa / hot tub skimmers that have self-contained filters are exempt from this requirement.

10.3.2 Strainer baskets shall be readily removable and easily cleanable.

10.3.3 The area of each opening in the strainer basket shall not exceed 0.05 in^2 (0.3 cm^2).

10.3.4 For swimming pool skimmers, the total open area in the strainer basket shall be 30 in^2 (194 cm^2) or greater. For spa / hot tub skimmers, the total open area in the strainer basket shall be 11 in^2 (71 cm^2) or greater.

10.3.5 For swimming pool skimmers, the internal volume of the strainer basket shall be 160 in^3 (2,620 cm^3) or greater. For spa / hot tub skimmers, the internal volume in the strainer basket shall be 44 in^3 (720 cm^3) or greater.

10.4 Equalizer line

10.4.1 A skimmer design may have an equalizer line that prevents air from becoming entrained in the suction line.

10.4.2 Consult local codes to determine if skimmer installation requires an equalizer line. If an equalizer line is required for skimmer installation, any submerged suction equalizer outlet shall be covered by an appropriately certified and sized suction fitting (cover, sump, and fasteners) that is certified in accordance with ANSI/APSP-16.[5] It is the responsibility of installers, service technicians and facility operators to comply with local codes and regulations. If it is acceptable to disable the equalizer line during installation / service, such work shall be conducted in accordance with the skimmer manufacturer's instructions.

For skimmer designs that incorporate an equalizer line, one of the following shall occur:

— if the skimmer manufacturer does supply a suction fitting (along with the skimmer), the skimmer manufacturer shall specify the minimum flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer. The skimmer manufacturer shall mandate installation of the skimmer with the provided suction fitting which shall be certified to ANSI/APSP-16[5] with a flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer; or

— if the skimmer manufacturer doesn't supply a suction fitting (along with the skimmer), the skimmer manufacturer shall specify the minimum flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer. The skimmer manufacturer shall mandate the installation of a suction fitting that is certified to ANSI/APSP-16[5] with a flow rating that meets or exceeds the maximum flow rate of the skimmer equalizer.

10.4.3 When the skimmer is operating at the maximum design flow rate and the water level is lowered to 2 in (51 mm) below the lowest overflow level of the weir (see Section N-5.2.4), the equalizer line (if provided) shall prevent air from being entrained in the pump suction line (see Section N-5.4).

10.4.4 When the skimmer is operating normally at the maximum design flow rate and up to 75% of the open area in the strainer basket is blocked, the flow rate (leakage) past the equalizer line (if provided) shall not exceed 10% of the total flow rate through the skimmer (see Section N-5.3).

10.5 Cover and mounting ring

10.5.1 A skimmer shall have a removable cover with a mounting ring. The cover and ring shall be free of sharp edges. The exposed surface of the cover shall be free of projections and have a permanent skid-resistant finish. A means of securing the cover in place shall be provided so that the cover cannot be dislodged, unintentionally removed, or otherwise become unstable during use.

10.5.2 Each type and model of polymer skimmer cover shall meet the UV exposure and structural integrity requirements in Sections 10.5.2.1 and 10.5.2.2. Type and model differences that require separate testing include shape, structure, material, color, plating, and finish. Skimmer covers that are too large to fit in the UV exposure chamber may have material bar samples molded, exposed, and tested in a manner consistent with methods developed for ANSI/APSP–16[5] suction fittings.

10.5.2.1 The cover shall be exposed to ultraviolet light and water spray in accordance with ASTM G154,[9] using the common exposure condition, Cycle 3 found in Table X2.1 of ASTM G154[9] for a period of 750 h (see Section N-5.5.2). The sample shall experience no crazing, cracking or geometrical deformation.

10.5.2.2 Skimmer covers that pass the UV exposure test shall be tested for structural integrity in accordance with Section N-5.5.3. A skimmer cover shall not deflect more than 0.35 in (9.0 mm), permanently deform, crack, or lose material exclusive of plating or finish when subjected to a point load of 300 lb ± 5 lb (136 kg ± 2.2 kg).

10.5.2.3 Requirement for evaluation of exposed ridges

After all structural testing is completed, the covers shall be evaluated for exposed ridges. Ridges shall be considered exposed when open to the atmosphere. Exposed ridges shall conform to Section 10.5.3.

10.5.3 Skimmer cleanability

10.5.3.1 The cover shall be designed to be easily cleanable. Covers with interior exposed structural ridges shall conform to the following. Nonexposed structural ridges are exempt from Sections 10.5.3.1.1, through 10.5.3.1.3.

10.5.3.1.1 Ridges with a height of less than 1/4 in (0.25 in, 6.4 mm) are exempt from radius or fillet requirements.

10.5.3.1.2 Ridges with a height greater than or equal to 1/4 in shall have a minimum radius of 1/4 in (0.25 in, 6.4 mm) or provide a 135°, 1/4 in (0.25 in, 6.4 mm) fillet at the base of the ridges (See Figure 2).

10.5.3.1.3 Ridges forming an open box, triangle, or any shape shall not have a depth greater than the internal width of the shape.

10.6 Trimmer valves

Trimmer valves shall not interfere with the performance of the skimmer.

10.7 Vacuum cleaner connections

Vacuum cleaner connections shall be in a convenient location for use and shall not interfere with normal operation of the skimmer.

10.8 Head loss

The actual head loss of a skimmer in normal operation shall not exceed the head loss indicated by the manufacturer's head loss claim by more than 5% or 0.25 psi, whichever is greater (see Section N-5.4). If a trimmer valve is present, the head loss shall be measured with the trimmer both 100% open, and again with the trimmer valve 50% open.

If a skimmer is equipped with an equalizer line, the actual head loss of a skimmer in equalizer operation shall not exceed the head loss indicated by the manufacturer's head loss claim by more than 5% or 0.25 psi, whichever is greater (see Section N-5.4)

10.9 Operation and installation instructions

10.9.1 The manufacturer shall provide written operation and installation instructions with each unit. The instructions shall include drawings, charts, head loss curves, and parts lists necessary for the proper installation, operation, and maintenance of the skimmer.

10.9.2 A skimmer equipped with an equalizer shall have, in its operation and installation instructions:

— a warning that the skimmer is to be installed with an equalizer wall or drain fitting certified to ANSI/APSP-16[5] to prevent hair or body entrapment at the skimmer equalizer;

— the skimmer manufacturer shall specify the minimum flow rating of the suction fitting (which meets or exceeds the maximum flow rating of the skimmer suction line); and

— to address jurisdictions that do not allow skimmers to be installed with equalizer lines, the skimmer manufacturer shall provide instructions for disabling (i.e., installation of the skimmer without the equalizer line) the equalizer line.

The skimmer manufacturer may or may not supply the suction fitting with the skimmer.

10.9.3 A skimmer's flow ratings (GPM, LPM) shall be specified by the manufacturer and conform to Sections 10.3.3.1 through 10.9.3.3, when applicable. When skimmers include water level based, maximum flow rating marks inside the housing, instructions shall indicate they are to be observed by users when the skimmer is off (i.e., no flow).

10.9.3.1 The minimum flow rating shall develop an even flow over the full width of the weir when tested at the skimmer's lowest operating water level (see Section N-5.2).

10.9.3.2 The maximum flow rating for each indicated operating water level shall not exceed the nominal pipe sizes specified by the manufacturer or entrain air in the suction line (see Section N-5.2). The maximum velocity for any nominal pipe size specified shall not exceed 6 FPS (1.83 MPS). Velocity calculations shall be based on the nominal inside diameter for ASTM D1785[9] schedule 40 PVC pipe.

10.9.3.3 The manufacturer may optionally specify water level based, maximum flow ratings within the operating range of the weir (e.g., the normal, mid-point operating level) that are higher than the maximum flow rating achieved when tested at the lowest operating water level of the weir (see Section N-5.2). When multiple water-level based flow ratings are used, each shall be indicated on a data plate inside the skimmer housing that is permanent, easy to read, and securely attached, cast or stamped at the appropriate water elevation. The elevation of these markings shall be set and observed when the pump is off.

10.10 Data plate

A skimmer shall have a data plate that is permanent, easy to read, and securely attached, cast or stamped into the cover or skimmer housing at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— skimmer model number;

— minimum design flow rate in GPM (LPM);

— maximum design flow rate in GPM (LPM); and

— multiple water level based maximum design flow rates in GPM (LPM) that refer to or are located adjacent water level marks located inside the skimmer housing, if applicable.

11 Mechanical chemical feeding equipment

This section contains requirements for mechanical chemical feeders that are used to dispense solutions, slurries, or solids in public or residential pools and spas / hot tubs. Components of mechanical feeding equipment, such as strainers, tubing connectors, and injection fittings supplied by the manufacturer as part of the chemical feed system, are also covered under this section. This section applies to fixed rate or single rate mechanical feeding equipment (for use with automatic control systems) and mechanical feeding equipment with adjustable output rates. This section does not contain requirements for chemical feeding equipment that relies on the flow rate of water in the recirculation system.

11.1 General

11.1.1 Mechanical chemical feeder parts that require cleaning and maintenance shall be accessible.

11.1.2 The mechanical chemical feeder shall be equipped to prevent unintended siphonage or other unintended discharge of chemicals and air into a swimming pool or spa / hot tub or piping systems.

11.2 Erosion resistance

11.2.1 Slurry feeders

When tested in accordance with the erosion resistance test described in Section N-6.2, a slurry feeder operating at the maximum output setting shall feed an agitated suspension of diatomaceous earth 5% (± 0.5%) by volume continuously for 2500 h at 20 ± 0.5 psi (138 ± 3 kPa) back pressure and shall have an output rate that is no less than 80% and no more than 120% of the manufacturer's maximum rated output. At the end of testing, the slurry feeder shall show no signs of erosion that could adversely affect proper operation.

11.2.2 Dry chemical feeders

When tested in accordance with the erosion resistance test described in Section N-6.2, a dry chemical feeder operating at the maximum output setting shall feed an applicable dry chemical continuously for 2,500 h at atmospheric pressure and shall have an output rate that is no less than 80% and no more than 120% of the manufacturer's maximum rated output. At the end of testing, the dry chemical feeder shall show no signs of erosion that could adversely affect proper operation.

11.3 Chemical resistance

11.3.1 When tested in accordance with the chemical resistance test described in Section N-6.3, mechanical chemical feeders exposed to the maximum in-use concentration of the applicable chemical(s) specified for the feeder, for a test period of 100 d, shall show no signs of erosion or structural deformation.

11.3.2 Following the 100-d chemical exposure specified in Section 11.3.1 and 24 h of operation at 100% output rate, mechanical chemical feeders shall conform to the uniformity of output requirements in Section 11.4.2. Fixed or single rate feeders for use with automatic controllers shall conform to Section 11.4.3.

11.4 Output rate

11.4.1 Mechanical chemical feeders shall have an output rate control mechanism that is adjustable in at least four increments over the full operating range. The mechanism for regulating the output rate shall be readily accessible when the feeder is installed in accordance with the manufacturer's instructions.

11.4.2 Mechanical chemical feeders shall deliver chemicals in slurries, solutions, or solids, at an output rate that is within ± 10% of feed rate indicator setting, over deliveries from 25% to 100% of the rated capacity when operated at the maximum back pressure recommended by the manufacturer (see Section N-6.5).

11.4.3 Fixed or single rate mechanical chemical feeders shall deliver chemicals in slurries, solutions, or solids, at an output rate that is within ± 10% of feed rate at 100% of the rated capacity when operated at the maximum back pressure recommended by the manufacturer (see Section N-6.5).

11.5 Hydrostatic pressure

Components of a mechanical chemical feeder that normally operates under pressure shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum operating pressure (see Section N-6.1).

11.6 Life test

When tested in accordance with the life test described in Section N-6.4, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units shall perform as intended by the manufacturer and shall continue to conform to the uniformity of output, suction lift, and pressure requirements of this section.

11.7 Shielding

Moving parts of the feeder shall be covered so that no openings are exposed.

11.8 Motors

11.8.1 Motors shall be continuous duty and shall conform to the requirements of Article 430 of NFPA 70, (NEC).[17]

11.8.2 Motors shall use standard voltages and cycles.

11.9 Suction lift

Positive displacement pump mechanical feeders operating with a suction lift of 4 ft (1.2 m) of water, at 80% back pressure and 100% of their rated capacity, shall deliver an output rate that is within ± 10% of the delivery specified by the manufacturer (see Section N-6.6).

11.10 Protection against overdosing

The manufacturer shall provide printed materials warning the user of the potential for elevated chemical concentrations and hazardous gas introduction into the pool or spa. At a minimum, the printed materials shall describe the potentially hazardous conditions, such as backwash and periods of no flow in the recirculation system. The steps to be taken during installation and operation to prevent such conditions shall be included. Feeders designed to be self-draining shall be exempt from this requirement.

11.11 Operation and installation instructions

The manufacturer shall supply operation and installation instructions with each mechanical chemical feeder. These instructions shall include the following:

— diagrams and a parts list to facilitate the identification and ordering of replacement parts;

— installation, operation, and maintenance instructions;

— reference to flooded suction installation and prevention of cross connections;

— reference to recommended use chemicals and maximum use concentrations;

— caution statement to address potentially hazardous conditions due to chemical overdosing (see Section 11.10);

— reference to one or more methods to stop chemical feed automatically when no return flow to the swimming pool or hot tub exists;

— model number of the unit; and

— applicable caution statements (prominently displayed).

11.12 Data plate

The data plate on mechanical chemical feeders shall be permanent; easy to read; and securely attached, cast, or stamped onto the feeder at a location readily accessible after normal installation. Data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— feeder model or serial number;

— maximum operating pressure rating in psi (kPa);

— reference to installation instructions for swimming pool and hot tub/spa applications for protection against overdosing during backwash and no-flow conditions;

— maximum output rating (volume of liquid or weight, or volume of solid chemicals, 24 h/d); and

— if the unit is a fixed rate or single rate mechanical chemical feeder include the following:

"Fixed / single rate feeder for use only with certified automatic controller."

The data plate shall indicate whether the mechanical chemical feeder is designed for swimming pool applications only or spa / hot tub applications only. A mechanical chemical feeder that is designed for both applications is exempt from this requirement.

12 Flow-through chemical feeding equipment

This section contains requirements for adjustable output rate flow-through chemical feeders and auxiliary components used for dispensing chemicals by a flow-through process in public and residential swimming pools or spas / hot tubs. Flow-through chemical feeders without adjustable output rates and gaseous feeding equipment are not covered under this section.

12.1 General

Parts of the feeder requiring cleaning and maintenance shall be accessible.

12.2 Chemical resistance

Flow-through chemical feeders exposed to the applicable chemicals per Section N-7.1 for a test period of 100 d shall show no signs of erosion or structural deformation.

12.3 Hydrostatic pressure

Flow-through chemical feeders shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum pressure rating (see Section N-7.2). The unit tested shall be one that has been exposed in accordance with the chemical resistance test per Section N-7.1 for a test period of 100 d.

12.4 Motors

Motors, if provided, shall be continuous duty and shall conform to the requirements of Article 430 of NFPA 70 (NEC).[17]

12.5 Output rate

12.5.1 The flow-through chemical feeder shall have an output rate control mechanism that is adjustable in at least four increments over the full operating range. The mechanism for regulating the output rate shall be readily accessible when the feeder is installed in accordance with the manufacturer's instructions.

Chemical feeders designed for one output rate or intended for use with a separate automated controller shall be exempt from this requirement.

12.5.2 The uniformity of output for a flow-through chemical feeder shall be tested and evaluated at settings of the output rate control mechanism equivalent to 50% and 100% of the rate of maximum chemical output recommended by the manufacturer. Chemical feeders designed for one output rate shall be evaluated at 100% of the maximum chemical output. The output of a flow-through chemical feeder shall be within ± 20% of the output specified by the manufacturer at each test setting of the output rate control mechanism. For each test setting, the output of the flow-through chemical feeder shall be repeatable within ± 10% when tested in accordance with Section N-7.3.

12.6 Protection against overdosing

The manufacturer shall provide printed materials warning the user of the potential for elevated chemical concentrations and hazardous gas introduction into the pool or spa. At a minimum, the printed materials shall describe the conditions that may result in such potentially hazardous conditions, such as backwash and periods of no flow in the recirculation system. The steps to be taken during installation or operation to prevent such conditions shall be included. Feeders designed to be self-draining shall be exempt from this requirement.

12.7 Flow-indicating device

12.7.1 Flow-through chemical feeders shall be provided with a flow-indicating device on the unit, or the installation instructions shall provide for the installation of a flow-indicating device for the full range of flow rates. Flow-through chemical feeders operated by an automated controller shall be exempt from this requirement.

12.7.2 When the chemical output of a flow-through chemical feeder is specified relative to the flow rate of water through the feeder (i.e., *X* gal/min [m^3/h] through the feeder = *Y* lb/d [kg/d] chemical output), the chemical feeder shall be supplied with a flow-indicating device (or instructions for installing such a device) for the full range of flow rates specified by the manufacturer.

12.7.3 Head loss

The manufacturer shall make available a head loss claim at the maximum and minimum settings for systems installed in the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

12.8 Operation and installation instructions

The manufacturer shall supply the following operation and installation instructions with each flow-through chemical feeder:

— diagrams and a parts list to facilitate the identification and ordering of replacement parts;

— installation, operation, and maintenance instructions;

— model number of the unit;

— caution statement to address potentially hazardous conditions due to chemical overdosing (see Section 12.6); and

— caution statements regarding the recommended use chemicals (prominently displayed).

12.9 Data plate

The data plate on flow-through chemical feeders shall be permanent; easy to read; and securely attached, cast, or stamped onto the feeder at a location readily accessible after installation. The data plate shall contain the following information:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— feeder model (serial number optional);

— maximum output rate;

— recommended use chemical(s); and

— a caution statement indicating that the use of chemicals other than those recommended by the manufacturer may be hazardous.

The data plate shall indicate whether a flow-through chemical feeder is designed for swimming pool applications only or spa / hot tub applications only. A flow-through chemical feeder that is designed for both applications is exempt from this requirement.

13 Filtration media

This section contains requirements for filtration media for use in commercial and residential filters.

13.1 Precoat filter media

Precoat media shall conform to the requirements of Section 4.

13.1.1 Precoat filter media

Precoat media shall meet the applicable requirements of Sections N-2.3 through N-2.8.

13.1.2 The manufacturer of precoat media shall provide written instructions for the installation of the media in a filter; for any specific preparation of the media for operation; and for the operation of filter with the media.

13.1.3 Precoat filter media labeling requirements

Precoat media shall contain the following information on the product packaging or documentation shipped with the product:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— product identification (product type, and tradename);
— net weight or net volume;
— when applicable, mesh or sieve size;
— lot number or other production identifier such as a date code;
— when appropriate, special handling storage and use instructions; and
— the specific certification mark of the certifying organization for certified products.

13.2 Sand and alternate sand-type filter media

13.2.1 Sand and alternate sand-type filter media shall conform to the requirements of Section 4.

13.2.2 Sand filter media

13.2.2.1 Filter sand shall be hard, silica-like material that is free of carbonates, clay, and other foreign material. The effective particle size shall be between 0.016 in (0.40 mm) and 0.022 in (0.55 mm), and the uniformity coefficient shall not exceed 1.75. Filters intended for use with an alternate media that does not conform to these requirements shall specify the alternate media on the data plate. The filter and the alternate media shall conform to the other applicable requirements of this Standard.

13.2.2.2 If a different media is used to support the filter media, it shall be rounded material that is free of limestone and clay and installed according to the manufacturer's instructions. When the support media and the filter media are installed in accordance with the manufacturer's recommendations, the filter media shall not intermix with the support media when operated and backwashed at least three cycles in accordance with Section N-2.4.

13.2.3 Sand and alternate sand-type filter media

Filter media in a sand-type filter shall conform to Sections 4.2, 6.1.8, 6.1.9, 6.3.5, and 13.3 when tested in a representative sand-type filter in accordance with Sections N-2.3 through N-2.5.

13.2.3.1 The manufacturer of sand and an alternate sand-type filter media shall specify the effective size and uniformity coefficient for the media. Effective size and uniformity coefficient evaluation shall be performed in accordance with ASTM C136[9] with sieves conforming to ASTM E11.[9] A minimum of five data points shall be measured for sizing. The particle size data shall be plotted as a smooth curve, which shall be used to read the sieve opening sizes at which 60% and 10% of particles can pass. The uniformity coefficient and effective size measured shall be ± 10% of the claimed uniformity coefficient and effective size or shall be within the claimed range of uniformity coefficient and effective size, whichever is larger.

13.2.3.2 The filtration rate and backwash rate for sand and alternate sand-type filter media shall be as specified in Section 6.3.9.

13.2.4 Installation and operating instructions

The manufacturer of sand and alternate sand-type media shall provide written instructions for the installation of the media in a filter, including requirements for a different support media; for any specific preparation of the media for operation; and for the operation of filter with the media.

13.2.5 Sand and alternate sand-type media labeling requirements

Sand and alternate sand-type filter media shall contain the following information on the product packaging or documentation shipped with the product:

- manufacturer's name and contact information (address, phone number, website, or prime supplier);
- product identification (product type, and tradename);
- net weight or net volume;
- when applicable, mesh or sieve size;
- uniformity coefficient for particle size;
- lot number or other production identifier such as a date code;
- when appropriate, special handling, storage and use instructions; and
- the specific certification mark of the certifying organization for certified products.

14 Ozone generation process equipment

14.1 General

Ozone generation process equipment covered by this section is intended for the secondary and supplemental disinfection of the water in the circulation system of public and residential recreational water facilities, including but are not limited to: pools, and spas / hot tubs, therapy pools, and interactive aquatic play features. Since these products are not intended to produce residual levels of disinfectant within the body of water, an EPA registered disinfecting chemical shall be added to impart a measurable residual. The measurable residual disinfecting chemical shall be easily and accurately measured by a water quality device certified to Section 20.

14.2 Ozone components

Ozone generation systems shall include but are not limited to the following components:

- ozone generator;
- ozone venturi injector;
- reaction / degas system;
- gaseous ozone destruct;
- ORP monitor / controller; and
- ambient ozone monitor / controller.

Smaller (residential) type ozone generators are not required to include all components of a commercial system.

14.3 Ozone generator

The ozone generator shall be designed to maintain ozone under vacuum from generation to the point of injection in the water stream. Automatic feed-gas flow control shall be incorporated to maintain a vacuum set-point and correct for variations in suction. Minimum protection (e.g., vacuum switch transducer, etc. to shut down the ozone power) against vacuum loss shall be included; and water backflow protection devices shall be included in the ozone gas delivery line.

14.4 Injection methods

Injection methods shall be designed to prevent off gassing in excess of the Occupational Safety and Health Administration (OSHA) standards for in-air ozone concentration. Ozone levels exceeding 0.1 ppm (0.2 mg/m^3) shall not be acceptable in the pool, spa / hot tub water when tested in accordance with Section N-8.2.

For companies under jurisdiction other than US regulation for ozone off gassing, those jurisdictions' regulations are the default.

14.5 Gas flow meter

Ozone generation systems shall be equipped with a gas flow meter.

14.6 Valve and component identification

All valves and performance devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

14.7 Cleanability

Parts of ozone generation systems requiring cleaning and maintenance shall be accessible.

14.8 Ozone resistant materials

Materials in direct contact with ozone gas shall be resistant to degradation by ozone at the ozone concentration specified by the manufacturer.

14.9 Compatible materials for operation

14.9.1 For use of alternate materials, at a minimum the supplier shall confirm compatibility with end use. Other materials may be used for construction of ozone generators if proper material compatibility is demonstrated. Acceptable documentation shall include component material manufacturer's compatibility charts or written warranty statement.

Tables 14.1 and 14.2 provide examples of ozone-resistant materials that are commercially available. These materials are recommended for use with dry gas with a maximum temperature of 104 °F (40 °C). Alternate materials may be used for ozone generators if material compatibility is demonstrated (see Section 14.18 Life test). The material supplier shall provide documentation of compatibility including component material manufacturer's compatibility charts or written warranty statement. Ozone resistant materials not in Table 14.1 and 14.2 shall be tested in accordance with Section N-7.1.

14.9.2 Components and piping

Table 14.1
Components and piping

	Ozone gas < 2500 ppm	Ozone gas > 2500 ppm
glass	X	X
ceramics	X	X
PVC	X	NR
CPVC	X	NR
UPVC (unplasticized)	X	NR
aluminum	X	X (4% wt max)
304 L stainless steel	X	X
316 L stainless steel	X	X
superalloys such as Inconel[1] and Hastelloy-C[2]	X	X
titanium	X	X
perfluoroalkoxy resin (PFA) such as Teflon®[3] or equivalent	X	X
fluorinated ethylene propylene (FEP) such as Teflon®[3] or equivalent	X	X
polytetrafluoroethylene (PTFE) such as Teflon®[3] or equivalent	X	X
ethylene tetrafluoroethylene (ETFE) such as Tefzel®[3] or equivalent	X	X
ethylene chlorotrifluoroethylene (ECTFE) such as Halar®[4] or equivalent	X	X
Neoprene® or equivalent	X	NR
polyvinylidene fluoride (PVDF) such as Kynar®[5] or equivalent	X	X
p-chlorotrifluoroethylene P-CTFE such as Kel-F®[6] 2800 and Neoflon®[7] or equivalent	X	X

[1] Special Metals Corporation

[2] Haynes International, Inc.

[3] Dupont

[4] Ausimont USA, Inc.

[5] Elf Atochem North America

[6] 3M Company

[7] Daikin Industries

NR – not recommended

NOTE — Abbreviations for components, piping, gasket and seals are in accordance with ASTM D4000.

14.9.3 Gaskets and seals

Table 14.2
Gaskets and seals

	Ozone gas < 2500 ppm	Ozone gas > 2500 ppm
p-chlorotrifluoroethylene (P-CTFE) such as Kel-F®[1] or equivalent	X	X
perfluorelastomer such as Kalrez®[2] or equivalent	X	X
perfluorinated copolymer such as Chem-Rez®[3] or equivalent	X	X
Gortex® or equivalent	X	X
PTFE tape	X	X
chlorosulfonated polyethylene such as Hypalon®[2] or equivalent	X	NR
vinylidene fluoride such as Viton®[2] or equivalent	X	X (4% wt max)
polydimethyl siloxane (silicone)	X	X (4% wt max)
ethylene propylene diene monomer (EPDM)	X	NR

[1] 3M Company
[2] Dupont
[3] Green, Tweed and Company
NR – not recommended

14.10 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

14.11 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10% (when tested in accordance with Section N-2.3).

14.12 Water flow meter

If the performance of a unit is dependent on a specified water flow rate, a means to monitor and control the flow shall be provided.

14.13 Oxidation-reduction potential (ORP) monitoring

Ozone systems shall be equipped with ORP monitoring equipment. The ORP monitoring equipment shall comply with the applicable requirements of Section 19.

14.14 Warning devices

The ozone generation system shall have a visual or audible alarm to alert facility staff of the ORP reading for the ozone system when it reaches below 650 mV.

14.15 Operational protection

Ozone generation systems shall have an automatic mechanism for ceasing ozone production whenever one or more of the following conditions exist:

— door open or cover panel removed from the generator cabinet;
— low feed-gas supply;
— loss of vacuum;
— high temperature of the ozone generator module;
— high temperature of the high voltage transformer;
— loss of water flow (including during backwash cycle); and
— high dew point in the ambient feed air (not necessary if oxygen is used).

NOTE — High dew point results in nitric acid production which can severely damage ozone generators and contaminate the water.

14.16 Ozone destruct

The injection and mass transfer components of an ozone generation system shall be equipped with a method of collecting undissolved gaseous ozone and destroying it before it is vented to atmosphere. The gaseous ozone concentration at the outlet of the ozone destruct system vent shall be 0 mg/m^3 (0.07 ppm).

14.17 Ozone output

Ozone generation systems shall be tested for ozone concentration and output rate in accordance with Section N-8.2.

14.18 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the output, pressure, and disinfection efficacy requirements of this section.

14.19 Disinfection efficacy

Process equipment designed for supplemental disinfection such as ion generators, ozone and ultraviolet light equipment shall demonstrate a 3 log (99.9%) or greater inactivation of influent bacteria when tested according to Section N-8.1.

Process equipment designed for secondary disinfection such as ion generators, ozone and ultraviolet light equipment shall demonstrate a 3 log (99.9%) or greater reduction of *C. parvum* when tested and evaluated according to Section 14.20.

Ozone equipment shall carry the following information in the installation and use instructions:

— Level 1 (L1): NSF/ANSI/CAN 50, Section 14.19, disinfection efficacy testing for 3 log (99.9%) or greater of <name organisms>, NSF/ANSI/CAN 50, Section 14.20 *Cryptosporidium parvum reduction* for a 3 log (99.9%) or greater in a single pass. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority.

— Level 2 (L2): NSF/ANSI/CAN 50, Section 13.19, disinfection efficacy testing for 3 log (99.9%) or greater of <name organisms>. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority.

14.20 *Cryptosporidium* reduction

Manufacturers of an ozone generation system with a claim of *C. parvum* reduction shall demonstrate a minimum of 3 log (99.9%) or greater reduction of *C. parvum* in a single pass when tested in accordance with Section N-8.4.

The ozone generation system shall reduce the number of live *C. parvum* oocysts from an influent challenge of at least 5000 (5×10^3) infectious oocysts per liter by at least 99.9% when tested in accordance with Section N-8.3. The *C. parvum* oocysts shall be from a calf source. The viability shall be greater than 50% determined by excystation.[25] The oocysts shall be stored with 1,000 IU/mL penicillin and 1,000 µg/mL streptomycin at 39 °F (4 °C) and shall be used within eight weeks of collection. The live *C. parvum* oocysts shall not be inactivated by any means including chemical or UV irradiation prior to passing through the ozone generation system.

> NOTE — It has been reported that the oocyst wall of viable oocysts may deform. Excystation is performed as an indication of the potential of the oocyst wall to deform and is not done to measure the infectivity of the organism. The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

14.21 Operation and installation instructions

— drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers;

— output rate (in pounds or kilograms per day or hour);

— maximum daily operation time (if not designed for continuous operation; and

— level of disinfection efficacy.

14.22 Information on ozone off-gassing and removal devices

Information shall be provided to the user concerning the potential for off-gassing of ozone and required ozone removal devices, if applicable.

[25] The in vitro excystation method is specified in *Development of a Test to Assess Cryptosporidium parvum Oocysts Viability: Correlation with Infectivity Potential,* American Water Works Association Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235 <www.waterresearchfoundation.org>.

14.23 Data plate

Data plate(s) shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain the following:

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number;

— serial number or date of manufacture;

— certification mark of the ANSI-Accredited testing and certification organization;

— electrical requirements (volts, amps, Hertz) for operation;

— type of feed-gas;

— rated feed-gas flow rate (SCFH or LPM);

— rated ozone production (grams per hour [g/h] or pounds per day [lb/d]);

— method of cooling and coolant flow rates;

— level of disinfection certification (L1 or L2);

— maximum daily operation time (if not designed for continuous operation);

— caution statements (prominently displayed) including a statement that the unit should be used with an EPA registered disinfection chemical to impart a measurable residual concentration in the water; and

— a statement identifying if the unit is suitable for supplemental disinfection or for secondary disinfection.

15 Ultraviolet (UV) light process equipment

15.1 General

UV light process equipment covered by this section is intended for the secondary and supplemental treatment of public and residential swimming pools and spas / hot tubs. Since these products are not intended to produce residual levels of disinfectant within the body of the swimming pool or spa, these products are intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority. The residual chemical shall be easily and accurately measureable by a field test kit.

15.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

15.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

15.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

15.5 Performance indication

A supplemental UV system shall be provided with an effective means to alert the user when a component of this equipment is not operating.

A secondary UV system shall incorporate on the control panel a constantly visible readout of the actual flow (in US GPM), the actual calculated dose (in mJ/cm^2) and the actual lamp intensity (in w/m^2). It is acceptable for the display to constantly cycle through the parameters. The cycle duration shall not take more than 15 s.

15.6 Operation and installation instructions

15.6.1 Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— whether the system has a mechanical cleaning system or requires an external chemical cleaning system installed per Section 15.13.1;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— maximum daily operation time (if not designed for continuous operation); and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

15.6.2 UV systems claiming inactivation of cysts, the installation and operational instructions or product manual shall contain the following:

— reactor configuration type (U, S, etc.);

— number of lamps per reactor;

— lamp designation or model number;

— sensor designation or model number;

— UVT of water (minimum value or a range of UVTs under which validation was performed);

— organism used in testing;

— correlation between test organism and *C. parvum*;

— effective log inactivation of organism at maximum flow rate or validated flow rates;

— effective UV dose delivered at specified wavelength and flow rate; and

— whether the system has a mechanical cleaning system or requires an external chemical cleaning system installed per Section 15.13.1

15.7 Data plate

Data plate shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain the following:

— equipment name and function(s);

— manufacturer's name and contact information (address, phone number, website, or prime supplier);

— model number designation;

— electrical requirements for operational volts, amps, and Hertz of the unit;

— serial number or year of construction;

— maximum rated operating pressure in kPa (psi);

— prominently displayed caution statement:

"*UV light is harmful to eyes and exposed skin; turn off electrical supply before opening unit.*"

— caution statement that the unit should be used with registered or approved disinfection chemicals to impart required residual concentrations;

— model and number of UV lamp(s);

— maximum daily operation time (if not designed for continuous operation);

— maximum design flow rate in GPM (LPM); and

— a statement identifying if the unit is suitable for supplemental disinfection or for secondary disinfection.

15.8 Disinfection efficacy

Ultraviolet light process equipment designed for supplemental disinfection shall demonstrate a 3 log (99.9%) or greater inactivation of influent bacteria when tested according to Section N-8.1.

Ultraviolet light process equipment designed for secondary disinfection shall demonstrate a 3 log (99.9%) or greater inactivation of *C. parvum* when tested and evaluated according to Section 15.18 and is exempt from Section N-8.1 testing if during secondary validation the lamp intensity (per Section 15.5) is equal to or greater than the lamp intensity after the unit has completed life testing. Section N-8.1 shall be required if the dose is less.

Ultraviolet light process equipment designed for supplemental disinfection shall carry the following information in the installation and use instructions and be noted in the official certification listings:

> *"This unit has demonstrated an ability to provide three log inactivation of <name organisms>. This unit has not demonstrated an ability to provide three log kill or inactivation of <name organisms if applicable>. This product is designed for supplementary disinfection and is intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority."*

Ultraviolet light process equipment designed for secondary disinfection shall carry the following information in the installation and use instructions and be noted in the official certification listings:

> *"This unit has been tested to confirm a minimum inactivation equivalent of 3 log (99.9%) C. parvum in accordance with NSF/ANSI/CAN 50 and the US EPA UV DGM. This product has met the requirements of NSF/ANSI/CAN 50, Section N-8.1: Disinfection Efficacy, for the ≥ minimum of a 3 log (99.9%) reduction of Enterococcus faecium [ATCC #6569] and Pseudomonas aeruginosa [ATCC #27313]. This product is intended for secondary disinfection and is intended for use with appropriate residual levels of EPA registered disinfecting chemicals. Specific residual levels of EPA registered disinfecting chemicals may be required by the regulatory agency having authority."*

15.9 Valve and component identification

All valves and performance indication devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

15.10 Operating temperatures

The unit and all its components shall be designed to withstand a maximum operating temperature of 102 ± 5 °F (39 ± 3 °C).

15.11 Operational protection

Units shall be equipped with an automatic mechanism for shutting off the power to the UV light source whenever the cover is removed.

15.12 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the operational protection, pressure, and disinfection efficacy requirements of this Section.

Life testing shall be conducted within the operating temperatures of its intended end use; swimming pool 75 ± 10 °F (24 ± 6 °C) or spas and hot tubs, 65 to 104 °F (18 to 40 °C).

Life testing is not required on UV units being tested for *Cryptosporidium* inactivation (Section 15.18) because the NSF ETV UV Protocol and US EPA UV DGM[20] requires a 100-h burn in for the lamp prior to testing.

15.13 Cleaning

15.13.1 For systems utilizing quartz sleeves to separate the water passing through the chamber from the UV source, the system shall be designed to permit cleaning of the lamp jackets and the sensor window or lens without mechanical disassembly. All piping for in-place cleaning purposes shall be entirely independent of the water piping system in and out of the unit, and a drain shall be provided. The chamber shall be designed so that at least one end can be dismantled for general and physical cleaning.

15.13.2 For systems utilizing polytetra-fluoroethylene (PTFE) surface materials to separate the water passing through the UV chamber from the UV lamps, the unit shall be designed to be readily accessible to the interior and exterior of the PTFE. The unit shall be designed to permit use of either physical or chemical cleaning methods.

15.14 Ultraviolet (UV) lamps

UV lamps shall be readily accessible for replacement, and instructions for replacement shall be provided.

15.15 Chemical resistant materials

Internal surfaces exposed to direct ultraviolet light shall be resistant to use application conditions.

15.16 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

15.17 Hydrostatic pressure requirements

UV light process equipment that normally operates under pressure shall show no evidence of rupture, leakage, burst, or permanent deformation when subjected to a hydrostatic pressure 1.5 times the manufacturer's maximum operating pressure (see Section N-6.4).

15.18 UV *Cryptosporidium* inactivation and dose determination

Manufacturers of UV systems with a claim to inactivate cysts (such as *Cryptosporidium*, *Giardia*, etc.) shall demonstrate a minimum 3 log (99.9%) or greater inactivation of *C. parvum* in a single pass.

> NOTE — Operators of spray parks, spray pads, or interactive water features with no standing water should consider greater inactivation performance of 4 log (99.99%). The local public health authority may select different levels of log inactivation or power delivery for different applications such as competition lap pools, spas, wave pools, wading pools, etc.

15.18.1 Sample selection

When validating a range of aquatic or recreational water use UV systems for inactivation of cysts such as *C. parvum*, each of the following variables shall be used to determine which UV reactor / systems and components shall be tested within the range of product. Select at least two worst-case models from the range of products based upon all of the following variables.

— test the unit representative of the worst-case reactor hydraulics and UV dose delivery as determined by computational fluid dynamics modeling, including intensity and flow modeling;

— test the unit with the lowest power to highest flow rate;

— test one unit of each configuration (if family range contains U and S reactors, test each);

— test one unit of each UV lamp type (if alternate lamp types or suppliers, test each);

— in the case where the UV system utilizes low pressure (LP) lamps, it is sufficient to provide a data sheet of the lamp that includes the expected lamp life. In addition, the following characteristics of the lamp must be the same:

  — lamp length, the length of the lamp from base face to base face, ± 0.5 in;
  — the arc length, the lit length, ± 0.5 in;

  — the diameter, ± 10%;
  — the quartz material, fused silica, synthetic quartz, deep UV blocking;
  — electrode current, ± 0.2 A;
  — lamp wattage, ± 5 W;
  — output, 185/254 nm or 254 nm;
  — mercury source, elemental, spot amalgam, pocket amalgam; and
  — connections, single ended, double ended.

— test one unit of each UV sensor type (if alternate UV sensor types or suppliers, test each).

NOTE — The above variables require that multiple UV systems are tested in order to validate a range of products.

15.18.2 Testing

Products shall be tested to confirm single pass inactivation equivalent to 3 log (99.9%) or greater of *C. parvum* in accordance with NSF/EPA ETV – *Generic Protocol for Development of Test / Quality Assurance Plans for Ultraviolet (UV) Reactors*.[20] Only full stream testing shall be acceptable, there shall be no partial or side stream treatment testing.

The manufacturer of a reactor validated for performance under one of the following protocols shall submit details of the testing for evaluation and validation:

— US EPA UV DGM;[20]
— DVGW, W-294 Parts 1-3;[13] or
— ÖNORM, 5873 1 and 2.[8]

Validation of a range of reactors with pre-existing test data shall include testing of at least one (1) unit at one (1) set point to evaluate for potential changes in design, suppliers and corroborate previous data.

16 In-line electrolytic chlorinator or brominator process equipment

16.1 General

In-line electrolytic chlorinator or brominator process equipment covered by this section is intended for use in circulation systems of public and residential swimming pools and spas / hot tubs. Equipment shall produce a quantity of sodium hypochlorite or hydrobromous acid as stated by the manufacturer.

16.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

16.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

16.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

16.5 Performance indication

The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

16.6 Operation and installation instructions

Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— output rate (in lb or kg per day or hour);

— maximum daily operation time (if not designed for continuous operation; and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

16.7 Data plate

Data plate shall be permanent; easy to read; and securely attached, cast, or stamped onto the unit at a location readily accessible after normal installation. Data plate(s) shall contain at least the following:

— equipment name;
— manufacturer's name and contact information (address, phone number, website, or prime supplier);
— model number;
— electrical requirements – volts, amps and hertz;
— serial number or date of manufacture;
— caution statements (prominently displayed);
— output rate in pounds or kilograms per day per hour);
— maximum daily operation time (if not designed for continuous operation); and
— salt concentration range.

16.8 Valve and component identification

All valves and performance indication devices shall have a permanent, easily legible, and conspicuous label or tag identifying their operation.

16.9 Operating temperatures and pressures

If installed within the recirculating piping system, in-line electrolytic chlorinator or brominator process equipment shall be designed to withstand a maximum operating temperature of 102 ± 5 °F (39 ± 3 °C) and a minimum rated pressure of 50 psig (345 kPa).

16.10 Operational protection

Systems shall have an automatic mechanism for shutting off the electric power to the electrolytic cell whenever one or more of the following conditions exist:

— loss of electric power to the recirculation pump; or
— interruption of water flow through the electrolytic cell.

16.11 Warning devices

A visual or audible alarm shall be provided to warn the user when the cell voltages are not within the manufacturer's recommended range, or when the salt concentration falls below the manufacturer's recommended minimum level.

16.12 Chemical-resistant materials

Equipment parts shall incorporate materials that are resistant to the environment to which the parts will be subjected.

16.13 Output rate

16.13.1 The output rate shall be adjustable in at least four increments over the full operating range. Means for regulating shall be conveniently located when mounted according to the manufacturer's instructions.

16.13.2 Delivery

Units shall deliver chemicals at an output rate shown by the feed rate indicator ± 10% of the setting, over deliveries from 25% to 100% rated capacity.

16.14 Pressure requirements

Units shall meet a hydrostatic pressure of 1.5 times the manufacturer's maximum pressure rating applied to all parts of the feeder subject to pressure during operation when tested at 102 ± 5 °F (39 ± 3 °C).

16.15 Life test

When tested in accordance with the life test described in Annex N-9, a minimum of 8,000 operating hours shall be accumulated among the three units; no less than 3,000 operating hours shall be accumulated on one of the three units. At the conclusion of the testing, the units with 3,000 operating hours shall be evaluated to the delivery, pressure and operational protection requirements of this section.

16.16 Salt level

In-line electrolytic chlorinator or brominators shall be designed to operate satisfactorily on the dissolved salt concentration range specified by the manufacturer.

16.17 Head loss

The manufacturer shall make available a head loss claim for systems installed into the main line. The actual head loss shall not exceed the claimed head loss by more than 10%.

17 Brine (batch) type electrolytic chlorine or bromine generators

17.1 General

Batch and process type electrolytic brine chlorine or bromine generators covered by this section are intended for use in circulation systems of public and residential swimming pools and spa / hot tubs.

17.2 Cleanability

Parts of process equipment requiring cleaning and maintenance shall be accessible.

17.3 Design pressure (pressure vessels)

Units and components of process equipment that are subjected to pressure shall meet a working pressure of 50 psi (33 kPa) or be equipped with a pressure-reducing valve set at the manufacturer's working pressure.

17.4 Flow metering device

If the performance of a unit is dependent on a specified flow rate, a means to monitor and control the flow shall be provided.

17.5 Performance indication

The process equipment shall be provided with an effective means to alert the user when a component of this equipment is not operating.

17.6 Operation and installation instructions

Drawings and a parts list for easy identification and ordering of replacement parts shall be furnished with each unit and shall include:

— model number of the unit;

— instructions for proper size selection and installation;

— operation and maintenance instructions;

— a statement of the manufacturer's warranty;

— applicable caution statements (prominently displayed);

— ventilation requirements (if applicable);

— cross connection protection (if the unit is physically connected to a potable water supply);

— output rate (in pounds or kilograms per day or hour);

— maximum daily operation time (if not designed for continuous operation); and

— a warning, if the potential exists for release of high dosages of substances that may endanger bathers.

"Precoat pot" means a container with a valved connection to the suction side of the recirculation pump of a pressure diatomaceous earth (D.E.) type filter system used for coating the filter with D. E. powder or NSF/ANSI Standard 50-2007 19 and manufacturer approved substitute filter aid.

454.1.6.5.1 Equipment testing.

Recirculation and treatment equipment such as filters, recessed automatic surface skimmers, ionizers, ozone generators, disinfection feeders and chlorine generators shall be tested and approved using the NSF/ANSI Standard 50, Circulation System Components and Related Materials for Swimming Pool, Spas/Hot Tubs, dated April 2019 2007, which is incorporated by reference.

454.1.11.3 Construction standards for artificial lagoons.

If an artificial liner is utilized as a containment system, the artificial liner used to contain the water shall consist of a material certified under NSF/ANSI Standard 61-2017 19, Drinking Water System Components—Health Effects, dated March 13, 2017, hereby incorporated by reference, which has been deemed copyright protected, and is available for review at the Department of State, R.A. Gray Building, 500 South Bronough Street, Tallahassee, FL 32399-0250.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10458

95

Date Submitted	02/15/2022	**Section**	454.1.2.1.1	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

454.2.6.1.1 and R4501.6.1.1

Summary of Modification

Provides an ANSI approved standard for the plastering of pools and in-ground spas.

Rationale

APSP (now PHTA) developed the 12 Standard in conjunction with the National Plasters Council and International Code Council to ensure minimum plastering requirement for swimming pools and spas. This Standard has gone through the rigorous ANSI development process, as all APSP/PHTA Standards do, and provides guidance on plastering matters. This proposal does not create new requirements except where appropriate.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to building and property owners relative to cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to industry relative to the cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will help ensure a proper plaster was put on the pool, providing benefits to pool owners.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will help ensure a proper plaster was put on the pool by providing ANSI approved requirements to follow when plastering a pool or spa.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10458-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:27:01 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) opposes the inclusion of APSP/NPC/ICC-12 in the Florida Building Code. Inclusion of the standard in the code is unnecessary, redundant, and will add compliance and regulatory costs to swimming pool construction. Plaster manufacturers already publish application standard and specifications for their products. A general standard may not capture all application techniques and standards for all available products.

454.1.2.1.1 Plastering.

When applicable, the plastering of pools and permanently installed concrete spas shall be in accordance with APSP/NPC/ICC-12.

Add new APSP (PHTA) Standard as follows to Chapter 35:

ANSI/APSP/NPC/ICC 12 – 16, American National Standard for the Plastering of Swimming Pools and Spas......454.1.2.1.1

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

96

SW10465

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarifications are needed for frequently mis-applied code citations. These errors and omissions result in delays and costs to contractors and owners

Rationale

Low grade containers have failed prematurely resulting in chemical spills. Unapproved life rings have been observed at pools instead of certified versions. Logos and designs on floors/walls have been installed without concern for patron safety.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Nominal to None

Impact to building and property owners relative to cost of compliance with code

Nominal to None

Impact to industry relative to the cost of compliance with code

Nominal to None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

All 4 revisions have health and safety improvements

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code, and provides better products or methods

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade the code effectiveness.

1st Comment Period History

SW10465-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:31:31 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Requiring all proposed logo designs to be pre approved by the variance board adds time and cost to the swimming pool plan approval process. This proposal retains the subjective logo criteria of the current code. Proposed modifications SW10308 and SW10309 better address the issues with pool logos by removing the subjective criteria and creating objective logo criteria for commercial swimming pools.

- **454.1.2.3.2 Designs or logos.**
  Any design or logo on the pool floor or walls shall be such that it will not hinder the detection of a human in distress, algae, sediment, or other objects in the pool. Proposed dark designs and logos, or designs and logos greater than 12 inches X 12 inches, must have prior approval through the Department of Health's public swimming pool advisory & variance board.

- **454.1.3.3.1**
  All swimming pools shall be installed with a shepherd's hook securely attached to a one piece pole not less than 16 feet (4880 mm) in length, and at least one 16-24 ~~18~~-inch (~~457~~ mm) diameter lifesaving ring, approved or certified under a nationally recognized water safety device standard, with sufficient rope attached to reach all parts of the pool from the pool deck. Safety equipment shall be mounted in a conspicuous place and be readily available for use. Pools greater than 50 feet (15 250 mm) in length shall have multiple units with at least one shepherd's hook and one lifesaving ring located along each of the longer sides of the pools. Spa pools under 200 square feet (1.86 m^2) of surface area, and interactive water features or wading pools with 2 feet (610 mm) or less of water depth are exempt from this requirement.

  - **454.1.6.5.16.2 Hypohalogenation and electrolytic chlorine generators.**
    The hypohalogenation-type feeder and electrolytic chlorine generators shall be adjustable from 0 to full range. A rate of flow indicator is required on erosion-type feeders. The feeders shall be capable of continuously feeding a dosage of 6 mg/L to the minimum required turnover flow rate of the filtration systems. Solution feeders shall be capable of feeding the above dosage using a 10-percent sodium hypochlorite solution, or 5-percent calcium hypochlorite solution, whichever disinfectant is to be utilized at this facility. To prevent the disinfectant from siphoning or feeding directly into the pool or pool piping under any type failure of the recirculation equipment, an electrical interlock with the recirculation pump shall be incorporated into the system for electrically operated feeders. The minimum size of the solution reservoirs shall be at least 50 percent of the maximum daily capacity of the feeder. The solution reservoirs shall be marked to indicate contents. The solution reservoirs shall be manufactured to accommodate corrosive and oxidizers liquid chemicals.

  - **454.1.6.5.16.3 Feeders for pH adjustment.**
    Feeders for pH adjustment shall be provided on all pools. pH adjustment feeders shall be positive displacement type, shall be adjustable from 0 to full range, and shall have an electrical interlock with the circulation pump to prevent discharge when the recirculation pump is not operating. When soda ash is used for pH adjustment, the maximum concentration of soda ash solution to be fed shall not exceed 1/2-pound (0.2 kg) soda ash per gallon of water. Feeders for soda ash shall be capable of feeding a minimum of 3 gallons (11 L) of the above soda ash solution per pound of gas chlorination capacity. The minimum size of the solution reservoirs shall not be less than 50 percent of the maximum daily capacity of the feeder. The solution reservoirs shall be marked to indicate the type of contents. The solution reservoirs shall be manufactured to accommodate corrosive and oxidizers liquid chemicals.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10473

97

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Specific code changes that will improve safety and water quality for river rides.

Rationale

River rides do not have design criteria specified by code for these necessary issues, and these revisions will improve patron safety and improve water quality. Can prevent entrapment hazards of propulsion jets.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Nominal

Impact to industry relative to the cost of compliance with code

Nominal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

These revisions proposed are only about health and safety

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code and provides a better, safer product

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does no discriminate

Does not degrade the effectiveness of the code

Does not degrade code effectiveness

1st Comment Period History

SW10473-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:37:12 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. The requirements of this proposal are vague and will add cost construction and plan approval. Furthermore the ability to control access to river rides is a key safety feature that allows park operators to keep track riders and parents to keep track of their children, requiring multiple access points along a lazy river undermines that utility of limited access rivers. Additionally automatic skimmers decrease the efficiency of river rides and is not as effective as hand skimming the river ride water.

1st Comment Period History

SW10473-G2

Proponent	Philip de Tournillon	Submitted	4/17/2022 1:36:32 PM	Attachments	No

Comment:

To The State of Florida Health Department Proposed Code SW 10473 454.1.9.5. We are a long-standing, national and international lazy river Manufacturer and Consultant. We acknowledge that the proposed change was conceived to reduce safety risks, and is based upon logic appropriate and applicable to submerged suction outlets. Our system uses propulsion ports and the proposed changes are an unnecessary overreach. Propulsion ports, by function and definition, are unable to create suction entrapment. We have a decades-long safe-use history. If the proposed code is enacted along with the requirement to add particular grates, this will increase the “attractive nuisance” factor and will create an opportunity for finger holds as lazy river riders glide past the grated propulsion nozzles. This unintended consequence is not in the best interest of riders, facility operators, owners, facility designers, or builders. I respectfully look forward to further discussing this particular suggested Code Change affecting Propulsion Ports. Philip de Tournillon President Riverflow Pools LLC 2385 NW Executive Center Drive Suite 100 Boca Raton, Florida 33431 Office 954.889.0311 Email: phil@riverflowpools.com

454.1.9.5.5

Decking shall be provided at the entrance and exit points as necessary to provide safe patron access but shall not be smaller than 10 feet (3,048 mm) in width and length and shall be located at maximum of 150 feet (m) intervals. Additional decking along the ride course is not required except that decking shall be required at lifeguard walk locations and emergency exit points. These locations must be provided with clear pathways to each entrance and exit locations. Any structure or landscaping should not prohibit clear line-of-sight or restrict any rescue requirements.

454.1.9.5.6

Access and exit shall be provided at the start and end of the ride and additional exit locations shall be located along the ride course as necessary to provide for the safety of the patrons, maximum 150 feet (m) spacing. Propulsion jets ~~shall~~ may be installed in the walls of the river ride~~. In the alternative, propulsion jets maybe installed~~ or in the floor ~~if they are covered~~. All propulsion jets must be covered with ~~by~~ a suitable grate that will inhibit entrapment or injury of the pool patrons' feet or limbs and these grates shall not protrude into the river ride; they shall be flush with the floor or wall.

454.1.9.5.7 Surface overflow skimmer systems shall be provided evenly around the entire river with a minimum of one every 50 feet (m) of perimeter. Alcoves and areas where water will not be rapidly moved by propulsion jets shall install an additional skimmer with opposing water return inlet. Surface overflow design systems other than traditional gutters or skimmers must be shown to effectively skim the water surface of the entire river ride through engineering calculations and demonstrated hydraulics. .

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10492

98

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Equipment technology improvements warrant revisions to code.

Rationale

This code change allows for the improved capability of flowmeters because the current pool products have greater accuracy and do not require the wide range of fluctuation. Meters placed after all other equipment including the heaters will ensure the actual return-to-pool flowrate is observed after water passes through all plumbing and equipment.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

These devices show the pool is operating to design, so health is the benefit.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not, includes more products

Does not degrade the effectiveness of the code
Does not degrade

1st Comment Period History

SW10492-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:38:02 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

454.1.6.5.13 Rate of flow indicators.

A rate of flow indicator, reading in gpm, shall be installed on the return line after all other equipment and diversions including the heater(s). The rate of flow indicator shall be properly sized for the design flow rate and shall be capable of measuring from one-half three-quarters (0.75) to at least one-and one-half quarter (1.25) times the design flow rate. The flow measuring device shall have an operating range appropriate for the anticipated flow rates and be installed where it is readily accessible to read and for routine maintenance. The clearances upstream and downstream from the rate of flow indicator shall comply with manufacturer's installation specifications.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10509

99

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Small clarifications for specialized pool issues that need to be explained better in code to avoid errors of interpretation, and the need for repairs or variance.

Rationale

Pools and spas built with ADA access points have been designed such that the remainder of the pool perimeter violates code. This code change will better instruct design, and will prevent mitigations to protect patron safety. Pools and spas with inlets off center account for numerous variances per year, allowing directional inlets will solve this necessary inlet/skimmer pair code issue. Skimmer pools are a max. of 20' wide, so this should be adequate for nearly all jobs. Spas are normally less than 10' across.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
None
Impact to building and property owners relative to cost of compliance with code
Nominal
Impact to industry relative to the cost of compliance with code
Nominal
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Both health and safety for ADA revision. Inlet is health related, water quality
Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Improves code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

SW10509-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:42:17 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. The ADA compliance language is redundant, all public spaces must comply with ADA standards unless exempted or not regulated as a public space. Additionally, proposed modification SW10319 more clearly addresses the skimmer/inlet alignment clarification issue by providing a construction tolerance for the alignment.

454.1.2.5.6 Disabled access.
Permanent or portable steps, ramps, handrails, lifts or other devices designed to accommodate handicapped individuals in swimming pools may be provided, and code compliance is required where ADA equipment is not installed. Lifts mounted into the pool deck shall have a minimum 4-footwide (1219 mm) deck behind the lift mount.

454.1.6.5.3.2.4 Wall-inlet fitting.
A wall-inlet fitting shall be provided directly across from each skimmer, or shall have a directional flow inlet across from the skimmer that directs flow toward the skimmer.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10515

100

Date Submitted	02/15/2022	**Section**	454.1.1.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Sizing criteria for pools was changed in 2020 7th ed. to allow very small pools at facilities. Many of these are overcrowded and can become a health issue.

Rationale

Former code requirements were sufficient for housing developments and other large scale amenities. The proponents in favor of the change indicated the change was for multi-story hotels, not for ground level pools. "The new FBC 2020 7th addition drastically changed, and has impacted commercial pools substantially. The code change has shrunk the size of commercial pools 40, 50 and even 60% in some cases. The key component to the formula is the square footage per bather. The FBC section 454.1 only requires 20 sf/bather. The NFPA (National Fire Protection Association)101-2018, requires 50 sf/bather. If the FBC requires commercial pools to follow the minimum sf/bather requirement, then it would almost align to the old commercial pool sizing requirements." quote from Florida pool design engineer

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Undeterminable

Impact to industry relative to the cost of compliance with code

Undeterminable

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Substantial connection with health due to water quality, and welfare due more limited use at present

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves and restores code for better products

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

1st Comment Period History

SW10515-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:44:39 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Proposed Modification SW10181 more clearly and thoroughly addresses concerns with the 2020 FBC Sizing Code.

454.1.1.1 Sizing.

~~The pools provided at a transient facility shall be able to accommodate one bather per five living units, while the bathing load at a nontransient facility shall be at least one bather per seven living units. Recreational vehicle sites, campsites and boat slips designated for live-aboards shall be considered a transient living unit. For properties with multiple pools, this requirement includes the cumulative total bathing load of all swimming pools, spas, wading pools and interactive water features. The bathing load for conventional swimming pools, wading pools, interactive water features, water activity pools and special purpose pools shall be computed either on the basis of one person per 5 gpm (0.32 L/s) of recirculation flow, or one person per each 20 square feet (1.9 m^2) of surface area, whichever is less. The bathing load for spa type pools shall be based on one person per each 10 square feet (0.9 m^2) of surface area. Where a pool's turnover rate is calculated to be less than 3 hours, that pool shall comply with Section 454.1.7.9 for automated controllers.~~

The bathing load for conventional swimming pools, wading pools, interactive water features, water activity pools less than 24 inches (610 mm) deep and special purpose pools shall be computed on the basis of one person per 5 gpm (0.32 L/s) of recirculation flow. The bathing load for spa type pools shall be based on one person per each 10 square feet (0.9 m2) of surface area. The filtration system for swimming pools shall be capable of meeting all other requirements of these rules while providing a flow rate of at least 1 gpm (0.06 L/s) for each living unit at transient facilities and ¾ gpm (0.04 L/s) at non-transient facilities. Recreational vehicle sites, campsites and boat slips designated for live-aboards shall be considered a transient living unit. For properties with multiple pools, this requirement includes the cumulative total gpm of all swimming pools, excluding spas, wading pools and interactive water features. All other types of projects shall be sized according to the anticipated bathing load and proposed uses. For the purpose of determining minimum pool size only, the pool turnover period used cannot be less than 3 hours.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10516

101

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Special purpose pools criteria

Rationale

Each Epsom salt float tank special purpose pool requires a variance from these code sections because of their special construction shape, size and material. The attached document is posted on the Dept. of Health webpage for the purveyors of this float service to more easily follow the path to acquisition of an operating permit. Each if these items and others are listed that a manufacturer reviews with their client and determine how best to proceed. Some of the listed code citations in the attachment are requested in code variance proceedings and are denied by the Department because they are related to health and safety. There are nearly 60 of the special purpose pools being operated in the state today.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Better

Impact to building and property owners relative to cost of compliance with code

Less time spent, and thus less cost

Impact to industry relative to the cost of compliance with code

Less time spent, and thus less cost

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, safety and health

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code, provides guidance not currently provided

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not

Does not degrade the effectiveness of the code

Does not

454.1.9.7

'Epsom salt float tanks' are special purpose pools leased by the public for a brief period of time to float quietly immersed in water with dissolved Epsom salt. Florida Building Code sections in 454.1 through 454.1.10 apply to these pools, and only the following code sections do not apply to these pools as these code requirements are not necessary for health or safety in these special purpose pools: 454.1.2.1 (a); 454.1.2.2.4, 454.1.3.1.2, 454.1.3.2, 454.1.4.2.2, 454.1.6.1, 454.1.6.5.10.5, 454.1.6.5.11, 454.1.6.5.14, 454.1.6.5.16.6(3), and 454.1.6.5.3.2.5

2020 Float Tank Code

To acquire an operating permit from the Department of Health, a special purpose pool owner shall acquire a variance from the Department or utilize one of the manufacturer's variances, and comply with the applicable provisos listed after the state codes cited below. The operation and design construction of Epsom Salt Float Rooms and Tanks are often in violation of certain requirements of Florida Administrative Code (FAC) Chapter 64E-9, and the Florida Building Code (FBC) Chapter 4, section 454.1 that generally apply to conventional pools as follows.

FAC/FBC Chapter	Requirement
64E-9.004(5)	Recirculation system must operate any time pool is open
454.1.2.1 (a)	Water line tile requirement; floor and wall color must be white or light pastel
454.1.2.2.4	The minimum water depth shall be 3 feet
454.1.2.3.5	Pool rules sign
454.1.2.5	Access shall consist of ladders, stairs, recessed treads or swimouts
454.1.3.1.2	Clear deck width, deck slope
454.1.3.2	Overhead obstruction clearance of 4 feet from water surface
454.1.4.2.2	Lighting requirements for indoor pools
454.1.5.5	Equipment enclosure must have minimum 3 x 6-foot opening
454.1.5.7	Equipment area lighting must provide 30-foot-candle
454.1.6.1	Unisex restrooms must include a urinal
454.1.6.5.1	NSF/ANSI Standard 50-certified recirculation filter is required
454.1.6.5.10.5	Main drain must be connected to a collector tank
454.1.6.5.11	Automatic makeup water control
454.1.6.5.14	Heater must be plumbed with a bypass and influent & effluent valves
454.1.6.5.16	Automatic feeders for disinfection and pH control required
454.1.6.5.16	NSF/ANSI Standard 50-certified disinfectant feeder is required
454.1.6.5.16.4.2	Ozone generating equipment shall meet NSF/ANSI Standard 50
454.1.6.5.16.4.2	NSF/ANSI Standard 50-certified Ozone generator is required
454.1.6.5.16.4.4	Air flow meter required for ozone system
454.1.6.5.16.6 (3)	UV validation requirements by USEPA method
454.1.6.5.16.6 (3)	USEPA method to validate UV light disinfection is required
454.1.6.5.3.2.5	6-inch water line tile required for skimmer pools
454.1.6.5.6	Plastic pipe used in the recirculation system shall be imprinted with the manufacturer's name and the NSF-pw logo for potable water applications.

Mitigation of special condition(s) and those specific for safety and health issues are addressed as follows:

1. **Before an operation permit can be granted** by the Department of Health (DOH), the owner shall provide either:

   (1) a UL certificate of compliance for #1563, Standard for Electrical Spas, OR

   (2) evidence of a final electrical inspection for the special purpose pool(s).

   Such evidence will be

   (a) an approved electrical inspection to show compliance with the Florida Building Code grounding and bonding requirements of FBC Chapter 4, section 454.1.10.4 for public pools, OR

   (b) other evidence acceptable to the jurisdictional building department official

2020 Float Tank Code

Inspection(s) shall be conducted by either the local building department electrical inspector or by a Florida state-licensed electrician.

Email a digital copy of the approved inspection report to the Bureau of Environmental Health Water Programs email: PoolInspectRequest@FLHealth.Gov.

2. **The owner will ensure** that the recirculation treatment system provides complete water treatment for at least three (3) full water volume turnovers between each patron's float session manually or by electronic controls. The applicant shall provide turnover specifications for each Float unit as follows:

Special Purpose Pool (Model/Type)	Volume	Time: 3 Turnovers

Each pool shall be equipped with a timer to ensure the turnover requirement is met.

3. **The owner shall** initiate fecal indicator bacteria testing within seven (7) days of opening the float facility to the public.

   The pool owner shall use a Department-certified water laboratory to test for and enumerate E. coli bacteria in a 100-mL water sample collected from each special purpose pool. Samples shall be collected twice, once per week for two (2) consecutive weeks after several client's float sessions on that day.

   The owner shall, within one (1) day of receipt of lab test results, email the digital scanned (or photographed) copies of the lab testing report. The report shall include results from the logged pool water chemistry for halogen (chlorine or bromine) residual and pH of the facility from the time of the 100 ml water sample collection.

   The digital sample results report must be emailed to the Bureau of Environmental Health Water Programs: PoolInspectRequest@FLHealth.Gov.

4. **The manufacturer** shall meet the applicable standards for suction outlet drain covers and equipment area safety features, as required in section 514.0315, Florida Statutes, for daily use in a special purpose pool(s).

   To remain in compliance, the pool owner must maintain the pool drain anti-entrapment cover(s) and fully functional over the operational life of the special purpose pool(s).

5. **The pool owner** must provide entrance/exit access for a step riser above 10" outside the special purpose pool, with a support handrail or grab bar within reach of the float room door entrance/exit.

6. **The facility owner or operator** must maintain at least 4 feet of wet deck area available for patron egress in front of the float room entrance/exit opening.

7. **The owner** must provide a code-compliant pool rules sign with posted inside the float device room. Font may be reduced to ½ inch from the code requirement. The sign shall include the following language as written in FBC sections 454.1.2.3.5- 1., 5., 7., and 454.1.8.13- 1., 3.: *No food or beverages in pool or on pool wet deck; … Shower before entering.; … Do not swallow the pool water; … Maximum water temperature: 104°F (40°C); … Pregnant women, small children, people with health problems and people using alcohol, narcotics or other drugs that cause drowsiness should not use a float tank without first consulting a doctor.*

8. The halogen feeder shall be maintained in good operating order. A halogen feeder installed in accordance with swimming pool code requirements for the special purpose pool(s) precludes the need for either an ultraviolet light system or an ozone generating system to be certified to NSF or USEPA

criteria. Ozone and UV device(s) provided by manufacturer shall be considered only as an optional supplemental oxidizer system.

Use of hydrogen peroxide for residual disinfection of water is prohibited.

9. **Within seven (7) days of installation completion** a 'change list' shall be provided, which document(s) any replacements or modifications made to Department-approved or Building Official-approved equipment.

   Such document shall provide the make and model numbers of any equipment installed on the float room(s) that is not listed in the approved variance.

   The 'change list' shall be forwarded to the DOH Bureau of Environmental Health at email PoolInspectRequest@FLHealth.gov.

10. **Applicant** shall submit evidence in the form of documents and laboratory tests attesting floors have slip resistance as defined in FBC section 454.1. All units shall have approved, code-compliant slip resistant floor(s).

11. **Any changes <u>shall be approved in advance</u>** by the DOH Bureau of Environmental Health, to the existing variance for a model which is no longer valid, or for representations made in the original variance application and subsequent documents submitted by the manufacturer or the owner for approval to any dimensions, components, water treatment systems, or to any equipment

    This does not apply to 'like-for-like' repairs.

Florida Department of Health

Bureau of Environmental Health Water Programs: PoolInspectRequest@FLHealth.Gov.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10519

102

Date Submitted	02/15/2022	**Section**	454.2.6.1.1	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

454.1.2.2 and R4501.6.1.1

Summary of Modification

Provides an ANSI approved standard for the plastering of pools and in-ground spas.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (PHTA). APSP (now PHTA) developed the 12 Standard in conjunction with the National Plasters Council and International Code Council to ensure minimum plastering requirement for swimming pools and spas. This Standard has gone through the rigorous ANSI development process, as all APSP/PHTA Standards do, and provides guidance on plastering matters. This proposal does not create new requirements except where appropriate.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to building and property owners relative to cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to industry relative to the cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will help ensure a proper plaster was put on the pool, providing benefits to pool owners.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will help ensure a proper plaster was put on the pool by providing ANSI approved requirements to follow when plastering a pool or spa.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10519-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:45:45 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) opposes the inclusion of APSP/NPC/ICC-12 in the Florida Building Code. Inclusion of the standard in the code is unnecessary, redundant, and will add compliance and regulatory costs to swimming pool construction. Plaster manufacturers already publish application standard and specifications for their products. A general standard may not capture all application techniques and standards for all available products.

454.2.6.1.1 Plastering.

When applicable, the plastering of pools and permanently installed concrete spas shall be in accordance with APSP/NPC/ICC-12.

Add new APSP (PHTA) Standard as follows to Chapter 35:

ANSI/APSP/NPC/ICC 12 – 16, American National Standard for the Plastering of Swimming Pools and Spas......454.2.6.1.1

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10526

103

Date Submitted	02/15/2022	**Section**	454.1	**Proponent**	Jennifer Hatfield
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

454.2.1 and R4501.2, on elevated pools

Summary of Modification

This proposal adds a definition for "elevated pool" and requires these type of pools to be designed and constructed in accordance with ANSI/PHTA/ICC 10 - 2021.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). This proposal seeks to recognize elevated pools and spas in the Florida Building Code with a reference to the ANSI/PHTA/ICC 10 -2021 Standard. There is currently no code guidance on this type of structure. The reasoning for the creation of an ANSI/PHTA/ICC Standard on elevated pools and spas stems from multiple sources. Jurisdictions and regulators seek guidance on this issue as the number of elevated pools and spas constructed and installed has increased greatly in recent years. Various issues including leaking and other consumer issues has led to litigation. The specialized construction of an elevated pool or spa including materials, piping, values, waterproof systems, and leak detection equipment should be addressed. Design and construction guidelines in this Standard - and those already in the Florida Building Code - seeks to diminish these issues.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

May have a minimal cost related to time spent on learning these new requirements.

Impact to building and property owners relative to cost of compliance with code

Could increase costs but while ensuring proper construction and safety guidelines are met for these type of pools.

Impact to industry relative to the cost of compliance with code

May have a minimal cost related to time spent on learning these new requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this code change ensures elevated pools and spas are required to meet an ANSI approved standard that ensures proper construction guidelines are met, including aspects that protect the general public related to safety and welfare.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This change strengthens and improves the code by providing for a standard laying out what is required of these types of pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

No, rather it improves it.

1st Comment Period History

SW10526-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:48:43 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes the adoption of ANSI/PHTA-10 2022 in the Florida Building Code. Proposed Modifications SW10323 and SW10324 adequately address leaking issues presented by elevated swimming pools and provides a path to adequately dampproof existing elevated pools in Florida when undertaking resurfacing projects.

454.1 Definitions (add new as follows)

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

Add new section as follows:

454.1.12 Elevated Pools.

Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.

Add new standard under the APSP (PHTA) Standards listed in Chapter 35 as follows:

ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic

Venues Integrated into a Building or Structure 454.1.12

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10527

104

Date Submitted	02/15/2022	**Section**	454.1.2.8.1	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

Summary of Modification

Clarify water depth

Rationale

Clarity of depth on sun shelf. Many errors have been made due to unclear language.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Health issue

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies code language

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate

Does not degrade the effectiveness of the code

Does not degrade

1st Comment Period History

SW10527-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:51:09 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes this Modification. Proposed Modification SW10195 addresses sunshelf depth.

454.1.2.8.1 Sun shelf areas must be a minimum of 20 inches (508 mm) wide and provide a minimum of 10 square feet (0.93 m2) of horizontal surface adjoining on the edge of the pool (three sides of shelf must be surrounded by pool deck) over a distance of not less than 3 feet (914 mm). The sun shelf edge that adjoins the pool edge must be continuous. The sun shelf floor shall be horizontal or shall a have uniform slope from a zero-depth entry, and its maximum depth shall be between 8 inches (203 mm) minimum and 12 inches (254 mm) maximum below the water surface. In pools utilizing automatic recessed surface skimmers, there shall be at least one skimmer in each sun shelf area.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10528

105

Date Submitted	02/15/2022	**Section**	454.1.3.1.6	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No

Alternate Language Yes

Related Modifications

Summary of Modification

Obstruction limitation for pools perimeter 454.1.3.1.6, and shutoff timer for heated spa pools 454.1.8.

Rationale

1.3.1.6 Wet deck obstructions adjacent to deeper water reduce the opportunity for rescue of a patron who is drowning. Life safety "shephard's hooks" are size limited, thus water depth and perimeter obstructions combine to make pool less accessible for patron rescue, at pools without life guards. 1.8.6.3 Adding the requirement for the 15 minute timer to heated spa pool systems will assist with patrons knowing when they should exit the spa to ensure they do not get hyperthermia.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

Obstruction is None, heated spa timer is Nominal

Impact to industry relative to the cost of compliance with code

Obstruction is None, heated spa timer is Nominal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Both address health and safety for patrons

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Both improves code, first clarifies, second recovers former code requirement

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Neither discriminate

Does not degrade the effectiveness of the code

Neither degrade

Alternate Language

1st Comment Period History

SW10528-A1

Proponent Dallas Thiesen **Submitted** 4/14/2022 4:57:41 PM **Attachments** Yes

Rationale:

The depth of water has no bearing on the ability to rescue a bather in distress. Limiting obstructions based on water depth does not increase bather safety.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Deals with ability to rescue bathers in distress.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Clarifies the the building code.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials or products.

Does not degrade the effectiveness of the code

Clarifies the the building code.

~~Amend:~~

~~**454.1.3.1.6**~~
~~Twenty percent of the deck along the pool perimeter may be obstructed as long as any one obstruction does not exceed 10 percent of the pool perimeter or 20 feet (6096 mm), whichever is less, in any one area where water depth is 5 feet (1524 mm) or less. No perimeter wet deck may be obstructed where deck level to pool floor vertical distance is over 5 feet (1524mm). No lowered portion of the wet deck may be obstructed. Obstructions shall have a wet deck area behind or through them, with the near edge of the walk within 15 feet (4572 mm) of the water except approved slide obstructions shall have the near edge of the walk within 35 feet (10668 mm) of the water. These obstructions must be protected by a barrier or must be designed to discourage patron access. Obstructions shall not include pool exit points. When an obstruction exists in multiple areas around the pool, the minimum distance between obstructions shall be 4 feet (1219 mm).~~

Add as 454.1.8.6.3

Heated systems shall incorporate a 15-minute patron activated timer on the therapy pump circuit.

Amend:

454.1.3.1.6
Twenty percent of the deck along the pool perimeter may be obstructed as long as any one obstruction does not exceed 10 percent of the pool perimeter or 20 feet (6096 mm), whichever is less, in any one area where water depth is 5 feet (1524 mm) or less. No perimeter wet deck may be obstructed where deck level to pool floor vertical distance is over 5 feet (1524mm). No lowered portion of the wet deck may be obstructed. Obstructions shall have a wet deck area behind or through them, with the near edge of the walk within 15 feet (4572 mm) of the water except approved slide obstructions shall have the near edge of the walk within 35 feet (10668 mm) of the water. These obstructions must be protected by a barrier or must be designed to discourage patron access. Obstructions shall not include pool exit points. When an obstruction exists in multiple areas around the pool, the minimum distance between obstructions shall be 4 feet (1219 mm).

Add as 454.1.8.6.3

Heated systems shall incorporate a 15-minute patron activated timer on the therapy pump circuit.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10529

106

Date Submitted	02/15/2022	**Section**	454.1.12	**Proponent**	bob vincent
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Surf pools criteria

Rationale

Surf pools do not yet have code written for them, and this is a start for that. Two have been designed for Florida, but neither built yet. 2021 law that passed: F.S. section 514.0115(8) Until such time as the department (of health) adopts rules for the supervision and regulation of surf pools, a surf pool that is larger than 4 acres is exempt from supervision under this chapter if the surf pool is permitted by a local government pursuant to a special use permit process in which the local government asserts regulatory authority over the construction of the surf pool and, in consultation with the department, establishes through the local government's special use permitting process the conditions for the surf pool's operation, water quality, and necessary lifesaving equipment. This subsection does not affect the department's or a county health department's right of entry pursuant to s. 514.04 or its authority to seek an injunction pursuant to s. 514.06 to restrain the operation of a surf pool permitted and operated under this subsection if the surf pool presents significant risks to public health. For the purposes of this subsection, the term "surf pool" means a pool that is designed to generate waves dedicated to the activity of surfing on a surfboard or an analogous surfing device commonly used in the ocean and intended for sport, as opposed to the general play intent of wave pools, other large-scale public swimming pools, or other public bathing places.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

Very few of these will be constructed.

Impact to building and property owners relative to cost of compliance with code

Nominal

Impact to industry relative to the cost of compliance with code

Nominal

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

YES, it does

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves code and readies the state for the next iteration of pool sports and play features.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not discriminate.

Does not degrade the effectiveness of the code

Does not degrade

454.1.12- Surf Pools

454.1.12.1 General.
A surf pool is a type of water impoundment used as a public bathing place as defined in Section 514.011, Florida Statutes, that is man-made and has either: a total water surface area of at least one-quarter acre (m^2) in size, with an impervious containment system such as an artificial liner, and incorporates a method of disinfection that results in a disinfectant residual in the swimming zone(s) that is protective of the public health. Such surf pools shall be designed and constructed within the limits of sound engineering practice and the provisions of Section 454.1.12.

454.1.12.2 Sizing and sanitary facilities
The maximum bathing load for a surf pool with a disinfection system approved by the local authority shall be limited by total square footage of the entire area that allows for surfing with 100 square feet (m^2) in water more than 4 feet deep. Sanitary facilities serving patrons of an artificial lagoon shall meet the Florida Building Code, Plumbing, criteria and are exempt from the fixture count requirements in Section 454.1.6.1.1. All sanitary facilities shall be located as near to the designated surfing area(s) as prudent to ensure patron use, but not more than 200 feet (61 m) walking distance from the designated surfing area(s).

454.1.12.3 Construction standards
If an artificial liner is utilized as a containment system, the artificial liner used to contain the water shall consist of a material certified under NSF/ANSI Standard 61-2021, Drinking Water System Components—Health Effects, dated April 14, 2021, hereby incorporated by reference, which has been deemed copyright protected, and is available for review at the Department of State, R.A. Gray Building, 500 South Bronough Street, Tallahassee, FL 32399-0250. The liner or artificial bottom, the floor, and the walls, if any, shall be white or light pastel in color and shall have the characteristic of reflecting rather than absorbing light. The liner material color shall have a wet luminous reflectance value (CIE Y value) of 50.0 or greater, as determined by test results provided by the manufacturer, utilizing testing methodology from ASTM D4086, ASTM E1477 or ASTM E1347. The design of such liner system is the responsibility of a professional engineer licensed in Florida. If any designated surfing area, or portion thereof, is designed with swimming pool features, including concrete vertical walls and floors, such areas of the pool shall be designed in compliance with Sections 454.1.2.2.2, 454.1.2.2.3 and 454.1.2.2.4. Additionally, debris skimmers shall be provided in such areas at least every 40 linear feet (12.19 m). Zero depth entry areas shall be designed in compliance with Sections 454.1.11.5 and 454.1.11.6.

454.1.12.4 Access
Points of access shall be provided as needed to provide adequate entrance to and exit from the surf pool. Means of access may consist of ladders, stairs, recessed treads, and swimouts, designed in compliance with Section 454.1.2.5, zero depth entry areas, and docks, in any number and combination that is appropriate for the intended use(s) of the surf pool. Permanent or portable steps, ramps, handrails, lifts or other devices designed to accommodate handicapped individuals may be provided. Lifts mounted into the wet deck shall have a minimum 4-foot-wide (1219 mm) deck behind the lift mount.

454.1.12.5 Decks and walkways.
Decks and walkways, if utilized to access a designated surfing area, shall be designed in compliance with Sections 454.1.3.1.1 and 451.1.3.1.2. Zero depth entry areas may slope toward the water for no more than 15 feet (mm), as measured from the water's edge outward. Beyond this area, the deck or other surface shall slope away from the surf pool at a minimum of 2 percent to a maximum of 4 percent, and shall be ADA compliant.

454.1.12.6 Safety.
The portion(s) designated for surfing shall meet the safety requirements in Section 454.1.3.3.The depth at the deepest point in any designated swimming/surfing area shall be indicated, along with the other rules and regulations signage required in Section 454.1.2.3.5. Where access to a portion with a vertical wall is not blocked or obstructed by an approved substantial barrier, NO DIVING markers and depth markers shall be installed in accordance with Section 454.1.2.3.1, except that markers are not required on inside vertical walls. Signage may be substituted for markers if approved by the local authority, and such markers or signs are required only along the accessible perimeter. Markings shall be of such materials that will not fade over time. A lifeguard safety plan shall be submitted to the health department for prior approval and implemented by the owner/operator.

454.1.12.7 Electrical systems for artificial lagoons.
Electrical equipment wiring and installation, including the bonding and grounding of components, shall comply with Chapter 27 of the Florida Building Code, Building. Outlets supplying pump motors connected to single-phase 120-volt through 240-volt branch circuits, whether by receptacle or by direct connection, and outlets supplying other electrical equipment and underwater luminaires operating at voltages greater than the low voltage contact limit, connected to single-phase, 120 volt through 240 volt branch circuits, rated 15 or 20 amperes, whether by receptacle or by direct connection, shall be provided with ground-fault circuit interrupter protection for personnel. Any portions of the artificial lagoon designated for swimming at night shall comply with the lighting requirements in Sections 454.1.4.2.1 and 454.1.4.2.3.

454.1.12.8 Equipment rooms.
Equipment rooms shall comply with Section 454.1.5.

454.1.12.9 Treatment systems.
The design of the treatment system is the responsibility of a professional engineer licensed in Florida. Chemical disinfection of recirculated water immediately following the filtration process shall achieve a measurable residual in the surf pool water that is continuously protective of public health and shall be in compliance with section 454.1.6.5.16 .The equipment that feeds or generates the chemical shall be NSF/ANSI Standard 50 certified and subject to review and approval by the local authority. The disinfectant chemical shall be applied in accordance with the manufacturer’s instructions, and must be an NSF/ANSI Standard 60 certified chemical, or a US EPA registered microbial biocide. Any other chemical applied to the water for water quality treatment must be applied in accordance with the manufacturer’s instructions and must be an NSF/ANSI Standard 60 or Standard 50 certified chemical. If remote chemical monitoring sensors are used, one (1) chemical sensor shall be installed in or directly adjacent to each designated surf area. Vacuum systems shall not be used in designated swimming area(s) while such area(s) is (are) open for swimming, and all suction outlets shall comply with the requirements of Section 514.0315, Florida Statutes.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Building

SW10522

107

Date Submitted	02/15/2022	**Section**	35	**Proponent**	Jennifer Hatfield
Chapter	35	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

FBC-R, Chapter 46

Summary of Modification

Updates to existing APSP (PHTA) Standards.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). The proposal updates existing ANSI approved industry standards with the most recent editions.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
No expected impact

Impact to building and property owners relative to cost of compliance with code
No expected impact

Impact to industry relative to the cost of compliance with code
No expected impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
Provides for the latest ANSI industry safety and construction standards.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction
Improves the code by ensuring the latest standard editions are adopted.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities
It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10522-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:47:25 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

APSP (PHTA Standards)

Pool & Hot Tub Alliance
~~Association of Pool and Spa Professionals~~
2111 Eisenhower Avenue, Suite 500
Alexandria, VA 22314

ANSI/APSP/ICC 3—14
American National Standard for Permanently Installed Residential Spas and Swim Spas
454.2.6.1

ANSI/APSP/ICC 4~~—12~~(R2022)
American National Standard for Aboveground /Onground Residential Swimming Pools Includes Addenda A Approved April 4, 2013
454.2.6.1

ANSI/APSP/ICC 5-~~11~~(R2022)
American National Standard for Residential Inground Swimming Pools
454.2.6.1

ANSI/APSP/ICC 6—13
American National Standard for Residential Portable Spas and Swim Spas
454.2.6.1

ANSI/~~APSP~~PHTA/ICC 7~~—13~~2020
American National Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins
454.2.6.1, 454.2.6.3, 454.2.6.6

ANSI/APSP 16—20~~17~~2022
American National Standard for Suction Outlet Fitting~~s~~ Assemblies (SOFA) for Use in ~~Swimming~~ Pools, ~~Wading Pools,~~ Spas, and Hot Tubs
454.1.6.5.12

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Plumbing

SW10210

108

Date Submitted	02/11/2022	**Section**	403.1	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Summary of Modification

Allows for indoor and outdoor pools to be treated the same for purposes of sanitary fixture counts.

Rationale

Table 403.1 of the Florida Building Code, Plumbing specifies the fixture count for indoor swimming pools but the results seem high because the deck area is counted at one occupant per only 15 sf, while the 454.1.6.1/Plumbing ignores deck area up to 3x pool area. Indoor pools should be struck from the table. Indoor and outdoor pools should be treated the same for the purposes of restroom counts.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements. Treats indoor and outdoor pools the same for purposes of sanitary fixture counts.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements. Treats indoor and outdoor pools the same for purposes of sanitary fixture counts.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements. Treats indoor and outdoor pools the same for purposes of sanitary fixture counts.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Restrooms that are easily accessible from the swimming pool area are an important part of maintaining a sanitary swimming environment.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

None, simplifies code requirements. Treats indoor and outdoor pools the same for purposes of sanitary fixture counts.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

None, simplifies code requirements. Treats indoor and outdoor pools the same for purposes of sanitary fixture counts.

403.1 (FBC, Plumbing)

[8th row, 3rd column of table 403.1] Coliseums, arenas, skating rinks, ~~pools~~and tennis courts for indoor sporting events and activities

…

[notes at end of Table 403.1] f. The required number and type of plumbing fixtures for indoor andoutdoor public swimming pools shall be in accordance with Section 403.6.

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Plumbing

SW10211

109

Date Submitted	02/11/2022	**Section**	403.6	**Proponent**	Dallas Thiesen
Chapter	4	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments No **Alternate Language No**

Related Modifications

Building 454.1.6.1Sanitary facilities

Summary of Modification

Simples required sanitary fixture calculations and creates a more gradual increase in required fixtures as the swimming pool size increases.

Rationale

Reference to unisex restrooms is outdated; single user restrooms are already allowed to contribute to minimum fixture requirements per 403.1.2 of this Code. For all other restrooms, urinals are optional per 424.2 of this Code, that should apply to outdoor pools as well. Reference to bathing load is confusing, requires separate calculation. The thresholds here are harsh. There is no reason that going from 2,500 to 2,501 square feet should cause four additional women's water closets to be required. Each threshold should be a single fixture.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None, simplifies code requirements.

Impact to building and property owners relative to cost of compliance with code

None, simplifies code requirements.

Impact to industry relative to the cost of compliance with code

None, simplifies code requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Bather access to restrooms is important to maintaining a safe and sanitary swimming environment.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves effectiveness of the code by simplifying and clarifying requirements.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify particular materials, products, methods, or systems of construction.

Does not degrade the effectiveness of the code

Improves effectiveness of the code by simplifying and clarifying requirements.

403.6 Sanitary facilities for public swimming pools. ~~**Swimming pools with a bathing load of 20 persons or less may utilize a unisex restroom. Pools with bathing loads of 40 persons or less may utilize two unisex restrooms or meet the requirement of Table 403.6. Unisex r**~~**Restrooms** ~~**shall meet all the requirements for materials, drainage and signage as indicated in Sections 454.1.6.1.1 through 454.1.6.1.4 of the *Florida Building Code, Building*. Each**~~ **shall include a water closet, a diaper change table,** ~~**a urinal,**~~**and a lavatory. Diaper changing Tables are not required at restrooms where all pools served are restricted to adult use only.** ~~**Pools with a bathing load larger than 40 persons shall provide separate sanitary facilities labeled for each sex.**~~ **The entry doors of all restrooms shall be located within a 200-foot (60 960 mm) walking distance of the nearest water's edge of each pool served by the facilities.**

Exception: Where a swimming pool serves only a designated group of residential dwelling units including hotel rooms and not the general public, poolside sanitary facilities are not required if all living units are within a 200-foot horizontal radius of the nearest water's edge, are not over three stories in height unless serviced by an elevator, and are each equipped with private sanitary facilities.

TABLE 403.6 PUBLIC SWIMMING POOL—REQUIRED FIXTURES COUNT PER SQUARE FOOT OF POOL SURFACE

~~SIZE[a] (square feet)~~	MEN'S RESTROOMS			WOMEN'S RESTROOMS	
	~~Urinals~~	WC	Lavatory	WC	Lavatory
~~0 - 2500 sq ft~~	~~1~~	1 per 2,500 for first 10,000, 1 per	1 per 5,000 for first 10,000, 1 per 10,000 for	1 per 1,250 for first 10,000, 1 per 2,500 for	1 per 5000 for first 10,000, 1 per 10,000 for

		5,000 for remainder exceeding 10,000	remainder exceeding 10,000	remainder exceeding 10,000	remainder exceeding 10,000
~~2501 - 5000 sq ft~~	~~2~~	~~1~~	~~1~~	~~5~~	~~1~~
~~5001 - 7500 sq ft~~	~~2~~	~~2~~	~~2~~	~~6~~	~~2~~
~~7501 - 10,000 sq ft~~	~~3~~	~~2~~	~~3~~	~~8~~	~~3~~

For SI: 1 square foot = 0.0929 m^2.

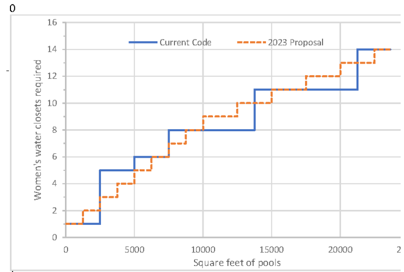
~~**a. Square footage of interactive water features (IWFs) is required to be included when calculating the "size of pool" for the purposes of determining the type and number of fixtures for the sanitary facilities. For those facilities with an IWF in addition to the pool, causing the combined pool size square footage to exceed the threshold required category fixture count, a unisex restroom may be installed to satisfy the fixture requirement for every additional 1,250 square feet or fraction thereof. The interactive water feature flow for one unisex restroom shall not exceed 100 gpm, nor shall the bathing load exceed 20 patrons.**~~

403.6.1 Required fixtures.

Fixtures shall be provided as indicated on Table 403.6. The fixture count of Table 403.6 is deemed to be adequate for the pool and pool deck area that is up to three times the area of the pool surface provided. ~~**An additional set of fixtures shall be provided in the men's restroom for every 7,500 square feet or major fraction thereof for pools greater than 10,000 square feet. Women's restrooms shall have a ratio of three to two water closets provided for women as the combined total of water closets and urinals provided for men. Lavatory counts shall be equal.**~~

		2020 Florida					occupants/sf occupants/sf 2500	5000	1250	5000	men	women
	Urinal	Men's WC	Men's WC + Urinals	Men's Lavatory	Women's WC	Women's Lavatory	Men's WC + Urinals	Men's Lavatory	Women's WC	Women's Lavatory	2023 Proposal - Florida now	2023 Proposal - Florida now
1	1	1	2	1	1	1	1	1	1	1	-1	0
1250	1	1	2	1	1	1	1	1	1	1		
1251	1	1	2	1	1	1	1	1	2	1		
2500	1	1	2	1	1	1	1	1	2	1		
2501	2	1	3	1	5	1	2	1	3	1	-1	-
3750	2	1	3	1	5	1	2	1	3	1		
3751	2	1	3	1	5	1	2	1	4	1		
5000	2	1	3	1	5	1	2	1	4	1		
5001	2	2	4	2	6	2	3	2	5	2		
6250	2	2	4	2	6	2	3	2	5	2		
6251	2	2	4	2	6	2	3	2	6	2		
7500	2	2	4	2	6	2	3	2	6	2		
7501	3	2	5	3	8	3	4	2	7	2		
8750	3	2	5	3	8	3	4	2	7	2		
8751	3	2	5	3	8	3	4	2	8	2		
10000	3	2	5	3	8	3	4	2	8	2		
10001	3	2	5	3	8	3	5	3	9	3		
12500	3	2	5	3	8	3	5	3	9	3	0	1
12501	3	2	5	3	8	3	5	3	10	3		
13749	3	2	5	3	8	3	5	3	10	3	0	2
13750	4	3	7	4	11	4	5	3	10	3	-2	-1
15000	4	3	7	4	11	4	5	3	10	3		
15001	4	3	7	4	11	4	6	3	11	3		
17500	4	3	7	4	11	4	6	3	11	3		
17501	4	3	7	4	11	4	6	3	12	3		
20000	4	3	7	4	11	4	6	3	12	3		
20001	4	3	7	4	11	4	7	4	13	4		
21249	4	3	7	4	11	4	7	4	13	4		
21250	5	4	9	5	14	5	7	4	13	4		
22500	5	4	9	5	14	5	7	4	13	4		
22501	5	4	9	5	14	5	7	4	14	4	-2	0
23610	5	4	9	5	14	5	7	4	14	4	-2	0
23640	5	4	9	5	14	5	7	4	14	4	-2	0

2031 Amer	7916	3	2	5	3	8	3	4	2	7	2
2044	6867	2	2	4	2	6	2	3	2	6	2
Marilla Par	14640	4	3	7	4	11	4	5	3	10	3




25000

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Residential

110

SW10439

Date Submitted	02/15/2022	**Section**	4501.17.1.15	**Proponent**	Jennifer Hatfield
Chapter	45	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

454.2.17.1.15

Summary of Modification

Streamlines the mesh barrier provisions by removing listed requirements found in the ASTM F2286 Standard and simply requiring compliance with that Standard, which is what manufacturers of these types of barriers design to and comply with - no technical changes are being made.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). The manufacturers of these types of barriers design and fabricate to ASTM F2286. The installation instructions for the product reflects the requirements of the standard. There isn't any reason for the Florida Code to have the detailed information in it as the installation instructions for the product has to reflect the requirements of the standard. Referring to the standard streamlines and simplifies the code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code
No impact, if anything easier to just note compliance with the listed standard.
Impact to building and property owners relative to cost of compliance with code
No impact, if anything easier to just note compliance with the listed standard.
Impact to industry relative to the cost of compliance with code
No impact, if anything easier to just note compliance with the listed standard.
Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public
This section of code provides for pool safety requirements and specifically mesh barriers. Streamlining the code to require compliance with a longstanding industry standard that manufacturers use today in Florida, supports

public safety.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by streamlining and making it simpler by deleting the standard requirements laid out and referencing the standard.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10439-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:08:25 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

R4501.17.1.15
A mesh safety barrier meeting the requirements of Section R4501.17, installed in accordance with the manufacturer's instructions and complying with ASTM F2286, and the following minimum requirements shall be considered a barrier as defined in this section. Where a hinged gate is used with a mesh fence, the gate shall comply with Section R4501.17.1.8. Mesh fences shall not be installed on top of above-ground/on-ground private swimming pools.:

1. Individual component vertical support posts shall be capable of resisting a minimum of 52 pounds (24 kg) of horizontal force prior to breakage when measured at a 36 inch (914 mm) height above grade. Vertical posts of the child safety barrier shall extend a minimum of 3 inches (76 mm) below deck level and shall be spaced no greater than 36 inches (914 mm) apart.
2. The mesh utilized in the barrier shall have a minimum tensile strength according to ASTM D 5034 of 100 lbf, and a minimum ball burst strength according to ASTM D 3787 of 150 lbf. The mesh shall not be capable of deformation such that a 1/4-inch (6.4 mm) round object could not pass through the mesh. The mesh shall receive a descriptive performance rating of no less than "trace discoloration" or "slight discoloration" when tested according to ASTM G 53, Weatherability, 1,200 hours.
3. When using a molding strip to attach the mesh to the vertical posts, this strip shall contain, at a minimum, #8 by ½ inch (12.7 mm) screws with a minimum of two screws at the top and two at the bottom with the remaining screws spaced a maximum of 6 inches (152 mm) apart on center.
4. Patio deck sleeves (vertical post receptacles) placed inside the patio surface shall be of a nonconductive material.
5. A latching device shall attach each barrier section at a height no lower than 45 inches (1143 mm) above grade. Common latching devices that include, but are not limited to, devices that provide the security equal to or greater than that of a hook-and-eye-type latch incorporating a spring actuated retaining lever (commonly referred to as a safety gate hook).
6. The bottom of the mesh safety barrier shall not be more than 1 inch (25 mm) above the deck or installed surface (grade).

Add new standard under the ASTM Standards listed in Chapter 46 as follows:

ASTM F2286-16 Standard Design and Performance Specification for Removable Mesh Fencing for Swimming Pools, Hot Tubs, and Spas R4501.17.1.15

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Residential

SW10440

111

Date Submitted	02/15/2022	**Section**	4501.2	**Proponent**	Jennifer Hatfield
Chapter	45	**Affects HVHZ**	No	**Attachments**	Yes
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language Yes**

Related Modifications

Chapter 4, Sections 454.1 and 454.2.1, on elevated pools

Summary of Modification

This proposal adds a definition for "elevated pool" and requires these type of pools to be designed and constructed in accordance with ANSI/PHTA/ICC 10 - 2021.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). This proposal seeks to recognize elevated pools and spas in the Florida Building Code with a reference to the ANSI/PHTA/ICC 10 -2021 Standard. There is currently no code guidance on this type of structure. The reasoning for the creation of an ANSI/PHTA/ICC Standard on elevated pools and spas stems from multiple sources. Jurisdictions and regulators seek guidance on this issue as the number of elevated pools and spas constructed and installed has increased greatly in recent years. Various issues including leaking and other consumer issues has led to litigation. The specialized construction of an elevated pool or spa including materials, piping, values, waterproof systems, and leak detection equipment should be addressed. Design and construction guidelines in this Standard - and those already in the Florida Building Code - seeks to diminish these issues.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

May have a minimal cost related to time spent on learning these new requirements.

Impact to building and property owners relative to cost of compliance with code

Could increase costs but while ensuring proper construction and safety guidelines are met for these type of pools.

Impact to industry relative to the cost of compliance with code

May have a minimal cost related to time spent on learning these new requirements.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Yes, this code change ensures elevated pools and spas are required to meet an ANSI approved standard that ensures proper construction guidelines are met, including aspects that protect the general public related to safety and welfare.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This change strengthens and improves the code by providing for a standard laying out what is required of these types of pools.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

No, rather it improves it.

Alternate Language

1st Comment Period History

SW10440-A1

Proponent Dallas Thiesen **Submitted** 4/15/2022 11:15:03 AM **Attachments** Yes

Rationale:

Defining "Elevated Pool" is needed for clarity in the code but need more specificity. ANSI/PHTA/ICC 10-2021 should not be incorporated in to the Florida Building Code.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

None

Impact to building and property owners relative to cost of compliance with code

None

Impact to industry relative to the cost of compliance with code

None

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Deals with safety of elevated swimming pools.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Adds clarity to the code

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

Does not specify materials, products, or methods.

Does not degrade the effectiveness of the code

Adds clarity to the code

1st Comment Period History

SW10440-G1

Proponent Dallas Thiesen Submitted 4/14/2022 4:18:26 PM Attachments No

Comment:

The Florida Swimming Pool Association (FSPA) Opposes the adoption of ANSI/PHTA-10 2022 in the Florida Building Code.

R4501.2 Definitions

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water **integrated in to a building or structure** that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

-

~~**R4501.24 Elevated Pools.**~~

~~Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.~~

-

~~*Add new standard under the APSP (PHTA) Standards listed in Chapter 46 as follows:*~~

-

~~ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure R4501.24~~

R4501.2 Definitions *(add new as follows)*

ELEVATED POOL. Any pool, spa, cold plunge, water feature, catch basin, overflow trough, or body of water that is 1) inside a weather envelope or 2) outside a weather envelope, and installed over occupied/conditioned space, or installed over occupiable space (mechanical room, crawlspace, etc.), or installed over unoccupied/non-conditioned spaces (parking garages), or installed in an above grade with no occupied, occupiable or unoccupied space below.

Add new section as follows:

R4501.24 Elevated Pools.
Elevated pools shall be designed and constructed in accordance with ANSI/PHTA/ICC 10.

Add new standard under the APSP (PHTA) Standards listed in Chapter 46 as follows:

ANSI/PHTA/ICC 10 - 2021 American National Standard for Elevated Pools, Spas and Other Aquatic Venues Integrated into a Building or Structure R4501.24

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Residential

SW10520

112

Date Submitted	02/15/2022	**Section**	4501.6.1.1	**Proponent**	Jennifer Hatfield
Chapter	45	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

454.2.6.1.1 and 454.1.2.2

Summary of Modification

Provides an ANSI approved standard for the plastering of pools and in-ground spas.

Rationale

APSP (now PHTA) developed the 12 Standard in conjunction with the National Plasters Council and International Code Council to ensure minimum plastering requirement for swimming pools and spas. This Standard has gone through the rigorous ANSI development process, as all APSP/PHTA Standards do, and provides guidance on plastering matters. This proposal does not create new requirements except where appropriate.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to building and property owners relative to cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to industry relative to the cost of compliance with code

This proposal will not increase the cost of construction; rather, it will help ensure a proper plaster was put on the pool, decreasing the costs to consumers associated with having to redo a bad plaster job.

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

This proposal will help ensure a proper plaster was put on the pool, providing benefits to pool owners.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

This proposal will help ensure a proper plaster was put on the pool by providing ANSI approved requirements to follow when plastering a pool or spa.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10520-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:46:35 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) opposes the inclusion of APSP/NPC/ICC-12 in the Florida Building Code. Inclusion of the standard in the code is unnecessary, redundant, and will add compliance and regulatory costs to swimming pool construction. Plaster manufacturers already publish application standard and specifications for their products. A general standard may not capture all application techniques and standards for all available products.

R4501.6.1.1 Plastering.

When applicable, the plastering of pools and permanently installed concrete spas shall be in accordance with APSP/NPC/ICC-12.

Add new APSP (PHTA) Standard as follows to Chapter 46:

ANSI/APSP/NPC/ICC 12 – 16, American National Standard for the Plastering of Swimming Pools and Spas......R4501.6.1.1

TAC: Swimming Pool

Total Mods for **Swimming Pool** in **Pending Review : 113**

Total Mods for report: 113

Sub Code: Residential

SW10523

113

Date Submitted	02/15/2022	**Section**	46	**Proponent**	Jennifer Hatfield
Chapter	2712	**Affects HVHZ**	No	**Attachments**	No
TAC Recommendation	Pending Review				
Commission Action	Pending Review				

Comments

General Comments Yes **Alternate Language No**

Related Modifications

FBC-B, Chapter 35

Summary of Modification

Updates to existing APSP (PHTA) Standards.

Rationale

This proposal is being submitted on behalf of the Pool & Hot Tub Alliance (formerly APSP). The proposal updates existing ANSI approved industry standards with the most recent editions.

Fiscal Impact Statement

Impact to local entity relative to enforcement of code

No expected impact

Impact to building and property owners relative to cost of compliance with code

No expected impact

Impact to industry relative to the cost of compliance with code

No expected impact

Impact to small business relative to the cost of compliance with code

Requirements

Has a reasonable and substantial connection with the health, safety, and welfare of the general public

Provides for the latest ANSI industry safety and construction standards.

Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction

Improves the code by ensuring the latest standard editions are adopted.

Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities

It does not.

Does not degrade the effectiveness of the code

It does not.

1st Comment Period History

SW10523-G1

Proponent	Dallas Thiesen	Submitted	4/14/2022 4:47:50 PM	Attachments	No

Comment:

The Florida Swimming Pool Association (FSPA) Supports this Modification.

APSP (PHTA Standards)

Pool & Hot Tub Alliance
~~Association of Pool and Spa Professionals~~

2111 Eisenhower Avenue, Suite 500
Alexandria, VA 22314

ANSI/APSP/ICC 3—14
American National Standard for Permanently Installed Residential Spas and Swim Spas
R4501.6.1

ANSI/APSP/ICC 4~~—12~~(R2022)
American National Standard for Above-ground/On-ground Residential Swimming Pools
R4501.6.1

ANSI/APSP/ICC 5~~—11~~(R2022)
American National Standard for Residential In-ground Swimming Pools
R4501.6.1

ANSI/APSP/ICC 6—13
American National Standard for Residential Portable Spas and Swim Spas
R4501.6.1

ANSI/~~APSP~~PHTA/ICC 7~~—13~~2020
American National Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs and Catch Basins
R4501.6.1, R4501.6.3, R4501.6.6