

**Final Report for Project Entitled:**

**Corrosion of Roofing Fasteners**

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by

Kurtis R. Gurley, Ph.D., kgurl@ce.ufl.edu, (352) 392-9537 x 1508  
Forrest J. Masters, Ph.D., P.E., masters@ce.ufl.edu, (352) 392-9537 x 1505

**Designated Project Leader:** Kurtis R. Gurley

Engineering School for Sustainable Infrastructure & Environment



## Table of Contents

1. Disclaimer .....	1
2. Applicable Sections of the Code and related documents.....	1
3. Review of phase 1 and phase 2 and Executive Summary of phase 3 .....	1
4. Project Description .....	2
4.1. Test protocol (TAS 114 Appendix E) .....	2
4.2. Description of specimens tested .....	2
4.2.1. Test-1 (160 samples).....	2
4.2.2. Test-2 (60 samples).....	3
4.2.3. Test-3 (150 samples).....	3
4.3. Corrosion scale – performance metric.....	4
5. Results of corrosion scoring .....	5
5.1. Test-1 Results.....	5
5.1.1. Test-1 Discussion .....	7
5.2. Test-2 Results.....	8
5.2.1. Test-2 Discussion .....	9
5.3. Test-3 Results.....	9
5.3.1. Test-3 Discussion .....	11
6. Conclusions .....	12
7. Appendix A: Test-1 Corrosion results (photos and scores for samples of each specimen type) .....	13
8. Appendix B: Test-2 Corrosion results (photos and scores for samples of each specimen type) .....	26
9. Appendix C: Test-3 mid-test Corrosion results (765 of 1000 hours) .....	32
10. Appendix D: Test-3 Corrosion results (photos for a sample of each specimen type) .....	38

## **1. Disclaimer**

This report presents the findings of research performed by the University of Florida. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the sponsors, partners and contributors. The Roofing Technical Advisory Committee of the Florida Building Commission will provide a final disposition on the implications for the Florida Building Code.

## **2. Applicable Sections of the Code and related documents**

- 1622.1.2, Florida Building Code—Building
- 1506.4 – 1506.7, Florida Building Code—Building
- 1517.5.1 – 1517.5.2, Florida Building Code—Building
- TAS 114 Appendix E
- ASTM A 90
- ASTM A 641
- ASTM B117-11
- ASTM G85-11

## **3. Review of phase 1 and phase 2 and Executive Summary of phase 3**

The project goal is to experimentally evaluate the corrosion resistance of metal fasteners for roof systems and screen enclosures. The 2013 - 2014 survey study (phase 1) found that corrosion is commonly observed. Electrogalvanized fasteners were most likely to exhibit corrosion among the common corrosion resistant applications, and thus the focus of the 2014 – 2015 experimental study of corrosion (phase 2 study). The roofing fastener test sequence consisted of electrogalvanized 1¼ inch roofing coil nails. Three manufacturers were tested. Configurations included a) out of the box (control), b) installed into substrate and tested (in-situ case), and c) installed into substrate, removed and tested (extreme case). Testing was conducted in accordance with TAS 114 Appendix E. An integer 1 - 8 corrosion scale was created to score the degree of corrosion on the head and shaft of the fasteners. It was found that one manufacturer clearly outperformed the other two with regard to corrosion resistance of out of the box fasteners. The specimens tested in phase 2 (2014 -2015) were electrogalvanized, but no standard compliance was noted (e.g. ASTM A641, Miami-Dade approved, TAS 114 App-E, etc.). Thus the phase 2 study results represent a baseline of the scattered performance of fasteners classified only as electrogalvanized.

The current 2015 – 2016 experimental study (phase 3) continues the testing roof system fasteners in a corrosion chamber, applying the TAS 114 Appendix E protocol and applying the customized corrosion scoring scale created for phase 2. In phase 3, the emphasis is on testing fasteners that are ASTM A641 compliant (prescriptive) or Miami Dade County approved (performance based TAS 114 Appendix E). Electrogalvanized, electroplated, mechanically galvanized, hot dipped, and stainless steel fasteners are included in the test matrix. Roofing, deck/patio, screen enclosure, and tile screw fasteners are included.

This report presents the results of testing completed on 370 specimens. 160 were tested simultaneously in test-1, 60 were tested simultaneously in test-2, and 150 were tested simultaneously in test-3. The results and analysis of test-1 were documented in the interim report issued on February 15, 2016, and will be repeated herein as well for completeness of this

document. The results and analysis of test-2 and test-3 are documented herein for the first time.

#### 4. Project Description

##### 4.1. Test protocol (TAS 114 Appendix E)

The test protocol followed TAS 114 Appendix E, which calls for compliance with ASTM G85 Annex A5. The corrosion testing apparatus was factory programmed to follow the ASTM G85 Annex A5 protocol. The acetic acid-salt spray (fog) test was conducted for 140 cycles (test-1 and test-2) or 500 cycles (test-3), where one cycle consists of one hour of fog exposure and one hour of dry-off. The sequences were run without interruption. The salt solution composition, chamber temperature, and water purity were monitored to conform to requirements.

##### 4.2. Description of specimens tested

All test samples were procured off the shelf from Florida suppliers.

##### 4.2.1. Test-1 (160 samples)

Test-1 includes electrogalvanized (EG), mechanically galvanized (MG), electroplated (EP), hot dipped (HD) and stainless steel (SS) fasteners. 10 samples of each of 16 different specimen types were tested, for a total of 160 samples. All samples were tested out-of-the-box. Table 1 describes these specimen types. Test-1 was run for 280 hours (140 cycles).

Group number	Product type	Coating type	Certification	Supplier location
1	1 ¼ nail	EG	ASTM F1667	Orlando
2	1 ¼ nail	EG	Not marked	Orlando
3	1 ¼ coil nail	EG	Not marked	Orlando
4	1 ¼ coil nail	EG	ASTM F1667	Gainesville
5	1 ¼ coil nail	EG	ASTM A153 Class D	Orlando
6	#8 2 ½ tile screw	MG	ASTM B695 Class 55 2006 IRC Compliant	Orlando
7	#8 2 ½ tile screw	EP	Not marked	Bradenton
8	1 ¼ coil nail	EG	ASTM F1667	Bradenton
9	1 ¼ coil nail	HD	Not marked	Sarasota
10	1 ½ screws	HD	Not marked	No info
11	10d 3" RS	SS	MDC Approved	Miami
12	1 ¼ RS nail	HD	ASTM F1667	Miami
13	1 ¼ nail	EG	MDC Approved ASTM F1667	Miami
14	1 ¼ coil RS nail	EG	MDC Approved ASTM A641	Miami
15	1 ¼ coil RS nail	EG	MDC approved, ASTM A641	West Palm
16	#8 2 ½ tile screw	MG	ASTM B695 Class 55 2006 IRC Compliant	West Palm

Notes:  
 ASTM F1667 → ASTM A641 compliant  
 ASTM A153 Class D thicker zinc coating than ASTM A641  
 ASTM B695 → mechanical galvanizing standard, Class 55 → 0.0022" zinc thickness  
 EG → electrogalvanized, EP → electroplated, MG → mechanically galvanized, HD → hot dipped,  
 SS → stainless steel

#### 4.2.2. Test-2 (60 samples)

The results of test-1 (to be described in Section 5) indicated that hot dipped fasteners performed very well. Feedback from FRSA members (January 22, 2016) included the suggestion that the hot dipped coating application may produce a zinc layer that is brittle, and therefore more susceptible to damage from the field installation process. Test-2 was designed to determine whether the process of fastener installation damages the corrosion resistant coating of hot dipped nails. Test-2 includes one electrogalvanized (EG) specimen type as a control, and two hot dipped (HD) specimen types. For each of the three specimen types, 10 were tested out-of-the-box, and 10 were installed into a wood block and removed prior to testing. The removal process was to cut away the wood substrate rather than pull the nail, in order to avoid causing additional surface damage to the sample.

Table 2 describes the specimen types for test-2. Test-2 was run for 280 hours (140 cycles). As noted at the bottom of the table, the hot dipped specimens were the same types as those in test-1.

Table 2: test-2: 3 specimen types, 10 samples of each out-of-the-box, 10 samples of each installed and removed prior to testing Status: completed 280 hours (140 cycles)				
Group number	Product type	Coating type	Certification	Testing Configuration
1	1 ¼ coil nail	EG	Not marked	Out of box
2	1 ¼ coil nail	EG	Not marked	Installed and removed
3*	1 ¼ coil nail	HD	Not marked	Out of box
4*	1 ¼ coil nail	HD	Not marked	Installed and removed
5**	1 ¼ RS nail	HD	ASTM F1667	Out of box
6**	1 ¼ RS nail	HD	ASTM F1667	Installed and removed

Notes:  
 ASTM F1667 → ASTM A641 compliant  
 \* same specimen type as Group 9 in test-1  
 \*\* same specimen type as Group 12 in test-1

#### 4.2.3. Test-3 (150 samples)

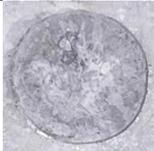
Test-3 focusses on sheet metal and concrete screws commonly used for screen enclosures. 10 samples of each of 11 different stainless steel ceramic coated specimen types were tested, and 8 samples of each of 5 non-stainless steel specimen types were tested, for a total of 150 samples. All samples were tested out-of-the-box for 1000 hours (500 cycles). Table 3 describes these specimen types.

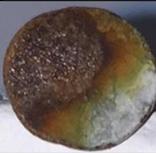
Table 3: test-3: 11 specimen types, 10 samples of each, and 5 specimen types, 8 samples of each Status: completed 1000 hours (500 cycles)				
Group number	Product type	Use	Certification	Coating
1	Hex 3/8 x 5 304 Stainless white	Masonry	MDC Approved	Ceramic
2	Hex 3/8 x 7 304 Stainless white	Masonry	MDC Approved	Ceramic
3	Hex 1/4 x 3 ¼ 304 Stainless silver	Masonry	MDC	Ceramic

			Approved	
4	Hex 1/4 x 2 1/4 304 Stainless silver	Masonry	MDC Approved	Ceramic
5	Hex 1/4 10 x 2 SMS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
6	Hex 1/4 12 x 3/4 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
7	Hex 5/16 14 x 1 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
8	Hex 3/8 14 x 1 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
9	Hex 5/16 12 x 2 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
10	Hex 1/4 12 x 3/4 SDS Stainless white	Screen enclosure	MDC Approved	Ceramic
11	Hex 1/4 10 x 2 SMS Stainless white	Screen enclosure	MDC Approved	Ceramic
12	Hex 5/16 14 x 3/4" non-Stainless bronze	Screen enclosure	unknown	Ceramic
13	Hex 5/16 1/4" x 2-1/4" non- Stainless bronze	Masonry	Unknown	Ceramic
14	Group 10 from test-1	unknown	Unknown	HD
15	Hex 1/4 10 x 4" non- Stainless bronze	Screen enclosure	Unknown	Ceramic
16	Hex 9/16 3/8" x 3" non-Stainless bronze	Masonry	Unknown	Ceramic

#### 4.3. Corrosion scale – performance metric

The TAS 114 Appendix E pass/fail criterion is greater than 5% surface corrosion indicates failure. However, the purpose of this study is to investigate the relative performance of fasteners. This requires a finer gradation of performance than pass/fail can provide. An integer scale of 1 – 8 was created to classify the degree of corrosion observed on the fasteners, where 1 indicates no corrosion and 8 indicates heavy corrosion with scaling. Table 4 provides a description of these classifications as well as a visual sample of each. The assignment of a corrosion score for each fastener is subjective to some degree, but the scale is designed such that this subjectivity does not span more than two adjacent scores. For example, 7 vs. 8 may be subjective, but 6 vs 8 provides a clear distinction. In this manner, the subjectivity does not dilute the significance of results when viewed on an eight-point scale.

Table 4: Corrosion scale description and sample images	
1: No corrosion observed	
2: Edge corrosion only	

3: Light partial surface corrosion	
4: Light full surface corrosion	
5: Partial heavy surface corrosion	
6: Partial heavy and partial light full surface corrosion	
7: Heavy full surface corrosion without scaling	
8: Heavy full surface corrosion with scaling	

## 5. Results of corrosion scoring

The 1-8 corrosion score was assigned to each tested specimen separately for the head and shaft of the fastener. The scores were assigned based on visual inspection of the specimens as well as inspection of post-test photos taken of each specimen. Photos and scores for one or two samples of each specimen type are provided in Appendices A, B and C.

### 5.1. Test-1 Results

Test-1 results were previously presented in the February 15, 2016 interim report, and repeated here. The full scoring results (ten samples from each of the 16 groups) are provided in Figures 1 through 4. In each of these figures, the commonly colored bars correspond to the 10 individual samples of that specimen type. The bottom of the graph identifies the specimen type by group number as defined in Table 1 and referenced in Appendix A. The vertical axis presents the 1-8 corrosion scale score. The light blue bar spanning each commonly colored bar group is the mean value of the 10 samples in that group. The results are separated into figures 1 through 4 as follows:

- Figure 1: All 1 ¼" electrogalvanized (EG) nails compliant with ASTM A641, but not approved for Miami-Dade. Nail head results (left) and nail shaft results (right).

- Figure 2: All 1 ¼" EG nails compliant with ASTM A641, and approved for Miami-Dade (HVHZ). Nail head results (left) and nail shaft results (right).
- Figure 3: #8 2 ½" roof tile screws, two mechanically galvanized specimen types and one electroplated specimen type. Head and shaft results were identical.
- Figure 4: Two hot dipped 1 ¼" nail specimen types, one hot dipped 1 ½" screw fastener specimen type, and one 10d 3" stainless steel patio/deck nail specimen type. Head results shown. Shaft results almost identical, not shown.

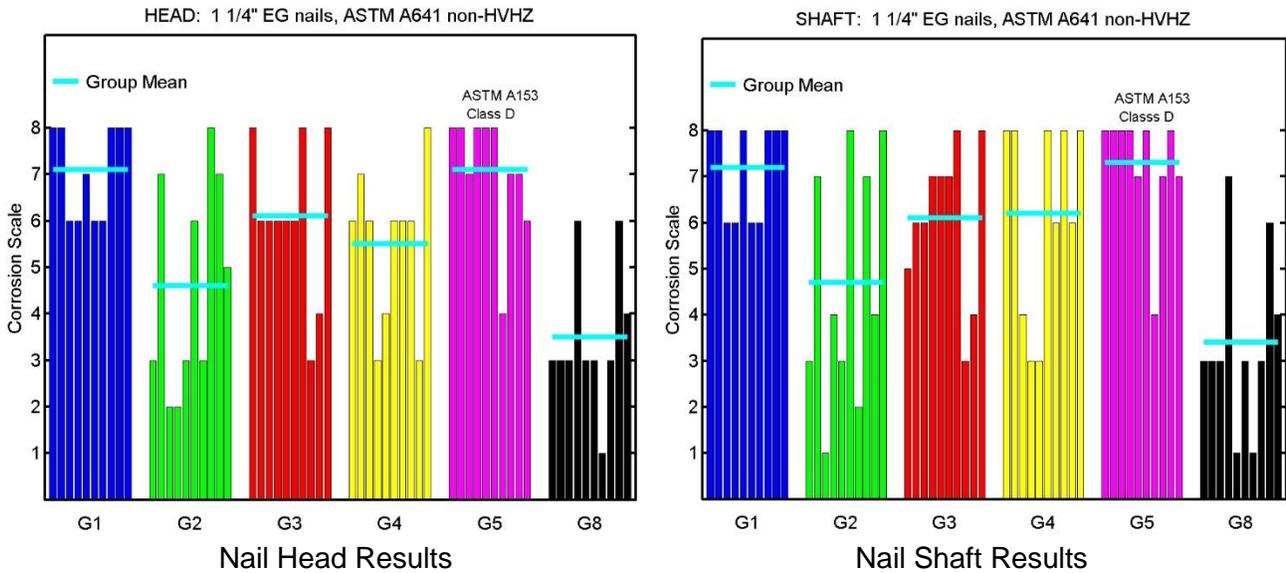


Figure 1: Test-1 Corrosion scale results for 1 ¼" EG nails, not HVHZ compliant.

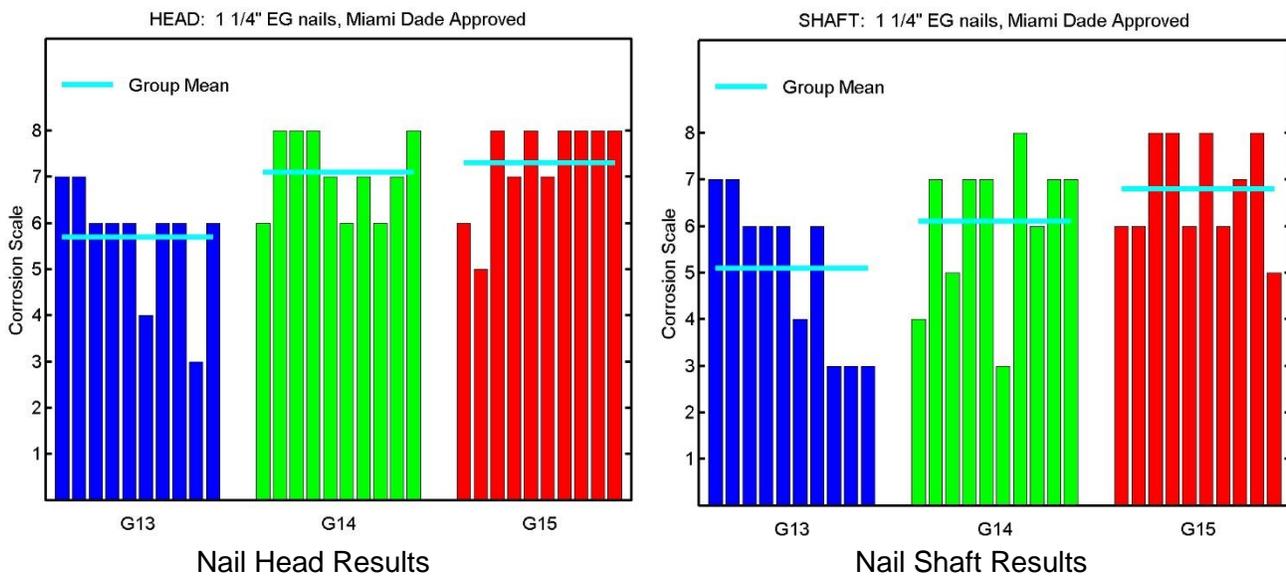


Figure 2: Test-1 Corrosion scale results for 1 ¼" EG nails, HVHZ compliant.

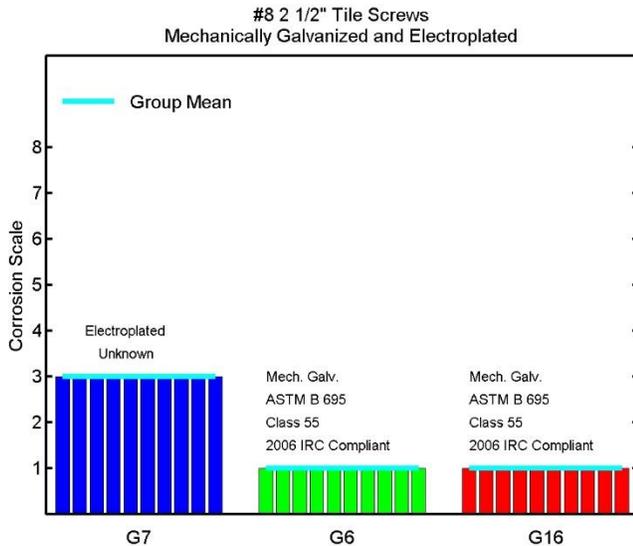


Figure 3: Test-1 Tile screws (head and shaft results identical)

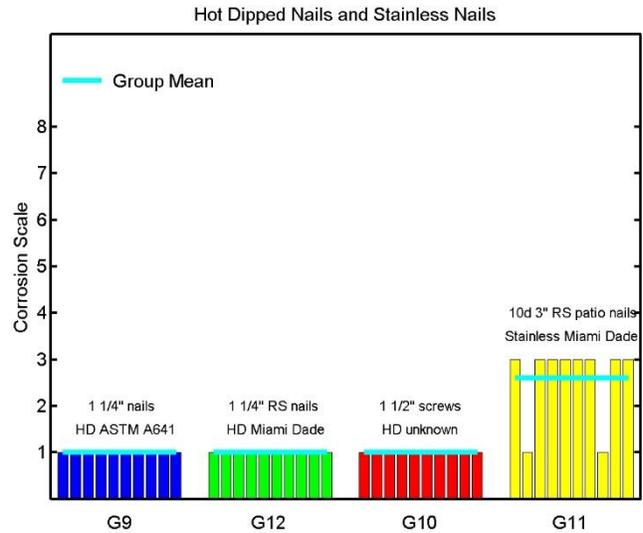


Figure 4: Test-1 Hot dipped and stainless steel (head shown, shaft results almost identical)

### 5.1.1. Test-1 Discussion

Findings are summarized as follows. Refer to Appendix A for sample photos of the specimen types being discussed (G1 – G16).

- Figure 1: Electrogalvanized fasteners that are marked as ASTM A641 compliant did not generally perform any better than those in the phase 2 2014-2015 study. Only the G8 specimen type (page 19) demonstrated a consistent resistance to corrosion, where the predominant result was partial light surface corrosion. The other specimen types (G1 through G5, pages 13-17) resulted in at least half, more typically all, samples with heavy corrosion.
- Figure 1: The electrogalvanized fastener marked as ASTM A153 Class D compliant should have a thicker zinc coating than ASTM A641 compliant fasteners. However, specimen type G5 (page 17) was among the worst performers.
- Figure 2: Electrogalvanized fasteners that are marked as Miami-Dade compliant show no better performance than the ASTM A641 fasteners in Figure 1. Specimen types G13 through G15 (pages 22-24) had heavy corrosion in at least half of all samples.
- Figure 3: The mechanically galvanized roof tile fasteners (G6 and G16, pages 18 & 25) showed no sign of corrosion. The test was not run for the required 500 cycles.
- Figure 3: The electroplated roof tile fasteners (G7, page 18) showed only partial light corrosion in all samples tested. The test was not run for the required 500 cycles.
- Figure 4: The two hot dipped nail specimen types (G9 and G12, pages 20 & 21), and the one hot dipped screw specimen type (G10, page 20) showed no corrosion.
- Figure 4: The stainless steel ring shank patio/deck nail specimen type (G11, page 21) showed partial light corrosion on the shaft, and very light to no corrosion on the head.

## 5.2. Test-2 Results

Test-2 was conducted after the submission of the February 15, 2016 interim report. The full scoring results (ten samples from each of the 6 groups) are provided in Figures 5 and 6. In both of these figures, the commonly colored bars correspond to the 10 individual samples of that specimen type. The bottom of the graph identifies the specimen type by group number as defined in Table 2 and referenced in Appendix B. The vertical axis presents the 1-8 corrosion scale score. The light blue bar spanning each commonly colored bar group is the mean value of the 10 samples in that group.

- Figure 5: 1 ¼” electrogalvanized (EG) nails, no code compliance marked on box. Nail head results (left) and nail shaft results (right). Tested out-of-the-box and installed-removed as marked in the figure.
- Figure 6: 1 ¼” hot dipped smooth shank coil nail specimen (no code compliance marked), 1 ¼” hot dipped rink shank nail specimen (ASTM F1667). Tested out-of-the-box and installed-removed as marked in the figure.

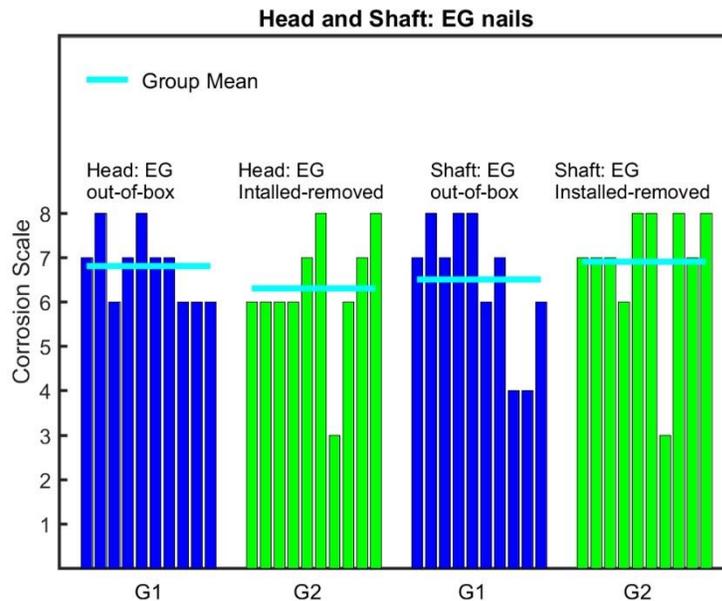


Figure 5: Test-2 Corrosion scale results for 1 ¼” EG nails, no certification marking. Blue: tested out-of-the-box. Green: installed-removed prior to testing

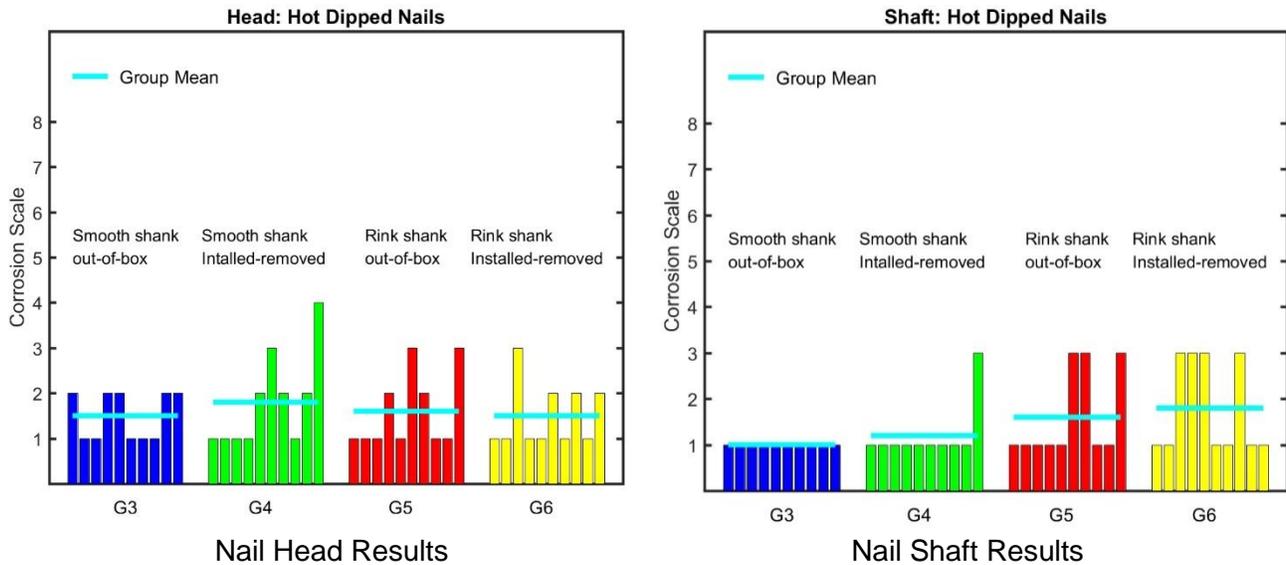


Figure 6: Test-2 Corrosion scale results for 1 ¼” Hot dipped nails, tested out-of-the-box and installed-removed as noted

### 5.2.1. Test-2 Discussion

Findings are summarized as follows. Refer to Appendix B for sample photos of the specimen types being discussed (G1 – G6).

- Figure 5: Results are consistent with those of test-1 EG nails, demonstrating a high level of head and shaft corrosion. The process of installing and removing the fasteners did not improve or worsen the corrosion performance.
- Figure 6: The two hot dipped nail specimen types tested out-of-the-box (G3 and G5, pages 28 and 30) performed well, with a few samples showing very minor spots of corrosion on the head and shaft. Those two same specimen types tested after installation and removal (G4 and G6, pages 29 and 31) also demonstrated good corrosion resistance. Those samples with a score of 2 had very minor corrosion on the edge of the head. Those samples with a score of 3 had only minor corrosion on a very small portion of the surface area. Note that a score of 2 does not apply to shaft results, as is specifically applies to the edge of the nail head. No significant difference between the corrosion resistance of installed-removed vs out-of-the-box tested nails was observed.

### 5.3. Test-3 Results

Test-3 was conducted after the submission of the February 15, 2016 interim report. The full scoring results (ten samples from Groups 1 – 11, eight samples from Groups 12 - 16) are provided in Figures 7 through 9. In these figures, the commonly colored bars correspond to the individual samples of that specimen type. The bottom of the graph identifies the specimen type by group number as defined in Table 3 and referenced in Appendix C. The vertical axis presents the 1-8 corrosion scale score. The light blue bar spanning each commonly colored bar group is the mean value of the samples in that group.

- Figure 7: 304 stainless steel ceramic coated masonry screws (four sizes). Screw head results (left) and screw shaft results (right). 10 samples of each.
- Figure 8: 316 stainless steel ceramic coated sheet metal and self-driving screws (seven sizes). Screw head results (left) and screw shaft results (right). 10 samples of each.
- Figure 9: non-stainless masonry, sheet metal and self-driving screws. Screw head results (left) and screw shaft results (right). Eight samples of each.

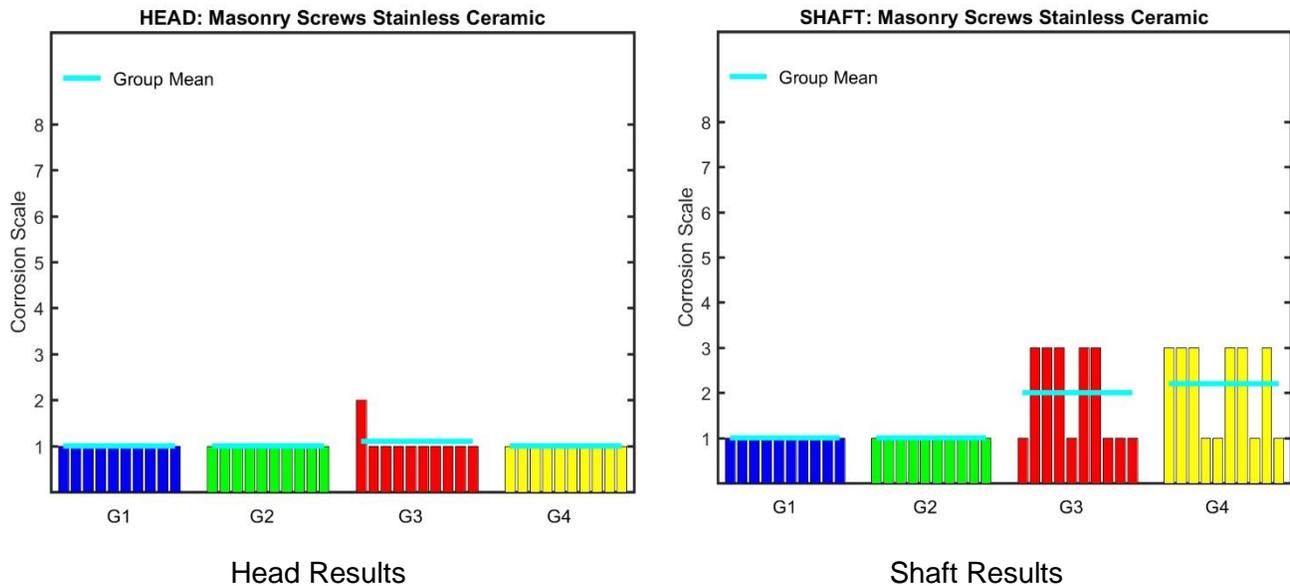


Figure 7: Test-3 Corrosion scale results for stainless steel ceramic coated masonry screws. Ten samples of each.

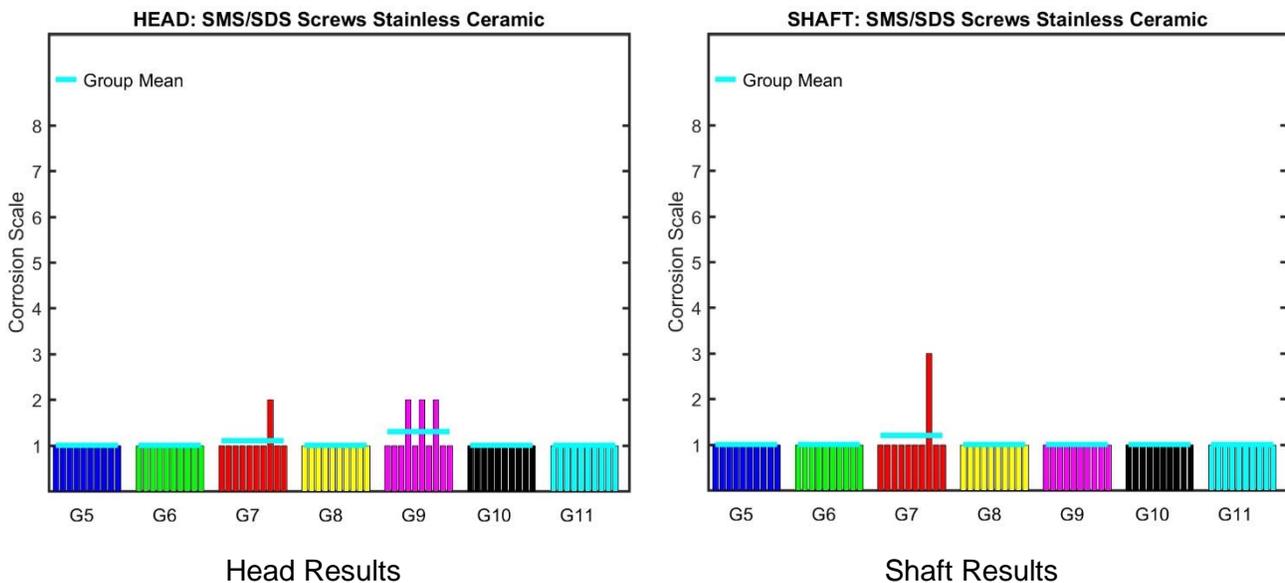


Figure 8: Test-3 Corrosion scale results for stainless steel ceramic coated self-driving and sheet metal screws. Ten samples of each.

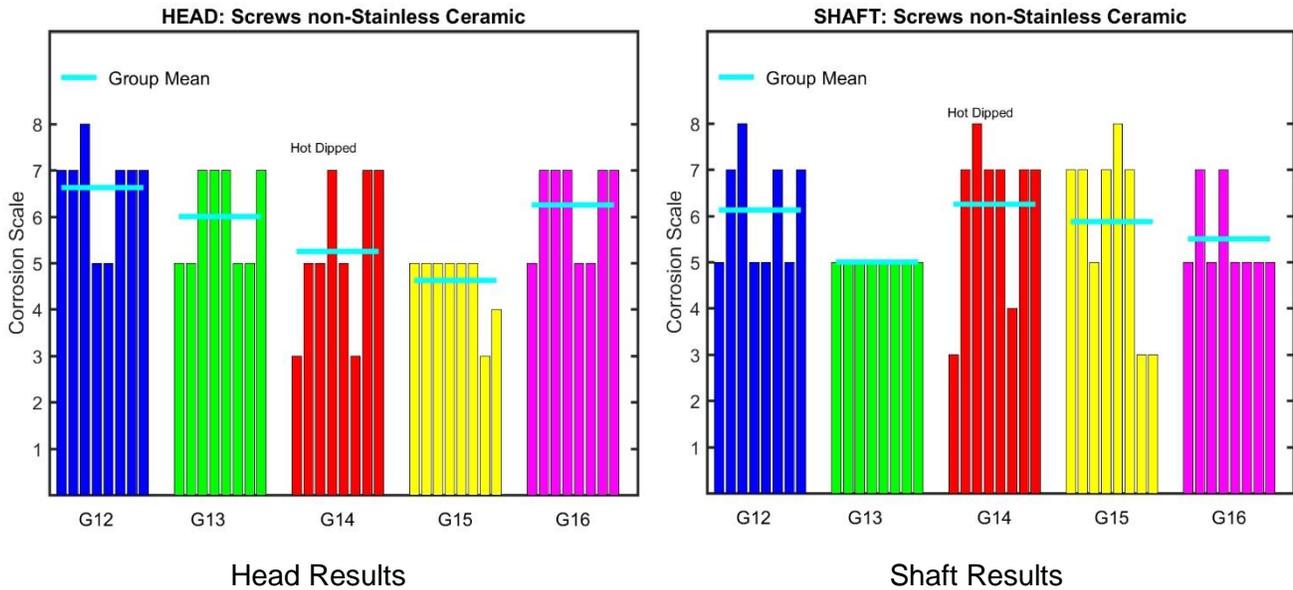


Figure 9: Test-3 Corrosion scale results for non-stainless steel masonry, self-driving and sheet metal screws. Eight samples of each.

### 5.3.1. Test-3 Discussion

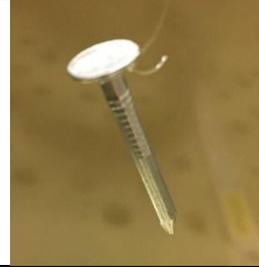
Findings are summarized as follows. Refer to Appendix C for sample photos of the specimen types being discussed (G1 – G16, pages 38 through 53).

- Figure 7: All of the 304 stainless steel ceramic coated masonry screws (G1 – G4, pages 38 through 41) exhibited similar corrosion resistance. As seen in the Appendix C photos taken post-test before and after wire brushing, the ceramic coating peeled from the head and shaft, exposing the steel. A minor amount (a few spots) of corrosion was observed in several samples (scores of 2 and 3), less than the 5% surface corrosion TAS 114 pass/fail standard. The ceramic coating is intended to provide a barrier between the stainless steel and the metal being driven through in order to prevent unlike metal reactions. These samples were not tested as-installed through unlike metal, where degradation of the coating may initiate corrosion.
- Figure 8: All of the 316 stainless steel ceramic coated sheet metal and self-driving screws (G5 – G11) exhibited similar corrosion resistance. As seen in the Appendix C photos taken post-test before and after wire brushing, the ceramic coating peeled from the head and shaft in G5 – G9 (pages 42 through 46), exposing the steel. However, the ceramic coating for G10 and G11 (pages 47 and 48) remained intact. A minor amount (a few spots) of corrosion was observed in several samples (scores of 2 and 3), less than the 5% surface corrosion TAS 114 pass/fail standard. These samples were not tested as-installed through unlike metal, where degradation of the coating may initiate corrosion.
- Figure 9: The non-stainless steel sheet metal and self-driving screws (G12 – G16, pages 49 through 53) exhibited extensive corrosion in most samples, coupled with loss of the ceramic coating.

## 6. Conclusions

- It is assumed that Miami-Dade approved EG fasteners have been certified as TAS 114 Appendix E compliant. However, the results thus far did not reveal a single EG sample that passed that standard's criterion of < 5% surface corrosion. Each of the 30 such fastener samples tested had a score of at least 3 (partial light surface corrosion) on both the head and shaft, and most samples displayed significant heavy corrosion. Each of the three EG specimen types marked as Miami-Dade approved (test-1 G13 through G15) only referenced ASTM A641, not TAS 114 Appendix E.
- The hot dipped, mechanically galvanized and stainless steel ceramic coated specimens demonstrated little or no corrosion from test-1, test-2 and test-3.
- The corrosion resistance of hot dipped specimens does not appear to be influenced (damaged) by installation. However, due to a relatively small sample size and the inclusion of only two specimen types, this conclusion is indicative rather than definitive.
- The test-3 results revealed some degradation to the ceramic coating on the stainless steel specimens. The exposed stainless steel did not exhibit significant corrosion. However, unlike metal reactions due to loss of the coating barrier were not evaluated since these specimens were tested out of the box and not in an installed configuration.

**7. Appendix A: Test-1 Corrosion results (photos and scores for samples of each specimen type)**

Test-1 Group 1: Set up and two of ten samples 1 ¼" EG, ASTM A641, non-HVHZ	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 6	Sample 3 Shaft classification: 6
	
Sample 10 Head classification: 8	Sample 10 Shaft classification: 8
	

Test-1 Group 2: Set up and two of ten samples 1 1/4" EG, ASTM A641, non-HVHZ	
Sample pre-testing	Group pre-testing
	
Sample 1 Head classification: 3	Sample 1 Shaft classification: 3
	
Sample 6 Head classification: 6	Sample 6 Shaft classification: 8
	

<p>Test-1  Group 3: Set up and two of ten samples  1 ¼" EG coil, ASTM A641, non-HVHZ</p>	
<p>Sample pre-testing</p> 	<p>Group pre-testing</p> 
<p>Sample 9  Head classification: 4</p> 	<p>Sample 9  Shaft classification: 4</p> 
<p>Sample 10  Head classification: 8</p> 	<p>Sample 10  Shaft classification: 8</p> 

Test-1 Group 4: Set up and two of ten samples 1 1/4" EG coil, ASTM A641, non-HVHZ	
Sample pre-testing	Group pre-testing
	
Sample 4 Head classification: 3	Sample 4 Shaft classification: 3
	
Sample 7 Head classification: 6	Sample 7 Shaft classification: 6
	

Test-1 Group 5: Set up and two of ten samples 1 ¼" EG coil, ASTM A153 Class D, non-HVHZ	
Sample pre-testing	Group pre-testing
	
Sample 7 Head classification: 4	Sample 7 Shaft classification: 4
	
Sample 10 Head classification: 6	Sample 10 Shaft classification: 7
	

Test-1 Group 6: Set up and one of ten samples #8 2 1/2" mechanically galvanized tile screw, ASTM B 695 Class 55 2006 IRC Compliant	
Sample pre-testing	Group pre-testing
	
Sample 1 Head classification: 1	Sample 1 Shaft classification: 1
	

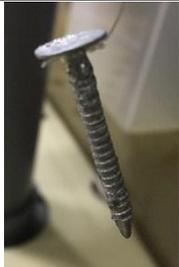
Test-1 Group 7: Set up and one of ten samples #8 2 1/2" electroplated tile screw, Compliance unknown	
Sample pre-testing	Group pre-testing
	
Sample 1 Head classification: 3	Sample 1 Shaft classification: 3
	

Test-1 Group 8: Set up and two of ten samples 1 ¼" EG coil, ASTM A641, non-HVHZ	
Sample pre-testing 	Group pre-testing 
Sample 4 Head classification: 6 	Sample 4 Shaft classification: 7 
Sample 7 Head classification: 1 	Sample 7 Shaft classification: 1 

<p>Test-1</p> <p>Group 9: Set up and one of ten samples</p> <p>1 ¼" Hot Dipped coil, Compliance unknown, non-HVHZ</p>	
Sample pre-testing	Group pre-testing
	
Sample 7 Head classification: 1	Sample 7 Shaft classification: 1
	

<p>Test-1</p> <p>Group 10: Set up and one of ten samples</p> <p>1 ½" Hot Dipped screws, compliance unknown</p>	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 1	Sample 3 Shaft classification: 1
	

<p>Test-1</p> <p>Group 11: Set up and one of ten samples</p> <p>10d 3" ring shank Stainless Steel, patio/deck nails, HVHZ</p>	
Sample pre-testing	Group pre-testing
	
Sample 8 Head classification: 1	Sample 8 Shaft classification: 3
	

<p>Test-1</p> <p>Group 12: Set up and one of ten samples</p> <p>1 1/4" Hot Dipped ring shank coil, ASTM A641, HVHZ</p>	
Sample pre-testing	Group pre-testing
	
Sample 7 Head classification: 1	Sample 7 Shaft classification: 1
	

Test-1 Group 13: Set up and two of ten samples 1 ¼" EG, ASTM A641, HVHZ (?)	
Sample pre-testing	Group pre-testing
	
Sample 4 Head classification: 6	Sample 4 Shaft classification: 6
	
Sample 9 Head classification: 3	Sample 9 Shaft classification: 3
	

<p style="text-align: center;">Test-1            Group 14: Set up and two of ten samples            1 1/4" EG ring shank coil, ASTM A641, HVHZ</p>	
Sample pre-testing	Group pre-testing
	
<p>Sample 3            Head classification: 8</p>	<p>Sample 3            Shaft classification: 5</p>
	
<p>Sample 6            Head classification: 6</p>	<p>Sample 6            Shaft classification: 3</p>
	

Test-1 Group 15: Set up and two of ten samples 1 1/4" EG ring shank coil, ASTM A641, non-HVHZ (?)	
Sample pre-testing	Group pre-testing
	
Sample 7 Head classification: 8	Sample 7 Shaft classification: 6
	
Sample 9 Head classification: 8	Sample 9 Shaft classification: 8
	

Test-1 Group 16: Set up and one of ten samples #8 2 1/2" mechanically galvanized tile screw, ASTM B 695 Class 55 2006 IRC Compliant	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 1	Sample 3 Shaft classification: 1
	

**8. Appendix B: Test-2 Corrosion results (photos and scores for samples of each specimen type)**

Test-2 Group 1: Pre-test and two of ten samples 1 ¼" EG unrated: out-of-the-box	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 6	Sample 3 Shaft classification: 7
	
Sample 8 Head classification: 6	Sample 8 Shaft classification: 4
	

<p style="text-align: center;">Test-2            Group 2: Pre-test and two of ten samples            1 ¼" EG unrated: installed and removed</p>	
<p>Sample 2 pre-testing</p> 	<p>Sample 4 pre-testing</p> 
<p>Sample 2            Head classification: 6</p> 	<p>Sample 2            Shaft classification: 7</p> 
<p>Sample 4            Head classification: 6</p> 	<p>Sample 4            Shaft classification: 6</p> 

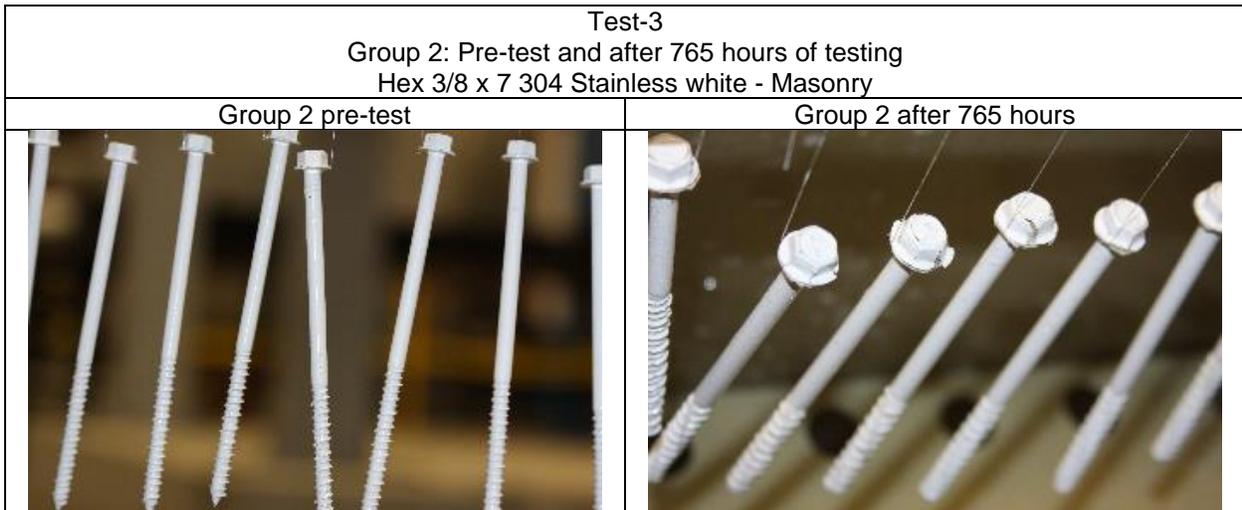
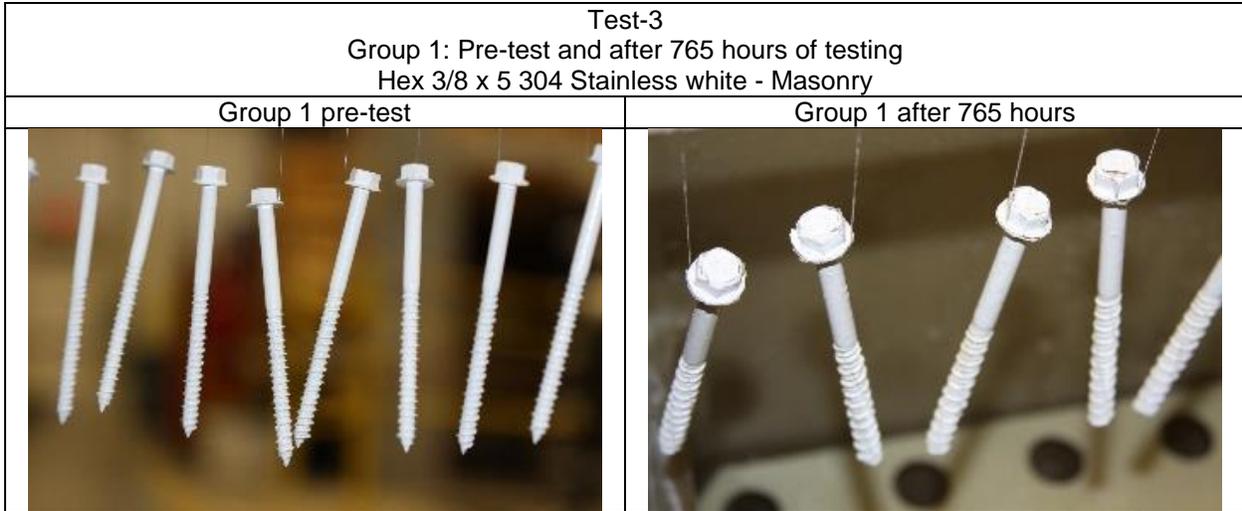
Test-2 Group 3: Pre-test and two of ten samples 1 1/4" Hot Dipped smooth shank: out-of-the-box	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 1	Sample 3 Shaft classification: 1
	
Sample 4 Head classification: 2	Sample 4 Shaft classification: 1
	

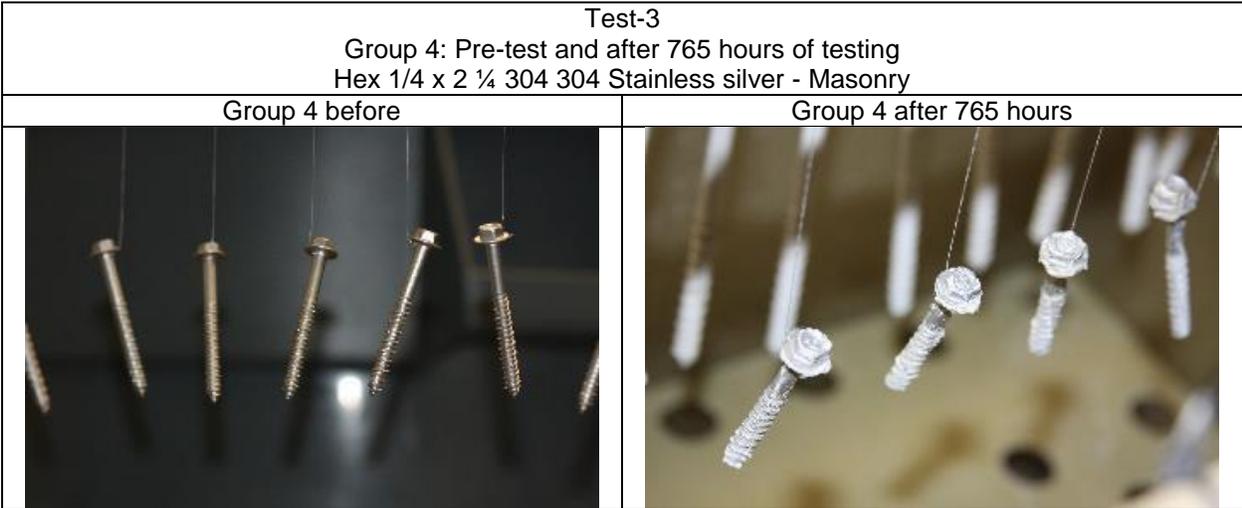
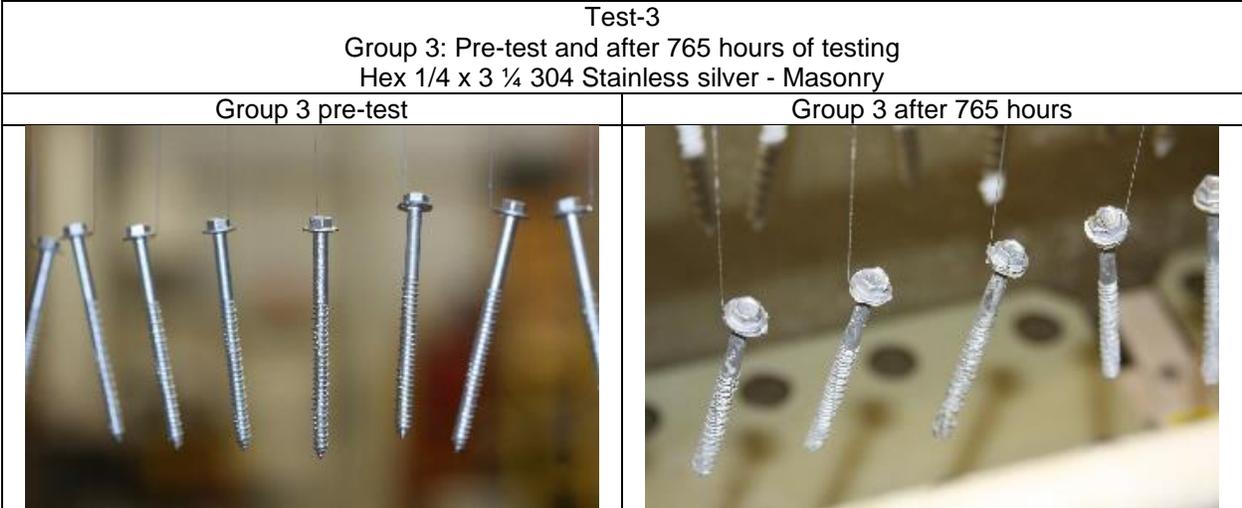
<p style="text-align: center;">Test-2            Group 4: Pre-test and two of ten samples            1 1/4" Hot Dipped smooth shank: installed and removed</p>	
Sample 5 pre-testing	Sample 9 pre-testing
	
Sample 5 Head classification: 2	Sample 5 Shaft classification: 1
	
Sample 9 Head classification: 2	Sample 9 Shaft classification: 1
	

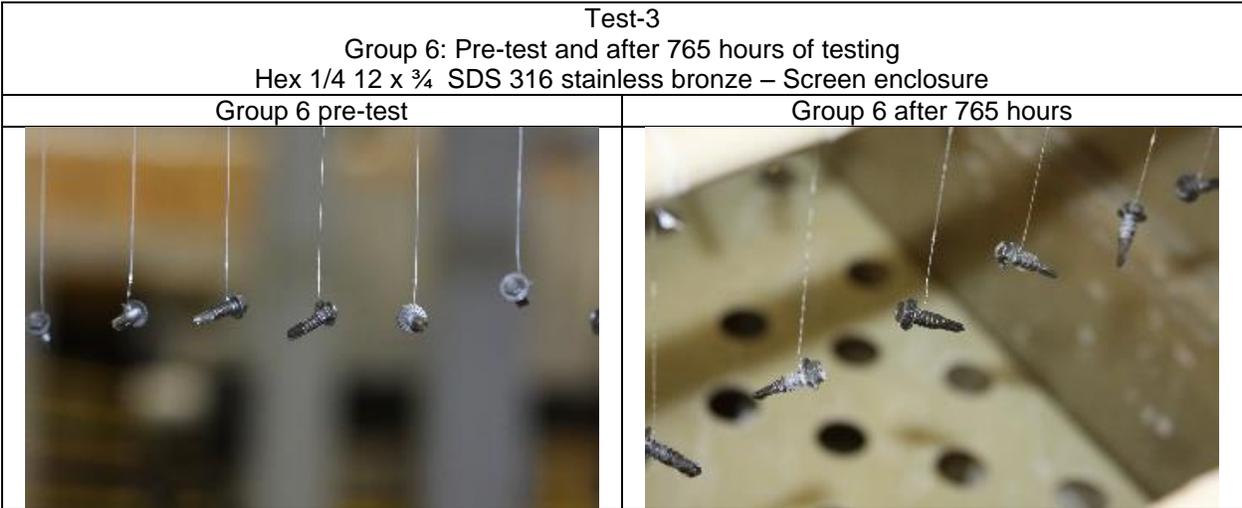
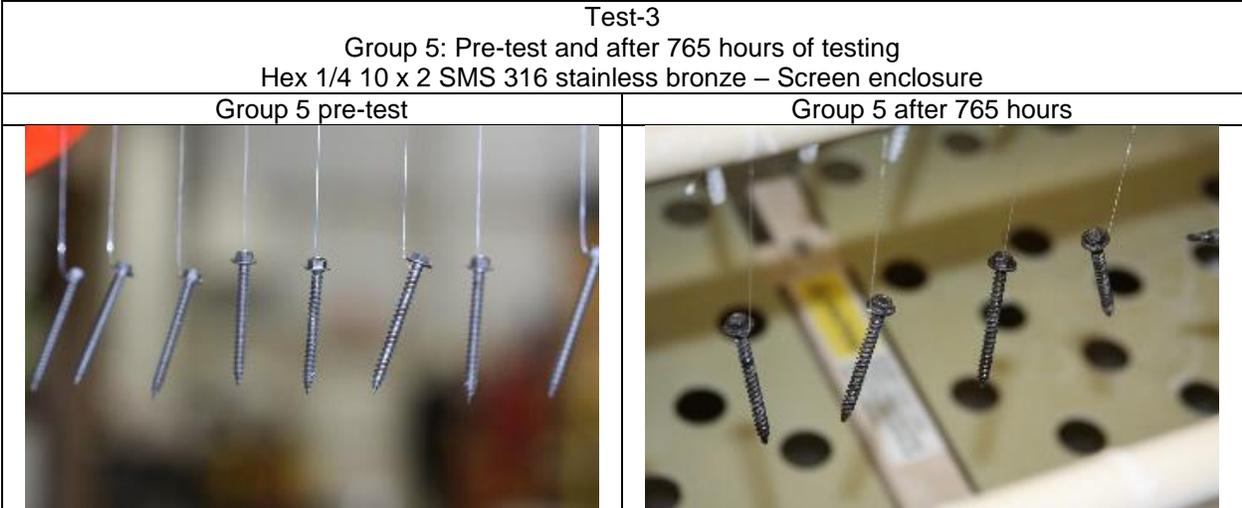
Test-2 Group 5: Pre-test and two of ten samples 1 ¼" Hot Dipped ring shank: out-of-the-box	
Sample pre-testing	Group pre-testing
	
Sample 3 Head classification: 1	Sample 3 Shaft classification: 1
	
Sample 6 Head classification: 3	Sample 6 Shaft classification: 3
	

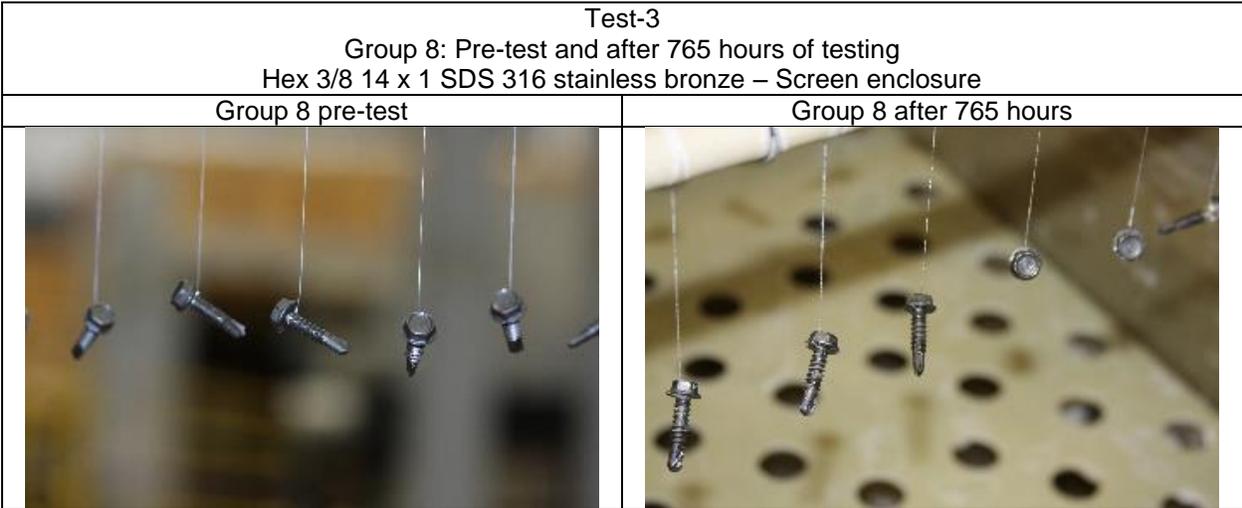
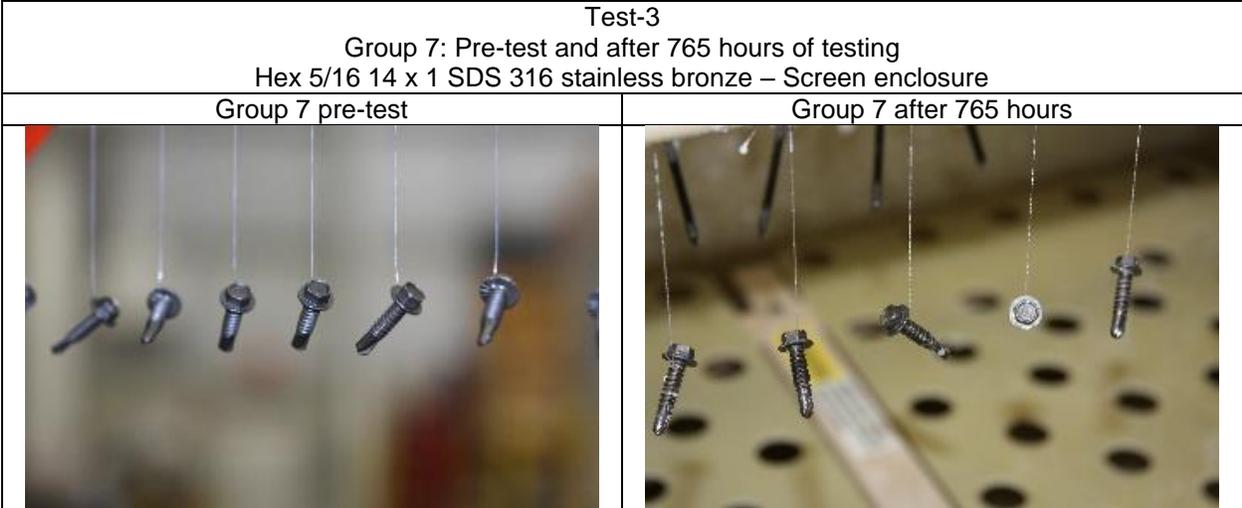
Test-2 Group 6: Pre-test and two of ten samples 1 ¼" Hot Dipped ring shank: installed and removed	
Sample 2 pre-testing	Sample 8 pre-testing
	
Sample 2 Head classification: 1	Sample 2 Shaft classification: 1
	
Sample 8 Head classification: 2	Sample 8 Shaft classification: 3
	

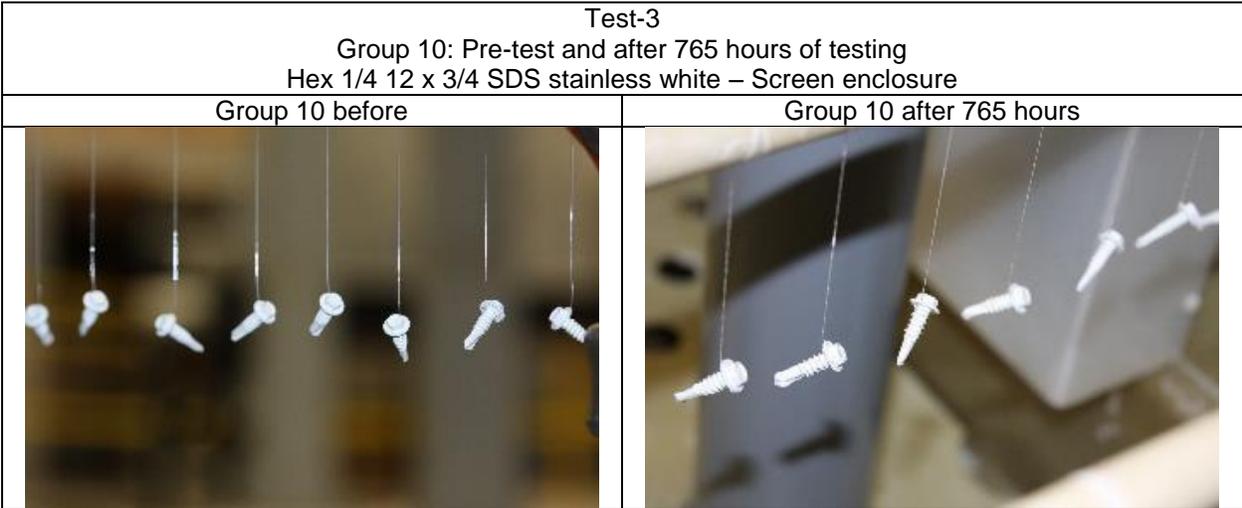
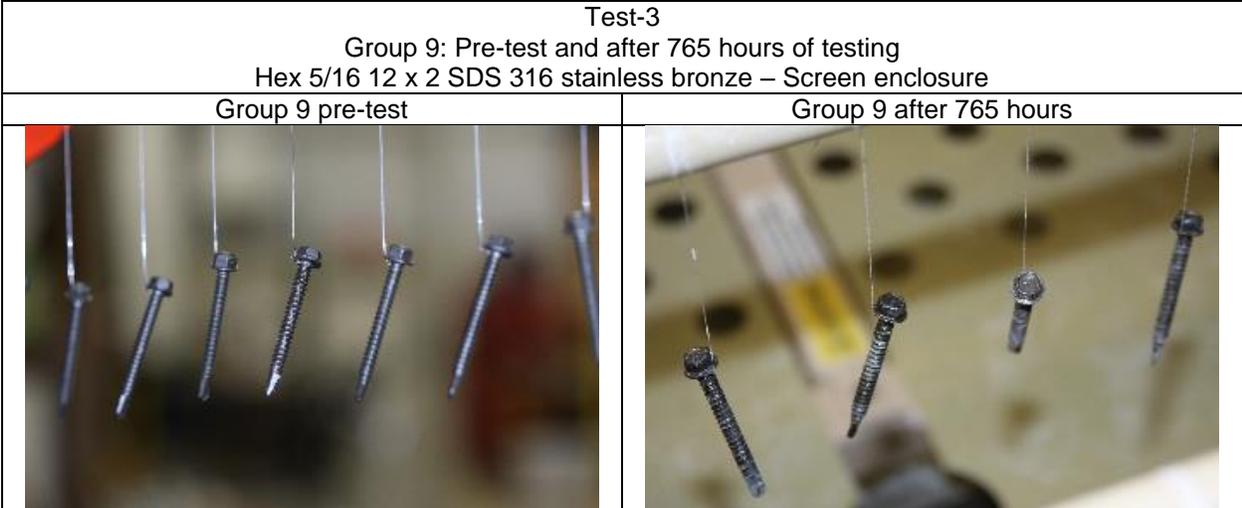
**9. Appendix C: Test-3 mid-test Corrosion results (765 of 1000 hours)**











Test-3

Group 11: Pre-test and after 765 hours of testing  
Hex 1/4 10 x 2 SMS stainless white – Screen enclosure

Group 11 pre-test



Group 11 after 765 hours



10. Appendix D: Test-3 Corrosion results (photos for a sample of each specimen type)

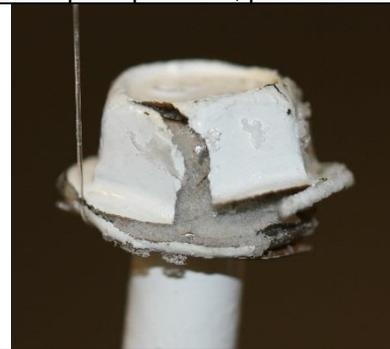
Test-3 Group 1: Pre-test and one of ten samples Hex 3/8 x 5 304 Stainless white - Masonry Group 1 pre-test	
	
Sample 4 post-test, pre-brushed	Sample 4 post-test, pre-brushed
	
Sample 4 post-test, post-brushed	Sample 4 post-test, post-brushed
	

Test-3  
Group 2: Pre-test and one of ten samples  
Hex 3/8 x 7 304 Stainless white - Masonry  
Group 2 pre-test



Sample 3 post-test, pre-brushed

Sample 3 post-test, pre-brushed



Sample 3 post-test, post-brushed

Sample 3 post-test, post-brushed



Test-3  
Group 3: Pre-test and one of ten samples  
Hex 1/4 x 3 1/4 304 Stainless silver - Masonry  
Group 3 pre-test



Sample 3 post-test, pre-brushed

Sample 3 post-test, pre-brushed



Sample 3 post-test, post-brushed

Sample 3 post-test, post-brushed



Test-3  
Group 4: Pre-test and one of ten samples  
Hex 1/4 x 2 1/4 304 304 Stainless steel - Masonry

Group 4 pre-test



Sample 5 post-test, pre-brushed

Sample 5 post-test, pre-brushed



Sample 5 post-test, post-brushed

Sample 5 post-test, post-brushed



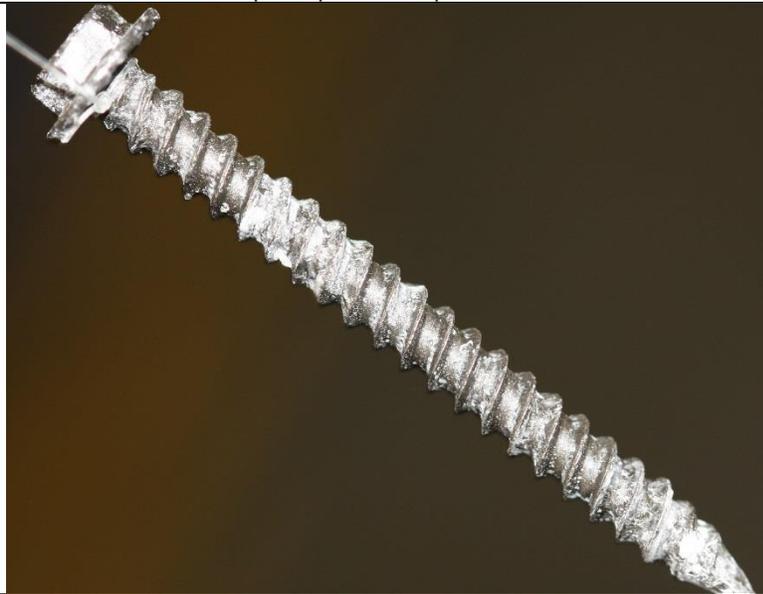
Test-3  
Group 5: Pre-test and one of ten samples  
Hex 1/4 10 x 2 SMS 316 stainless bronze – Screen enclosure

Group 5 pre-test



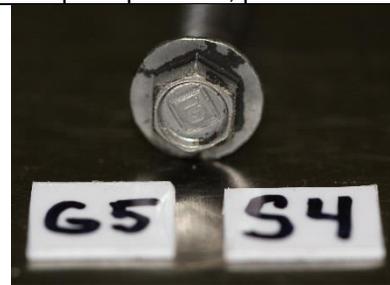
Sample 4 post-test, pre-brushed

Sample 4 post-test, pre-brushed



Sample 4 post-test, post-brushed

Sample 4 post-test, post-brushed



Test-3  
Group 6: Pre-test and one of ten samples  
Hex 1/4 12 x 3/4 SDS 316 stainless bronze – Screen enclosure

Group 6 pre-test



Sample 6 post-test, pre-brushed

Sample 6 post-test, pre-brushed



Sample 6 post-test, post-brushed

Sample 6 post-test, post-brushed



Test-3  
Group 7: Pre-test and one of ten samples  
Hex 5/16 14 x 1 SDS 316 stainless bronze – Screen enclosure  
Group 7 pre-test



Sample 1 post-test, pre-brushed

Sample 1 post-test, pre-brushed



Sample 1 post-test, post-brushed

Sample 1 post-test, post-brushed



Test-3  
Group 8: Pre-test and one of ten samples  
Hex 3/8 14 x 1 SDS 316 stainless bronze – Screen enclosure  
Group 8 pre-test



Sample 7 post-test, pre-brushed

Sample 7 post-test, pre-brushed



Sample 7 post-test, post-brushed

Sample 7 post-test, post-brushed



Test-3  
Group 9: Pre-test and one of ten samples  
Hex 5/16 12 x 2 SDS 316 stainless bronze – Screen enclosure

Group 9 pre-test



Sample 9 post-test, pre-brushed



Sample 9 post-test, post-brushed



Sample 9 post-test, pre-brushed



Sample 9 post-test, post-brushed



Test-3  
Group 10: Pre-test and one of ten samples  
Hex 1/4 12 x 3/4 SDS stainless white – Screen enclosure  
Group 10 before



Sample 5 post-test, pre-brushed

Sample 5 post-test, pre-brushed



Sample 5 post-test, post-brushed

Sample 5 post-test, post-brushed



Test-3  
Group 11: Pre-test and one of ten samples  
Hex 1/4 10 x 2 SMS stainless white – Screen enclosure

Group 11 pre-test



Sample 2 post-test, pre-brushed

Sample 2 post-test, pre-brushed



Sample 2 post-test, post-brushed

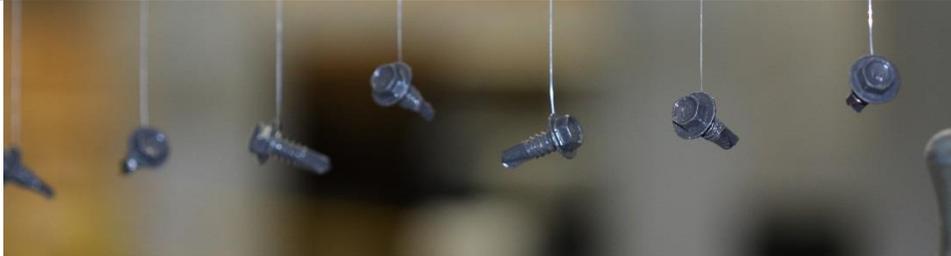


Sample 2 post-test, post-brushed



Test-3  
Group 12: Pre-test and one of ten samples  
14 x 3/4" SDS – unmarked

Group 12 pre-test



Sample 1 post-test, pre-brushed

Sample 1 post-test, pre-brushed



Sample 1 post-test, post-brushed

Sample 1 post-test, post-brushed



G 12 S1

Test-3  
Group 13: Pre-test and one of ten samples  
2 1/4" x 1/4" masonry – unmarked

Group 13 pre-test



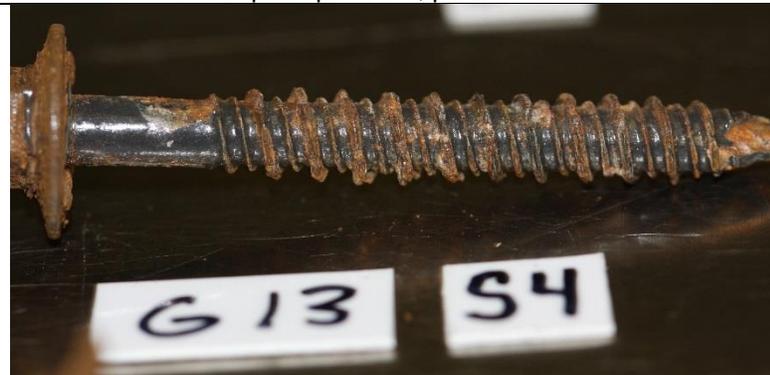
Sample 4 post-test, pre-brushed

Sample 4 post-test, pre-brushed



Sample 4 post-test, post-brushed

Sample 4 post-test, post-brushed



Test-3  
Group 14: Group 10 from test-1  
unmarked

Group 14 pre-test



Sample 2 post-test, pre-brushed

Sample 2 post-test, pre-brushed



Sample 2 post-test, post-brushed

Sample 2 post-test, post-brushed



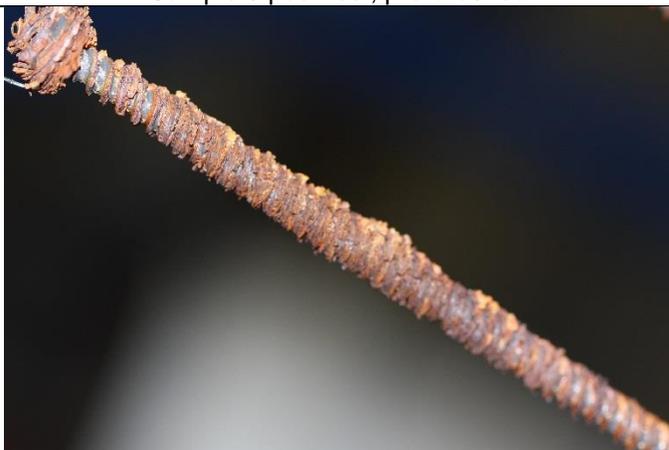
Test-3  
Group 15: Pre-test and one of ten samples  
10 x 4" SMS - unmarked

Group 15 pre-test



Sample 5 post-test, pre-brushed

Sample 5 post-test, pre-brushed



Sample 5 post-test, post-brushed

Sample 5 post-test, post-brushed



Test-3  
Group 16: Pre-test and one of ten samples  
3/8" x 3" masonry - unmarked

Group 16 pre-test



Sample 5 post-test, pre-brushed

Sample 5 post-test, pre-brushed



Sample 5 post-test, post-brushed

Sample 5 post-test, post-brushed

