2009 IECC Building Envelope Tightness Verification and Duct Leakage Pressure Testing

Matthew Vande
architect, HERS

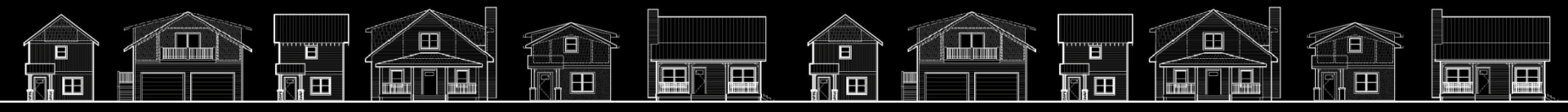
Amy Musser
Ph.D., P.E., HERS

VandeMusser Design, PLLC

VANDEMUSSER
DESIGN
PLLC

Testing - New To The Energy Code!

- Air tightness test of
  - House (blower door test)
  - Ductwork (duct blaster test)
- Not just a visual inspection by the code official anymore
  - May be done by 3rd party
  - Tests require equipment
  - House air tightness may be visually verified using checklist (test required for 2012 IECC)



Why Build Tight Houses?

Air leakage:

- Accounts for 25%-40% of the heating and cooling energy in a typical American home

VS.

Ventilation systems:

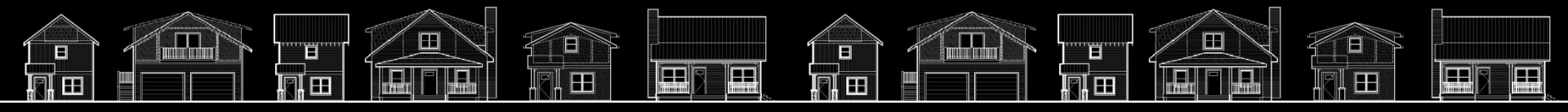
- Consume much less energy (~10% or less)
- Amount of air flow is controlled
- Location of source air can be controlled

What Is a Blower Door Test?

- A powerful fan that attaches and seals to the door (typically the entrance door to the home)
- blows air into or out of the house to pressurize or depressurize the home.
- The inside-outside pressure difference will cause air to force its way through any cracks in the building thermal envelope.
- Measuring the flow rate at the specified test pressure gives an indication of the leakiness of the envelope

Blower Door Test

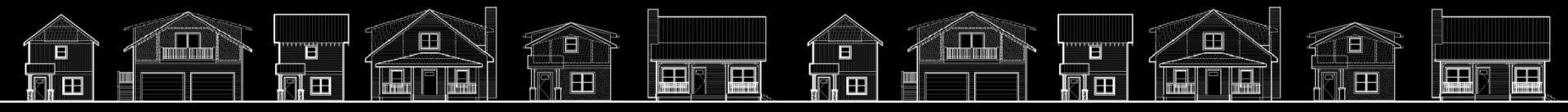
- How it works:
  - Place large fan with frame in door
  - Close/lock doors, windows, etc.
  - A few things can be taped off
    - ventilation fans, dryer vent
  - Interior doors open
  - HVAC system off, registers open
  - Depressurize home to 50 Pa pressure
  - Measure fan flow rate
    - Normalize to house volume (ACH50)
      - required method in 2012 IECC
    - Normalize to house surface area (CFM50/sf)
      - Less sensitive to home's geometry



2009 IECC - Table 1102.4.2

TABLE N1102.4.2
AIR BARRIER AND INSULATION INSPECTION

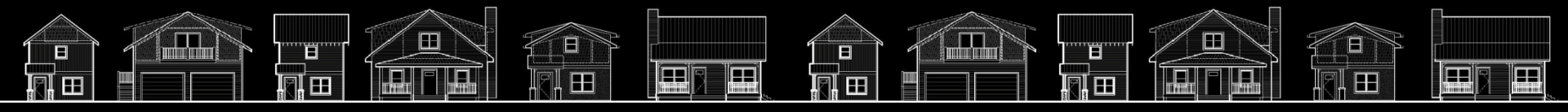
COMPONENT	CRITERIA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material.
Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed Attic access (except unvented attic), knee wall door, or drop down stair is sealed.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
Floors (including above garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of floor.
Crawlspace walls	Insulation is permanently attached to walls. Exposed earth in unvented crawlspaces is covered with Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are airtight, IC rated and sealed to drywall. Exception—fixtures in conditioned space.
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior wall	Air barrier extends behind boxes or air sealed type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units.
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
Fireplace	Fireplace walls include an air barrier.



Air Sealing / Infiltration

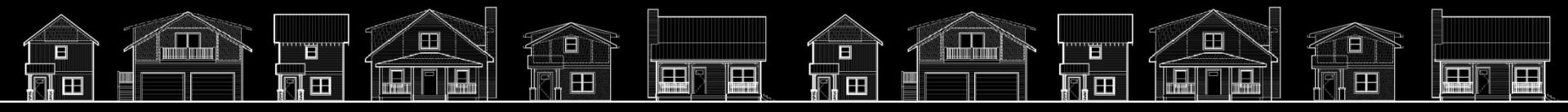
Requirements:

- 2009 IECC
  - air sealing checklist (N1102.4.2), OR
    - checklist option is unlikely to result in tighter homes
  - blower door test ≤ 7 ACH50
    - 7 ACH50 is not a very difficult target
- 2012 IECC
  - blower door test ≤ 3 ACH50
    - ***3 ACH50 is very aggressive, but possible.***
  - NE study – about 30% savings on heating
  - transitioning from a checklist option to 3 ACH50 is likely to be ***very*** difficult.



Blower Door Test Results

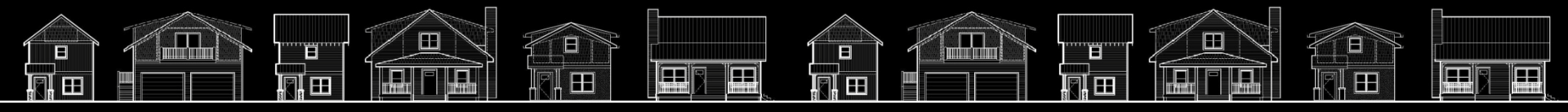
- What the results mean – ACH50
  - “air changes per hour” at 50 Pa depressurization
  - Based on volume of house
  - Can be more difficult goal for homes with a lot of surface area
- What the results mean – CFM50 / sf
  - “Cubic feet per minute” at 50 Pa depressurization
  - Based on surface area of house



Air Sealing / Infiltration Challenges

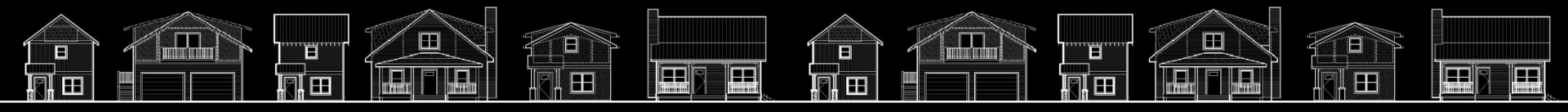
Checklist approach:

- Descriptions are pretty vague
  - Unlikely to get desired result without a lot of education and inspection.
- The code states that the items on this list should, “where required by the code official”, be “field verified” by “an approved party independent from the installer of the insulation.”
  - Does this allow a builder to self-certify?
  - Will the person signing truly understand what they’re verifying?
- Conclusion in the Nebraska study – unlikely to see substantial improvement in airtightness using checklists



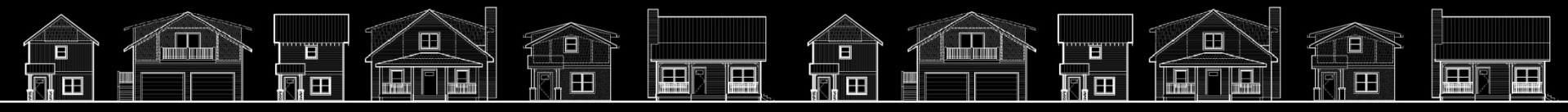
Air Sealing / Infiltration Challenges

- Who can perform the test?
  - HERS raters (or BPI Analyst)
    - Widely available in metro areas
    - Already have equipment and training
    - Cost of a 3rd party blower door test estimated at $75-100
    - Travel to remote areas could be cost prohibitive
  - Builders
    - Only larger builders are likely to buy equipment
    - 2012 IECC refers to “an approved third party”
  - Code official
    - Unlikely, although this may be a good answer in very rural areas
    - Air sealing Inspections could be difficult to coordinate



Air Sealing / Infiltration Challenges

- Equipment is required
  - Approximately $2500 new
  - Availability problem in rural areas
  - Annual equipment calibration required (can self-calibrate)
    - Who is checking this, other than HERS providers?
- Some training (~1 day) is needed
  - This would be bare bones training… essentially how to run the equipment.
  - Ability to diagnose problems takes experience



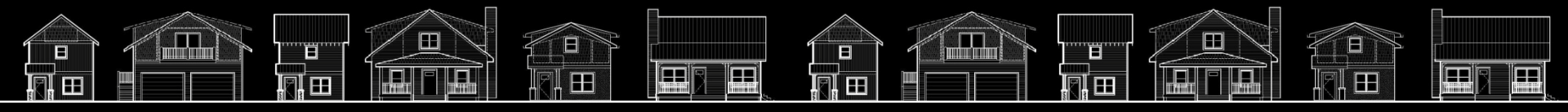
Airtightness Testing Challenges

Challenges

- Test performed at final when certain “fixes” are difficult and a CO is needed quickly.
- Air sealing checklist is not likely to get someone who has never tested before down to 3 ACH50
- A target of 3 ACH50 is very aggressive for home designs with a lot of surface area.
- Going from no test to 3 ACH50 without a phase-in period is likely to be very unpleasant… for everyone.

Possible solutions

- Allow a temporary CO to be issued until a passing blower door test occurs.
- Provide enhanced air-sealing guidelines for builders and designers
- Amend the code to allow an alternative CFM50/surface area alternative.
- Adopt a phase in period during which all homes are tested, but the 3 ACH50 goal is reached gradually.



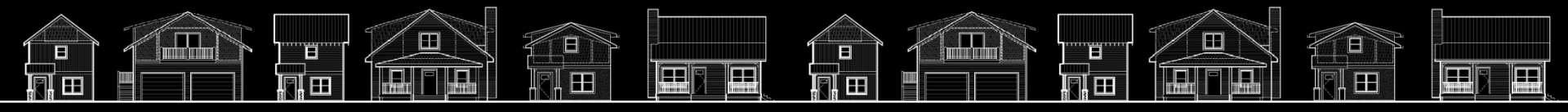
Airtightness Testing Challenges

Challenges

- Not always easy to see where leaks are

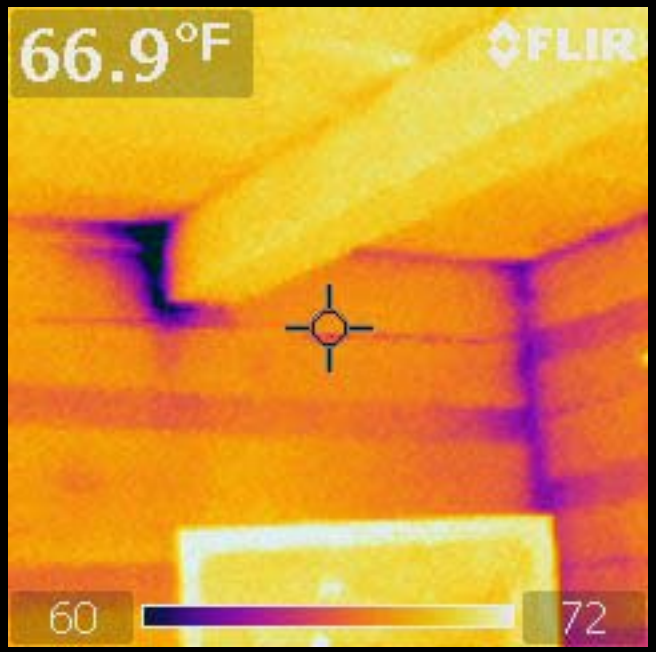
Possible solutions

- Smoke pencils are minimally helpful
- Can feel leakage with hand
- Look for cobwebs
  - Spiders like moving air
- Look for discolored / dark insulation
  - It's acting as an air filter!
- Pay special attention to areas related to air quality – garages, crawlspaces, etc.
- IR camera is very helpful



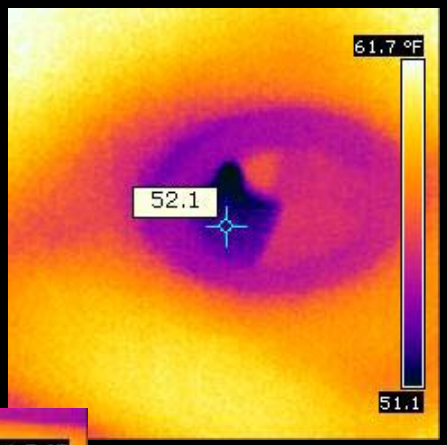
Infrared (IR) Camera

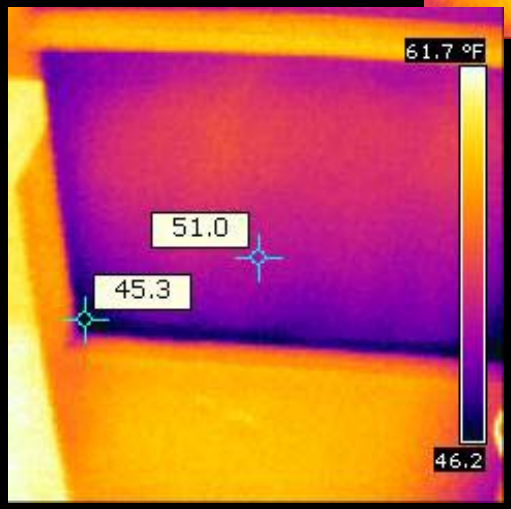
- Use with a blower door
  - Can increase appearance of infiltration heat loss (gain)
  - Can assist in finding air leaks
    - They show up “feathery” in the image
  - Camera cost: $2,000+
  - Need to have cooperative weather and a functioning HVAC system to use.
  - Tests done for code usually happen prior to HVAC startup.



Air Sealing

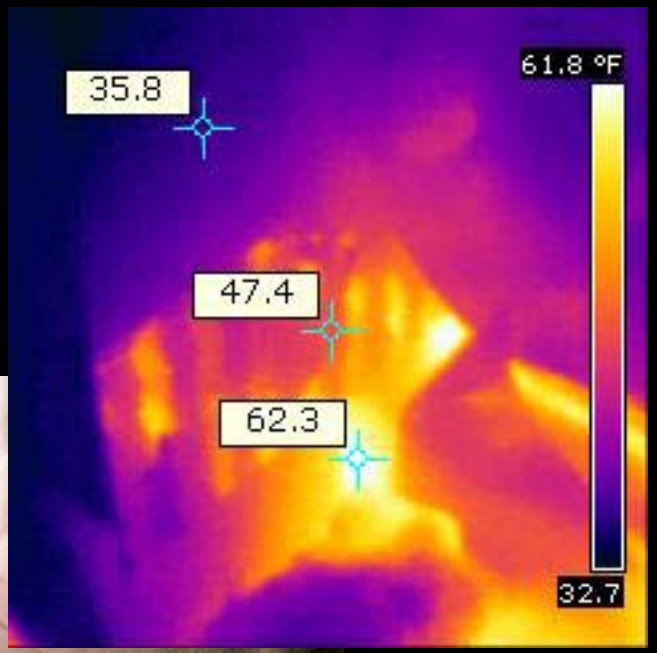
- Small areas that add up:
  - Around duct boots
  - Around hatches
  - Can lights
  - Outlets
  - Baseboard
  - Doors/windows





Air Sealing – What NOT To Use

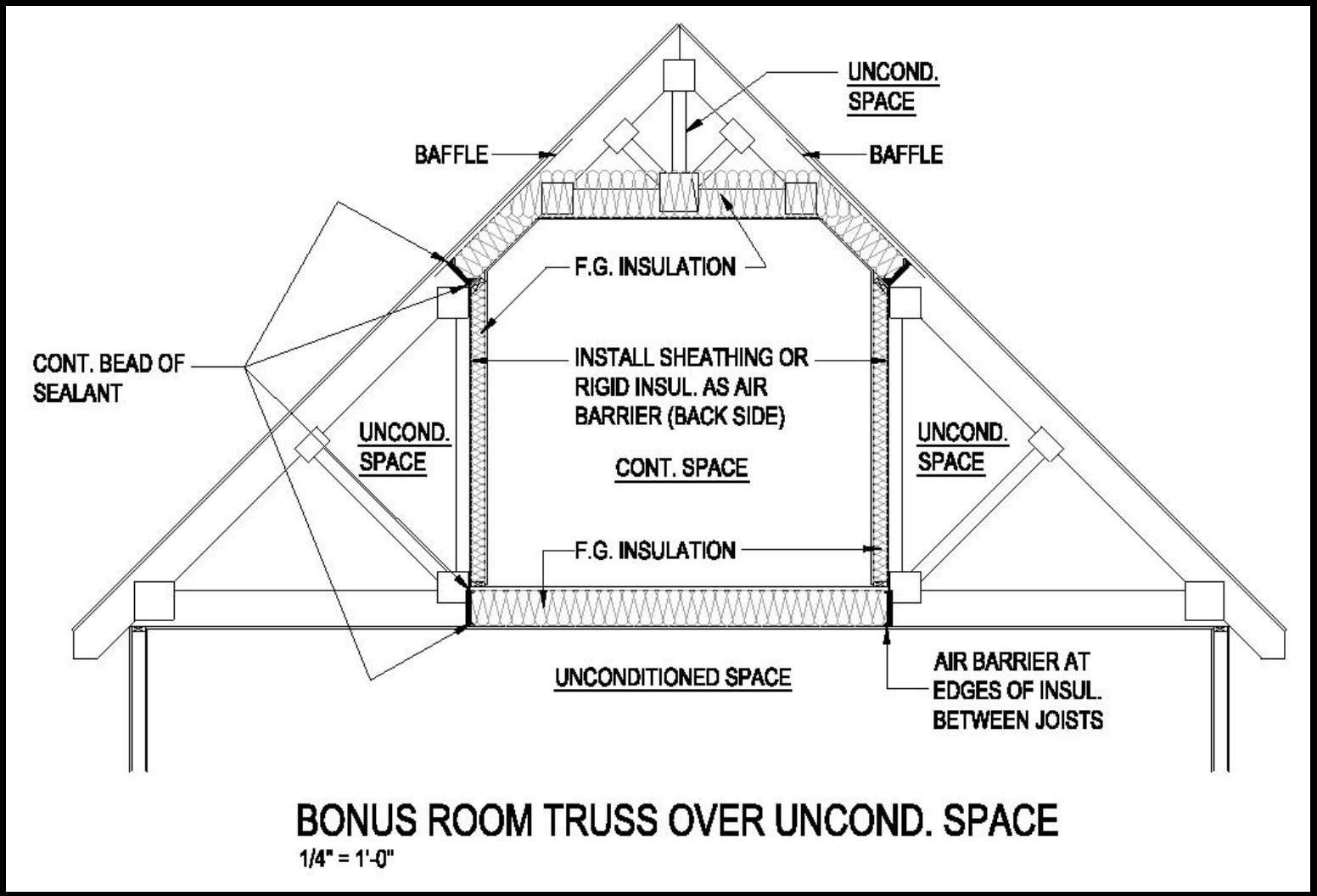
Fiberglass stuffed in a hole = ineffective!



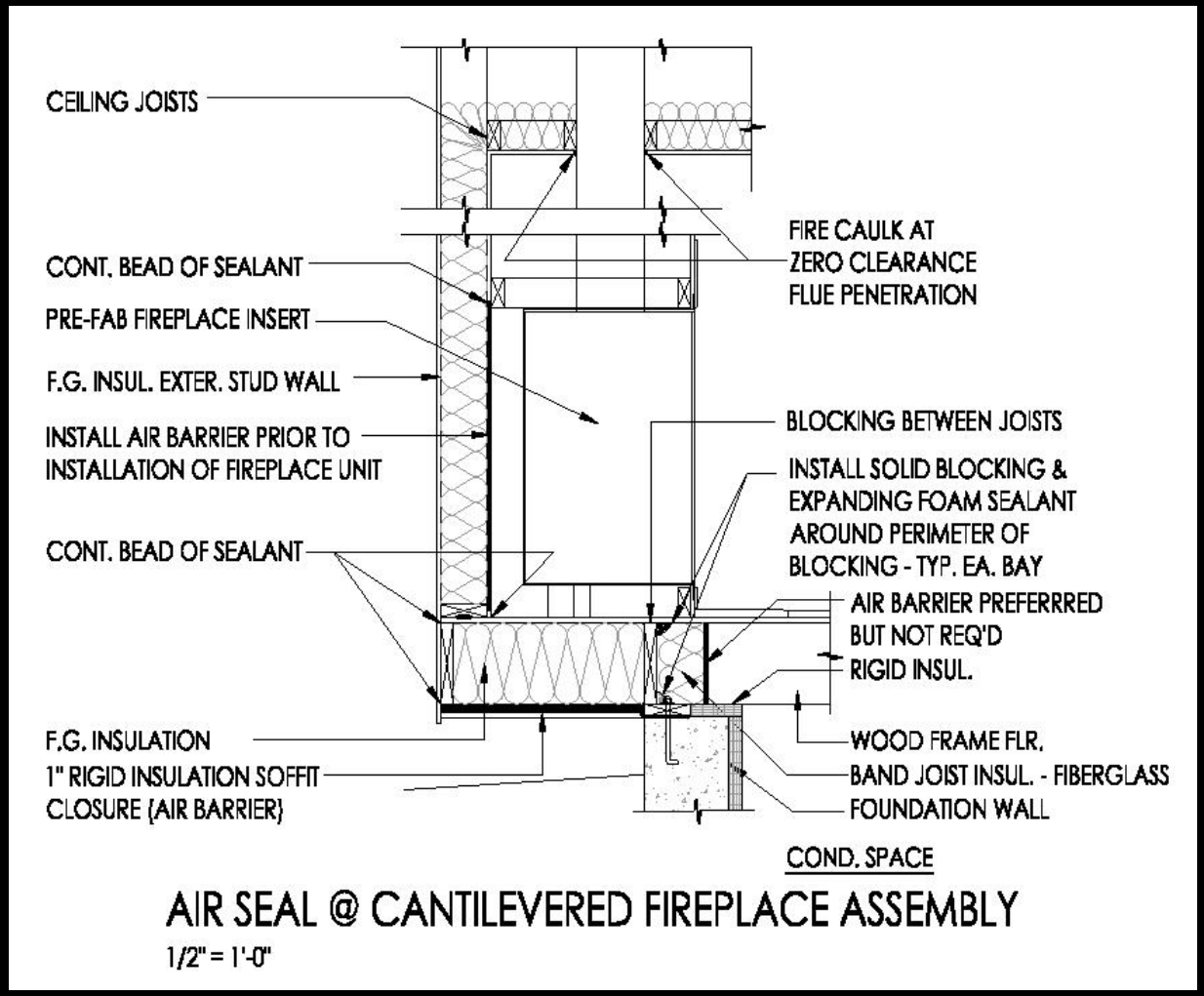
- Use solid materials to block large areas
- Seal cracks and small holes with spray foam
- Do not use stuffed fiberglass!

Seal Holes To Exterior

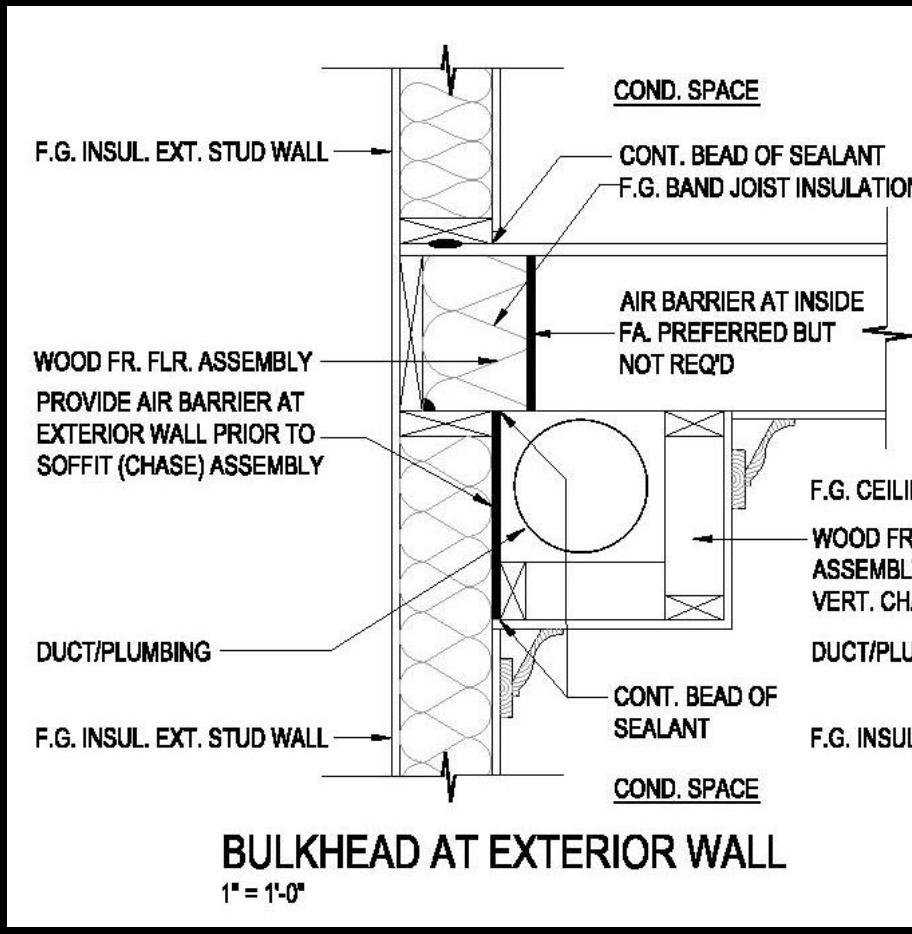
Resources – Detail Examples



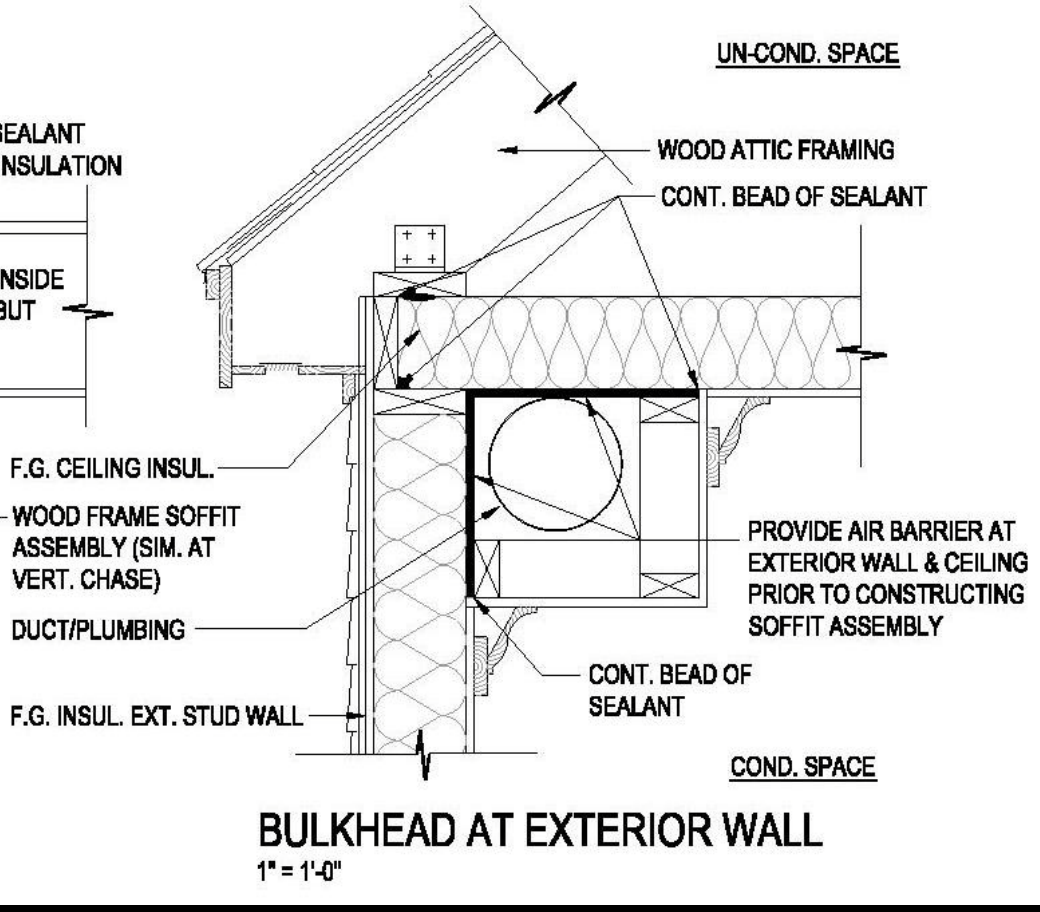
Resources – Detail Examples



Resources – Detail Examples

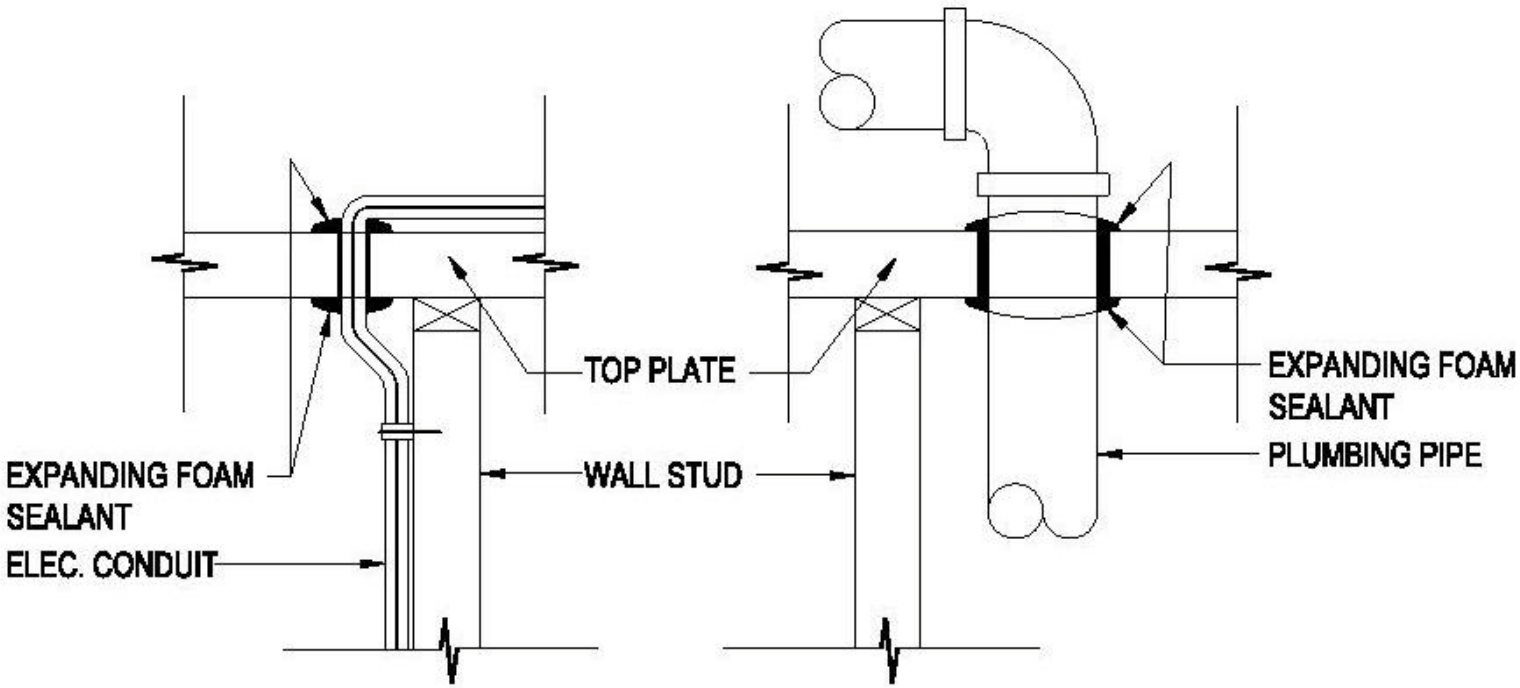


BULKHEAD AT EXTERIOR WALL
1" = 1'-0"



BULKHEAD AT EXTERIOR WALL
1" = 1'-0"

Resources – Detail Examples



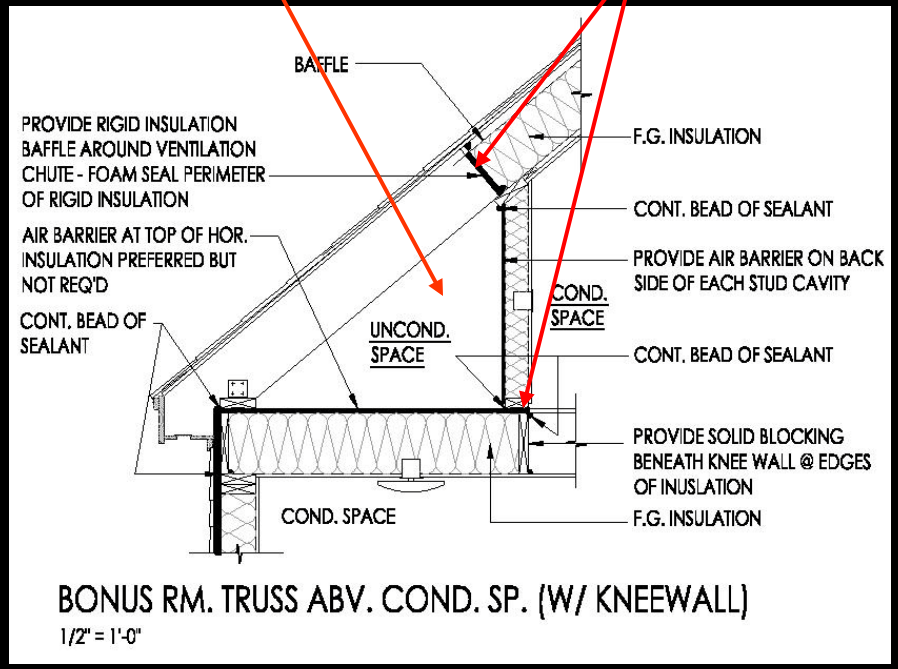
AIR SEAL @ ELEC. & PIPE PENETRATIONS

1" = 1'-0"

Case Study Example

this space not very accessible

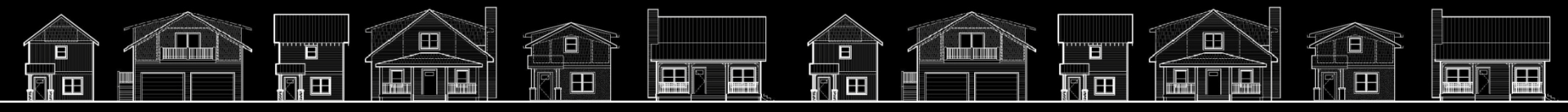
solid blocking installed, but not air sealed well between TJIs.



- New home built in 2008
- Target: 3.5 ACH50
- Tested at: 4.5 ACH50
- Key problems
  - kneewall detail not airtight
  - studor vent in wall that connected to exterior
- Solution – barely passed
  - left blower door with builder all day
  - caulked everything accessible from interior of home

Advanced Tricks For Tight Houses

- Floors
  - Caulk bottom plates to subfloor
  - Spray foam on cantilevers
  - Extra attention to plumbing holes
- Ceilings
  - Glue/caulk interior wall top plates to drywall
  - Caulk every thing with a metal housing to drywall prior to installation of trim kit
  - OR spray foam at roof deck
- Walls
  - Offset sheathing between floors, caulk gaps
  - Casement windows
- “Final” details (from least to most desperate...)
  - Pour water in traps
  - Caulk baseboard trim to floor
  - Install fireplace balloon
    - Gas fireplaces are the worst
  - Install baby-proofing electrical outlet covers (interior and exterior walls)

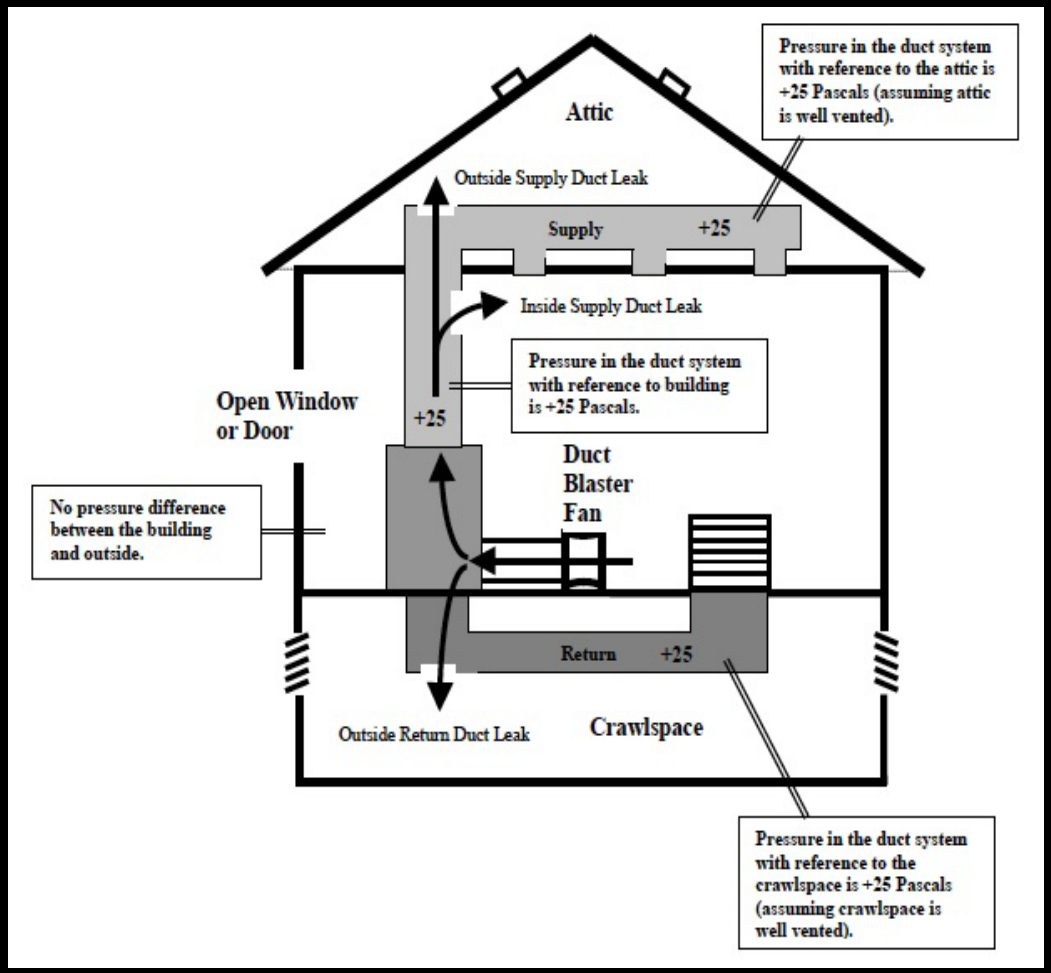


What Is a Duct Blaster Test?

- A diagnostic tool designed to measure the air-tightness of forced air heating, ventilating and air-conditioning (HVAC) ductwork.
- A duct blaster consists of a calibrated fan for measuring an air flow rate and a pressure sensing device to measure the pressure created by the fan flow.
- The combination of pressure and fan flow measurements are used to determine the ductwork airtightness.

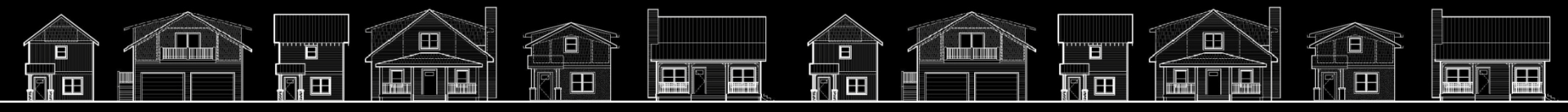
Duct Blaster Test

- How it works
  - Tape off duct supply and return registers and outside air intake
  - Attach fan to a centralized return (or at air handler)
  - Pressurize ducts to 25 Pa
  - Measure fan flow rate
    - Normalize to conditioned area (CFM25/100 sf) – “percent duct leakage”



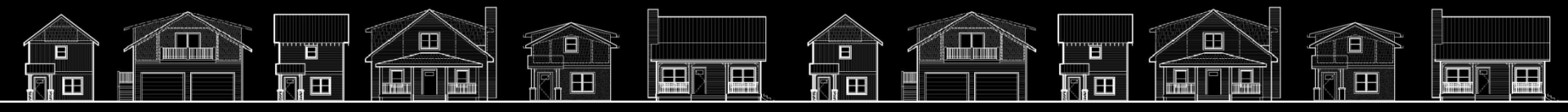
Duct Blaster Test

- Two versions of this test:
  - “Total duct leakage”
    - Can be performed at rough-in or final
    - House is kept at ambient pressure
    - Does not differentiate between leakage inside and outside of conditioned space
  - “Duct leakage to outside”
    - Perform test with blower door and house also pressurized to 25 Pa
    - Measures only leakage outside conditioned space



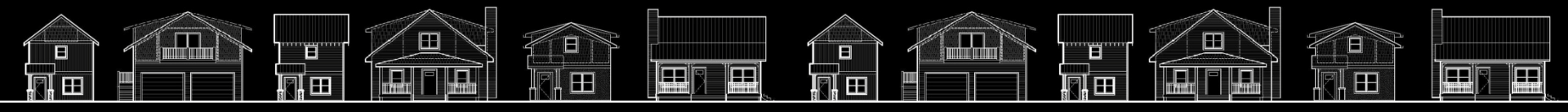
Duct Blaster Test

- When to perform test?
  - At final (“total leakage” and/or “leakage to outside”)
    - most accurate, but hardest to troubleshoot
    - best choice for ducts located in an area that will be accessible at final (unfinished basement, unconditioned attic, etc.)
  - At rough-in with air handler (“total leakage” only)
    - easier access to troubleshoot, but should always come back and visually verify that boots are sealed to subfloor/drywall.
    - desirable if ducts will be inaccessible later
  - At rough-in without air handler (“total leakage” only)
    - least reliable as a quality indicator, visual verification of sealed boots and air handler needed.
    - avoid if quality duct installation is your goal

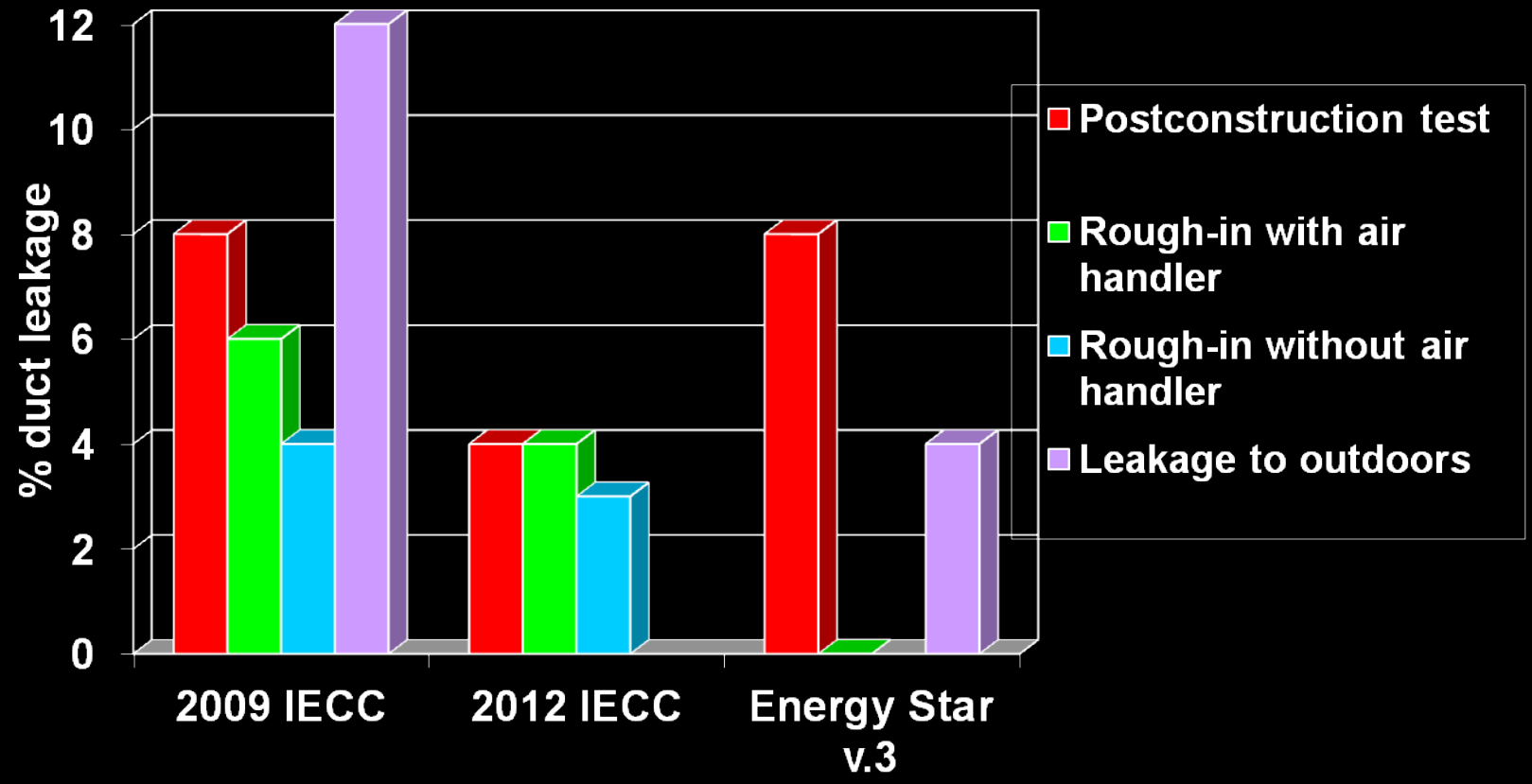


Duct Blaster Test

- Ducts or air handler outside conditioned space:
  - 2009 IECC:
    - Post-construction
      - 8% leakage to outdoors OR
      - 12% total duct leakage
    - At rough-in
      - 6% total duct leakage with air handler OR
      - 4% total duct leakage without air handler
  - 2012 IECC:
    - a) 4% total duct leakage at completion
    - b) 4% total duct leakage at rough-in with air handler
    - c) 3% total duct leakage at rough-in without air handler
- This is not difficult to achieve if you address the major sources of leakage

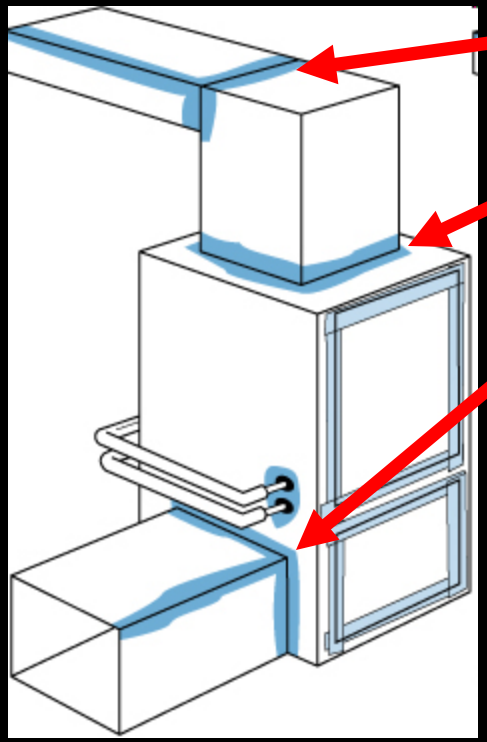


Duct Blaster Test

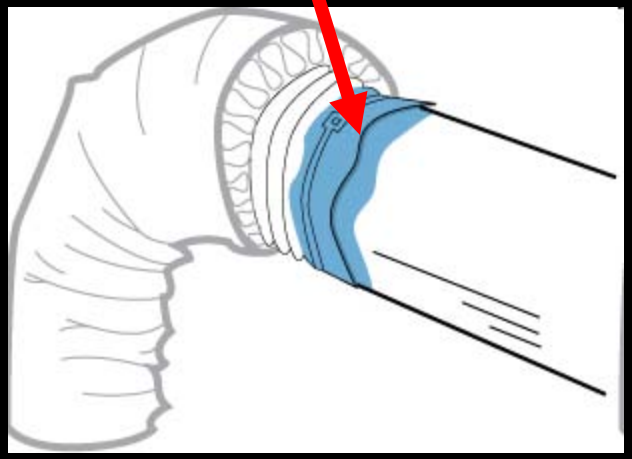


Duct Sealing – Areas To Seal

MASTIC!!!



Air handler

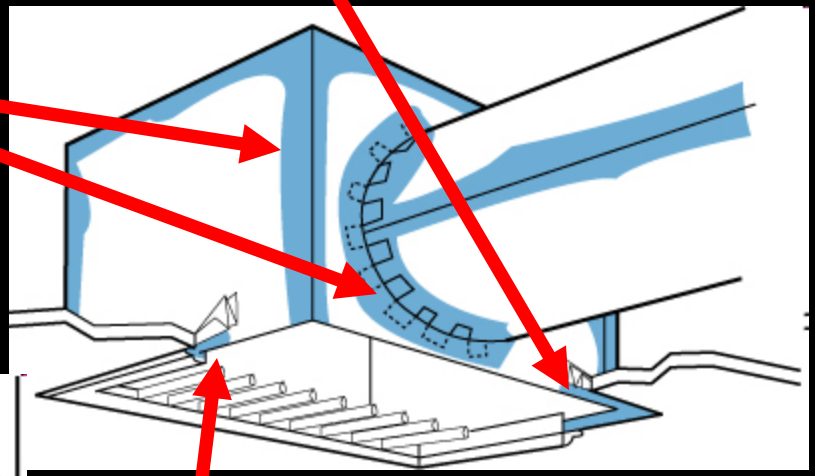


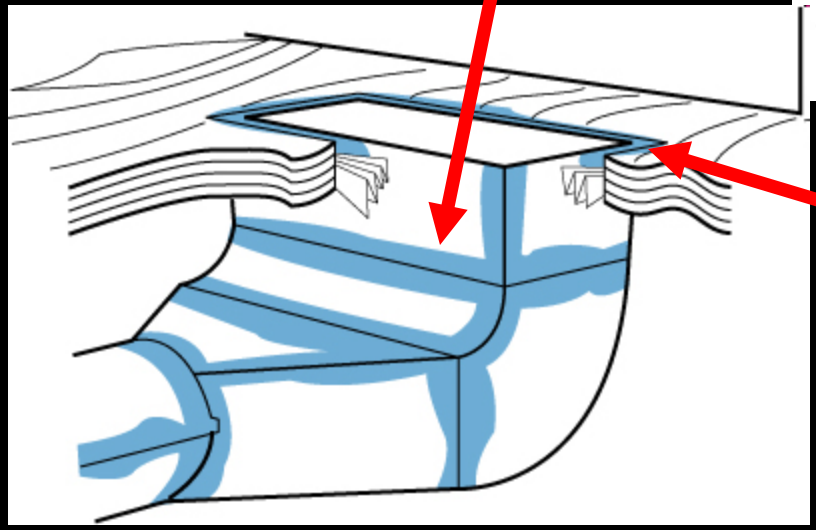
Flex connections

Duct Sealing – Areas To Seal

CAULK

MASTIC!!!





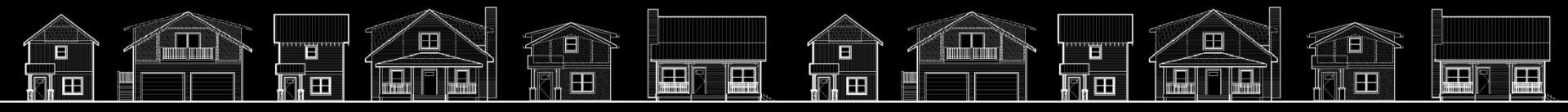
Area where duct boot penetrates floor / ceiling

Duct Blaster Testing Challenges

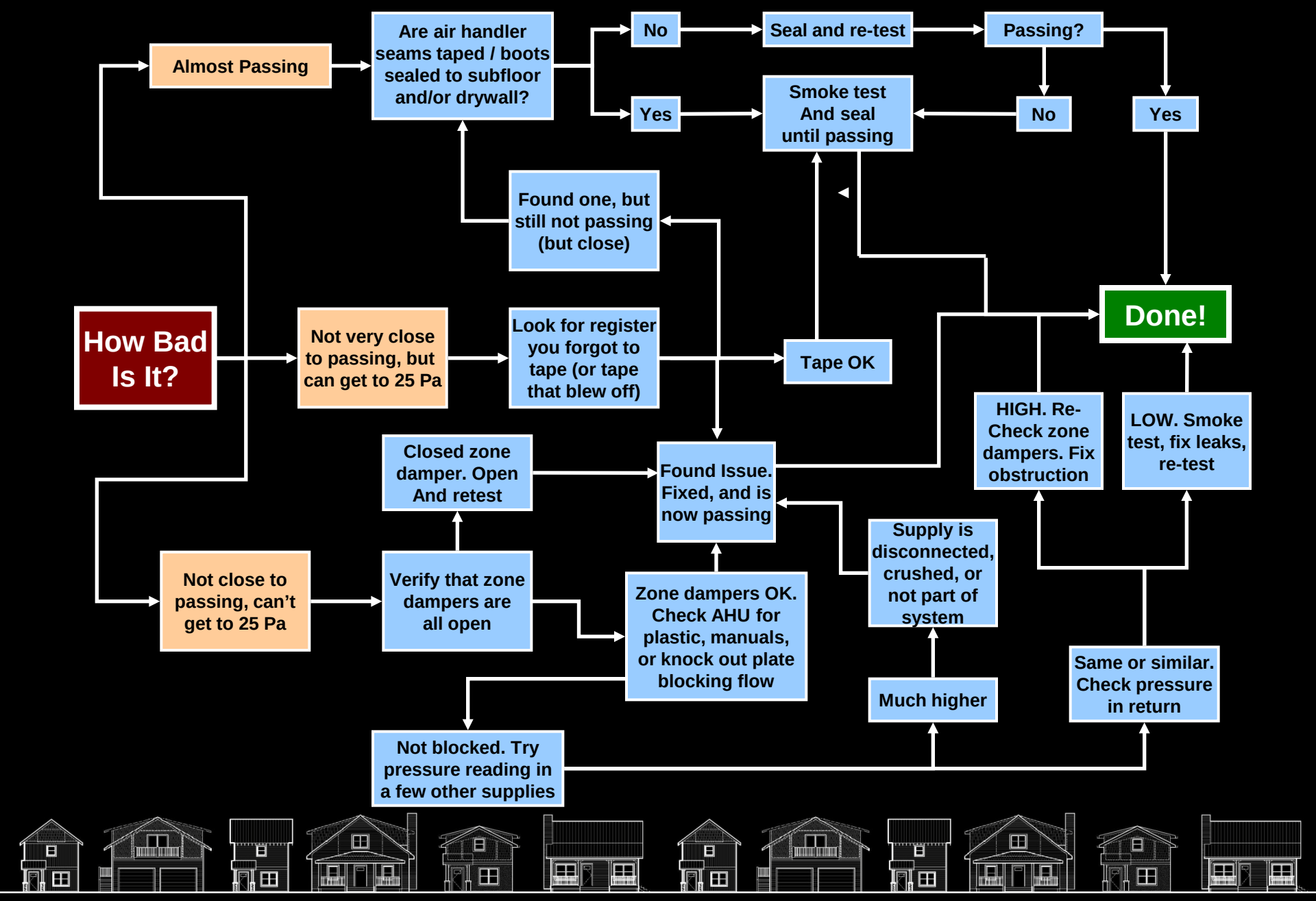
- Troubleshooting
  - Relatively easy to do with theatrical smoke
    - $50-$100 machine at party stores
- Some areas still hard to detect
  - Leaky ducts in wall / floor cavities
    - 2009 IECC: use of building cavity for supply air not permitted, but allowed for return air.
    - 2012 IECC: use of building cavity for supply/return no longer permitted.
  - Leaks under insulation (smoke is filtered out)
  - Sometimes have to fix big leaks before you see small ones
  - Cabinet kick plates are a huge problem
    - impossible to tape off unless ducted to face of kick plate
    - usually not done well
  - Caulking / sealing duct boot to subfloor / drywall / paneling is essential to passing.

Duct Blaster Testing Challenges

- Who performs the test? 2009 and 2012 IECC leave it to the code official to decide…
  - HVAC Installer
    - May be able to find and correct leaks more quickly / cheaply
  - HERS rater
    - HERS raters are widely available in metro areas
    - already have equipment and training
    - Independent, third-party – no conflicts of interest
  - Code official / building inspector
    - May be the only viable option in rural areas
- Equipment is required (~$1,800)
  - availability poses a problem for rural areas
  - the “leakage to outdoors” test also requires a blower door setup.
  - annual equipment calibration required (can self-calibrate)
- Some training (~1 day) is needed
  - This teaches you how to use the equipment… diagnosing takes experience



Duct Blaster Troubleshooting Flow Chart



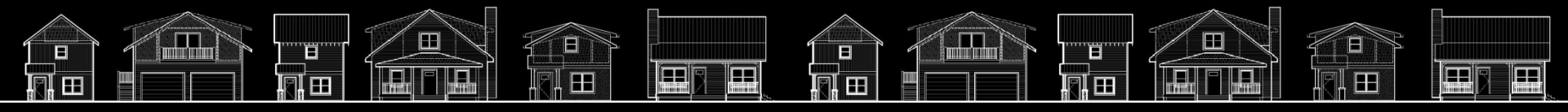
Case Studies: Avoid Disappointment

900 SF condominiums

- Tested 2 units at rough-in with air handler
  - 30 CFM25
  - 3.3% total leakage
- Tests at final
  - 300 CFM25
  - 33% total leakage
  - boots not sealed to drywall, ½" gap seen
- Retest
  - boots sealed to drywall
  - 40 CFM25 (4.4% total leakage)
  - installer initially skeptical, but convinced at end.

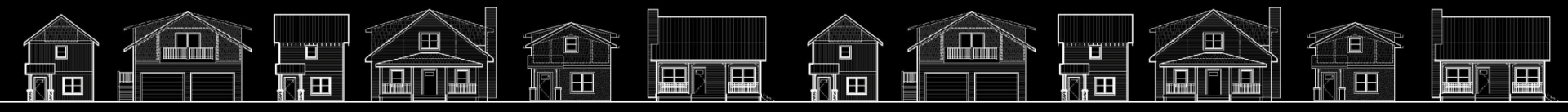
6,000 SF high-end home

- 90% of ductwork between floors and behind drywall
- 6 cabinet kickplates
- air handler not installed pre-drywall
- Pre-drywall duct-only test
  - 50 CFM25 (<1% total leakage)
- Test at final
  - 480 CFM25 (8% total leakage)
  - Kick plates not connected, difficult to reach and seal
  - air handler / trunk connection leaky & difficult to reach
  - boots not caulked to flooring / drywall
- Retest – barely achieved 6% total



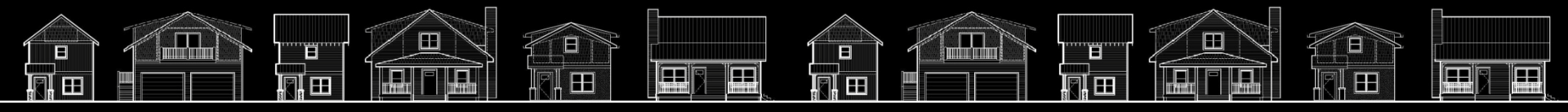
Case Studies: Avoid Long And Frustrating Testing Sessions

- 4,000 SF home
  - 10ºF outside, tape not sticking well.
  - Rough-in test: could not get ducts to 25 Pa
  - Measured 2 Pa in supplies, 250 Pa in return plenum
  - Found manuals in plastic sleeve blocking inside of air handler
  - Had to re-tape blown-off tape on returns
  - System then passed
- 4,000 SF home (3 zones)
  - Rough-in test: measured 5 Pa in main floor supplies, 250 Pa in return plenum
  - HVAC installer said zone dampers defaulted open
  - Looked for AHU obstruction, found none
  - Checked supplies on another floor: 250 Pa
  - Manually turned zone damper on original floor to open it
  - System then passed



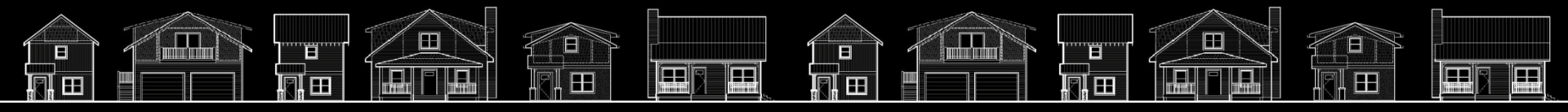
Case Studies: Avoid Wildlife

- 2,000 SF house
  - tested at 4% total at rough-in
  - tested at 10% total at final
  - boots checked and sealed to drywall
  - ducts located between floors
  - smoke test
    - smoke coming out of can lights on lower level
    - removed ceiling tiles in dropped lay-in ceiling of lower level
    - smoke coming out of flex duct at multiple points.
    - Installer of ceiling had punctured flex duct with metal channels.
- 3,000 SF home
  - ducts installed prior to all windows/doors
  - something chewed hole in ductwork, test requested to make sure all holes had been re-sealed.
  - taped ducts and started fog machine
  - large raccoon breaks through tape at return
  - chaos ensues



In Summary

- The implementation of the IECC requirements is a good thing.
- There will initially be a steep learning curve for everyone
  - Builders
  - HVAC installers
  - Code officials
- In the end, this will simply become standard practice and not difficult to do.
- The logistics will need to be worked out for rural areas, but it’s all feasible to incorporate.
- Don’t wait until the end of the job to do it right – it’s way more expensive!



Questions?