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Investigation of the Effectiveness and Failure Rates of Whole-House Mechanical Ventilation Systems in Florida

FSEC-CR-2002-15

Final Report

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Mo Madani

Department of Business and Professional Development
1940 North Monroe Street
Tallahassee FL 32399

Authors

Jeffrey K. Sonne
Charles Withers
Robin K. Vieira

1679 Clearlake Road
Cocoa, Florida 32922, USA
(321) 638-1000

www.floridaenergycenter.org

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1. EXECUTIVE SUMMARY

The 2014 Florida Energy Code requires a tested ACH50 <= 5 for new Florida homes. At the same time, the 2014 Florida Mechanical Code requires mechanical ventilation be provided for any home that has an ACH50 < 5. The combination of these two requirements means most new Florida homes will need mechanical ventilation. What happens when a system fails? Do occupants repair it? Are failures a common enough problem that this is a concern? Answering these questions will help the Commission determine if there should be a limit to how tight a home can be built or if other steps should be taken to warn occupants of mechanical ventilation failures.

Toward answering these questions the Florida Solar Energy Center (FSEC) has conducted a 21-home field study investigating the effectiveness and failure rates of whole-house mechanical ventilation systems installed in Florida homes over the last 15 years. In each home researchers:

- Conducted a homeowner survey to assess homeowner awareness of the ventilation system and its purpose and maintenance practices
- Inspected and tested the ventilation system to assess its operational status, level of ventilation it is currently providing and likely reason(s) for any issues discovered.

Survey Findings

Survey results showed that, while overall homeowners feel ventilation is important for health and are aware they have a ventilation system, they have very mixed knowledge about their ventilation system and its operation. On a number of occasions the surveyor needed to provide guidance to the homeowner to help them differentiate the space cooling and heating system from the ventilation system. Answering a question on maintenance practice, most noted cleaning or changing out filters but none indicated they maintain or inspect the outdoor air grille or vent cap. When asked if they are satisfied with the overall performance of the ventilation system, 10 of the 21 homeowners answered "yes," two answered "I guess," eight answered "I don't know" or similar and one answered "no" (because of humidity concerns).

Testing Results

Only three of 21 houses (14.3%) were found to have ventilation air flow close to the design level with the type of ventilation system specified. Two of these were turned off by the homeowner, so only 1 out of the 21 homes (4.8%) were actually delivering the expected ventilation as found. Only 12 of the 21 houses (57.1%) were found to be capable of operating.

Nine (43%) of 21 mechanical ventilation systems are not operational for various reasons, including two of the systems having been disconnected. Of those that are functional, another five were deemed to have significant performance issues. An additional system (and likely three others) relies on an air handler closet located standard on/off switch to turn on a bathroom exhaust fan to provide continuous whole house ventilation even though the switch can be overridden by a bathroom on/off switch. A number of performance issues were identified including failed controllers and dampers, partially disconnected or crushed ducts, dirty filters, and outdoor air intakes installed directly over the air conditioning condenser unit hot air discharge. The report provides a summary of the findings at each study home along with a discussion of the results.

Recommendations

Based on the findings of this field study, specific code related recommendations include:

- Require general labeling that:
    - Indicates the home has a ventilation system
    - Provides labels on key components of the ventilation system
        - Ducts labeled as ventilation system duct (including flow direction indication preferred)
        - Grilles noted as vent system intake or discharge
        - Dampers noted as ventilation system dampers
        - Key ventilation fan components labeled as appropriate (ERV as ERV, supply vent fan as such, etc.)
        - Ventilation controllers
- Require general summary documentation written for occupants that:
    - Describes what a ventilation system is and how it differs from the air conditioning system
    - Describes how to tell if the vent system is operable, and suggested frequency of verification (may require improvement in some systems currently on the market)
    - Describes the location of ducts, dampers, ERV, fan units, filters, and control(s)
    - Indicates recommended filter and intake/discharge grille(s) service frequency
- Require alarm indication that covers failure of every component of the ventilation system
    - Alarms could be visual, audio or both and should signal on the event of fan failure, damper failure, or when loss of control /communication occurs
    - One example of a visual alarm notice (if occupant is educated) can even be the absence of an “operational” green light in the case where local low voltage or system voltage is lost due to failed transformer or a tripped circuit breaker
- Require intake grille or other vent collar heights to be at least 2 inches, mechanically attached to grille or vents, with seams and joints sealed with mastic or other code approved duct sealant
- Disallow filter locations that require ladders to access; consider exception to this if an alarm feature is implemented indicating a need for service

- Do not require houses to become tighter than already specified by code. Consider increasing allowed leakage to 7 ACH50 in climate zones 1 and 2 (all of Florida)
- Require either damper controlled passive or mechanical make-up air relief air to any home with high capacity kitchen exhaust fan with flow rates capable of 400 cfm or more regardless of combustion equipment; indoor house pressure with reference to outdoors should be tested (with kitchen exhaust fan running at is maximum flow rate) not to exceed 3 Pascals.
- The builder must submit a test report for the mechanical ventilation system that indicates:
    - the location of the system
    - any air intake location
    - any filter locations
    - the control status as designed and
    - the tested cfm flow.

2. INTRODUCTION

The 2014 Florida Energy Code requires a tested ACH50 <= 5 for new Florida homes. At the same time, the 2014 Florida Mechanical Code requires mechanical ventilation be provided for any home that has an ACH50 < 5. The combination of these two requirements means most new Florida homes will need mechanical ventilation. What happens when a system fails? Do occupants repair it? Are failures a common enough problem that this is a concern? Answering these questions will help the Commission determine if there should be a limit to how tight a home can be built or if other steps should be taken to warn occupants of mechanical ventilation failures.

It was not within the scope of this project to determine any occupant health issues in each study home due to lack of ventilation or to take issue with the ASHRAE committees that work on ventilation standards for residences (e.g, ASHRAE 62.2). This scope was limited to the reliability of whole house mechanical ventilation systems as found in Florida houses to operate and to deliver the effective cfm they were designed to provide.

Health and Safety Concerns

While the 2014 code's airtightness requirement is only slightly tighter than typical new construction in the state (Withers et. al. 2012 and Cummings et. al. 2003), an established tightness limit is anticipated to result in tighter Florida home construction. As described in FSEC's recently completed Airtightness and Ventilation Approaches report (Sonne and Vieira 2014), there are serious concerns related to mechanical ventilation failure in very tight houses:

- Decrease in indoor air quality
- Moisture problems such as elevated indoor humidity levels and mold growth during cold weather
- Combustion safety problems from unbalanced air flow: in very tight homes, unbalanced air flow (due to e.g. exhaust fans without make-up air, unbalanced return air, or duct leakage) can cause depressurization of the interior space which in turn can cause spillage or back-drafting of atmospherically vented combustion devices (hot water heaters, furnaces, boilers, and fireplaces). This can introduce combustion gases, including carbon monoxide, into the home. Flame roll-out and the potential for a house fire are also possible in more extreme cases.

A 1999 Canadian field study (CMHC 1999) provides an example of the combustion safety problems that depressurization due specifically to mechanical ventilation failure can create:

> *In one house, the supply fan was not functioning. The homeowners were not aware of the problem because they still heard the sound of the exhaust fan. The result was backdrafting of the fireplace and the potential for backdrafting of other combustion appliances.*

While sealed combustion equipment is gaining popularity in northern states, mild Florida winters make high efficiency sealed combustion furnaces less cost effective here, so the state is likely to continue to see significant use of atmospherically vented combustion equipment (Sonne and Vieira 2014). As a result, the depressurization issues indicated above will continue to be valid concerns.

Ventilation System Failure Rates

As further discussed in the FSEC Airtightness and Ventilation Approaches report, limited available research raises concerns about mechanical ventilation system failure rates. A 2002 Washington State research study (Lubliner et al. 2002) included a survey which showed occupants in homes with mechanical ventilation to believe ventilation is important for health, but testing in the same homes found significant problems with the ventilation systems:

> *Only 29% (5/17) of the systems integrated with central heating systems complied with either the prescriptive or performance requirements of the code.*
>
> *… The field research data reveal that the technical details of the whole house ventilation requirements are widely misunderstood. Only 32% of all systems surveyed met VIAQ performance requirements. Exhaust systems not integrated with central heating were more compliant than other systems, complying with the code 71% (10/14) of the time (all prescriptively). Only 60% of those also met the performance airflow targets of the code.*

The 1999 Canadian field study noted above found 12% of the 60 heat recovery ventilators (HRVs) inspected for the project to not be operational because of component failure and also identified balancing, installation faults and a lack of homeowner understanding as issues.

Eklund, et.al. in a study published in 2014 involving 29 Washington State homes found that significant mechanical ventilation issues continue:

> *During the initial site visits, the terminus hoods and dampers on many of the exhaust systems were found to be partially blocked or had obstructed operation due to lint buildup or improper installation. This contributes to additional static pressure, higher energy consumption, and reduced flow rate. … One measurement taken with a dirty fan before cleaning showed almost 30% higher energy use.*

Fourteen of the 29 mechanical ventilation systems included in this study were found to have control issues, eight had dirty components and six were malfunctioning.

Considering the significant increase in whole-house mechanical ventilation the new Florida Code requirements will bring about, the potential for problems from mechanical ventilation failure as homes get tighter, and findings of the effectiveness and failure research available to date from other states, the Florida Building Commission funded this study.

3. RESEARCH APPROACH

A field research study was undertaken to investigate the effectiveness of systems to deliver desired flows and total failure rates of whole-house mechanical ventilation systems installed in Florida over the last 15 years. The study approach closely followed the study's Statement of Work stipulations that the study be conducted in 20 homes around the state that had mechanical ventilation systems installed and include:

- A homeowner survey for each home to assess awareness of the ventilation system and its purpose and maintenance practices
- Inspection and testing of each home's ventilation system to assess its operational status, level of ventilation it is currently providing and likely reason(s) for any issues discovered.

A homeowner recruiting postcard (see Appendix A) was developed together with a project web page (see Appendix B) that provided general project and contact information. When a homeowner called or emailed that they were interested in the project, scheduling staff provided additional information about the project and worked with the homeowner to find a date and time for a visit.

Postcards were mailed out to 937 addresses gathered from an Energy Rating registration database. The addresses used for the mailing were limited to homes that have a mechanical ventilation system capable of meeting energy code in terms of system type (so runtime ventilation without controller/minimum on-time was not included). Most Energy Rating registrations in the state have occurred over the past two years, so in an effort to make sure that older homes were well represented in the study and increase overall participation, a second postcard mailing was made to 264 of the older homes in the original mailing.

A total of 47 homeowner responses were received, from which a total of 21 homes were eventually included in the study. In addition to trying to make sure older homes were represented as noted above, scheduling staff also worked to limit the number of homes in the study built by any one builder and vary the mechanical ventilation system types.

House visits included administering the 27-question homeowner survey (see Appendix C) and testing according to the study's testing protocol (see Appendix D).

4. TEST PROTOCOL

Each house in the study was visited by two research staff who, in addition to completing a survey with the homeowner, inspected the mechanical ventilation system and measured the ventilation system flow rate(s). The process began with a short tour of the home led by the homeowner. Owners were asked to show or indicate where central ducted space conditioning equipment and its controls were located. They were also asked to show or indicate where the mechanical ventilation system and its controls were located. Often, owners were not aware where the mechanical ventilation system or controls were located or how they operated.

Following the brief tour, a researcher would begin locating mechanical ventilation system. A blank copy of the testing protocol form can be found in Appendix D.

The primary focus of ventilation system inspection and measurement was to assess:

- Control operational status as found (enabled or disabled)
- Functional status (operable or inoperable)
- Maintenance or performance issues

- Evidence of occupant alteration or damage to system
- Type of system
- Type of control(s)
- Location of system components and controls
- Measured air flow rate(s) of the mechanical ventilation system

Evaluation of the mechanical ventilation system involved inspection of all accessible components of the system including intake and discharge grilles, ductwork, dampers, control modules, and powered fan units such as ERVs. Inspections looked for issues such as:

- Difficult owner access to on/off controls
- Dirty filters or obstructions at intake and discharge grilles
- Poor location of intake or discharge vents
- Poorly hung ducts, duct leakage
- Inadequate vent duct insulation if located in an attic
- Runtime vent systems enabled with minimum ventilation control were inspected to verify operable outdoor air (OA) damper operation, and that the control would activate both the air handler unit and the OA damper as needed.
- Operable fans in ERV or other mechanical ventilation fan equipment

Two primary pieces of equipment were used in this study to measure OA flow rates: the Energy Conservatory FlowBlaster and a hotwire anemometer. The FlowBlaster is designed to measure air flow rates at intake and discharge grilles. The hotwire anemometer is designed to measure air velocity rates; air flow rate can be calculated by multiplying the velocity in feet per minute (fpm) times the duct inner air surface area in square feet to result in flow at cubic feet per minute (cfm). More information on this test equipment is provided in Appendix E and equipment calibration documentation is provided in Appendix F.

Airflow measurements were typically taken at intake grilles located outside and, if applicable, at OA supply discharge or exhaust intakes located indoors (see Figure 1). The FlowBlaster was the preferred

Figure 1. Measuring outdoor air flow of a runtime ventilation system using a FlowBlaster.

instrument for measuring OA flow rates due to its accuracy and ease of use. In some cases the hotwire was used in-line with the OA duct. The hotwire was used when the OA intake location was inaccessible with an 18 foot extension ladder or considered unsafe to access without additional safety equipment. The hotwire measurement was also performed in addition to the FlowBlaster measurement in cases where there was already an access made into the OA duct. The pre-existing small access holes (less than ½ inch wide) were presumably made for an airflow measurement by others prior to the research visit. Pre-existing holes were found sometimes covered with foil tape and other times left unsealed.

Generally OA ducts were found to be intact with minimal leakage likely, based solely upon visual inspection and a few measurements. In a few homes, comparisons between the in-line measurement point and the OA intake grille allowed evaluation of measureable duct leakage that occurred between the OA intake and the point of in-line measurement. For example, one home had about two times more measured air flow in the in-line location compared to the measurement at the OA intake grille. This home had two separate runtime vent with minimum control systems, and each of these had approximately half of the total airflow coming from within the attic soffit instead of through the intake grill. The OA came in at intakes located under a second-story attic soffit, then traveled through flex duct inside the attic, then turned down into an interior mechanical closet containing two ducted central AHU. Each separate OA duct terminated inside the return plenum.

The duct in this type of runtime vent design operates under negative pressure when the ventilation system opens the damper. Any leakage occurring downstream of the intake in this example will add to the airflow rate and in-line measurements made near the return plenum termination would measure the intake flow plus return type leakage. The difference between the in-line and grille intake measurement equals the duct leakage under operational conditions.

Visual inspection of both of these systems found that the flex duct connections at the OA intake grilles had come partially disconnected at the collar within a roof soffit. The particular collar was not more than one inch in this case, and is more likely to come loose than a collar at least three inches long. While this only presents the issue using one example, it highlights the importance upon OA duct tightness, especially when located in attic spaces.

Besides being an air quality source issue, duct leakage can also cause errors in ventilation rate measurements. The nature of error depends upon if the leakage in the OA duct occurs at positive or negative pressures, and where the air flow measurement is taken relative to the intake/discharge and location of leakage relative to the measurement.

When airflow measurements had to be taken outside during windy conditions, the measurement period was prolonged. Before measurements were recorded, general observations were made about the range in OA airflow measurement and wind conditions during the observed range of OA flow rates. If the wind was gusting, measurements were delayed until the wind speed was at its lower speeds.

In addition to the ventilation system information, house tightness testing and limited house pressure testing was completed. All houses had house airtightness tests completed either previously by an energy rater or by research staff. House pressures with reference to outdoors were taken in most homes to gather some data about the impact the ventilation system may have on house pressure. Pressures were measured under the following conditions (as applicable to the type of system):

- All HVAC off (baseline)
- Mechanical ventilation system on
- Central ducted system on, mechanical ventilation system off
- Central ducted on, mechanical ventilation system on
- Mechanical ventilation on, central ducted system on, and all exhaust fans on

5. FINDINGS

House Characteristics

As shown in Table 1, a total of 21 houses were included in the study ranging from 1,251 square feet to 5,014 square feet in size, with ages ranging from 1 year old to 28 years old (most having been built in the past three years when more ventilation systems started getting installed in Florida). Average ACH50 for the group is 3.8.**

Table 1. Ventilation Study Home Characteristics

House #	Conditioned Area (sq. ft.)	Year Built*	ACH50**
1	2317	2014	3.3
2	2140	2005	3.4
3	2003	2013	5.1
4	3083	2013	3.1
5	2996	2014	3.7
6	2032	2013	4.3
7	2458	2014	4.4
8	3141	2013	4.3
9	3495	2013	2.7
10	2036	2013	4.0
11	2213	2012	1.7
12	2003	1987	8.8
13	5014	2012	1.2
14	4010	2007 Reno / 2nd flr	3.5
15	1305	2012	4.9
16	1347	2012	4.4
17	1251	2013	4.0
18	2119	2014	3.4
19	2222	2013	4.7
20	1907	2008	3.5
21	1688	2010	1.3

* All ventilation systems were installed at time house was built, except house #12, ERV was installed in 2004.
** ACH50 = air changes per hour at 50pa test pressure house airtightness measurement; by original energy rater or study team.

The 21 study homes were located Central and North Florida as shown in Figure 2.

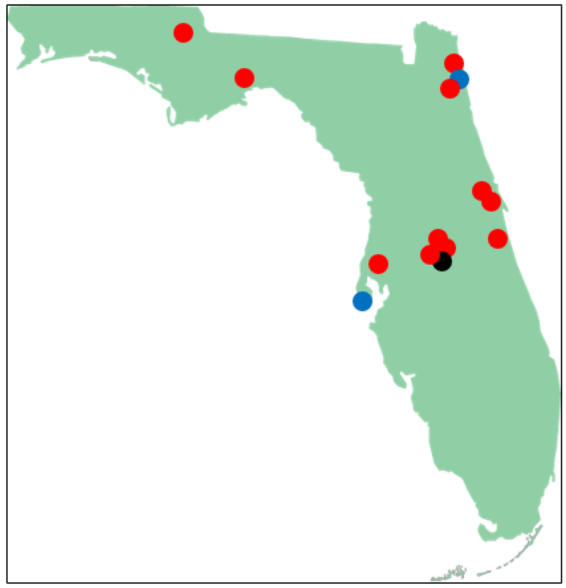

Figure 2. Study home locations. A red dot on the map represents one study home in this location, a blue dot indicates 3 homes and a black dot represents 4 homes.

Survey Responses

A 27-question homeowner survey was completed for each of the 21 study homes (blank survey provided in Appendix C). On a number of occasions the surveyor needed to provide guidance to the homeowner to help them differentiate their space cooling and heating system from their ventilation system.

Overall, homeowners felt ventilation is important for health, but indicated mixed knowledge about their ventilation system and its operation. Survey results include:

- Nineteen out of 21 homeowners answered affirmatively when asked "do you feel ventilation is important for health;" one was unsure and one response was unclear
- One homeowner had removed their mechanical ventilation system and one disconnected the ducts to the system (noting indoor air quality and odor issues and cost concerns respectively); in a third case, a runtime with control ventilation system was still connected, but the homeowner indicated they hadn't used it in the last approximately 2 ½ years out of cost concerns and because they do not like air conditioning or heat (they do however open windows on a regular basis)
- Eighteen out of 21 homeowners were aware that they had a mechanical ventilation system (including the two who were aware of the systems but had them disconnected); three were unsure
- When asked "what is the purpose of the ventilation system / why was it installed," 11 homeowners noted health, fresh air or similar, three said it came with the house or similar and four indicated they did not know, with the remaining answers including "being energy smart," durability, and to provide positive pressure
- When asked if they set the ventilation system's operation times and/or adjust the system's air flow rates or just allow it to run "hands-off" as it was originally set-up, 15 homeowners responded "hands off" or similar; two homeowners indicated they just turn it on and off and one stated that they typically keep their ERV on low but "kick it up to high" if someone burns something cooking

- When asked “What do you do, if anything, to maintain the ventilation system,” three homeowners stated they have service contracts, and of the 14 homes with runtime ventilation systems, nine owners answered that they clean or change the filter, and of the four homes with ERVs, three owners answered that they clean or change the filters; one homeowner with exhaust fan ventilation stated that they clean the vent in the bathroom but none indicated they maintain or inspect the outdoor air grille or vent cap
- When asked "Overall, how knowledgeable would you say you are about the ventilation system and its operation?" six responded "not at all" or similar, 11 responded "somewhat" or similar and 4 responded "very"
- When asked if they are satisfied with the overall performance of the ventilation system, 10 homeowners answered “yes,” two answered “I guess,” eight answered “I don’t know” or similar and one answered “no” (because of humidity concerns).

Testing Results

Table 2 below compares the type of ventilation system and air flow rates we expected to find (“Expected” columns) based on the rating database with the type of ventilation system and air flow rates we measured (“As found” columns). An “Operational Status” column indicates whether the ventilation system was capable of operation or not.

Ventilation system types in Table 2 include:

- Fans/ERV = Either exhaust-only ventilation or energy recovery ventilator
- Min. RTV = runtime ventilation with electronic control or logic designed to provide some minimum level of ventilation regardless of space conditioning load
- “Runtime vent w/o Min” = runtime ventilation with no electronic control or logic; ventilation only occurs when cooling/heating or thermostat fan set "on."

Table 2. Expected vs. As-found mechanical ventilation system types and flow rates.

House #	Expected			As-found					
	Ventilation System Type	Supply Rate (cfm)	Exhaust Rate (cfm)	Ventilation System Type	Capable of Operating?	Supply Rate (cfm)	Exhaust Rate (cfm)	Switched on or off?	Approxi-mately Meets Design?
1	Min. RTV	297	--	Min. RTV	Not operational	N/A	--	Off	No
2	ERV	70	70	ERV	Operational	59	91	On	Yes
3	Min. RTV	246	--	Min. RTV	Operational	83	--	Off	No
4	Min. RTV	374	--	Min. RTV	1 of 2	75 (sys 1)	--	Off/ Off	No
5	Min. RTV	262	--	Min. RTV	2 of 2 operational	97 / 115	--	Off/ Off	Yes
6	Min. RTV	246	--	Min. RTV	Operational	55	--	On	No
7	Min. RTV	191	--	Min. RTV	Operational	65	--	Off	No

8	Min. RTV	110	--	Non-existent	N/A	N/A	--	N/A	No
9	Fans/ERV	--	88	Runtime Vent w/o Min	Yes; damper manually controlled found closed	21	Not meas-ured*	Off	No
10	Fans/ERV	--	44	Runtime Vent w/o Min	Yes; Not controllable	19	Not meas-ured*	When air handler runs	No
11	Min. RTV	59	--	Min. RTV	Not operational	N/A	--	On	No
12	Fans/ERV	120	120	Non Existent-removed (ERV)	N/A	N/A	N/A	N/A	No
13	Fans/ERV (2)	30	40	ERVs (2)	Not operational	N/A	N/A	On/Off	No
14	Fans/ERV	200	200	ERV capable of 4 speeds	Operates at high speed with powder room exhaust switch	76/104/ 129/150	45/62/ 78/94	Off	No
15	Min. RTV	42	--	Min. RTV	No; Not controllable	46	--	With air handler	No
16	Min. RTV	42	--	Min. RTV	No; Not controllable	34	--	With air handler	No
17	Fans/ERV	43	43	ERV	Operational (high / low)	35/26	56/43	Off	Yes
18	Fans/ERV	--	71	Runtime Vent w/o Min	Yes; damper manually controlled found closed	46	Not meas-ured*	Off	No
19	Fans/ERV	--	51	Runtime Vent w/o Min	Yes; damper manually controlled found closed	27	100*	Off	No
20	Fans/ERV	50	0	ERV (dis-connected ductwork)	Not operational (4 speeds)	137/177/ 204/207	75/101/ 119/119	Off	No
21	Min. RTV	100	--	Min. RTV	Operational	46	--	Off	No

* A bathroom exhaust fan noted here was indicated as an optional mechanical ventilation system that could be controlled by either the bathroom wall switch or a remotely located switch in a mechanical closet. These fans were only operated by occupants as local bathroom ventilation control, not whole house ventilation.

Only houses 2, 5, and 17 (14.3%) were found to be delivering flow close to the design level with the type of ventilation system specified. Two of these were turned off by the homeowner, so only 1 out of the 21 homes (4.8%) were actually delivering the expected ventilation as found. Only 12 of the 21 houses (57.1%) were found to be capable of operating.

The “Operational Status” column in Table 2 above indicates whether the ventilation system was operational or not at the time of the study. It does not indicate if the homeowner utilized it adequately. It also does not indicate if the system operates as expected over long term periods. For example, a runtime vent with minimum ventilation control may be noted as “operational,” but may have been found with the control set to off. This study also was not designed to be able to determine how well the runtime vent with minimum systems provide ventilation as expected over long periods of time.

Of the 12 homes listed in Table 2 as capable of operating, some had issues. Two homes had fully operational mechanical ventilation systems without any significant issues. Five homes had systems which were operational but had the following performance issues:

- Houses 2 and 17: very dirty filters and dirty outdoor intake mesh screen for house 2
- House 5: significant outdoor air duct leakage from attic/soffit
- Houses 3 and 6: outdoor air intake directly above or near the air conditioner condensing unit (under low wind conditions at one home, tissue was used to verify that air from the condenser was reaching the inlet grille).

House 14 is an ERV which can be controlled via one of two bathroom exhaust fan switches (see House 14 in Appendix H). Turning on one of these switches turns on both the ERV and bathroom exhaust fan. While the ERV on its own in this case would provide slight positive pressure in the house with respect to outside, coupling it with the exhaust fan makes the system exhaust dominant (creating negative pressure in the house with respect to outside); so while the system is operational as intended, coupling ERV control with a bathroom exhaust fan is not recommended.

Figure 3. 3-way switchable master bath fan with light.

Four other homes (19%) (houses 9, 10, 18 and 19) had what appeared to be two different ventilation options; however the options were either not utilized or not designed to be able to provide a reasonable amount of mechanical ventilation. As such these could be considered potentially operational with limited ventilation capacity. One option utilized a bathroom exhaust fan. A switch was also provided in the mechanical closet (in three of four cases labeled “100% Ventilation”) for which the purpose was initially unclear. Talking with the homeowner at the fourth house tested with such a switch revealed that although the house had a separate runtime ventilation system (manual damper only), this switch turns on and off the master bathroom’s exhaust fan. According to the same homeowner, the switch was provided to comply with ENERGY STAR home program requirements. Further investigation revealed that this “100% Ventilation” switch could be overridden by turning on and off the same master bath fan from the switch plate in the master bathroom. So the mechanical closet switch is part of a 3-way switch which only affects the position of the switch in the bathroom (instead of up being on, up is off). It is also notable that the master bath fan includes a light that comes on with the fan (the light is not separately controllable), so 100% ventilation would require this light either being on at all times or somehow being disabled (see Figure 3). It is extremely unlikely that any homeowner would tolerate operation of a master bathroom fan and light left on for even most, if not all hours of each day, as would be required to meet ventilation standards. It is anticipated that the other three homes with "100% Ventilation" switches work in the same manner. The second option found in these four homes was a runtime vent without any minimum ventilation control capability. There was a manually controlled damper in three of the four homes found in the closed position. None of the owners were aware of this vent system or damper. A fourth home had no damper installed at all in the runtime vent. Even when the dampers were opened, the flow rates were lower than needed primarily due to static pressure losses from long runs of small 4 inch flexible duct, restriction from kinked duct, and limited pressure potential from return plenums that operate at only around 30 Pascals on average.

Finally nine (43%) of the 21 study homes were determined to not be operational. Not operational designations were given for the following reasons:

- Houses 1 and 11: unable to test due to controller failure
- House 4: one of two ventilation systems inoperable due to failure of damper to open
- House 8: a runtime ventilation system with control was shown on the energy rating, but no ventilation system was present at house (only standard bath fans controlled by simple on/off switch)
- Houses 12 and 20: ERV removed (house 12) or ERV ducts disconnected (house 20) by homeowner
- House 13: both ERV units had 120v service and breakers were on, but were not functional; the filters and cores were so clean they may have never operated (the owners were unaware of these units and indicated that they had not changed filters)
- Houses 15: inoperable as intended; ventilation only occurs when air handler is on (damper controllable, but not air handler)
- Houses 16: inoperable as intended; ventilation only occurs when air handler is on, apparently due to incorrect wiring (damper fixed 100% open).

In addition to the issues noted above in the operational assessment, several others were identified during testing. The number of occurrences of each issue between the 21 study homes is indicated in brackets:

- Partially crushed or kinked ducts—at outside wall edge / roof junction (see Figure 4) or at return plenum (4)
- Outdoor air ducts slipping off of soffit intake grille collars-- likely due to very short collar height of about 1 inch at the intake grille and installation difficulty in space restricted wall edge / roof junctions (2)
- Difficult access to ventilation system control located in attic (1)
- Uninsulated outdoor air duct in unconditioned attic (2)
- Rooftop outdoor air intake terminations (3)

- Second floor soffit or wall-- either requiring a tall ladder or getting up on the first floor roof to measure air flow (8).

Figure 4. Measuring clearance for outdoor air duct at exterior wall / roof junction.

Pressure Measurements

Pressure measurements were not a priority of this ventilation study, but provided an opportunity to evaluate the range of pressures that occur under specific operating conditions in mechanically ventilated homes. Pressure measurements provide evidence demonstrating the importance for make-up air relief in very tight homes with high flow kitchen exhaust equipment. The eleventh home tested in this study had an airtightness of only ACH50= 1.7, and a high capacity kitchen exhaust fan believed to have a maximum rated flow rate of 450 cfm. The home did not have any vented gas combustion appliances. The kitchen exhaust on high speed alone was capable of depressurizing the home to -42.9 Pascals with reference to outdoors! The runtime vent OA system of this home was found to be inoperable.

Testing and Survey Summaries

One-page summaries of the testing and survey results are provided for each of the 21 study homes in Appendix H.

6. DISCUSSION

Mechanical ventilation systems in Florida fall miserably far from providing intended ventilation. In all but one of the 21 study homes they are either not being turned on, or they have malfunctioned or they are not delivering the design ventilation or ventilation type specified. If they are capable of operation, they are not operated continuously (except in one case), and/or they do not have an adequate amount of ventilation air. As catalogued above, nine of 21 mechanical ventilation systems in this study (43%) were not operational for various reasons, including two of the systems having been disconnected. Of those that were functional, another five were deemed to have significant performance issues. An additional system (and likely three others) relies on an air handler closet located standard on/off switch to turn on a bathroom exhaust fan to provide continuous whole house ventilation even though the switch can be overridden by a bathroom on/off switch.

Ventilation System Use

Of homes with switch controllable ventilation systems, 15 of 19 systems were found to be in the off position. This finding as well as survey results provide strong evidence for the likelihood that mechanical ventilation systems are not used as intended by a majority of occupants. While the home visit only provides a "snapshot" of the home on the day of the visit, survey responses generally supported a strong case that ventilation systems were underutilized. As an example, consider some survey results such as in three separate cases homeowners were uncertain if they had a ventilation system. In addition, three others of the 21 homeowners (including the two who had their systems disconnected) were intentionally not using their ventilation systems. One homeowner indicated that they were not sure how to set their ventilation systems flow rates so they just used the lowest setting. So one not surprising but notable finding is that even if a ventilation is initially installed, a percentage of homeowners will likely choose not to use it.

This finding corresponds with FSEC staff conversations with Florida raters, mechanical designers and builders that a significant number of whole-house mechanical ventilation systems are either deactivated at time of occupancy, or are set to operate at minimum levels that do not achieve design ventilation rates.

Equipment and Controls Access

Access to ventilation equipment and controls is also an issue. If equipment is difficult to access, it is more likely to be poorly maintained. In one case the ventilation control is located in the attic which is only accessible via a tall portable ladder that must be placed within a small bathroom. In two of the study homes ERV filter cleaning requires attic access. In two other homes ceiling mounted ERVs avoid the necessity of attic access but still require either a ladder to reach a 10 foot ceiling in one case or moving a loveseat in the other.

Operation Verification

Difficulty or inability for occupants to determine if the system is functioning properly is another problem. On and off status should be located near control in an easily accessible location. In addition to on and off status, a service indicator should be present that indicates the failure of any component of the system. This service warning should activate if fan units, dampers, or electronic control portions of the system fail. Labeling should also be placed at control that is clear about how to interpret verification indicators. This should include an explanation that the system may not be operating correctly if no indicator light is on when the system is turned on. In one case, a commonly used runtime vent control with an on light and service light status indicator had no indicator light on when the system control was switched to "on". It turned out that this controller was not functional due to a failed electronic control which would not allow any lights to illuminate, even a service light. A note indicating the lack of any illumination when the system is switched on indicates a performance problem and constitutes the need for service is important to know. Component operational verification is particularly critical since this equipment is typically installed "out of the way," and verifying damper positions and airflow is not something a typical homeowner will be able to accomplish.

It is worth noting that a fair amount of effort was often required to locate components of the vent systems and verify if a given ventilation system was functional and operating at or near intended flow rates for even an experienced researcher.

Outside Air Duct Disconnects

While most OA ducts appeared to avoid significant duct leakage based upon visual inspection, there were a few cases where significant duct leaks occurred at terminal connections in unconditioned space. An example of this can be seen in Figure 5 where an outdoor air duct has partially slipped off of an intake grille collar. Disconnected ducts were only found in two ventilation systems (both at the same study home). These collar connections have been typically made within vented soffits which had less than 6 inches of clearance between the roof deck and top section of OA duct. This tight clearance

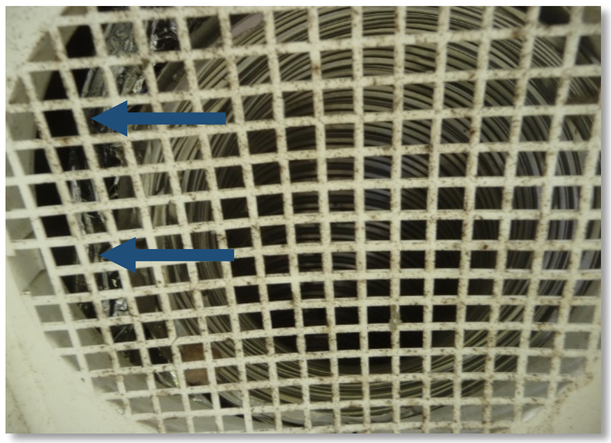

Figure 5. Outdoor air intake duct disconnected from grille collar, resulting in over 40% of the "outdoor air" coming from the attic/soffit area.

requires tight turns of duct right at the collar connection which can put additional mechanical stress on the duct and connection. This makes it very important for adequate collar height and mechanical fastening as well as appropriate sealing. Intake grille collar heights should be extended to at least 2 inches and in compliance with existing duct tightness codes to help insure a secure attachment.

Education

Based on both survey and testing results, education appears to be a key need:

- Mixed survey responses regarding controls and maintenance and testing results suggest a general lack of understanding by Florida homeowners about whole house mechanical ventilation
- On a number of occasions the surveyor needed to provide guidance to the homeowner to help them differentiate their space cooling and heating system from their ventilation system
- Ventilation controls are commonly not understood or used
- Most of the issues identified during testing are largely invisible to homeowners

- Some homeowners had talked to HVAC contractors about their ventilation systems or had maintenance performed; it was unclear whether the HVAC contractor had changed operation of the system
- Three homeowners said they relied on a service contract for ventilation system maintenance but it is unclear whether ventilation systems are actually being included in the service; in one home where the homeowner stated they relied on a service contract for ventilation system maintenance, the two ERVs were not functional.

In two homes in which the homeowner said they were satisfied with the performance of their ventilation system the systems were not functional at all, and in another two homes where the homeowners indicated satisfaction with their ventilation systems, the system was either operating with a significant performance issue or not as intended (runtime without control).

This finding combined with the other survey results is consistent with a 2014 ACEEE ventilation study finding for Washington State homes (Hales 2014):

> *The fact that over 90% of the occupants were satisfied with their system performance and indoor air quality even though over half of them did not have enough knowledge to operate or maintain the system is troubling, especially where the lack of knowledge correlates with unresolved operation and maintenance issues found by the WSU Energy Program field staff. It means that occupant satisfaction is not a good indicator of ventilation system performance. Further, if something was seriously wrong with the system, the home occupant would probably be unable to recognize it or take appropriate action.*

Ventilation Rates

A few striking observations can be made about the results shown above in Table 2 of the Findings section of this report:

1. Only one system (5%) was found on with a ventilation rate capable of meeting the rater specified flow rate.
2. It is apparent that measured flow rates are much lower than expected.
3. This study did not determine the mechanical contractor intent of the ventilation system or why the as found ventilation system was a different type or flow from that input by the energy rater.

Due to the uncertainty and limited available data on the expected mechanical ventilation flow rates, another method of comparison to International Residential Code (IRC) 2012 and ASHRAE 62.2-2010 requirements is offered here. While each of these homes was built with the intention of some kind of mechanical ventilation rate as indicated in Table 2, it is important to remember that these homes were not required to meet IRC 2012 requirements at the time of construction. IRC 2012 mechanical ventilation rates are established based upon the number of bedrooms and house square feet, and are found in Table M1507.3.3(1) of this code. ASHRAE 62.2-2010 ventilation rates are also based on the number of bedrooms and floor area which are used in a calculated method instead of a table. ASHRAE 62.2-2010 calculates the continuous ventilation as follows:

((Number of bedrooms+1) x 7.5) + (0.01 x sq.ft.)= cfm of continuous ventilation for home.

Table 3 below compares the measured mechanical ventilation system flow rate to the minimum requirement according to IRC 2012 and to ASHRAE 62.2-2010. Florida code does not reference the ASHRAE 62.2 standard, but some homebuilders of the newer homes in the study may have intended to meet this voluntary standard at the time of construction. Therefore, this ventilation standard is also shown for comparison. It is noted that most of the runtime vent control modules found in the study homes were designed by their manufacturers to meet the ASHRAE 62.2-2010 standard, if installed and used correctly. Such runtime controllers require contractors to set the correct bedroom, square feet of house area, and the ventilation flow rate using selectable settings inside the controller.

Table 3. Comparison between IRC 2012, ASHRAE 62.2, and measured mechanical ventilation rates.

House #	Ventilation System Type	No. of bedrooms / sq.ft.	IRC 2012 Minimum Vent Rate (cfm)	ASHRAE 62.2-2010 Vent Rate (cfm)	Measured Vent Rate (cfm)
1	Runtime Vent w/ Min	4 / 2317	75	61	0
2	ERV	4 / 2140	75	59	91
3	Runtime Vent w/ Min	4 /2003	75	58	83
4	Runtime Vent w/ Min	4/ 3083	90	68	75+0=75
5	Runtime Vent w/ Min	5 / 2996	75	75	97+115=212
6	Runtime Vent w/ Min	3 /2032	60	50	55
7	Runtime Vent w/ Min	3 / 2458	60	55	65
8	Runtime Vent w/ Min	4 / 3141	90	69	0
9	Fans/ERV	5 /3495	90	80	21
10	Fans/ERV	3 / 2036	60	50	19
11	Runtime Vent w/ Min	3 / 2213	60	52	0
12	Fans/ERV	3 / 2003	60	50	0, ERV removed
13	Fans/ERV (2)	4 / 5014	105	88	0+0
14	Fans/ERV	5 / 4010	90	78	150/129/104/76
15	Runtime Vent w/ Min	3 / 1305	45	43	46
16	Runtime Vent w/ Min	3 / 1347	45	43	34
17	Fans/ERV	3 /1251	45	42	56/43
18	Fans/ERV	4 / 2119	75	59	46
19	Fans/ERV	4 / 2222	75	60	27
20	Fans/ERV	4 / 1907	75	57	207/204/177/137*
21	Runtime Vent w/ Min	3 / 1688	60	47	46

* ERV was turned off and had ducts disconnected, but was functional. Measured flows are with ducts still connected at the ERV but disconnected at the terminal points.

The ASHRAE 62.2-2010 rates are lower than the IRC 2012 rates in all cases except one which is identical. The rates shown in the IRC2012 code and ASHRAE standard are based on continuous ventilation at that rate. If the ventilation is not continuous, then the rate must be increased to maintain a similar air change rate. The measured flow rates of 11 out of 21 homes were nearly equal to or higher than ASHRAE 62.2-2010. It is important to recall that most of these systems were found turned off. Another important factor to consider with runtime vent with minimum control systems is that a measured flow rate equal to the ventilation standard would require the central ducted system fan to operate 100% of the time. This results in many more hours of operation than when the ventilation rate is set higher. Longer runtime of the central system will result in higher energy use and likely elevated indoor humidity during low cooling load periods.

Simulated Energy Use based on House Tightness and Ventilation Strategy

Florida's climate is generally milder than in many other climate zones in the U.S. Therefore, the energy impact from tightening homes has a smaller impact than in harsher climates. It is instructive to consider the energy impacts accounting for house leakage and mechanical ventilation. The latest ASHRAE 62.2-2013 ventilation standard allows part of the house ventilation to occur due to leakage and requires the rest to occur from continuous ventilation. Allowing house leakage to account for some of the ventilation results in lower required mechanical ventilation rates as the house is leakier (Florida's 2014 code is based on the 2012 IECC and the ventilation rates were somewhat based on ASHRAE 62-2 2010).

A 2000 square foot Tampa one-story house at 3, 5 and 7 ACH50 would require 72, 60 or 48 cfm of mechanical ventilation, respectively to meet AHRAE 62.2-2013. Two story homes have greater stack effect and ventilation requirements are reduced further with increased air leakage rates.

In order to ascertain the energy use impacts for different air leakage rates, simulations for three air leakage rates were run. An enthalpy recovery ventilation system with 60% effectiveness and using 1 W per cfm of exchange air was modeled. Results are shown for three different ventilation methods for each of three air leakages for one and two-story homes in Tampa and Miami in Tables 4 through 7.

Table 4. *EnergyGauge* modeled energy use comparison for no ventilation, 2014 FL Code ventilation and ASHRAE 62.2-2013 ventilation for sample, single story, 2000 sq. ft., 3 bedroom, 2014 FL Code house in Miami.

ACH50	No ventilation		2014 FL Code Ventilation Requirement		ASHRAE 62.2-2013 Ventilation Requirement	
	cfm	kWh	cfm	kWh	cfm	kWh
3	0	10932	60	11645	70.0	11760
5	0	11079	60	11759	56.7	11722
7	0	11195	60	11856	43.3	11672

Table 5. *EnergyGauge* modeled energy use comparison for no ventilation, 2014 FL Code ventilation and ASHRAE 62.2-2013 ventilation for sample, two-story, 2400 sq. ft., 3 bedroom, 2014 FL Code house in Miami.

ACH50	No ventilation	2014 FL Code Ventilation Requirement	ASHRAE 62.2-2013 Ventilation

					Requirement	
	cfm	kWh	cfm	kWh	cfm	kWh
3	0	12740	60	13514	69.6	13634
5	0	12940	60	13675	48.1	13534
7	0	13099	60	13804	34.0	13502

Table 6. *EnergyGauge* modeled energy use comparison for no ventilation, 2014 FL Code ventilation and ASHRAE 62.2-2013 ventilation for sample, single story, 2000 sq. ft., 3 bedroom, 2014 FL Code house in Tampa.

ACH50	No ventilation		2014 FL Code Ventilation Requirement		ASHRAE 62.2-2013 Ventilation Requirement	
	cfm	kWh	cfm	kWh	cfm	kWh
3	0	10241	60	10898	71.9	11027
5	0	10368	60	11009	59.9	11009
7	0	10474	60	11112	47.9	10985

Table 7. *EnergyGauge* modeled energy use comparison for no ventilation, 2014 FL Code ventilation and ASHRAE 62.2-2013 ventilation for sample, two-story, 2400 sq. ft., 3 bedroom, 2014 FL Code house in Tampa.

ACH50	No ventilation		2014 FL Code Ventilation Requirement		ASHRAE 62.2-2013 Ventilation Requirement	
	cfm	kWh	cfm	kWh	cfm	kWh
3	0	12146	60	12855	72.8	13003
5	0	12315	60	13008	53.3	12933
7	0	12464	60	13140	34.0	12851

Thus the penalty for a slightly leakier house (I.e., from 5 ach50 to 7 ach50) without ventilation is at most 159 kWh. With ERV systems as modeled, the largest energy use penalty is 132 kWh for Florida code 2014 ventilation requirements going form 5 ach50 to 7 ach50. However, with reduced ventilation requirements for leaky homes under ASHRAE 62.2-2013, the total energy use is actually reduced for the leakier Florida homes as the air leakage is increased. This is due to the slight penalty in heating and cooling compared to the amount of energy the ventilation system uses at higher speeds.

With high operational failure rates, homeowners disconnecting systems and some homeowners unaware of maintenance issues, relying strictly on mechanical ventilation systems for fresh air is a potential health hazard. Allowing for some more infiltration may reduce risks, and at fairly low energy penalty.

7. RECOMMENDATIONS

Based on the findings of this field study, specific code related recommendations include:

- Require general labeling that:
    - Indicates the home has a ventilation system

- Provides labels on key components of the ventilation system
    - Ducts labeled as ventilation system duct (including flow direction indication preferred)
    - Grilles noted as vent system intake or discharge
    - Dampers noted as ventilation system dampers
    - Key ventilation fan components labeled as appropriate (ERV as ERV, supply vent fan as such, etc.)
    - Ventilation controllers
- Require general summary documentation written for occupants that:
  - Describes what a ventilation system is and how it differs from the air conditioning system
  - Describes how to tell if the vent system is operable, and suggested frequency of verification (may require improvement in some systems currently on the market)
  - Describes the location of ducts, dampers, ERV, fan units, filters, and control(s)
  - Indicates recommended filter and intake/discharge grille(s) service frequency
- Require alarm(s) indicating failure of every component of the ventilation system
  - Alarms could be visual, audio or both and should signal on the event of fan failure, damper failure, or when loss of control /communication occurs
  - One example of a visual alarm notice (if occupant is educated) can even be the absence of an "operational" green light in the case where local low voltage or system voltage is lost due to failed transformer or a tripped circuit breaker
- Require intake grille or other vent collar heights to be at least 2 inches, mechanically attached to grille or vents, with seams and joints sealed with mastic or other code approved duct sealant
- Disallow filter locations that require ladders to access; consider exception to this if an alarm feature is implemented indicating a need for service
- Do not require houses to become tighter than already specified by code. Consider increasing allowed leakage to 7 ACH50 in climate zones 1 and 2 (all of Florida)
- Require either damper controlled passive or mechanical make-up air relief air to any home with high capacity kitchen exhaust fan with flow rates capable of 400 cfm or more regardless of combustion equipment; indoor house pressure with reference to outdoors should be tested (with kitchen exhaust fan running at is maximum flow rate) not to exceed 3 Pascals.
- The builder must submit a test report for the mechanical ventilation system that indicates:
  - the location of the system
  - any air intake location
  - any filter locations
  - the control status as designed and
  - the tested cfm flow.

Since the above recommendations may require revision to a future edition of the Florida Building Code, each was analyzed using the criteria outlined in the currently adopted code modification form. This analysis is provided in Appendix G.

ACKNOWLEDGEMENTS

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REFERENCES

ASHRAE 62.2 (2010, 2013). "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings." American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA

Cummings, J; Withers, C.; McIlvaine, J.; Sonne, J.; Lombardi, M. (2003). *Air Handler Leakage: Field Testing Results in Residences*. FSEC-RR-138-03. Cocoa, FL: Florida Solar Energy Center. Accessed July 2014: http://www.fsec.ucf.edu/en/publications/html/FSEC-RR-138-03/index.htm

Eklund, K; Kunkle, R.; Banks, A.; Hales, D. (2014). "Ventilation Effectiveness Study Final Report." Portland, OR. Northwest Energy Efficiency Alliance.

"Field Survey of Heat Recovery Ventilation Systems." (1999). Canada Mortgage and Housing Corporation (CMHC). Accessed July 2014: http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/96215.htm

Hales, D.; Eklund, K; Kunkle, R.; Lubliner, M.; Banks, A. (2014). "A Field Study of Ventilation System Effectiveness in Low Air Leakage Residences." 2014 ACEEE Summer Study on Energy Efficiency in Buildings; August 2014, Washington, D.C. American Council for an Energy Efficient Economy. Accessed May 2015: http://aceee.org/files/proceedings/2014/data/index.htm

"International Residential Code for One- and Two-Family Dwellings." (2012). International Residential Code Council. International Code Council, Inc.

Lubliner, M.; Kunkle, R.; Devine, J.; Gordon, A. (2002). "Washington State Residential and Indoor Air Quality Code (VIAQ): Whole House Ventilation Systems Field Research Report." Residential Buildings: Technologies, Design, Performance Analysis, and Building Industry Trends. Accessed July 2014: http://aceee.org/files/proceedings/2002/data/papers/SS02_Panel1_Paper10.pdf

NEBB. (2015). Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems 2015- Eighth Edition. National Environmental Balancing Bureau Gaithersburg, Maryland. http://www.nebb.org/procedural-standards/

Sonne, J.; Vieira, R. (2014). *A Review of Home Airtightness and Ventilation Approaches for Florida Building Commission Research.* FSEC-CR-1977-14, Florida Solar Energy Center, Cocoa, FL, June 15, 2014.

Withers, C.; Cummings, J.; Nelson, J.; Vieira, R. (2012). A Comparison of Homes Built to the 2009 and 1984 Florida Energy Codes. FSEC-CR-1934-12. Cocoa, FL: Florida Solar Energy Center.
Accessed July 2014: http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-1934-12.pdf

APPENDICES

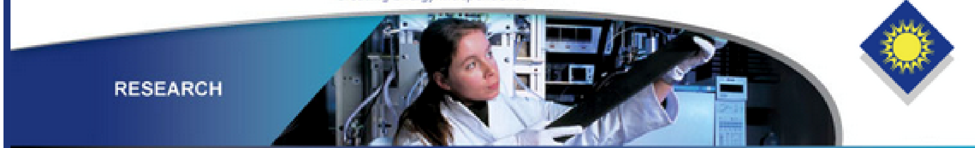
Appendix A-- Homeowner Recruiting Postcard

Appendix B-- Ventilation Study Web Page

Media Center | Employee Directory | Publications

FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence



| CONSUMER | EDUCATION | RESEARCH | | TESTING & CERTIFICATION |

Home > Research > Buildings > Vent Study

WANTED:

Florida homeowners to participate in a home ventilation study conducted by the Florida Solar Energy Center (FSEC), a research institute of the University of Central Florida.

What is this study about?

FSEC is conducting a study funded by the Florida Department of Business and Professional Regulation to learn about the performance of home ventilation systems installed in the state over the past 15 years.

Home ventilation system outdoor air intake grille under roof eave (intakes can also be found in other locations).

What does participating involve?

Participation involves taking a 15-minute survey and allowing us to test your ventilation system's performance. The total visit should take less than three hours.

Why should I sign up?

Testing your ventilation system would allow us to confirm if your system is operating properly and inform you about the results. You'll also receive a $150 participation incentive.

Does my home qualify for the study?

If you received this postcard we believe your home qualifies for the study:

If you haven't received the postcard, you may still qualify for the study if you have a single family Florida home that has a whole-house ventilation system with a control that turns the system on and off on a regular basis.

To find out more or sign up for the study, contact Cookie Cook at 321-638-1422 or e-mail at cookie@fsec.ucf.edu.

Privacy Policy | Terms and Conditions | Legal Notices

For more information about FSEC, please contact us or learn more about us.
Find us on Facebook!

Appendix C—Homeowner Survey

FSEC Mechanical Ventilation Homeowner Survey

Address: ______________________________ Date: __________________

____

1 How many people live in this house? ☐

2 Any pets? Y ☐ N ☐ [List]: ______________________________

3 Does this house have a whole-house mechanical ventilation system? Y ☐ N ☐ ? ☐

4 Where is this ventilation system located? ______________________________

5 Do you know the brand, model and/or type of ventilation system you have? __________

____

6 When was it was installed, or was it installed before you lived here? ______________

____

7 How many years have you lived here? ______________________________

8 What is the purpose of the ventilation system / why was it installed? ______________

____

9 Do you feel ventilation is important for health? ______________________________

____

10 Overall, how knowledgeable would you say you are about the ventilation system and its operation?
Not at all ☐ Somewhat ☐ Very ☐

11 Do you set the ventilation system's operation times and/or adjust the system's air flow rates,
or just allow it to run "hands-off" as it was originally set-up? ______________________

____

12 If you do set the ventilation system's operation times and/or flow rates, what settings do you
use? N/A ☐ ______________________________

____

13 Where is the control for the ventilation system located? ______________________

14 Is the ventilation system's control labeled? Y ☐ N ☐ ______________________

15 Is the ventilation system's control easy to understand and use? Y ☐ N ☐ ______

____

16 Do you have a user's manual for the ventilation system? Y ☐ N ☐ ____________

17 Was the user's manual explained to you? Y ☐ N ☐ N/A ☐ ________________

18 How did you learn how to operate the ventilation system? ______________________

____

19 What do you do, if anything, to maintain the ventilation system? ________________

____

20 If you clean the system (and change the filter(s), if/as applicable), how often do you do so?

____

21 Does your maintenance practice and schedule follow the recommendations in the user's manual?

Y ☐ N ☐ N/A ☐ ____

22 Is noise an issue with the ventilation system? Y ☐ N ☐ ________________

23 Are you satisfied with the performance of the ventilation system overall? Y ☐ N ☐

____

24 Would you install another ventilation system like this one? Y ☐ N ☐ ____________

25 Do you have any comments or questions about the ventilation system? ____________

____

26 How frequently do you open windows for ventilation (what season(s), how many times/week)?

____

27 Are there any typical or recurring comfort or indoor air quality issues in the house? If so, what are they and when do they occur (e.g. what season(s)/day/night)? Y ☐ N ☐ ______

____

Additional Notes:

Appendix D-- Test Protocol

DBPR VENTILATION STUDY TESTING PROTOCOL

Address ______________________________________ **Test Date** ____________

- Record ventilation system make and model ____
- Record ventilation system type (e.g. exhaust only, supply only, balance w/ or w/o ERV, HRV)

  ____
- Diagram ventilation system (separate sheet). Note which portions that are within the thermal and air barrier of home. Done ☐
- Record and photograph ventilation system component location(s) _______________________

  ____
  - Photos taken ☐
- Record how the ventilation system is controlled (e.g. remote control, wall panel) __________

  ____
- Determine if air flow balancing damper is present and note setting (approx. % open) _______

  ____
- Record vent system interior duct diameter or cross sectional area _______________________
- Note type and thickness of vent duct system insulation if any ___________________________
- Record ventilation system operational status / control setting (on, off, disconnected, deactivated, timer setting, ventilation rate setting, etc.) _________________________________

  ____
- Record and photograph filter location and condition ___________________________________

  ____

- Filter photo(s) taken ☐

- Tested as-found airflow rate(s) ____

  ____

- Test method ____

  - Testing photo(s) taken ☐

- Measure in wrt out dP with:

  - No HVAC on ____

  - Only house mech.vent system on (may require turning central ducted system on if no independent mech . vent fan) ____

  - Mech vent system on + all central ducted cooling systems ____________________

  - Mech vent system on + all central ducted cooling system+ all bath and kitchen exhausts

    ____

- Record any testing problems ____

- Record any ventilation system issues discovered and likely reasons for them (e.g. missing insulation, potential pollution sources near air intake, poorly installed or disconnected ducts, unbalanced HRV or ERV) ____

  ____

- Is there evidence of occupant adjustments to the system or flow rates _________________

  ____

- Other observations / notes ____

  ____

  ____

  ____

- House airtightness test completed DONE ☐ Notes ______________________________

____

- VENTILATION SYSTEM FILTERS AND SETTINGS LEFT AS INITIALLY FOUND DONE ☐

[This section is not part of testing protocol, but provides guidance on potential vent system flow rate measurement methods.]

Potential tools: small flow hoods (FlowBlaster), Solomat hot wire and vane anemometers, tracer gas and gas analyzer.

OA intake at soffit area ducted through attic and into central ducted system return plenum
Use low flow FlowBlaster (limit to under 300cfm) at OA intake grille.

If intake/discharge grilles cannot be accessed:
Could use tracer gas OA fraction measurement technique once with OA intake open and second measurement with OA closed (may have inline damper).
OR pitot tube traverse in duct.

Powered fan OA with grille at outside soffit area, side wall or through roof and then ducted to some indoor location(s) terminating either into central duct system or at one or more grilles. This system could be either an exhaust or supply air system depending upon the installation of the OA fan.
Use FlowBlaster at intake grille outside if safely accessible. Use FlowBlaster at indoor grilles if accessible. (Do both indoor and outdoor measurements if possible).
Do not walk on ceramic tile roof to measure through roof intake / discharge.

Exhaust fan pulling from one or more intake locations
Use low flow FlowBlaster (limit to under 300cfm) at OA each intake grille. If more than one ducted exhaust vent system, identify each intake grille for each system.

ERV
Measure flow at intake and discharge grilles.

Appendix E-- Air Flow Test Equipment and Measurement Method Description

Two primary pieces of equipment were used in this study to measure outside air (OA) flow rates: the Energy Conservatory FlowBlaster® and a hotwire anemometer. The FlowBlaster is designed to measure air flow rates at intake and discharge grilles. The hotwire anemometer is designed to measure air velocity rates. The air flow rate can be calculated by multiplying the velocity in feet per minute (fpm) times the duct inner air surface area in square feet to result in flow at cubic feet per minute (cfm).

FlowBlaster description: fan powered flow hood that captures air and measures the flow rate. The FlowBlaster is capable of measuring air in a range of 10-300 cfm in either an exhaust (return) or supply direction. The onboard fan is controlled by a programmable digital manometer (Energy Conservatory DG-700) that measures the differential pressure from within the capture hood with respect to outside the hood as well as the air flow sensor pressure within the FlowBlaster. The powered fan speed is automatically adjusted until the capture hood pressure with respect to outside is zero, where it then holds the speed. This programmable manometer is also capable of converting the flow sensor reading to the air flow rate. The manometer provides a continuous readout of the hood pressure and air flow rate so that one knows when to record the flow reading.

Further explanation is offered here for those unfamiliar with the advantage a powered flow hood has over a standard unpowered flow hood. Both types of devices use a hood to capture air at a grille or vent which results in air flow over the flow sensor. Standard unpowered flow hoods have been in use by test and balance firms for decades and are reasonably accurate in return (exhaust) grille flows. Measurement of residential style supply air discharge in one direction particularly along the ceiling plane (nearly perpendicular to flowhood direction) tends to result in an overestimation of air flow for some older style flow hoods than other relatively newer designed models. Depending upon the flow hood size and air flow rate being measured, the flow rate may be affected by placing a hood over the register. A powered flow hood uses just enough fan speed to eliminate any pressure drop created by the air flow hood assembly. The other advantage is when trying to make measurements outdoors during windy conditions. The powered fan will adjust for wind induced pressure differences between the hood and outdoors. In gusty conditions, even the powered hood will be challenged to maintain a neutral hood with respect to outside pressure. It is not recommended to make air flow measurements outdoors with any device during windy conditions greater than 10 mph. The preferred wind conditions of 0 to 4 mph from ASTM779, the building airtightness test standard, are good guidance, but not mandatory in ASTM779.

Hotwire description: The hotwire anemometer is an electronic device designed to measure air velocity. It uses a very fine wire that applies a very small electric current across the wire to maintain a specific temperature. Air flowing past the wire cools the wire requiring more current to be applied that is proportional to the air velocity. The hotwire used in this study was a Solomat hotwire model 127ms with a range of 2-2000 fpm and manufacturer stated accuracy of +/-5.0% of reading.

Airflow measurements were typically taken at intake grilles located outside and, if applicable, at OA supply discharge or exhaust intakes located indoors. The FlowBlaster was the preferred instrument for measuring OA flow rates due to its accuracy and ease of use. In some cases the hotwire was used inline with the OA duct. The inline hotwire measurement option was used when the OA intake location was inaccessible with an 18 foot extension ladder or considered unsafe to access without additional safety equipment. The hotwire measurement was also made in addition to the FlowBlaster measurement in cases where there was already an access made into the OA duct. The pre-existing small access holes found were presumably made for an airflow measurement by others.

When airflow measurements had to be taken outside during windy conditions, the measurement period was prolonged. Before measurements were recorded, general observations were made about the range in OA airflow measurement and wind conditions during the observed range of OA flow rates. If the wind was gusting, measurements were delayed until the wind speed was at its lower speeds.

Appendix F—Equipment Calibration

As described in Appendix E above, air flow was measured using either an Energy Conservatory FlowBlaster or a hotwire anemometer. The hotwire anemometer measures air velocity that can be used to calculate air flow when the velocity face area is known. The manufacturer stated accuracy, range, and resolution of measurement is shown in Table F-1.

Table F-1. Manufacturer specifications for range, accuracy, and resolution of measurement.

Device	Measurement (units)	Range	accuracy	resolution
Hotwire	Velocity (fpm)	2-2400	3.0% fs	1 fpm
FlowBlaster	Flow (cfm)	10-300	5% rdg	1 cfm

Equipment used to measure outdoor air flow rates were calibrated against a TSI model 8390 benchtop wind tunnel. Anemometer measurements were taken in a range from 0 fpm to 789 fpm. A velocity of 789 fpm would equate to about 155 cfm in a six-inch diameter duct. The plot of hotwire vs wind tunnel velocity is shown below (in Figure F-1) along with the linear least squares regression line and R^2. The linear regression fit shown was used to apply a correction to field measurements using the hotwire. The hotwire consistently measured velocity from 5% to 11% higher than the wind tunnel.

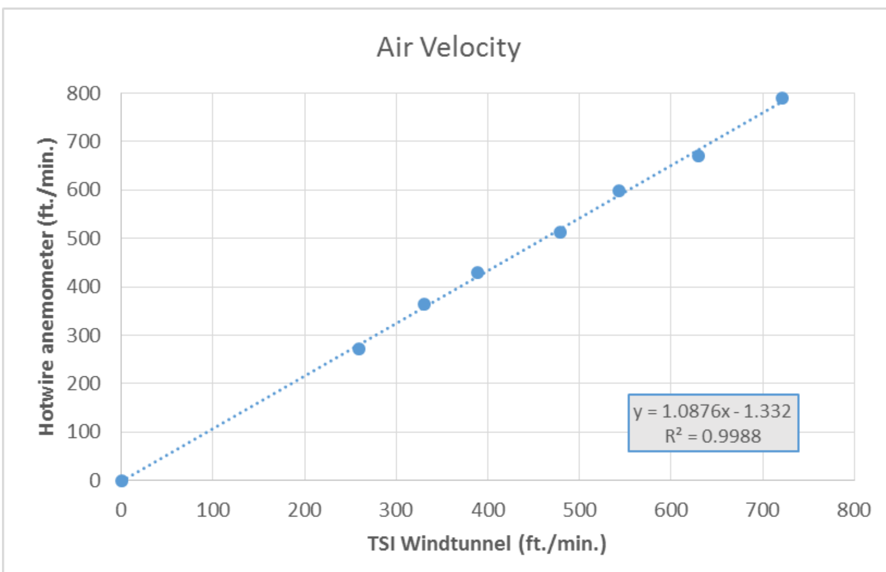


Figure F-1. Hotwire vs wind tunnel air velocity measurement

The FlowBlaster air flow was also compared to the wind tunnel. Flow hood style measurement accuracy has been observed to vary by the type of supply grille. The FlowBlaster was designed to minimize this, but three different types of calibrations were made for the FlowBlaster to see if there was any bias in types of air discharge and intake. One comparison was completed for air flow in the return configuration (exhaust or OA intake at a grille) shown in Figure F-2. Two other comparisons were made in the supply configuration (air discharged from grille into flow hood). One of the supply comparisons was with the air discharged into the hood with the flow parallel to the FlowBlaster assembly collection orientation (results shown in Figure F-3). The air could pass from the discharge direction into the

FlowBlaster without any change in direction. The second supply comparison was done using a weather sheltered discharge vent with a gravity damper. This type of vent is common for sidewall discharge of exhaust air and would result in the air flow directed 90 degrees perpendicular to the flow hood assembly orientation. The comparison results are shown in Figure F-4. The FlowBlaster is designed to operate at different ranges of air flow and uses different orifice sizes to do this and maintain accuracy. The different size flow orifices or “rings” are shown in the plots as ring 2 or ring 3. It was good to see that there was very little change in the flow accuracy based upon flow ring.

The FlowBlaster measurements in the return and supply discharge parallel to hood showed no significant trend in difference at different flow rates. These type of measurements had simple offset adjustments. The return measurements read 3 cfm to 4 cfm lower than the windtunnel regardless of flow rate. The supply discharge directly into flow hood had FlowBlaster readings of 0cfm to 3cfm lower than the wind tunnel. The supply discharged at 90 degrees to flow hood orientation had FlowBlaster readings differ by 9%-13% (an average of 10%) lower than the wind tunnel.

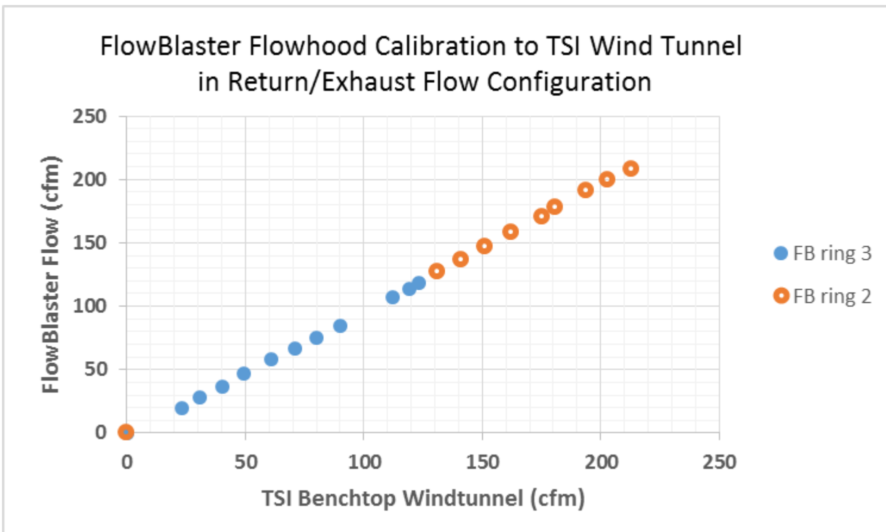


Figure F-2. FlowBlaster comparison to the wind tunnel in a return/exhaust configuration.

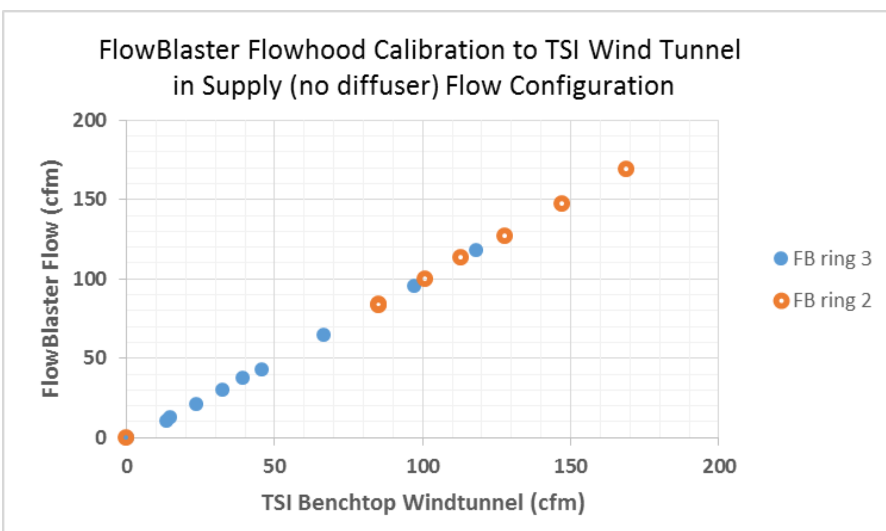


Figure F-3. FlowBlaster comparison to the wind tunnel in a supply configuration with air directly into flow hood assembly.

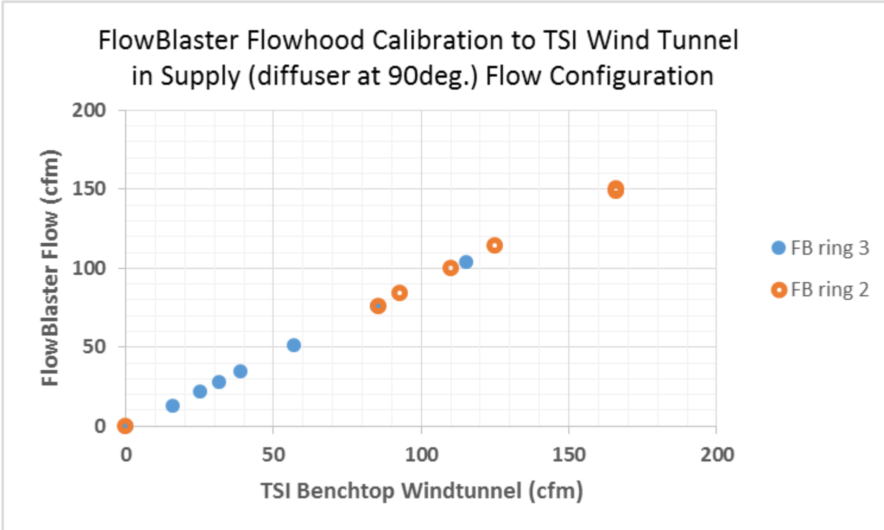


Figure F-4. FlowBlaster comparison to the wind tunnel in a supply configuration with air discharged into flow hood at 90 degrees to flow hood assembly.

Appendix G— Code Modification Analysis for Recommendations

Since the above recommendations may require revision to a future edition of the Florida Building Code, each was analyzed using the criteria outlined in the currently adopted code modification form. The analysis was separated into two recommendation groups:

- Group 1: Do not require houses to become tighter than already specified by code
- Group 2: All recommendations other than the house tightness recommendation.

Group 1: Do not require houses to become tighter than already specified by code

- Rationale: *The house tightness recommendation is intended to limit negative impacts of mechanical ventilation failure.*
- Fiscal Impact Statement
  - o Impact to local entity relative to enforcement of code (553.73(9)(b),F.S.): *No additional code enforcement required.*
  - o Impact to building and property owners relative to cost of compliance with code (553.73(9)(b),F.S.): *No additional cost to building and property owners.*
  - o Impact to industry relative to the cost of compliance with code (553.73(9)(b),F.S.): *No cost to affected industry.*
  - o Impact to small business relative to the cost of compliance with code (553.73(9)(b),F.S.): *No impact to small businesses.*
- Requirements
  - o Has a reasonable and substantial connection with the health, safety, and welfare of the general public (553.73(9)(a)2,F.S.): *This recommendation should increase the health, safety, and welfare of the general public.*
  - o Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction (553.73(9)(a)3,F.S.): *This recommendation strengthens the code by limiting the negative impacts of mechanical ventilation failure.*
  - o Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities (553.73(9)(a)4,F.S.): *This recommendation does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.*
  - o Does not degrade the effectiveness of the code (553.73(9)(a)5,F.S.): *This recommendation does not degrade the effectiveness of the code.*
- Is the proposed code modification part of a prior code version? *This recommendation refers to the 2014 Florida Energy Conservation Code airtightness requirement.*
  - o 1. The provisions contained in the proposed amendment are addressed in the applicable international code? (553.73(7)(g),F.S.) *This recommendation is consistent with 2012 and 2015 International Energy Conservation Code language.*
  - o 2. The amendment demonstrates by evidence or data that the geographical jurisdiction of Florida exhibits a need to strengthen the foundation code beyond the needs or regional variation addressed by the foundation code and why the proposed amendment applies to the state. (553.73(7)(g),F.S.): *As demonstrated in the discussion section above, this recommendation specifically applies to Florida.*

- 3. The proposed amendment was submitted or attempted to be included in the foundation codes to avoid resubmission to the Florida Building Code amendment process. (553.73(7)(g),F.S.): *No.*

Group 2: All recommendations made except for house tightness recommendation.

- Rationale: *All recommendations are intended to increase the reliability and effectiveness of whole house mechanical ventilation systems in Florida.*
- Fiscal Impact Statement
    - Impact to local entity relative to enforcement of code (553.73(9)(b),F.S.): *Each recommendation would require additional code enforcement.*
    - Impact to building and property owners relative to cost of compliance with code (553.73(9)(b),F.S.): *All recommendations would likely require some additional cost to building and property owners.*
    - Impact to industry relative to the cost of compliance with code (553.73(9)(b),F.S.): *Each recommendation would result in some cost to affected industry.*
    - Impact to small business relative to the cost of compliance with code (553.73(9)(b),F.S.): *These are residential code recommendations, so no impact to small businesses unless the small business manufactures or sells affected equipment.*
- Requirements
    - Has a reasonable and substantial connection with the health, safety, and welfare of the general public (553.73(9)(a)2,F.S.): *Each recommendation should increase 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 (553.73(9)(a)3,F.S.): *Each recommendation strengthens the code and provides better products and methods by providing a means to increase the reliability and effectiveness of whole house mechanical ventilation systems in the state.*
    - Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities (553.73(9)(a)4,F.S.): *None of the recommendations discriminate against materials, products, methods, or systems of construction of demonstrated capabilities; they should only improve affected products.*
    - Does not degrade the effectiveness of the code (553.73(9)(a)5,F.S.): *Each of the recommendations increases the effectiveness of the code by providing a means to increase the reliability and effectiveness of mechanical ventilation systems in the state.*
- Is the proposed code modification part of a prior code version? *No.*
    - 1. The provisions contained in the proposed amendment are addressed in the applicable international code? (553.73(7)(g),F.S.) *No.*
    - 2. The amendment demonstrates by evidence or data that the geographical jurisdiction of Florida exhibits a need to strengthen the foundation code beyond the needs or regional variation addressed by the foundation code and why the proposed amendment applies to the state. (553.73(7)(g),F.S.): *These recommendations should be made at the foundation code level as well.*

- 3. The proposed amendment was submitted or attempted to be included in the foundation codes to avoid resubmission to the Florida Building Code amendment process. (553.73(7)(g),F.S.): *Not to date.*

Appendix H—One Page House Summaries

House 1

Year Built:	2014
Conditioned Area:	2317
# of Bedrooms:	4
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Not operational
As found Settings:	Off

Outdoor air intake over AC condensing unit.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	297	N/A
Exhaust (cfm)	--	--

Testing notes:

1) Unable test due to failed ventilator controller; outdoor air damper closed
2) Outdoor air duct lacks mechanical support causing sagging and ripped outer jacket
3) Outdoor air intake directly over condenser unit hot air discharge

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / switch on or off
What do you do, if anything, to maintain the ventilation system?	Air handler filter gets cleaned every five months
Are you satisfied with ventilation system overall?	Yes
Survey notes:	Had to clarify difference between AC and vent system.

Ripped outdoor air duct outer jacket.

Outdoor air duct termination (left side) in return plenum.

House 2

Year Built:	2005
Conditioned Area:	2140
# of Bedrooms:	4
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Energy Recovery (ERV)
Operational Status:	Operational
As found Settings:	On

Energy recovery ventilator.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	70	59
Exhaust (cfm)	70	91

Testing notes:

1) No testing problems; ERV reported by homeowner but no rating so no "expected flow rate" data available
2) ERV filters inside unit very dirty; also large mesh screen of OA intake at exterior wall very dirty, partially clogged
3) According to owner, system should provide more OA than exhaust air, but filter loading resulted in 59 vs 91 cfm

- Survey Responses -

Do you feel ventilation is important for health?	Absolutely, more so when house new / off gassing
Does house have ventilation sys. / do you change vent settings?	Yes / mainly put on low and keep it on all the time
What do you do, if anything, to maintain the ventilation system?	Clean filter ~ every 6 months / according to indicator
Are you satisfied with ventilation system overall?	Yes- only one motor issue

Survey notes: I would not buy a house now without an ERV.

Dirty outdoor air intake.

Dirty ERV filters.

House 3

Year Built:	2013
Conditioned Area:	2003
# of Bedrooms:	4
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Operational
As found Settings:	Off

Outdoor air intake over AC condensing unit..

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	246	83
Exhaust (cfm)	--	--

Testing notes:

1) Outdoor air grille clean with a few small bugs
2) Outdoor air intake directly over condenser unit hot air discharge
3) Inadequate outdoor air damper support on one side, otherwise ducting hung well

- Survey Responses -

Do you feel ventilation is important for health?	Absolutely but would rather open windows
Does house have ventilation sys. / do you change vent settings?	Yes / just on and off
What do you do, if anything, to maintain the ventilation system?	Nothing
Are you satisfied with ventilation system overall?	I guess / indifferent
Survey notes:	I think they used the lowest flow because it doesn't seem to make a difference

Relatively clean outdoor air grille.

Outdoor air duct and damper in attic.

House 4

Year Built:	2013
Conditioned Area:	3083
# of Bedrooms:	4
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control (2)
Operational Status:	One of two operational
As found Settings:	Both off

Outdoor air inlet grilles in second floor soffit.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	374	Sys 1= 75 / Sys 2 inop
Exhaust (cfm)	--	--

Testing notes:

1) System 2 outdoor air damper failed to open
2) 3 cfm outdoor air bypass through closed damper on system 2

- Survey Responses -

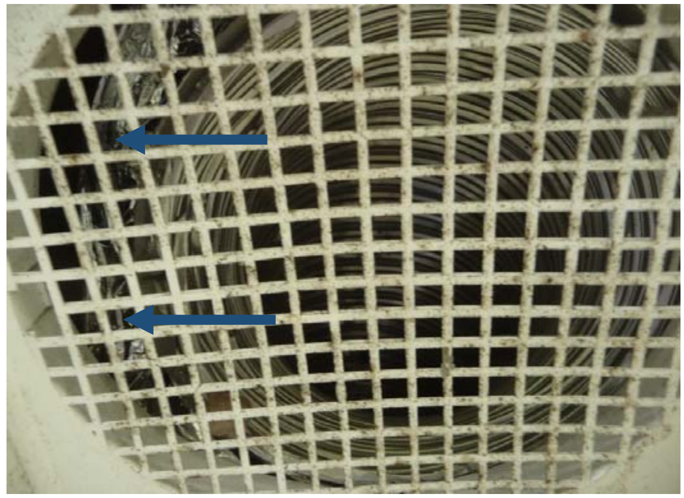
Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / yes, we switch it off when it gets colder
What do you do, if anything, to maintain the ventilation system?	Nothing except replace filters (bi-monthly)
Are you satisfied with ventilation system overall?	Yes
Survey notes:	Noted "balancing issue" but was referring to AC

Air handler with outdoor air duct and damper.

System 2 outdoor air damper inoperable.

House 5

Year Built:	2014
Conditioned Area:	2996
# of Bedrooms:	5
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control (2)
Operational Status:	Both operational
As found Settings:	Both off



Outdoor air duct disconnected from grille.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	262	Sys 1=97 / Sys 2=115*
Exhaust (cfm)	--	--

Testing notes:

1) Severe outdoor air duct leak due to some disconnection of flex to collar at grille intake
2) *Total values- system 1 includes 41% duct leakage from attic/soffit; system 2, 52% duct leakage from attic/soffit

- Survey Responses -

Do you feel ventilation is important for health?	I do; this has been emphasized by my friend
Does house have ventilation sys. / do you change vent settings?	Yes / no; hands off
What do you do, if anything, to maintain the ventilation system?	N/A
Are you satisfied with ventilation system overall?	Yes
Survey notes:	

Outdoor air grilles in second floor soffit.

Closeup indicating outdoor air damper position.

House 6

Year Built:	2013
Conditioned Area:	2032
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Operational
As found Settings:	On

Outdoor air intake near condensing unit (also airflow tester).

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	246	55
Exhaust (cfm)	--	--

Testing notes:

1) No testing problems

2) Outdoor air intake directly over condenser unit hot air discharge

3) Some duct constriction between roof deck and top of exterior wall

- Survey Responses -

Do you feel ventilation is important for health?	Yes(!); I have allergies
Does house have ventilation sys. / do you change vent settings?	Yes / pretty much hands off
What do you do, if anything, to maintain the ventilation system?	Change the ac filters (every 3 to 6 months)
Are you satisfied with ventilation system overall?	Yes

Survey notes:

Air Handler and outdoor air duct to return plenum.

Partial outdoor air duct constriction at exterior wall.

House 7

Year Built:	2014
Conditioned Area:	2458
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Operational
As found Settings:	Off

Soffit outdoor air intake grille.

- Testing -

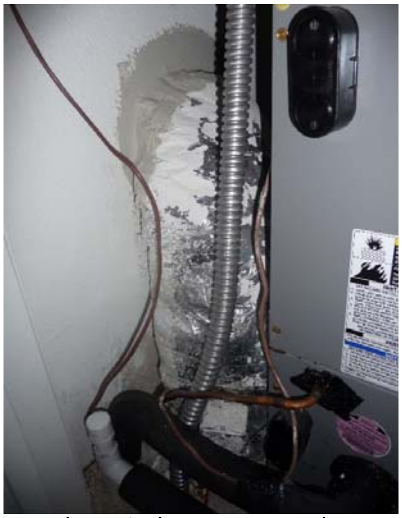
	Expected Flow Rate:	**Tested Flow Rate:**
Supply (cfm)	191	65
Exhaust (cfm)	--	--

Testing notes:

1) No testing problems
2) Filter in fair to good condition
3)

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / just turn it on and off
What do you do, if anything, to maintain the ventilation system?	No
Are you satisfied with ventilation system overall?	Don't' know purpose / don't know how to answer
Survey notes:	They replace the ac filter every three months



Outdoor air duct at return plenum.

Filter at air handler for both AC and ventilation.

House 8

Year Built:	2013
Conditioned Area:	3141
# of Bedrooms:	4
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	None (excpt bath fans)
Operational Status:	Not operational
As found Settings:	N/A

Bath exhaust grille in soffit.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	110	N/A
Exhaust (cfm)	--	60, 74, 22, 65*

Testing notes:

1) No vent system as claimed by rater; only standard bathroom fans controlled by simple wall on/off switch
2) *Flow rates are for four bathroom exhaust fans; 74 cfm bath fan exhausts into soffit (disconnected from grille)

- Survey Responses -

Do you feel ventilation is important for health?	I don't know
Does house have ventilation sys. / do you change vent settings?	Yes / no
What do you do, if anything, to maintain the ventilation system?	Contract with installer (also change filter 2x / year)
Are you satisfied with ventilation system overall?	I don't know that I would ever notice a difference
Survey notes:	Owner thought I was talking about AC when I said ventilation

Bathroom exhaust fan.

View from within exhaust discharge grille area due to disconnected duct (soffit should not be visible).

House 9

Year Built:	2013
Conditioned Area:	3495
# of Bedrooms:	5
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Runtime w/o control*
Operational Status:	Operat. if damper open
As found Settings:	Runtime damper closed

"100% Ventilation" switch in air handler closet likely used as part of 3-way switch to turn master bathroom exhaust fan on and off.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	--	21
Exhaust (cfm)	88	Not measured

Testing notes:

1) Runtime vent design with outdoor air duct connected to return plenum; manual damper at return
2) 4" outdoor air flex duct w/ hard kinked turn at the plenum resulting in significant limitation to outdoor air flow

*Also "100% Ventilation" switch-- based on later house tests in area, likely is part of 3-way master bath fan switch

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / no
What do you do, if anything, to maintain the ventilation system?	I clean the filter out at same time as I do the vinegar
Are you satisfied with ventilation system overall?	Not aware of anything it is doing for me.

Survey notes: "Nothing was explained to me about outside air"

Runtime outdoor air duct with hard kinded turn at plenum.

Runtime ventilation system outdoor air grille.

House 10

Year Built:	2013
Conditioned Area:	2036
# of Bedrooms:	3
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Runtime w/o control*
Operational Status:	On when AH is on
As found Settings:	Runtime damper open

Switch in air handler closet likely used as part of 3-way switch to turn master bathroom exhaust fan on and off.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	--	19
Exhaust (cfm)	44	Not measured

Testing notes:

1) Runtime vent design w/ outdoor air duct to return plenum but no electronic or manual damper / no way to close

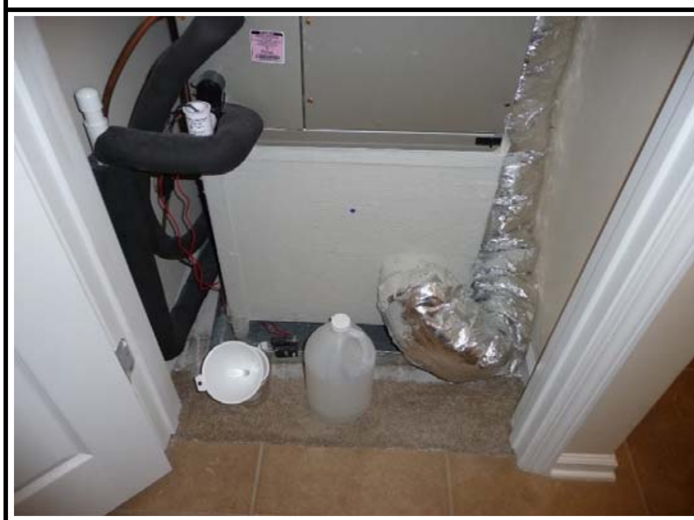
2) 4" runtime vent outdoor air duct is crushed at two points, restricting airflow

*Also "100% Ventilation" switch-- based on later house tests in area, likely is part of 3-way master bath fan switch

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes - I assume / we set the thermostats
What do you do, if anything, to maintain the ventilation system?	Replace filter an put vinegar in tubes every 30 days
Are you satisfied with ventilation system overall?	Yes

Survey notes:



Runtime outdoor air duct with hard kinded turn at plenum.

Runtime ventilation system outdoor air grille.

House 11

Year Built:	2012
Conditioned Area:	2213
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Not operational
As found Settings:	On

Outdoor damper in closed position.

- Testing -

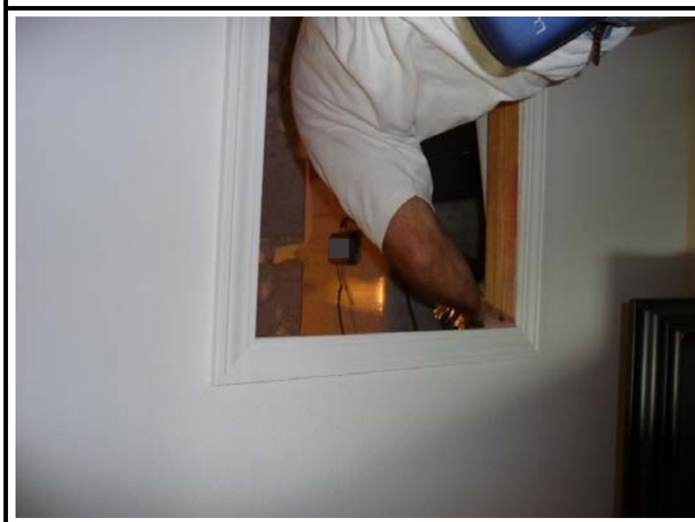
	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	59	N/A
Exhaust (cfm)	--	--

Testing notes:

1) Ventilation system set to "on" but control failure; damper 100% closed in failure mode
2) Difficult to access controller-- located in the attic which is only accessible via tall ladder in a small bathroom
3) Appears to be very tight house (rater measured ACH50 of ~1.7); house wrt out with kitchen exhaust on = -42.3pa

- Survey Responses -

Do you feel ventilation is important for health?	Absolutely
Does house have ventilation sys. / do you change vent settings?	Absolutely / no- "hands off"
What do you do, if anything, to maintain the ventilation system?	Think it's serviced once a year along with AC system
Are you satisfied with ventilation system overall?	Issue in large closet. Mold? AC issue?
Survey notes:	Homeowner has new contractor and is concerned about vent knowledge being transferred



Ventilation controller located in attic; access via small bath.

House significantly depressurized w/ kitchen exhaust.

House 12

Year Built:	1987
Conditioned Area:	1957 (Osceola Cnty)
# of Bedrooms:	3 (Osceola Cnty)
Ventilation Type	
- Expected:	Fans/ERV [removed]
- As found:	ERV [removed]
Operational Status:	Not operational
As found Settings:	[Off]

Air handler (ERV removed in 2014).

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	120	N/A
Exhaust (cfm)	120	N/A

Testing notes:

1) ERV installed in 2004 but removed in April 2014 (not available for testing)

2) ERV was removed due to ongoing indoor air quality and odor issues; perceived to be related to ERV (not clear if ERV is actually the cause / associated)

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Did / no- "hands off"
What do you do, if anything, to maintain the ventilation system?	Cleaned filters periodically (every 6 months)
Are you satisfied with ventilation system overall?	No [see notes]

Survey notes: Concerned ventilation system was "introducing too much humidity into the system"

House 13

Year Built:	2012
Conditioned Area:	5014
# of Bedrooms:	4
Ventilation Type	
- Expected:	Fans/ERV
- As found:	2x spot ERVs
Operational Status:	Both not operational
As found Settings:	One on / one off

One of two ERV units with disconnect switch (right).

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	30	N/A
Exhaust (cfm)	40	N/A

Testing notes:

1) Both ERV units were inoperable but have 120v service to each unit and breakers were on
2) No cause could be found for why either ERV would not turn on
3) Filters and areas around filters in excellent condition; appear never used / as new

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / as originally set
What do you do, if anything, to maintain the ventilation system?	Annual maintenance for A/C (included in that)
Are you satisfied with ventilation system overall?	Yes
Survey notes:	

Ceiling mounted ERV in hall.

Filters were very clean; possibly never used?

House 14

Year Built:	2nd floor added 2007
Conditioned Area:	4010
# of Bedrooms:	5
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Energy Recovery (ERV)
Operational Status:	Operational
As found Settings:	Off

Energy recovery ventilator.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	200	76/104/129/150*
Exhaust (cfm)	200	45/62/78/94*

Testing notes:

1) ERV on/off control via one of two 1st floor bathroom exhaust fan wall switches when in "standby" mode
2) *Four air flow values from low to high; standby mode setting operates at high flow
3) ERV (even in high) is outdoor air dominant; standby adds one or two bath fans making system exhaust dominant

- Survey Responses -

Do you feel ventilation is important for health?	Wanted to be cool
Does house have ventilation sys. / do you change vent settings?	Yes / no
What do you do, if anything, to maintain the ventilation system?	Change filter (not very often)
Are you satisfied with ventilation system overall?	Don't know because it doesn't seem to run much

Survey notes:

One of two bathrooms switches that turn the ERV on.

Energy recovery ventilator filter in fair condition.

House 15

Year Built:	2012
Conditioned Area:	1305
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Not as intended*
As found Settings:	On

Outdoor air duct and damper controller next to air handler.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	42	46
Exhaust (cfm)	--	--

Testing notes:

1) *Inoperable as intended; ventilation only occurs when air handler is on- damper controllable, but not air handler
2) Vent controller set to "on" as found, but incorrect wiring likely cause of failure of control to turn on air handler
3) Damper was able to be controlled by controller, but not AHU

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / run hands off
What do you do, if anything, to maintain the ventilation system?	Once a year clean filter (outside)
Are you satisfied with ventilation system overall?	Yes

Survey notes:

Outdoor air vent cap on roof.

Outdoor air duct in attic is uninsulated.

House 16

Year Built:	2012
Conditioned Area:	1347
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Not as intended*
As found Settings:	On

Outside air damper fixed open.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	42	34
Exhaust (cfm)	--	--

Testing notes:

1) *Inoperable as intended; ventilation only occurs when air handler is on

2) Vent controller Set to OVERRIDE as found, but incorrect wiring likely cause of failure of vent control to turn on air handler or actuate damper; damper was forced to be fixed at 100% open all the time

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Not sure / "hands off" as set
What do you do, if anything, to maintain the ventilation system?	Nothing (main house filter changed out twice a year)
Are you satisfied with ventilation system overall?	Don't know what to look for

Survey notes:

Open outdoor air damper visible from inside return plenum.

Outdoor air vent cap on roof.

House 17

Year Built:	2013
Conditioned Area:	1251
# of Bedrooms:	3
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Energy recovery (ERV)
Operational Status:	Operational
As found Settings:	Off

Energy recovery ventilator in living room.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	43	High 35 / Low 26
Exhaust (cfm)	43	High 56 / Low 43

Testing notes:

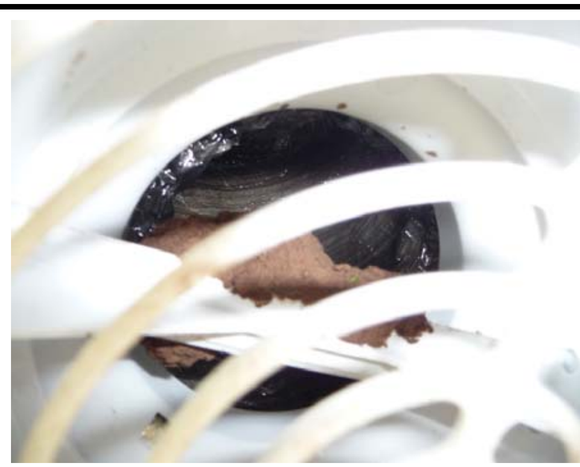
1) As found, system off, but operable at high and low speeds.
2) Outdoor air filter was dirty
3)

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / run "hands-off" as it was orignally set up
What do you do, if anything, to maintain the ventilation system?	Clean filter (once per year)
Are you satisfied with ventilation system overall?	Yes

Survey notes:

Dirty outdoor air filter.



Insect nest inside outdoor air grille.

House 18

Year Built:	2014
Conditioned Area:	2119
# of Bedrooms:	4
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Runtime w/o control*
Operational Status:	Operational
As found Settings:	Off

"100% Ventilation" switch likely used to turn on bathroom fan.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	--	46
Exhaust (cfm)	71	Not measured

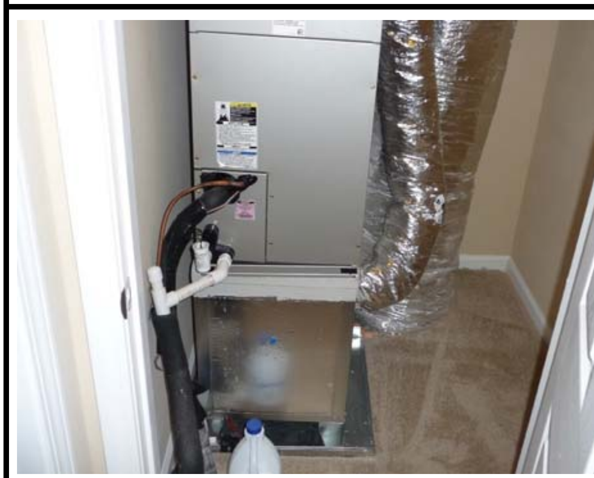
Testing notes:

1) Runtime vent design with outdoor air duct connected to return plenum; manual damper 100% closed

2) *Also "100% Ventilation" switch which, based on later house test in same area, likely controls master bath fan via 3-way switch (other switch in master bathroom), so bathroom switch can override 100% switch

- Survey Responses -

Do you feel ventilation is important for health?	Yes, for respiratory system
Does house have ventilation sys. / do you change vent settings?	Don't know / wouldn't know how to
What do you do, if anything, to maintain the ventilation system?	Absolutely nothing (clean AC filter)
Are you satisfied with ventilation system overall?	Hard to say / no-one has gotten sick
Survey notes:	When asked how learned about vent sys., said was instructed to "not turn off this switch"


Air handler with outdoor air duct to return plenum.


Outdoor air grille in second floor soffit.

House 19

Year Built:	2013
Conditioned Area:	2222
# of Bedrooms:	4
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Runtime w/o control*
Operational Status:	Operational
As found Settings:	Off

Either "100% Ventilation" switch in air handler closet (left) or master bath switch (right) can be used to turn bath fan on/off.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	--	27
Exhaust (cfm)	51	100

Testing notes:

1) Runtime vent with outdoor air duct to return plenum (manual damper 100% closed); two major kinks in 4" duct

2) *Also "100% Ventilation" switch in air handler closet is part of master bath exhaust fan 3-way switch--other switch in master bathroom can override "100%" switch; owner stated this system is for ENERGY STAR compliance

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / "hands off"
What do you do, if anything, to maintain the ventilation system?	Clean vent in master bathroom (~ 2 times per year)
Are you satisfied with ventilation system overall?	Yes

Survey notes:

3-way switchable master bath exhaust fan with light (light comes on with fan; not separately controllable).

Manual damper for runtime vent system outdoor air duct found in closed position.

House 20

Year Built:	2008
Conditioned Area:	1907
# of Bedrooms:	4
Ventilation Type	
- Expected:	Fans/ERV
- As found:	Energy recovery (ERV)
Operational Status:	Disconnected
As found Settings:	[Off]

Testing the ERV's airflow.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	50	137/177/204/207*
Exhaust (cfm)	N/A	75/101/119/119*

Testing notes:

1) Ventilation system ducts disconnected but vent system still in place and able to test as-is
2) *Four air flow values from low to high speed settings
3)

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes (but disconnected at the moment) / "hands off"
What do you do, if anything, to maintain the ventilation system?	N/A- unit currently disconnected
Are you satisfied with ventilation system overall?	Unable to answer at this time
Survey notes:	Decided to disconnect ventilation system within six months of moving in; cost concerns

Supply and exhaust air grilles on 2nd floor wall.

Close-up of supply and exhaust air grilles.

House 21

Year Built:	2010
Conditioned Area:	1688
# of Bedrooms:	3
Ventilation Type	
- Expected:	Runtime w/ control
- As found:	Runtime w/ control
Operational Status:	Operational
As found Settings:	Off

Outdoor air grille on front porch.

- Testing -

	Expected Flow Rate:	Tested Flow Rate:
Supply (cfm)	100	46
Exhaust (cfm)	--	--

Testing notes:

1) As found system was "off" but when used, dip switch allows cycle time setting (ventilation minutes per hour)
2) Also outdoor sensor control that limits outdoor air if temperature setpoints are exceeded
3) Filters clean; small wasp nest in outdoor air grille

- Survey Responses -

Do you feel ventilation is important for health?	Yes
Does house have ventilation sys. / do you change vent settings?	Yes / ran "as set" but last 2 1/2 years had it off
What do you do, if anything, to maintain the ventilation system?	Don't do anything; kill the wasps (do change AC filter
Are you satisfied with ventilation system overall?	I guess so
Survey notes:	Ran ~2 years as set; last 2 1/2 years had it off (to save money and doesn't like AC or heat)

Outdoor air duct viewed from inside return plenum.

Small wasp nest in outdoor air grille (bottom right).