Adapting to Tighter Enclosures through Scopes of Work

www.phrc.psu.edu

PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

NARI CEU Approved

ICC PREFERRED EDUCATION PROVIDER

PHRC

1

Description

One of the core aspects of any high-performance building is the ability to control air infiltration through the building enclosure. As Pennsylvania's Uniform Construction Code updates to the 2018 ICC codes, the main airtightness requirement will shift from a blower door result of 5 ACH50 down to 3 ACH50. What will it take for the residential construction industry to adapt to this change? This session will focus on the execution and installation of air sealing details around the building enclosure. Often, the keys to success involve properly designed details and material specifications, thus utilizing a well-crafted air sealing scope of work for subcontractors.

10

PHRC

10

Learning Objectives

1. Review the code provisions that are changing within Pennsylvania's Uniform Construction Code that address enclosure airtightness.
2. Discuss the challenges associated with aiming for 3 ACH50 instead of 5 ACH50 based on past experiences from other jurisdictions and case studies.
3. Analyze the role of scopes of work in subcontractor selection and management.
4. Examine ways to improve the air sealing process overall to maximize energy and cost efficiency in residential structures.

11

PHRC

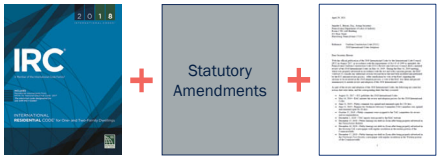
11

Code Update: What is Changing?

12

12

UCC Residential Code Summary: 2/14/22



Base code

RAC amendments

13

13

UCC Energy Code Summary: 2/14/22

Chapter 11

Residential Provisions

Coming Soon!

14

14

Why Does Air Sealing Matter?

15

15

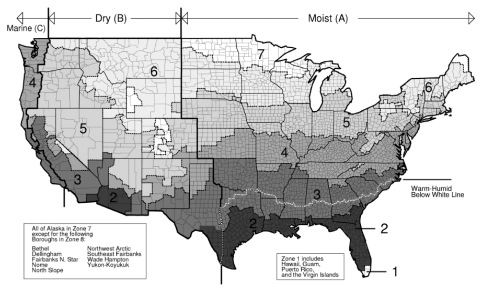
2018 IRC N1102.4.1.2 (R402.4.1.2) Testing

- The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding five air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with RESNET/ICC 380, ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). Where required by the building official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the building official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

16

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

16

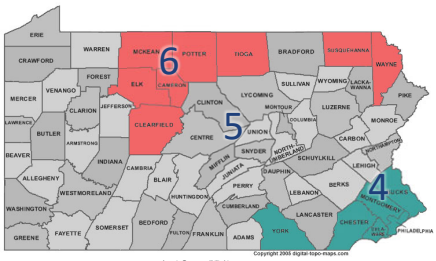


17

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

17

Climate Zones in PA



= NOT EXCEEDING

3 ACH_{50}

Copyright 2005 digital-topo-maps.com

Image Source: digital-topo-maps.com

18

PHRC

18

Blower Door Concept

- **Depressurize the home to an exaggerated pressure difference to quantify air infiltration and compare with established benchmarks**
- **ACH_{50} = Air Changes per Hour at pressure difference of 50 Pa**
  - Current limit in Pennsylvania is 5 ACH_{50} if tested
  - 50 Pa simulates roughly a 20 mph wind on all sides of the home

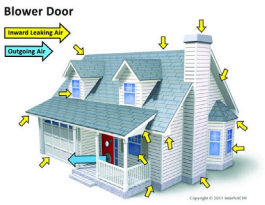


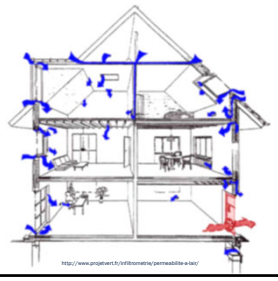
Image Source: https://www.naeci.com/blower-door-testing

19

PHRC

19

Airtightness Requirement: 3 ACH50



http://www.projetvert.fr/infiltrometrie/permeabilite-a-lair/

- Measured in Air Changes Per Hour at 50 Pascals (ACH50 / ACH_{50})
  - 50 pascals – equivalent to 20 MPH wind on the house

Value we need (Air Changes Per Hour @ 50 Pascals) | **Value from the blower door pressure gauge** (Cubic Feet Per Minute @ 50 Pascals) | **Constant** (60 minutes per hour)

$$ACH_{50} = \frac{CFM_{50} \times 60}{V} < 3$$

Volume of the House (Cubic Feet)

20

PHRC

20

How Do We Air Seal?

21

21

General Air Barrier *Methods*

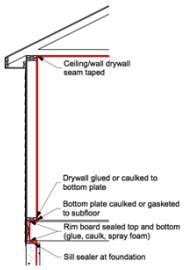
- Drywall Method
- Spray Foam Method
- Sheathing/Framing Method
- Housewrap Method

22

22

Drywall Method

- Notes:
  - Majority of homes utilize this method at ceilings (unless unvented attics installed).

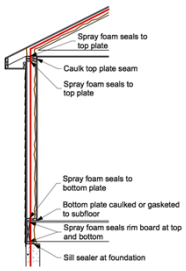


23

23

Spray Foam Method

- Notes:
  - Spray foam only effective in cavities and relies on sealed framing joints.

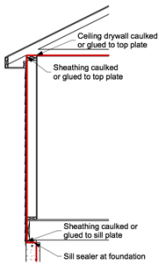


24

24

Sheathing/ Framing Method

- Notes:
  - Attention to detail!

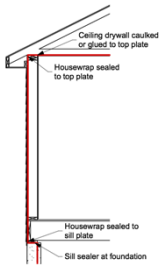


25

25

Housewrap Method

- Notes:
  - Many builders believe this is their method but are forgetting some of the key details.



26

26

What Do We Seal?

27

27

N1102.4 Air Leakage

- The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R1102.4.1 through R1102.4.5.

28

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

28

N1102.4.1 Building Thermal Envelope

- The building thermal envelope shall comply with Sections N1102.4.1.1 and N1102.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.
  - N1102.4.1.1 – Installation
  - N1102.4.1.2 – Testing

29

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

29

N1102.4.1.2 Testing

- The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding five air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with RESNET/ICC 380, ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). Where required by the building official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the building official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

30

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

30

N1102.4.1.1 Installation

- The components of the building thermal envelope as listed in Table N1102.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table N1102.4.1.1, as applicable to the method of construction. Where required by the building official, an approved third party shall inspect all components and verify compliance.

31

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

31

Table N1102.4.1.1 Air Barrier and Insulation Installation

- General requirements
- Ceiling/attic
- Walls
- Windows, skylights and doors
- Rim joists
- Floors
- Crawl space walls
- Shafts, penetrations
- Narrow cavities
- Garage separation
- Recessed lighting
- Plumbing and wiring
- Shower / tub on exterior wall
- Electrical / phone box on exterior walls
- HVAC register boots
- Concealed sprinklers

32

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

32

Walls

- **Air Barrier Criteria**
  - The junction of the foundation and sill plate shall be sealed.
  - The junction of the top plate and the top of exterior walls shall be sealed.
  - Knee walls shall be sealed.
- **Insulation Installation Criteria**
  - Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with material having an R-value of R-3 per inch min.
  - Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.

33

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

PHRC

33

34

Image Source: https://www.jlconline.com/how-to/exteriors/sealing-the-foundation-to-the-framing_o

PHRC

34

35

PHRC

35

Windows, Skylights and Doors

- **Air Barrier Criteria**
  - The space between window/door jambs and framing, and skylights and framing shall be sealed.
- **Insulation Installation Criteria**

36

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

36

37

37

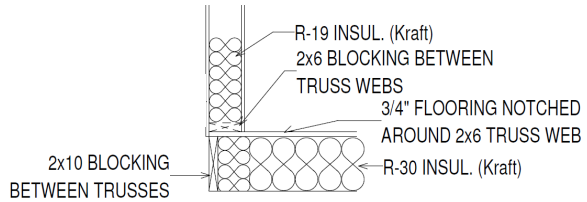
Floors

- **Air Barrier Criteria**
  - The air barrier shall be installed at any exposed edge of insulation.
- **Insulation Installation Criteria**
  - Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing or continuous insulation.

38

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

38



39

39

ENERGY STAR Rater Checklist

4. Air Sealing (Unless otherwise noted below, "sealed" indicates the use of caulk, foam, or equivalent material)				
4.1 Ducts, flues, shafts, plumbing, piping, wiring, exhaust fans, & other penetrations to unconditioned space sealed, with blocking / flashing as needed.	☐	☐	☐	-
4.2 Recessed lighting fixtures adjacent to unconditioned space ICAT labeled and gasketed. Also, if in insulated ceiling without attic above, exterior surface of fixture insulated to ≥ R-10 in CZ 4-8.	☐	☐	☐	☐
4.3 Above-grade sill plates adjacent to conditioned space sealed to foundation or sub-floor. Gasket also placed beneath above-grade sill plate if resting atop concrete / masonry & adjacent to cond. space. [27,28]	☐	☐	☐	☐
4.4 Continuous top plate or blocking is at top of walls adjoining unconditioned space, and sealed.	☐	☐	☐	☐
4.5 Drywall sealed to top plate at all unconditioned attic / wall interfaces using caulk, foam, drywall adhesive (but not other construction adhesives), or equivalent material. Either apply sealant directly between drywall and top plate or to the seam between the two from the attic above.	☐	☐	☐	☐
4.6 Rough opening around windows & exterior doors sealed. [29]	☐	☐	☐	-
4.7 Walls that separate attached garages from occupiable space sealed and, also, an air barrier installed and sealed at floor cavities aligned with these walls.	☐	☐	☐	☐
4.8 In multifamily buildings, the gap between the common wall (e.g., the drywall shaft wall) and the structural framing between units sealed at all exterior boundaries.	☐	☐	☐	☐
4.9 Doors adjacent to unconditioned space (e.g., attics, garages, basements) or ambient conditions made substantially air-tight with weatherstripping or equivalent gasket.	☐	☐	☐	☐
4.10 Attic access panels, drop-down stairs, & whole-house fans equipped with durable ≥ R-10 cover that is gasketed (i.e., not caulked). Fan covers either installed on house side or mechanically operated. [30]	☐	☐	☐	☐

Source: https://www.energystar.gov/sites/default/files/asset/document/National%20Rater%20Field%20Checklist%20ENERGY%20STAR%20Certified%20Homes_Rev10.pdf

40

40

Checklists Everywhere!

- IRC and above-code programs make it easy to develop a checklist of common areas to seal.
- However, not every home is achieving the same level of performance. Where is the disconnect?
  - How does a builder take this to the next level?

41

41

Status Check: Where Are You Now?

43

43

Don't Forget Who is Involved

- Which contractors impact overall air sealing (aside from the primary air sealing sub)?
  - Framing crew
  - MEP contractors
  - Exterior cladding/siding crew
- If a contractor is contributing to the overall airtightness of the building, do they have the materials and techniques to do this well?

44

44

NAHB Study

- Average New Home Uses 24 Different Subcontractors
  - *"The top-line results show that subcontracting remains as common as ever, with builders on average employing two dozen different subcontractors and subcontracting out 84 percent of their construction costs in the typical home they build."*

Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf

45

45

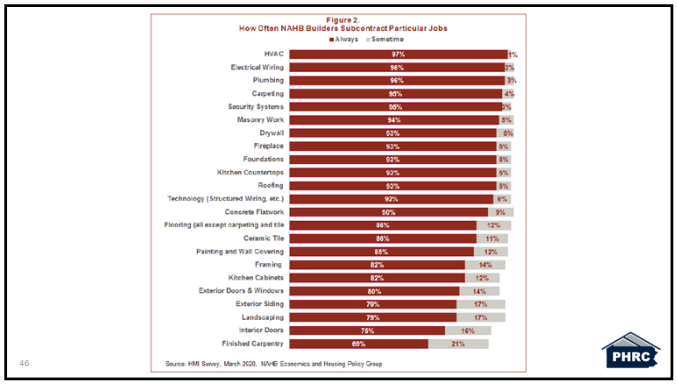
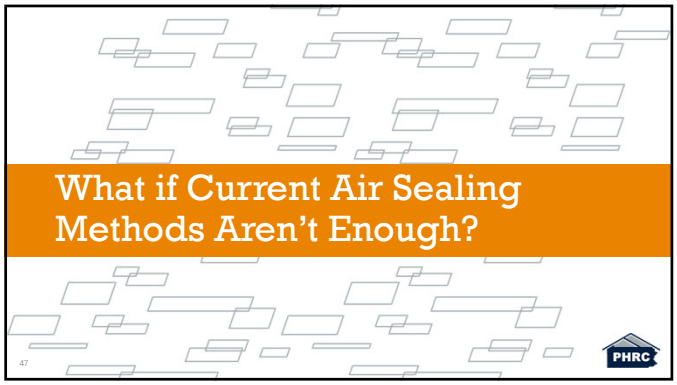
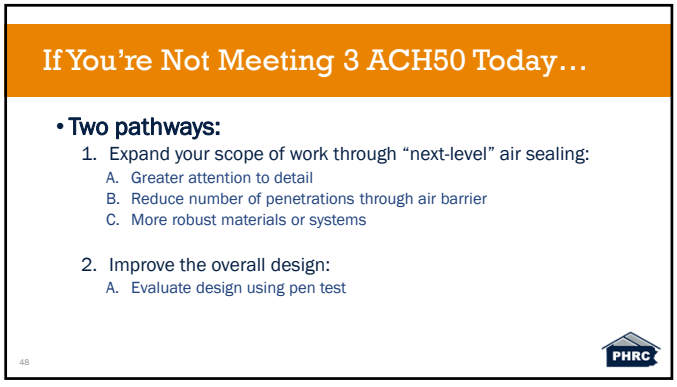


Figure 2.
How Often NAHB Builders Subcontract Particular Jobs
Always
Sometime
HVAC 97% 1%
Electrical Wiring 96% 3%
Plumbing 96% 3%
Carpeting 95% 4%
Security Systems 95% 3%
Masonry Work 94% 5%
Drywall 93% 6%
Fireplace 93% 5%
Foundations 93% 6%
Kitchen Countertops 93% 5%
Roofing 93% 6%
Technology (Structured Wiring, etc.) 92% 6%
Concrete Flatwork 90% 9%
Flooring (all except carpeting and tile 86% 12%
Ceramic Tile 86% 11%
Painting and Wall Covering 85% 13%
Framing 82% 14%
Kitchen Cabinets 82% 12%
Exterior Doors & Windows 80% 14%
Exterior Siding 79% 17%
Landscaping 79% 17%
Interior Doors 76% 16%
Finished Carpentry 69% 21%
Source: HMI Survey, March 2020. NAHB Economics and Housing Policy Group
46
PHRC

46


What if Current Air Sealing Methods Aren't Enough?
47
PHRC

47


If You're Not Meeting 3 ACH50 Today…
• Two pathways:
1. Expand your scope of work through "next-level" air sealing:
A. Greater attention to detail
B. Reduce number of penetrations through air barrier
C. More robust materials or systems
2. Improve the overall design:
A. Evaluate design using pen test
48
PHRC

48

Expand Scope of Work through "Next-Level" Air Sealing

49

49

A. Greater Attention to Detail

- In other words, keep going!
- Examples:
  - Ensure fully-aligned air barriers
  - Properly detail kneewalls and bonus rooms
  - Develop robust details at interior partitions
  - Reminder: Duct leakage outside of conditioned space = enclosure air leakage

50

50

ENERGY STAR – Fully-Aligned Air Barriers

2. Fully-Aligned Air Barriers[7] - At each insulated location below, a complete air barrier is provided that is fully aligned as follows:				
Ceilings: At interior or exterior horizontal surface of ceiling insulation in Climate Zones 1-3; at interior horizontal surface of ceiling insulation in Climate Zones 4-8. Also, at exterior vertical surface of ceiling insulation in all climate zones (e.g., using a wind baffle that extends to the full height of the insulation in every bay or a tabbed baffle in each bay with a soffit vent that prevents wind washing in adjacent bays).[8]				
2.1 Dropped ceilings / soffits below unconditioned attics, and all other ceilings.	☐	☐	☐	☐
Walls: At exterior vertical surface of wall insulation in all climate zones; also at interior vertical surface of wall insulation in Climate Zones 4-8.[9]				
2.2 Walls behind showers, tubs, staircases, and fireplaces.	☐	☐	☐	☐
2.3 Attic knee walls and skylight shaft walls. [10]	☐	☐	☐	☐
2.4 Walls adjoining porch roofs or garages.	☐	☐	☐	☐
2.5 Double-walls and all other exterior walls.	☐	☐	☐	-
Floors: At exterior vertical surface of floor insulation in all climate zones and, if over unconditioned space, also at interior horizontal surface including supports to ensure alignment. Alternatives in Footnotes 12 & 13.[11, 12, 13]				
2.6 Floors above garages, floors above unconditioned basements or crawlspaces, and cantilevered floors.	☐	☐	☐	☐
2.7 All other floors adjoining unconditioned space (e.g., rim / band joists at exterior wall or at porch roof).	☐	☐	☐	☐

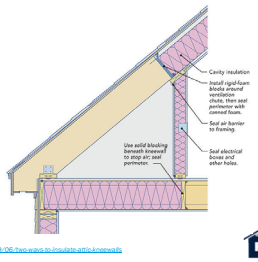
Source: https://www.energystar.gov/sites/default/files/asset/document/National%20Rater%20Field%20Checklist%20ENERGY%20STAR%20Certified%20Homes_Rev10.pdf

51

51

Kneewalls and Bonus Rooms

- Ensure full encapsulation of fibrous insulation
- "An insulated kneewall should be air-sealed as if it were an exterior wall."



Source: https://www.finehomebuilding.com/2012/09/06/two-ways-to-insulate-attic-kneewalls

52

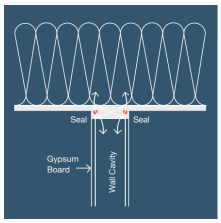
PHRC

52

52

Sealing Interior Partitions

- This is often sealed at the exterior wall
- Often missed on interior partitions
- More than tape and compound needed



Source: https://insulationinstitute.org/wp-content/uploads/2019/03/NAIMA_5-Priority-Air-Sealing-Locations-for-New-Homes.pdf

53

PHRC

53

53

54

PHRC

54

54

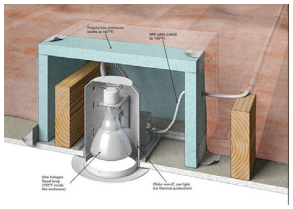
B. Reduce Number of Penetrations Through Air Barrier

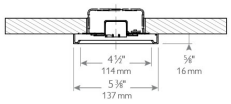
- **Examples:**
  - Replace can lights with surface-mounted fixtures
  - Install service cavities or plenum spaces

55

55

Replace Can Lights with Surface-Mounted Fixtures





Source: https://www.finehomebuilding.com/project-guides/insulation/air-sealing-can-lights-safely

Source: https://www.greenbuildingadvisor.com/article/rethinking-recessed-lighting

56

56

Install Service Cavities or Plenum Spaces

- **"A service cavity is a "wall-within-a-wall" — a secondary wall on the inside of an exterior wall.**
  - It can be framed conventionally, using vertical 2x4s or 2x3s, or it can be created by installing horizontal 2x2 or 2x3 strapping.
  - The main purpose of a service cavity (also called a "service core") is to provide room to run wiring, plumbing, and ductwork.
  - Most proponents of service cavities recommend the installation of an air barrier between the service cavity and the wall insulation."
  - Goal: *disentangling the various functions of a wall*. – Tedd Benson

Source: https://www.greenbuildingadvisor.com/article/service-cavities-for-wiring-and-plumbing

57

57

Install Service Cavities or Plenum Spaces

Source: https://fourseventive.com/blog/the-service-cavity-making-airtight-construction-easy-2/

Source: https://fourseventive.com/intello-plus/

58

58

C. Consider More Robust Materials or Systems

- **Examples:**
  - Proprietary sealants and gaskets
  - Spray foam insulation
  - Aerobarrier
  - Many others available!

59

59

Proprietary Sealants and Gaskets

Source: https://www.greatstuff.dupont.com/products/greatstuff-pro-gasket.html

Source: https://southern-energy.com/5-tips-build-efficient-homes/

60

60

Spray Foam Insulation

61

61

AeroBarrier

- AeroBarrier is an interior applied air sealing system that seals building envelope leaks up to 1/2".
- The waterborne sealant is aerosolized and injected into a pressurized home.
- The sealant is self-guided to the edges of visible and invisible leaks to create a seal by accumulating across the leak surface.

62

Source: https://aeroseal.com/aerobarrier/how-aerobarrier-works/

62

Improve the Overall Design

63

63

2. Better Design

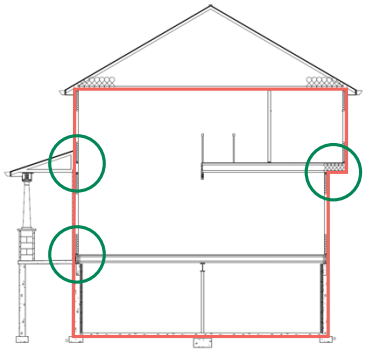
- What are some ways to improve the overall design?
  - Avoid unnecessary corners, intersections, and junctions
  - Bring ductwork into conditioned space
  - Use strategies such as the "pen test" to identify challenging details

64

64

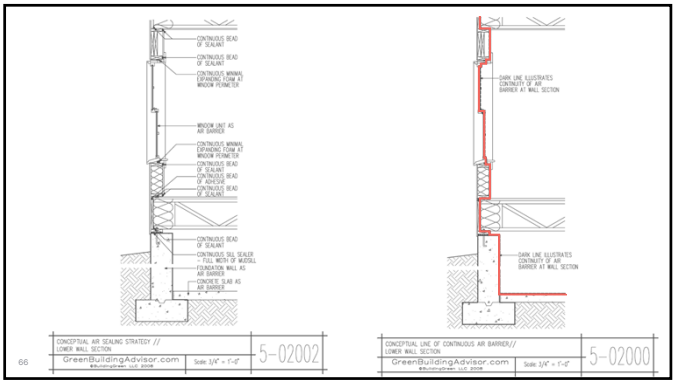
A. Pen Test

- Identify air barriers and intersections



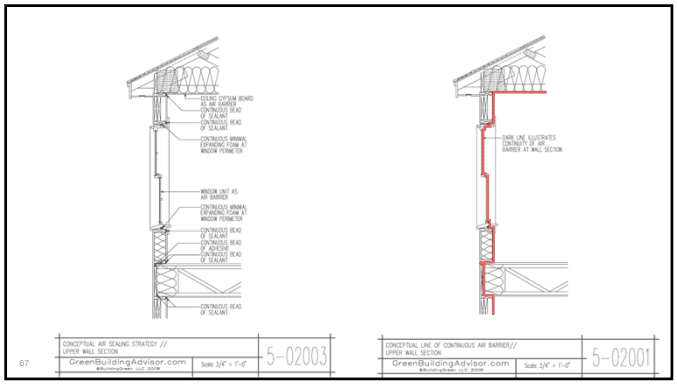
65

65



66

66



67

A Note on Whole-House Mechanical Ventilation

68

2018 Ventilation Requirements

- **R303.4 Mechanical Ventilation**
  - Where the air infiltration rate of a dwelling unit is 5 air changes per hour or less where tested with a blower door at a pressure of 0.2 inch w.c (50 Pa) in accordance with Section N1102.4.1.2, the dwelling unit shall be provided with whole-house mechanical ventilation in accordance with Section M1505.4.

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

69

M1505.4: Whole-House Mechanical Ventilation System

- **M1505.4.1System design.** The whole-house ventilation system shall consist of one or more supply or exhaust fans, or a combination of such, and associated ducts and controls. Local exhaust or supply fans are permitted to serve as such a system. Outdoor air ducts connected to the return side of an air handler shall be considered as providing supply ventilation.

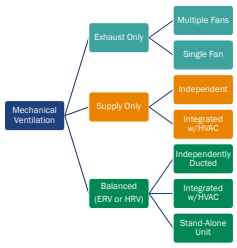
70

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

70

3 Design Solutions For Whole-House Mechanical Ventilation

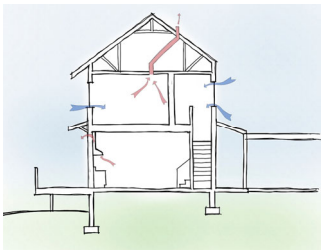
- Exhaust-only
- Supply-only
- Balanced system



71

71

Exhaust-Only Ventilation



Source: Ventilation Requirements & Code Changes, Ventilation Science & Requirements; Hamer Center

72

72

The Challenge

If unbalanced ventilation strategies rely on fresh air entering or exiting the home through gaps and cracks in the enclosure, what happens when fewer gaps and cracks are available?

or

If unbalanced ventilation is a common strategy but builders must tighten up enclosures per new codes, when does this strategy reach its limit?

73

73

Other Resources

- https://www.greenbuildingadvisor.com/article/air-sealing-an-attic
- https://www.greenbuildingadvisor.com/green-basics/air-barriers
- https://www.greenbuildingadvisor.com/article/questions-and-answers-about-air-barriers

74

74

Questions?

www.phrc.psu.edu

75

75