WELCOME!

2017 HPC NATIONAL HOME PERFORMANCE

Conference and Trade Show

Air Sealing – What Works and What Doesn't

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Appalachian State University

March 19–22, 2017 • Omni Nashville Hotel • Nashville, TN

Home Performance Coalition

Hosted by Tennessee Valley Authority (TVA)

In partnership with U.S. DEPARTMENT OF ENERGY

Reasons for the Research

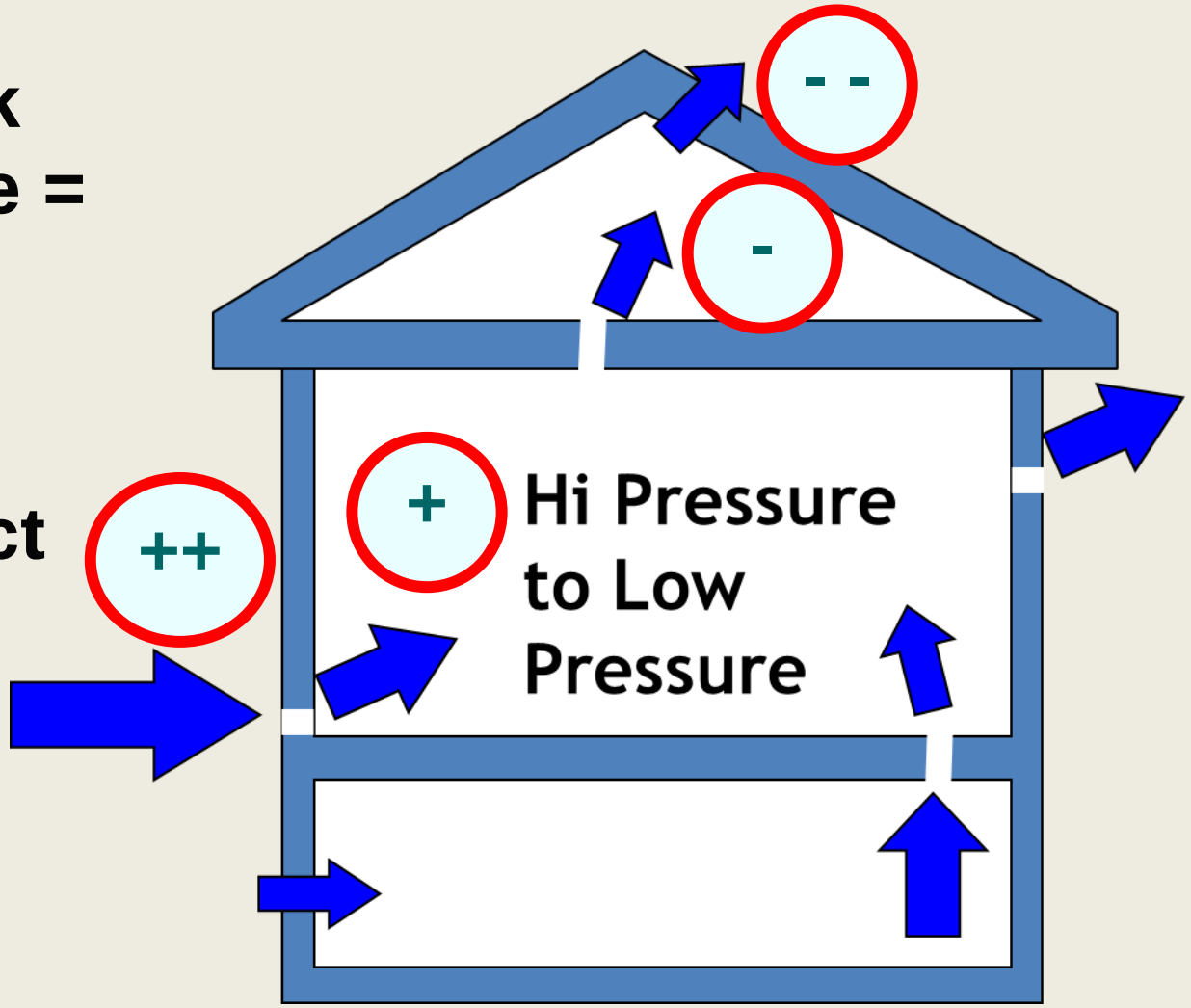
- Some builders doubt the impact of certain air sealing measures
- Serving on the North Carolina Energy Code Development Committee
  - Committee members need direct evidence of effectiveness
  - Committee members don't trust results from "outsiders"
  - We had concerns about some of the practices we had observed – fiberglass insulation as an air sealant/ sill sealer on top plates/ untaped housewrap
- Graduate students were bored

Outline for the Presentation

- Brief intro – Boone/ App State
- Testing results for specific air leaks
- Results of DOE Survey in NC
- Results of DOE Survey in 8 States
- Priorities for Air Sealing
- New Products

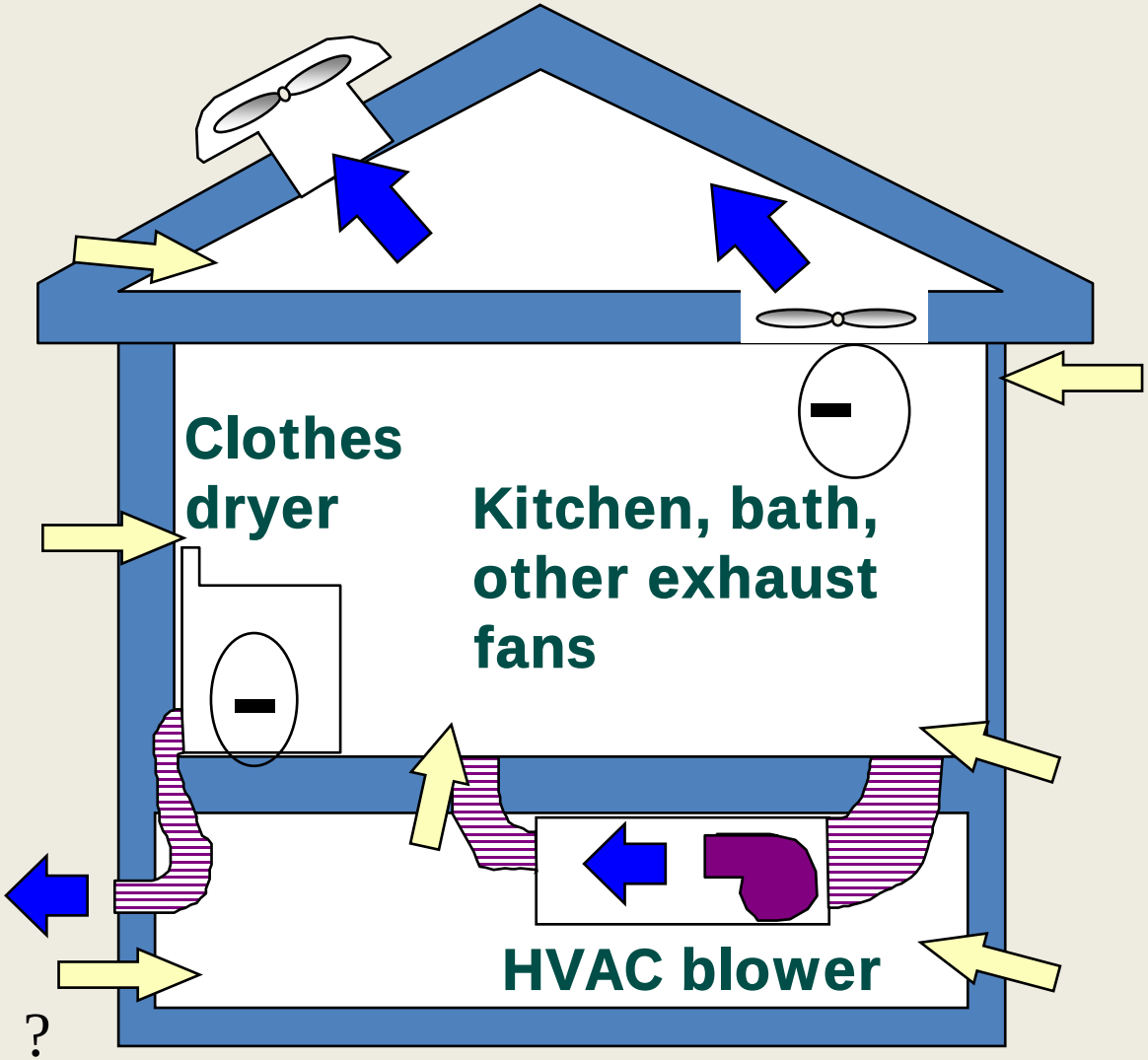
Needs for Air Leakage to Occur

1. **Hole or crack**
2. **Driving Force = Pressure Difference**
    1. **Wind**
    2. **Stack Effect**
    3. **Fans and Blowers**
3. **What goes in must come out**

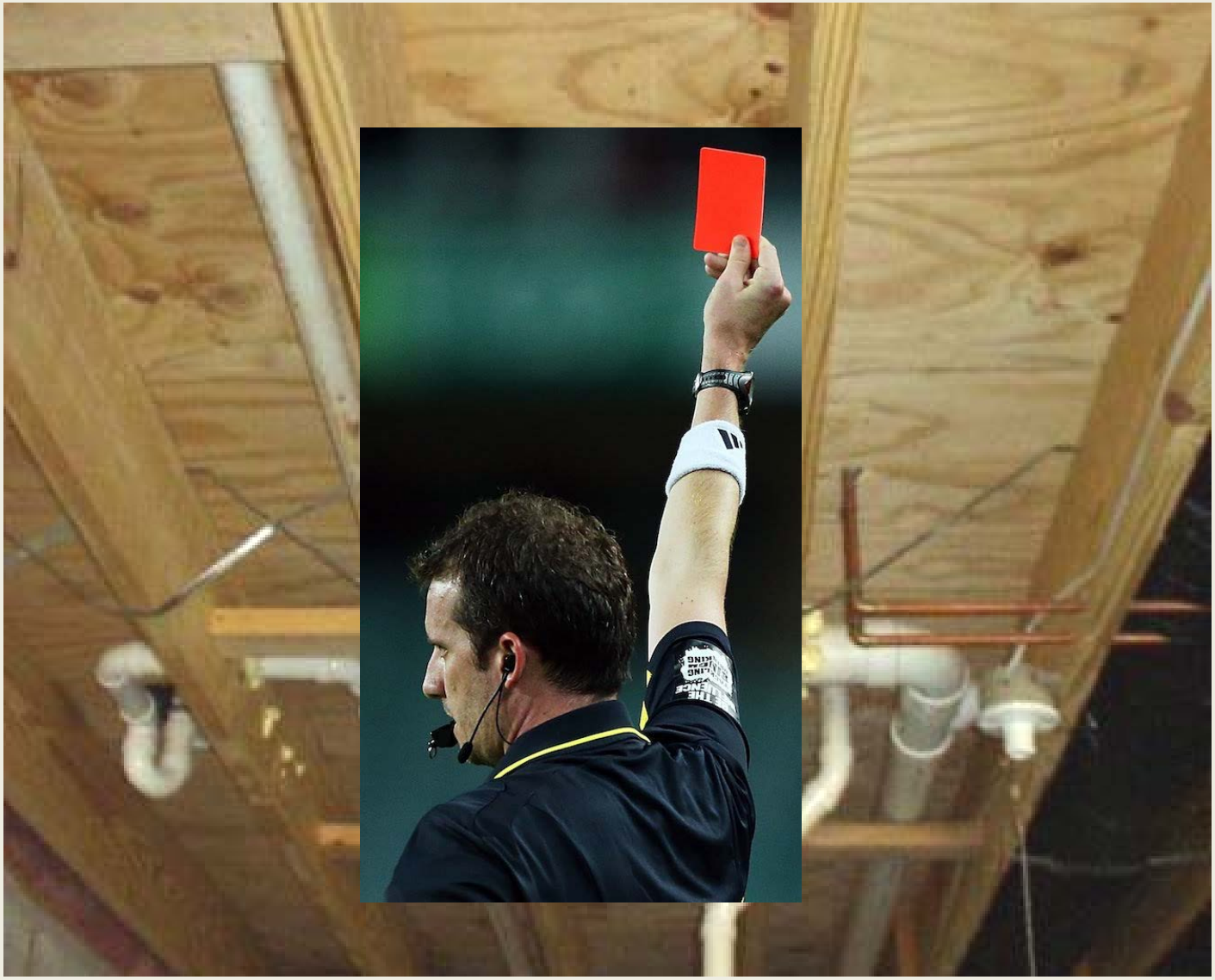


Mechanical Pressures

- Bath:
  - 50 -100 cfm
- Dryer
  - 200 cfm
- Central Vacuum
  - 150 cfm
- Air Handler
  - 400 cfm/ton
- Kitchen:
  - 100 cfm up to _____?



Air Leakage Controls?



How Much Air Leaks Through a Hole?

Cubic feet/ minute of air leakage is a function of:

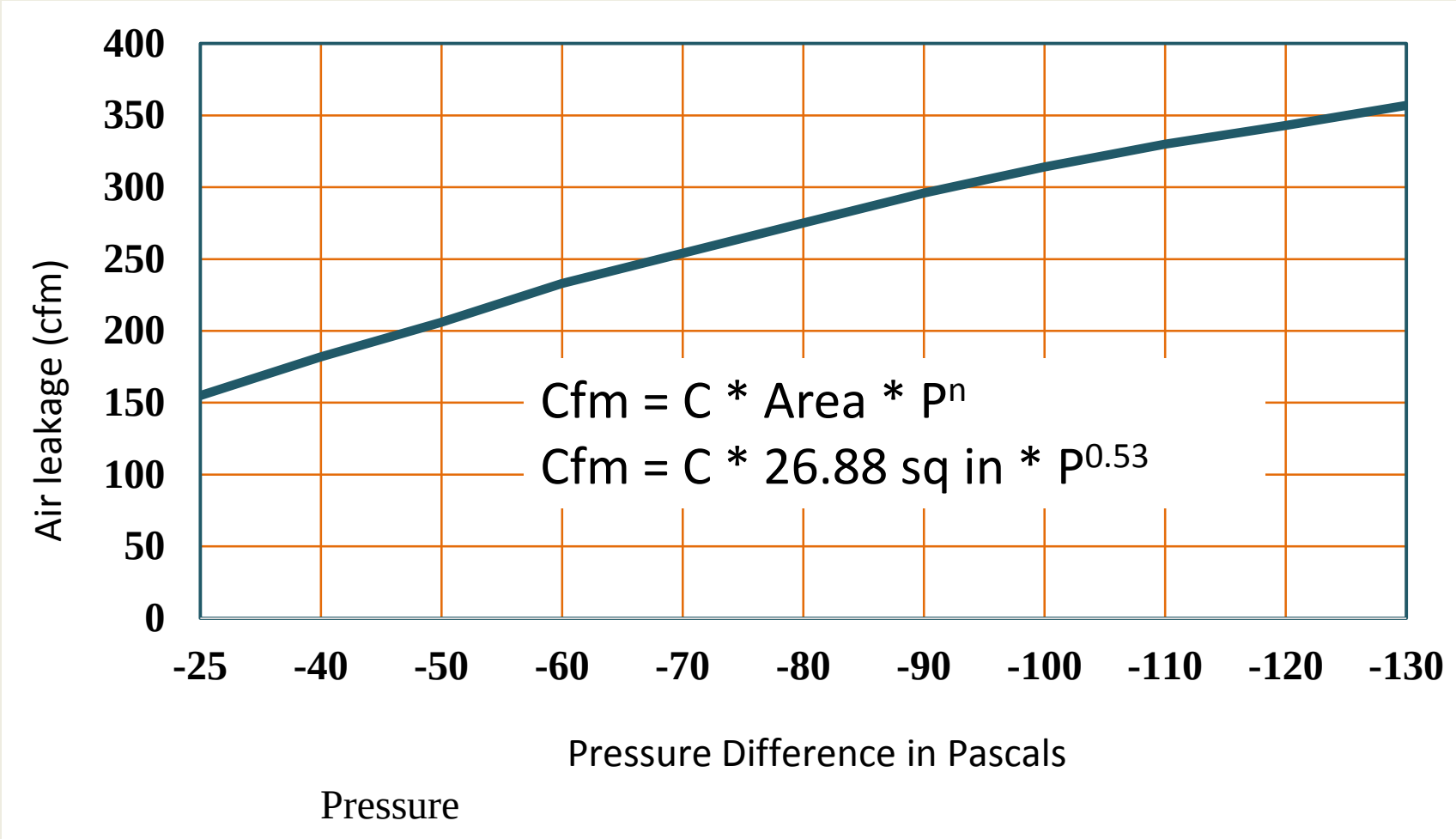
- Area of the hole or crack

  and

- Pressure (the driving force pushing air through the hole)

These cracks are 4 feet (48 inches) long and 0.28” wide (a little over ¼”)

Air Leakage Through the Cracks

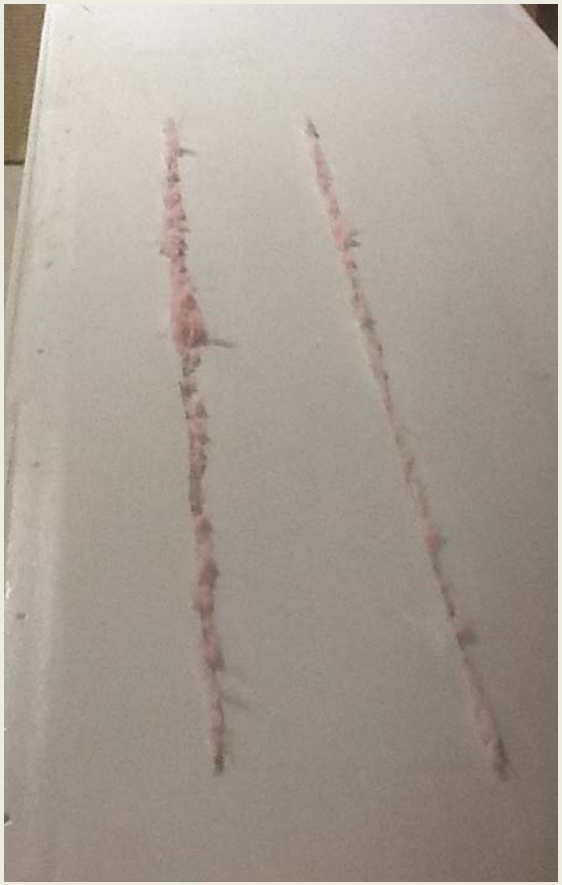


Pressure
Differe

Sealing the Cracks

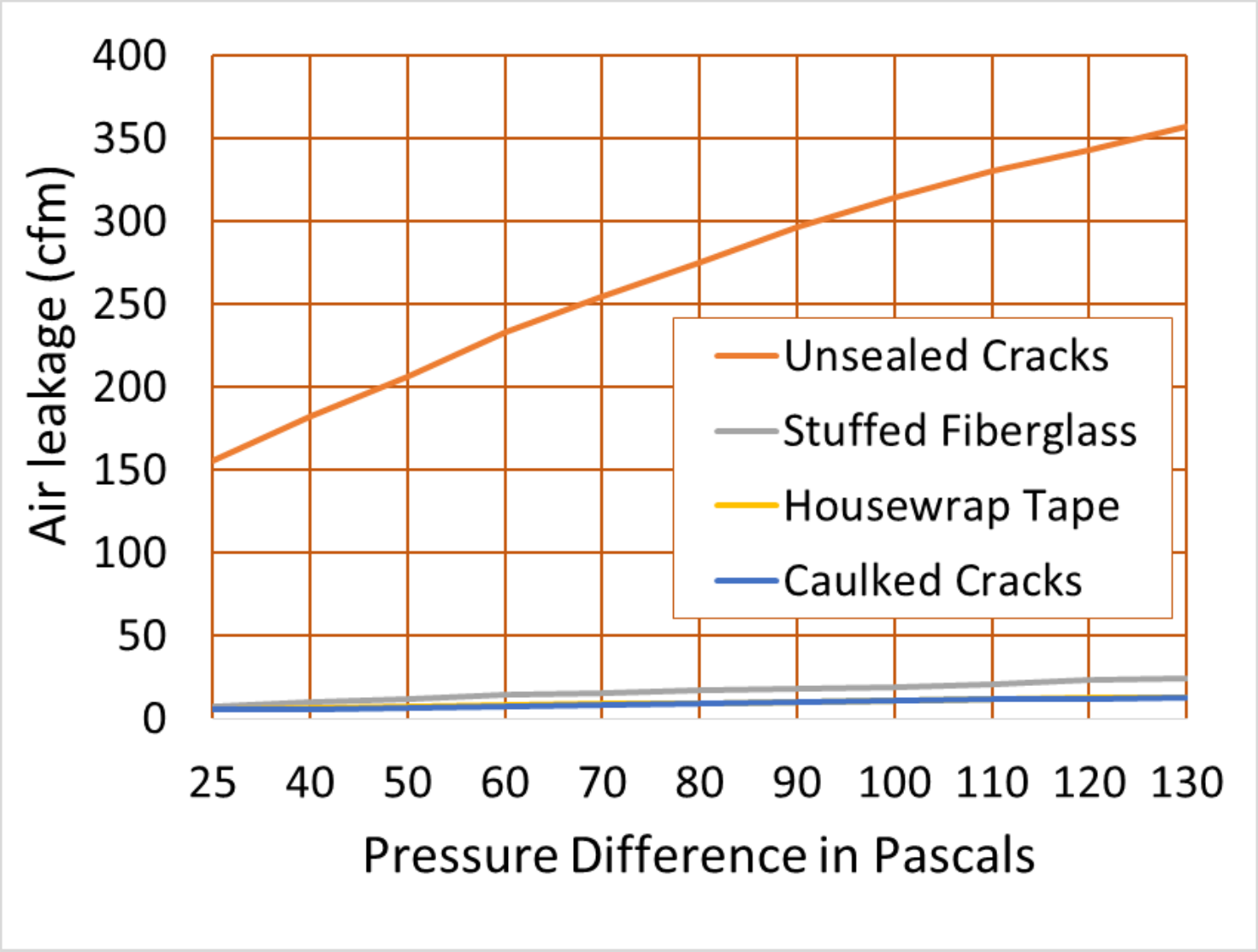
Housewrap tape

Fiberglass

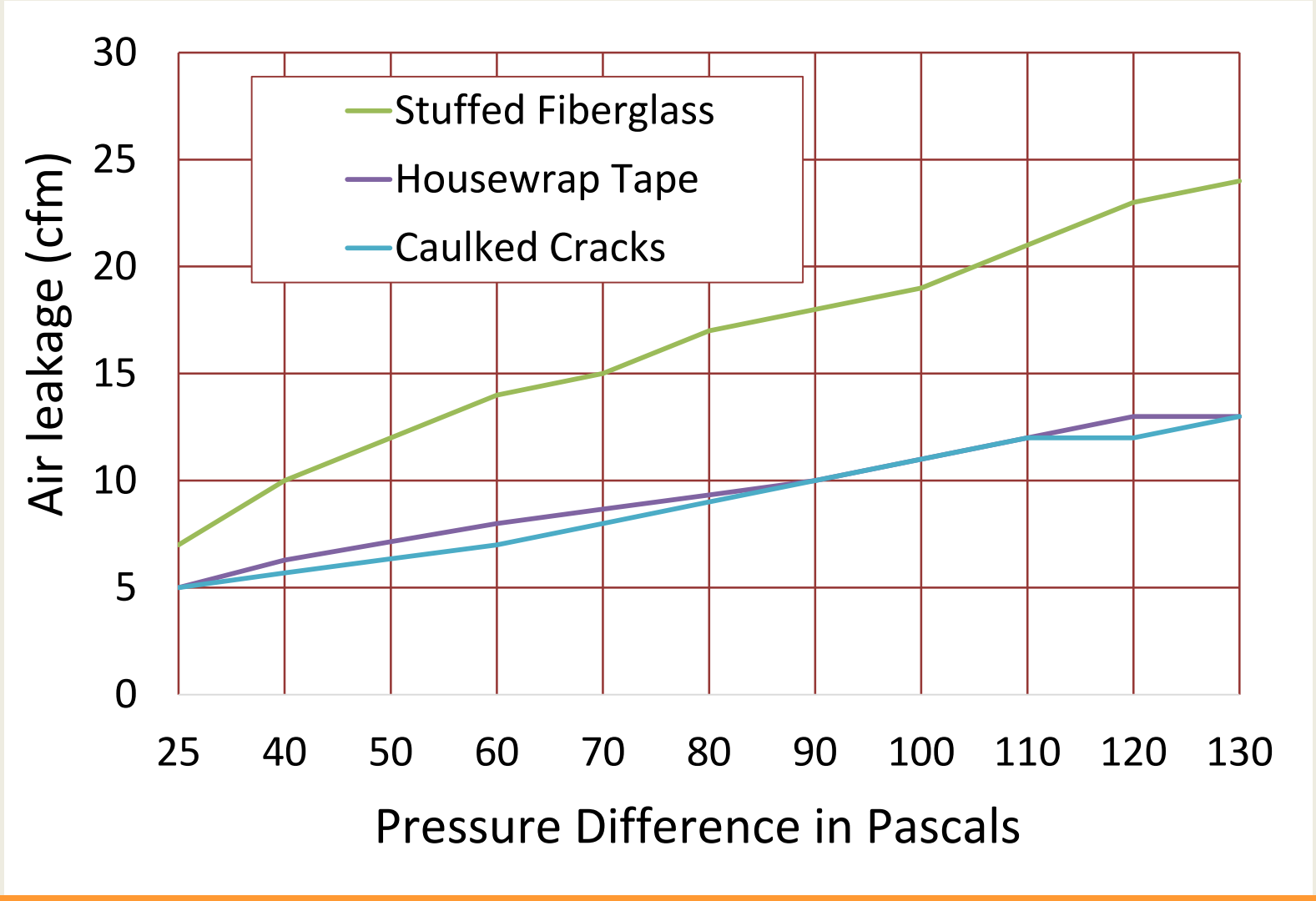


Caulking

Sealing the Cracks



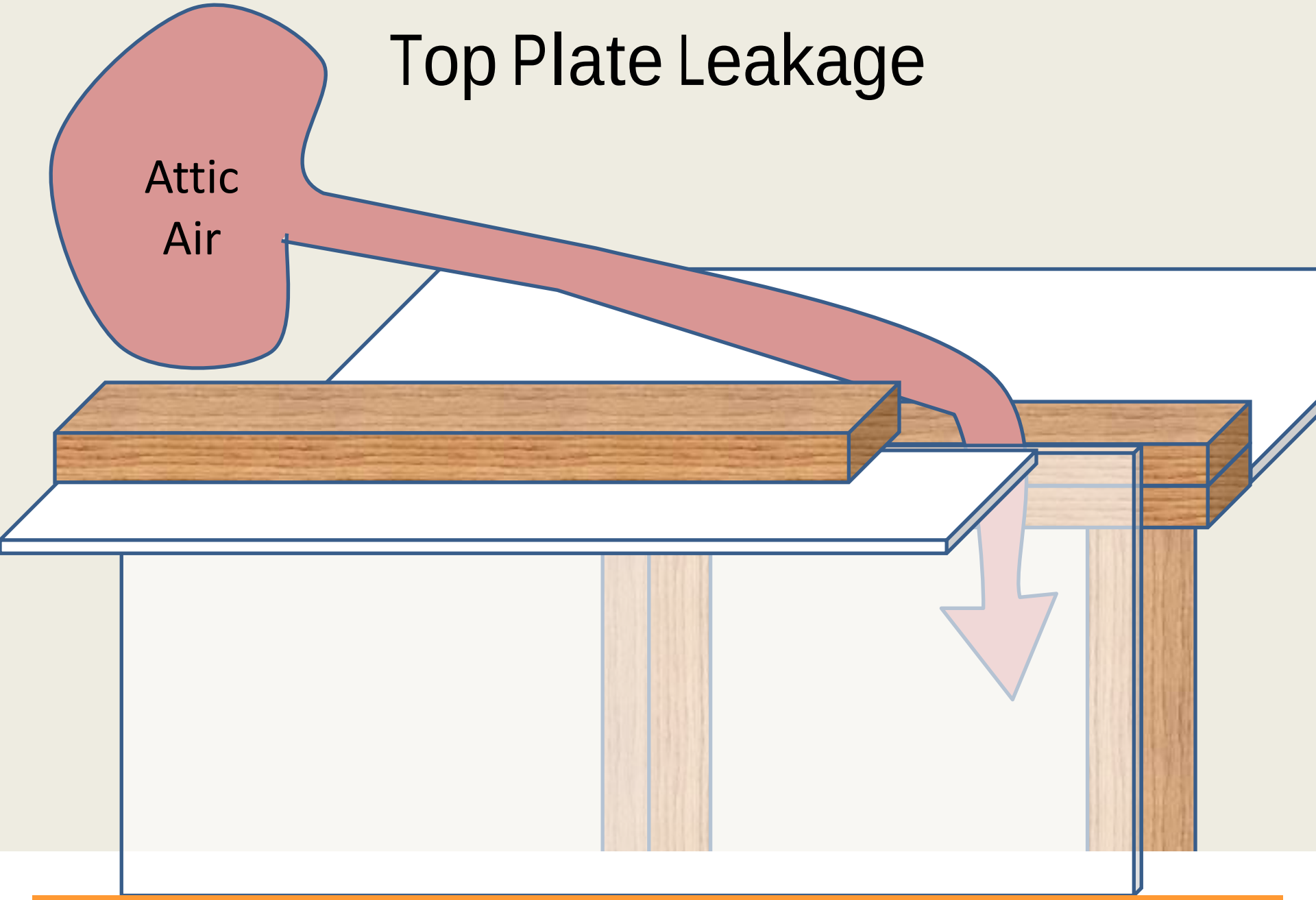
Sealing the Cracks



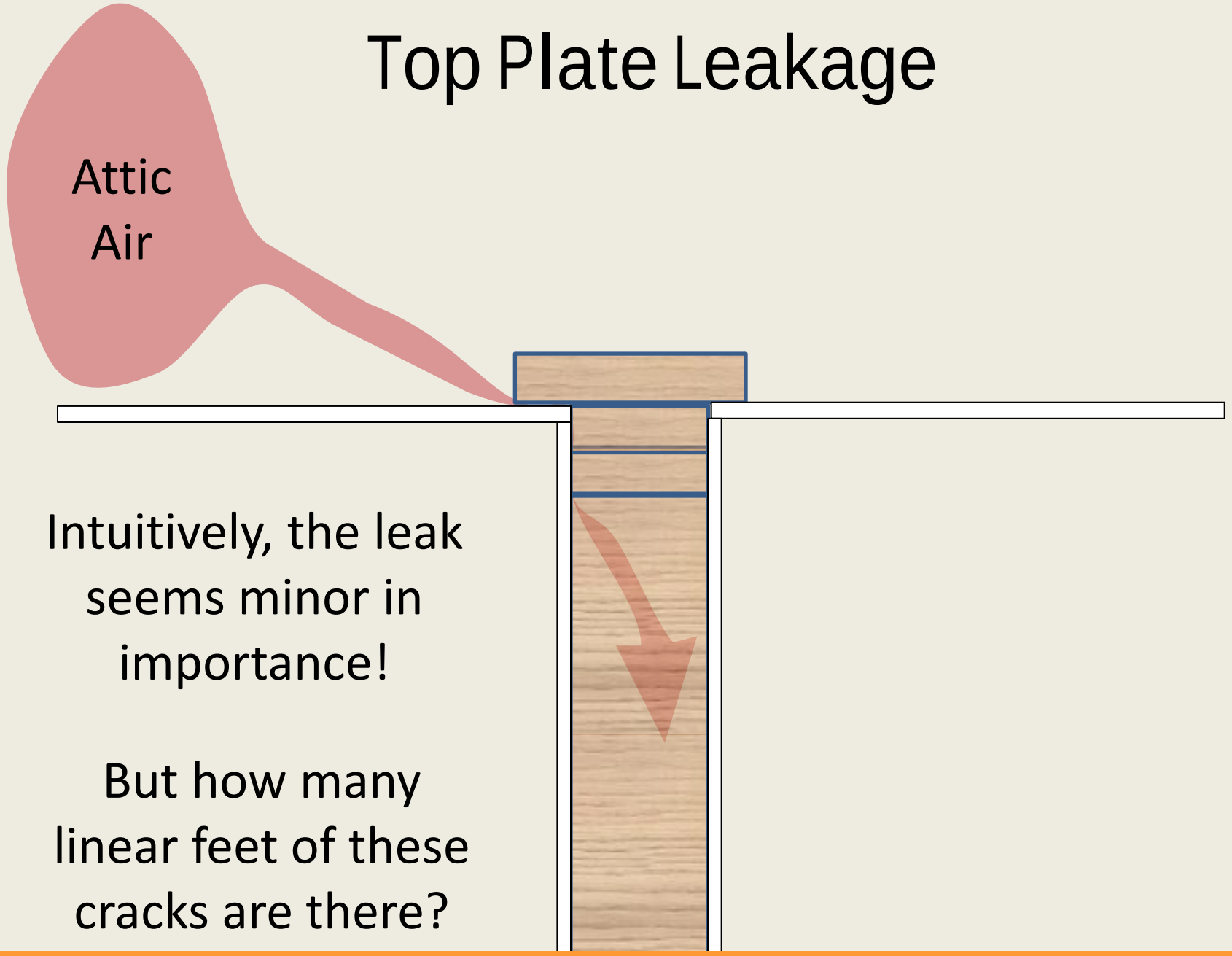
Top Plate Leakage

Sealing Top Plates in Attics is Now Required by Code in Many States, Including North Carolina

Top Plate Leakage



Top Plate Leakage

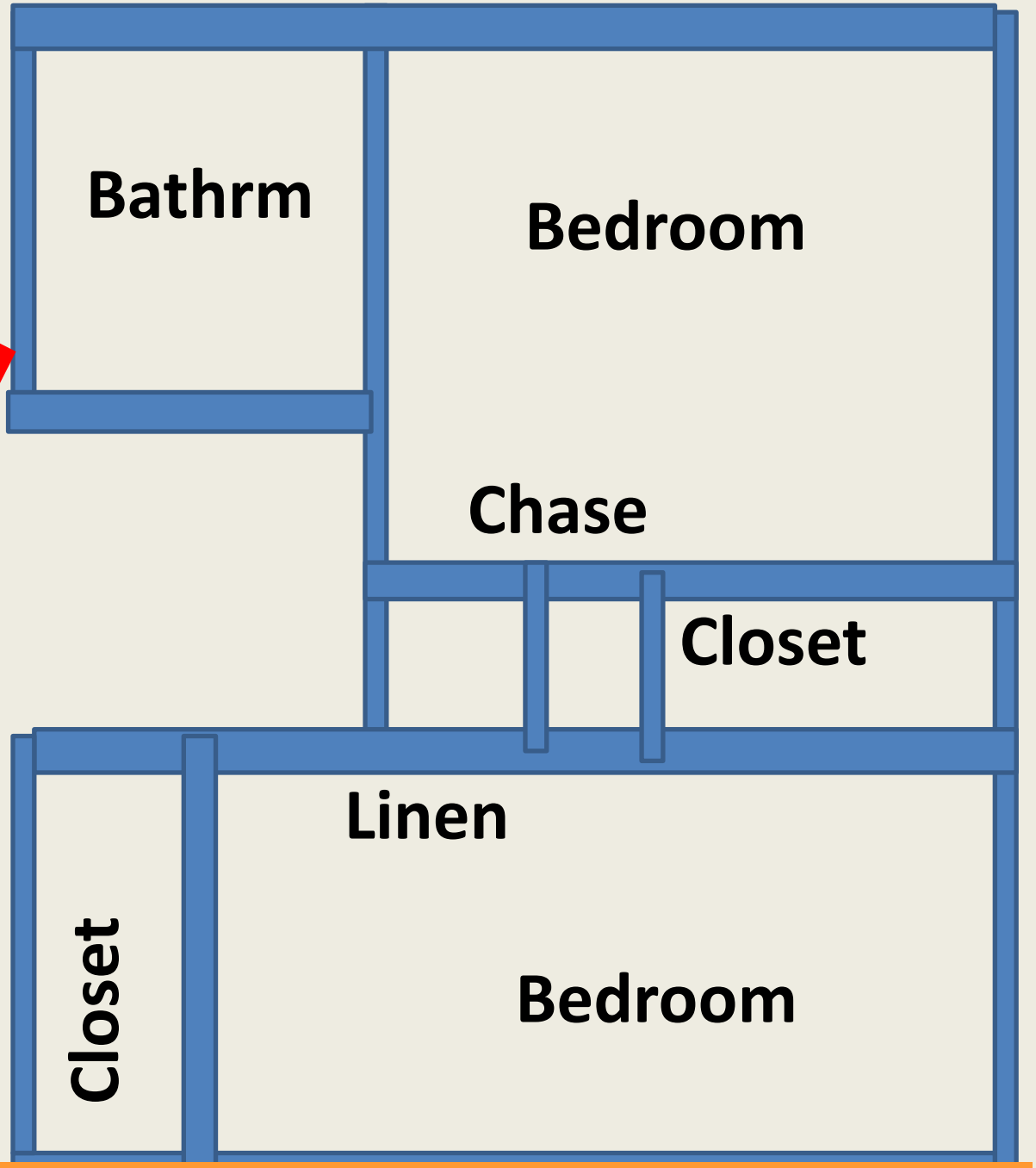


Intuitively, the leak seems minor in importance!

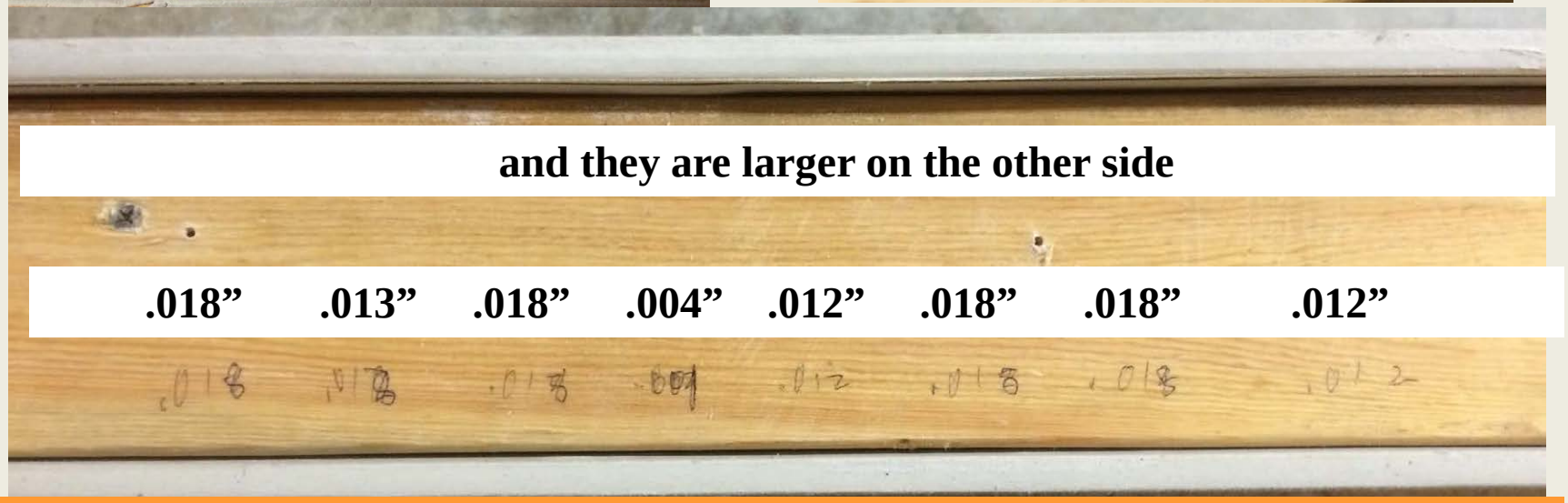
But how many linear feet of these cracks are there?

Length of Cracks – Test Attic

206 lin ft of cracks

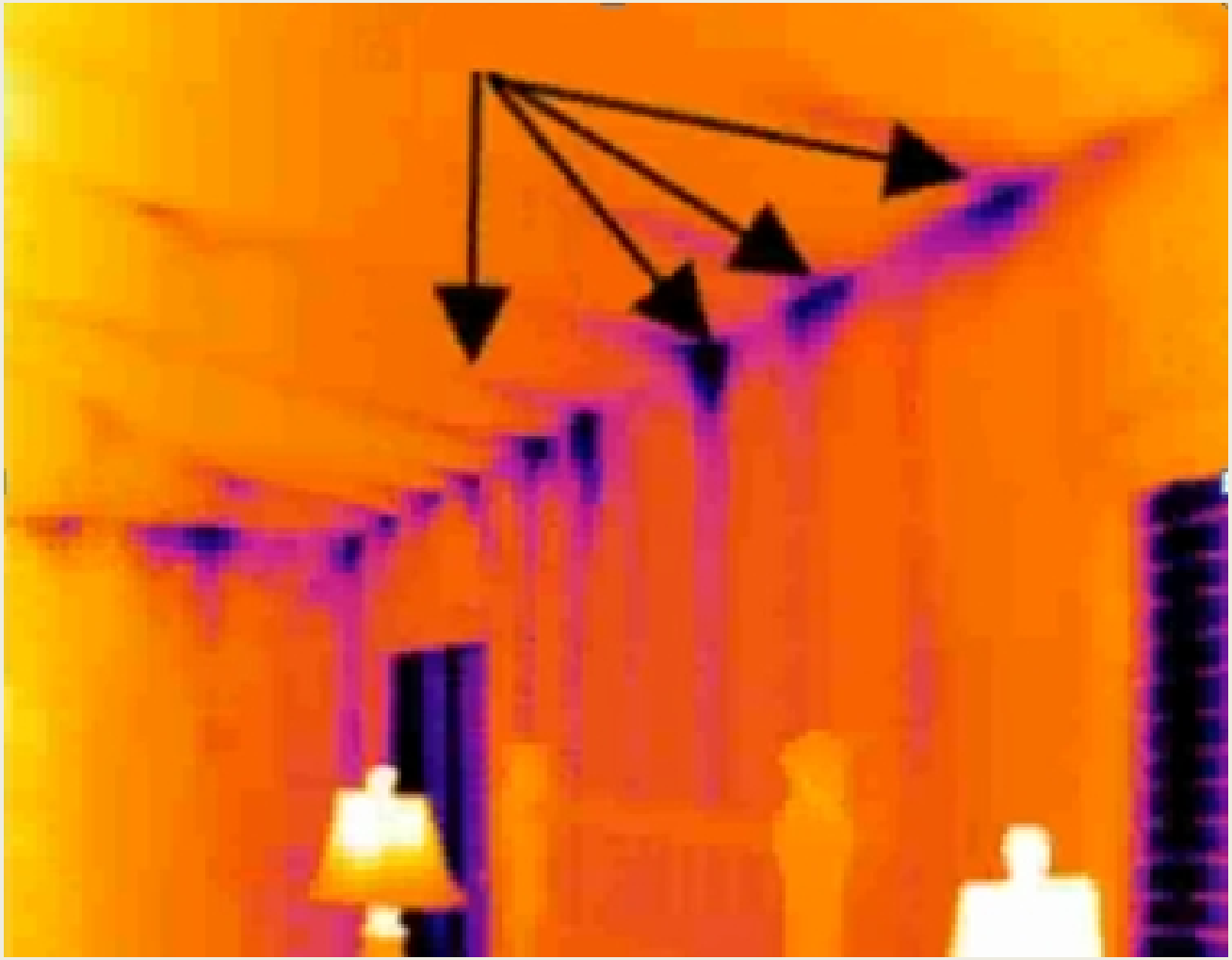


How Large is the Gap?



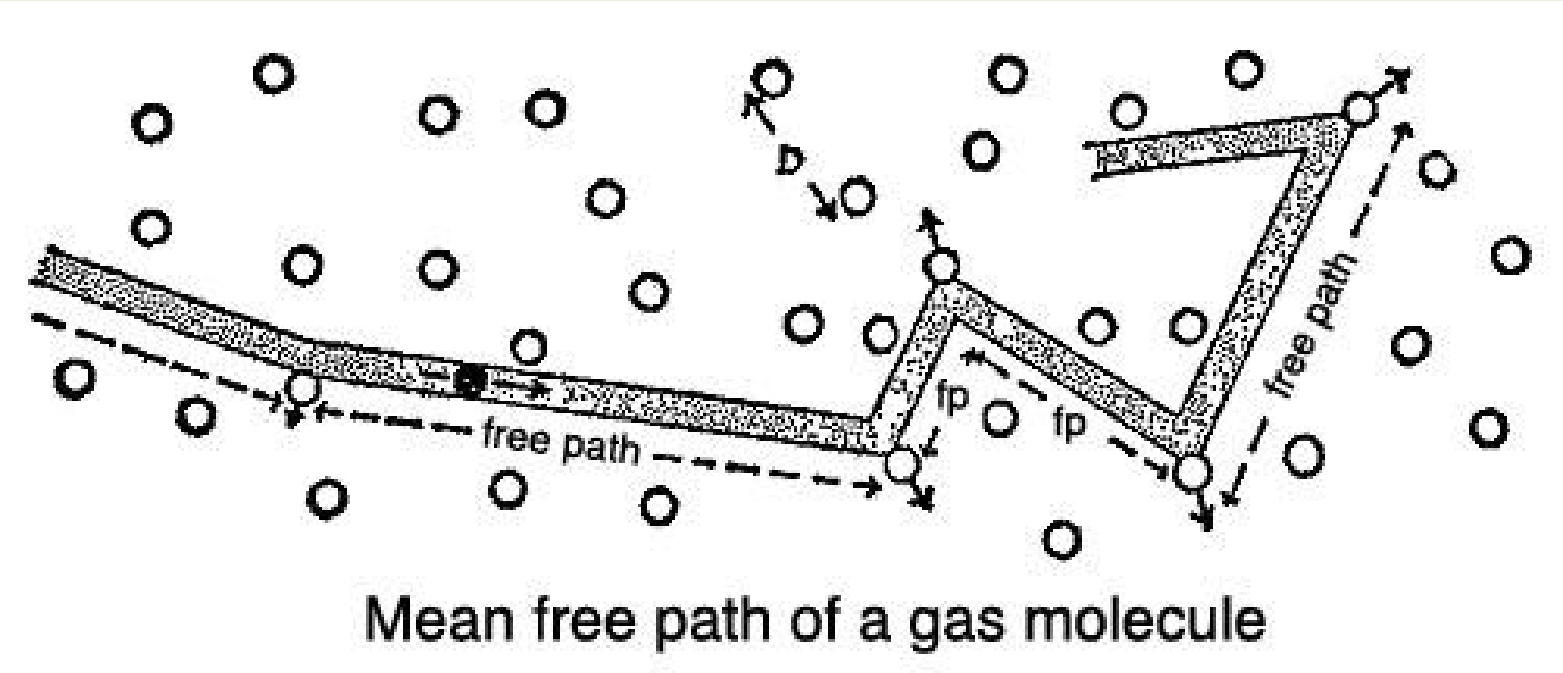
Sealants Must Be Continuous

Wall Washing from Drywall/ Top Plate Leaks



http://www.homebuildinglessons.com/TDBlog/2012/05/18/

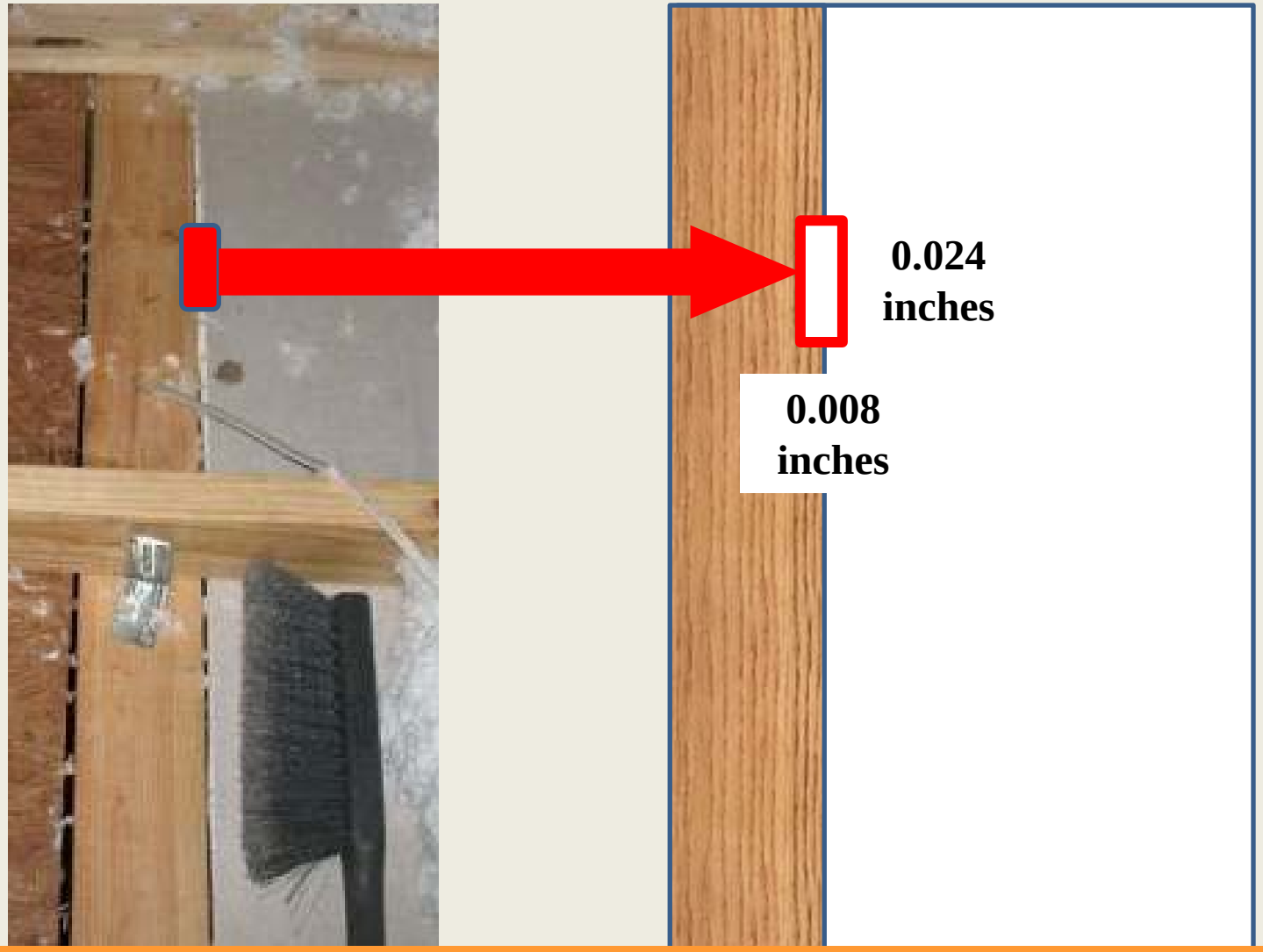
Getting to the Hole: Mean Free Path of Air Molecule



Mean free path of a gas molecule

http://practicalphysics.org/estimate-molecular-size-more-formal-method.html

So How Many Air Molecules Fit in a Tiny Crack?



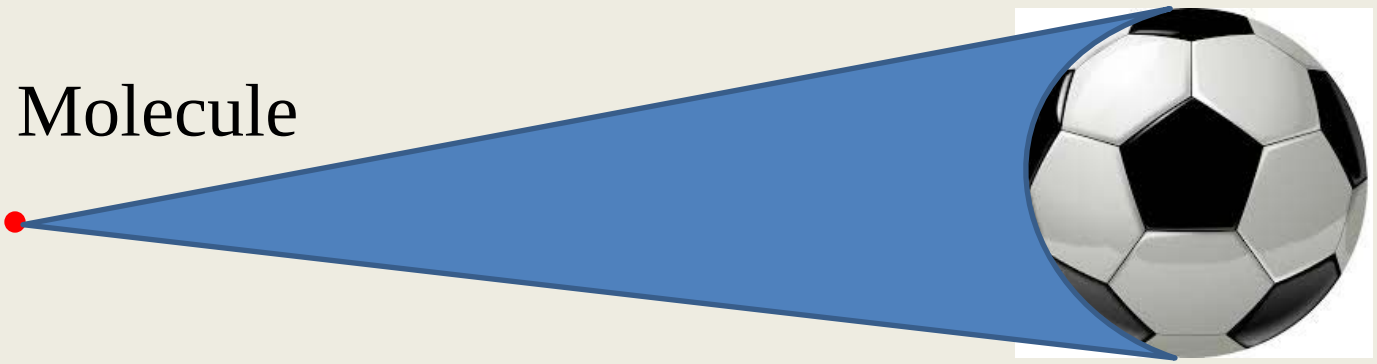
Mean Free Path of Air Molecule if a Soccer Ball (Goal is the Hole)

Easiest Shot in Soccer

How Large is the Drywall Gap?

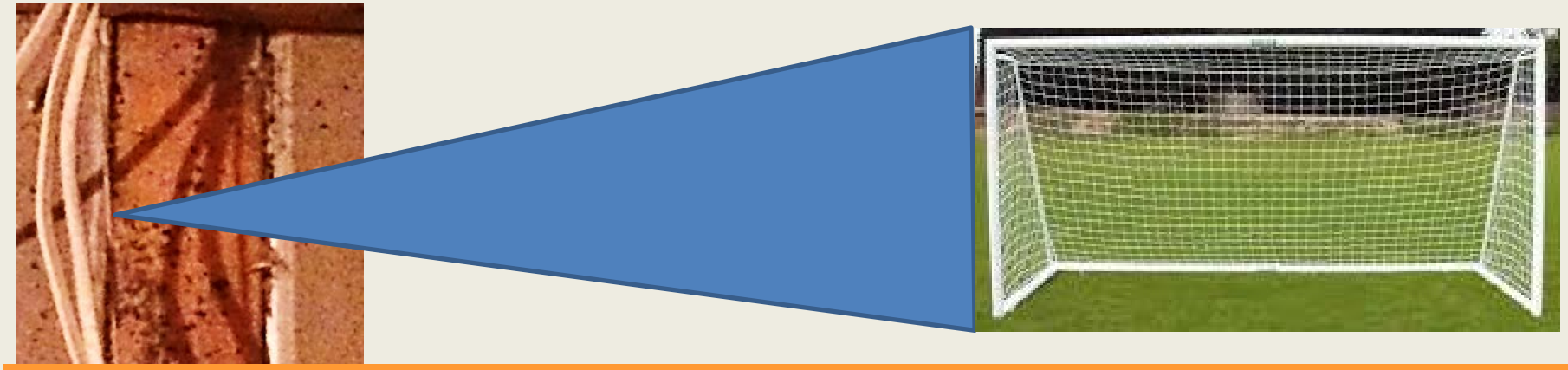
Soccer Ball

Air Molecule



Drywall Seam
(0.008 inch)

How Big Would the Goal Be?



Would Messi Have Missed Kicking an Air Molecule through the Drywall Gap?

Would Messi Have Missed Kicking an Air Molecule through the Drywall Crack?

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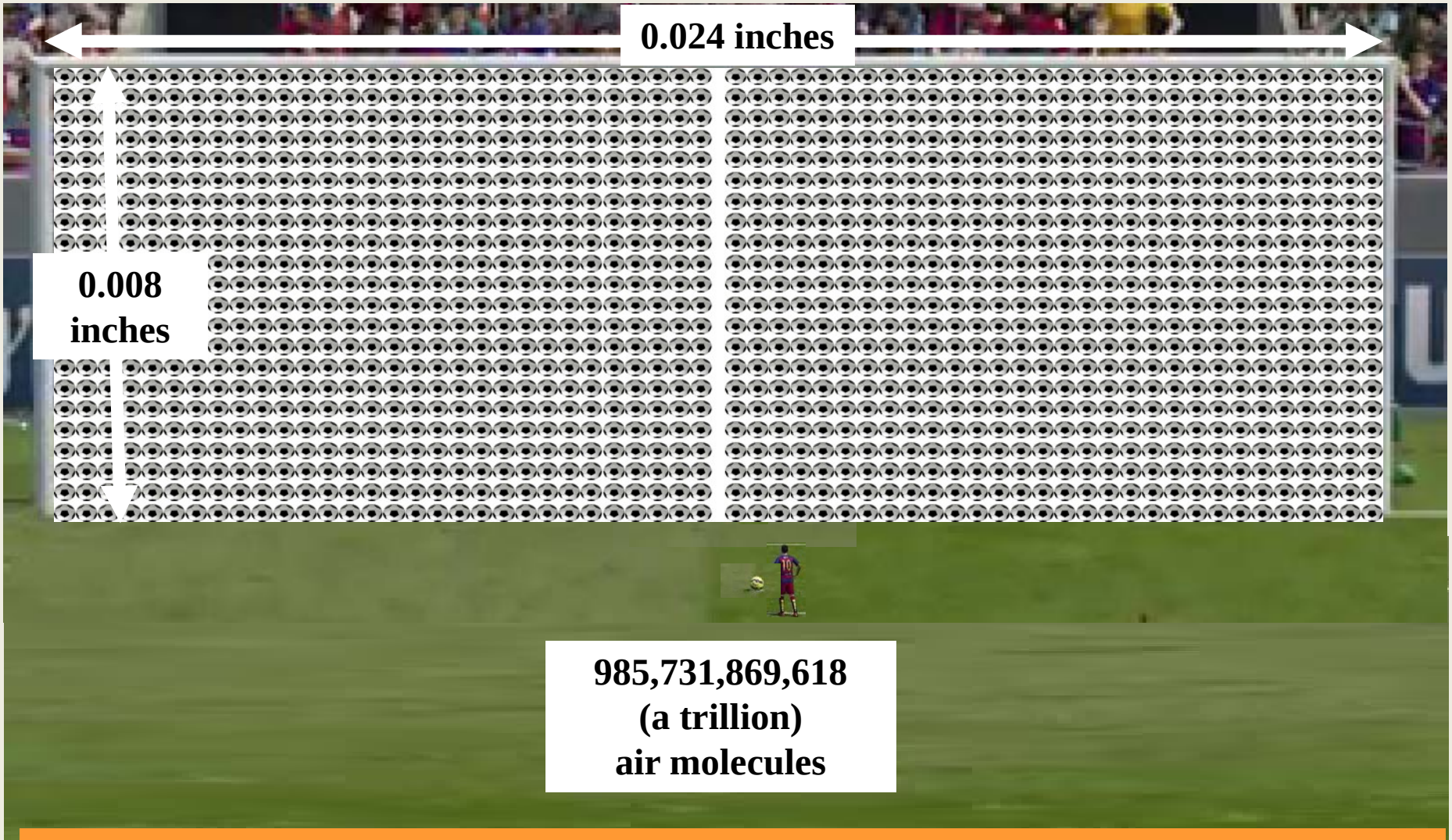
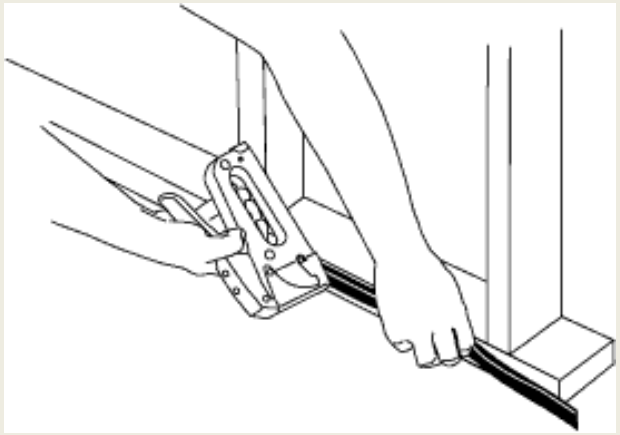
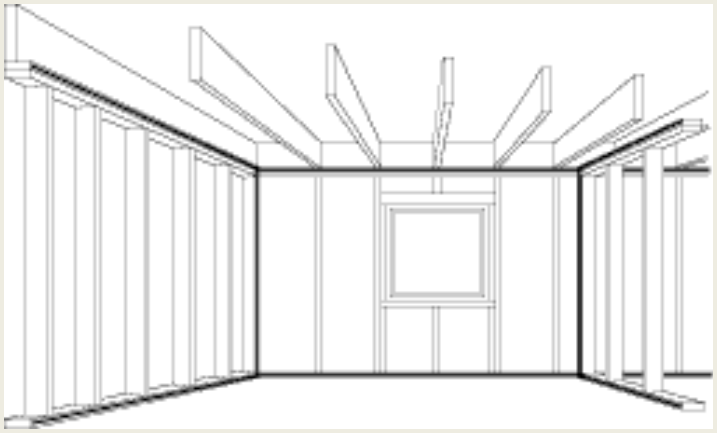


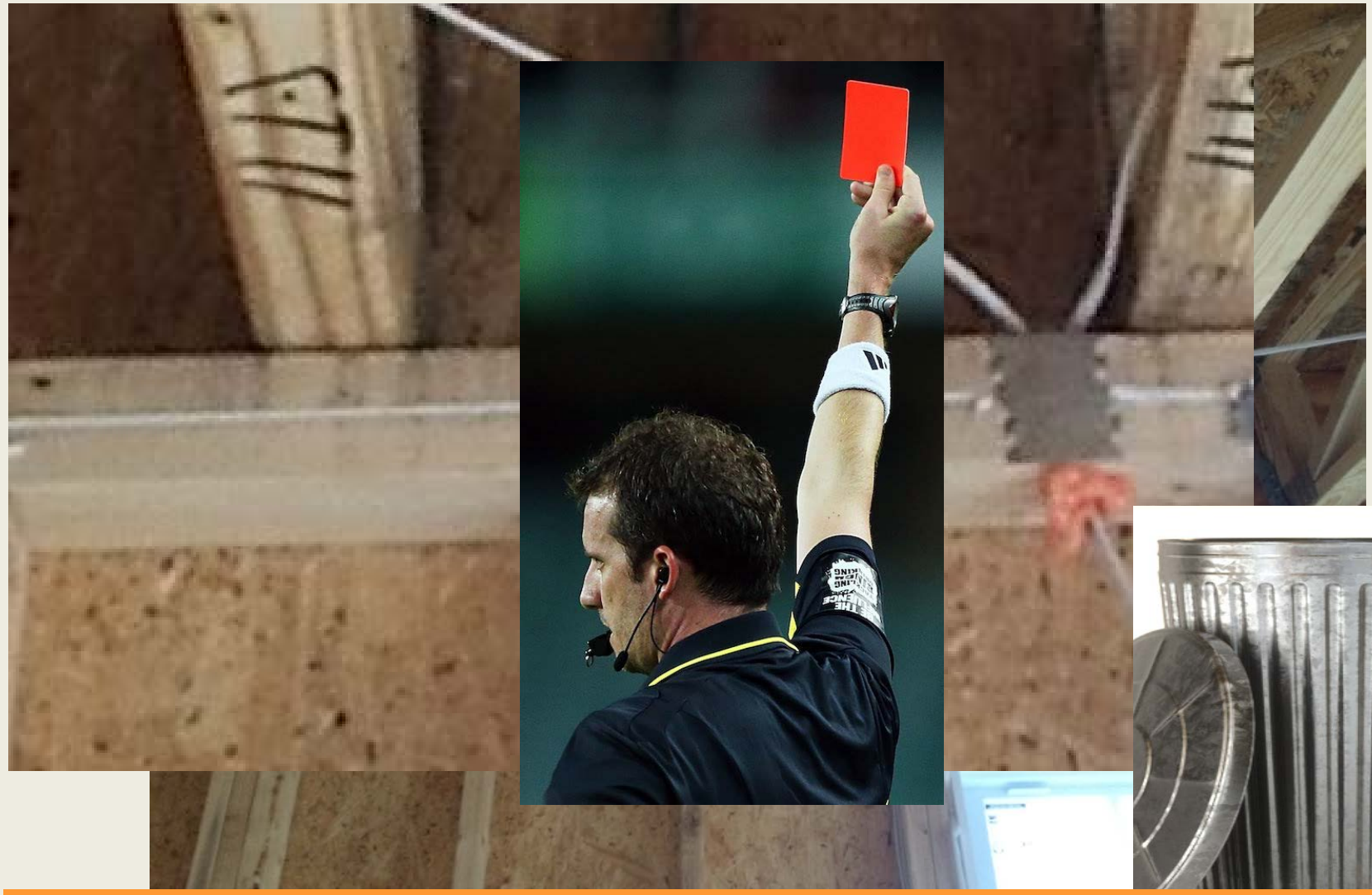
Sealant Options – Top Plate to Drywall

- Sill sealer or gasket pre drywall
- Caulk during drywall
- Seal after drywall
  - Spray foam
  - Caulk or mastic
  - Liquid seal





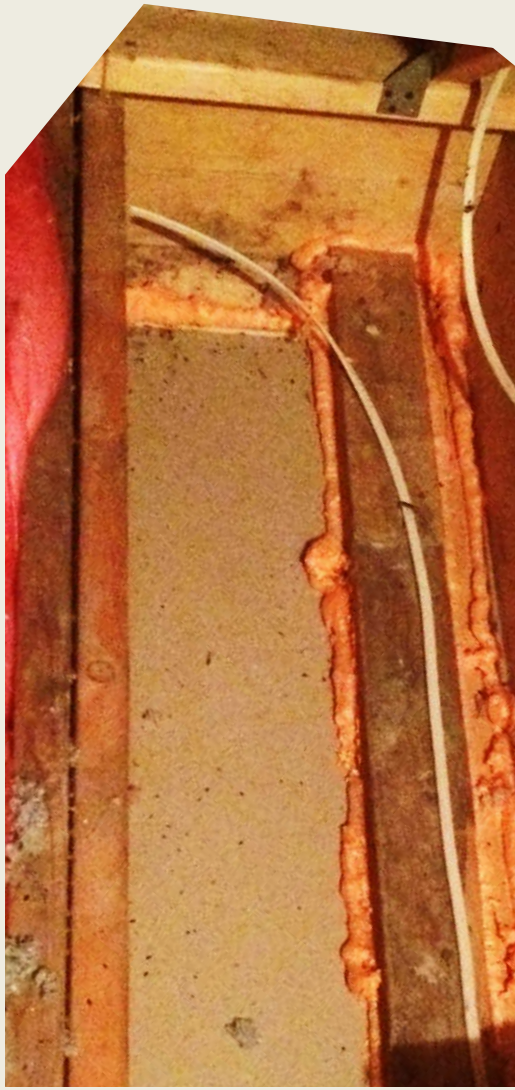
How About Caulk Applied in Advance?



Gasket from Spray-on Foam

Such as Owens Corning's, EnergyComplete™

Spray Foam from Above



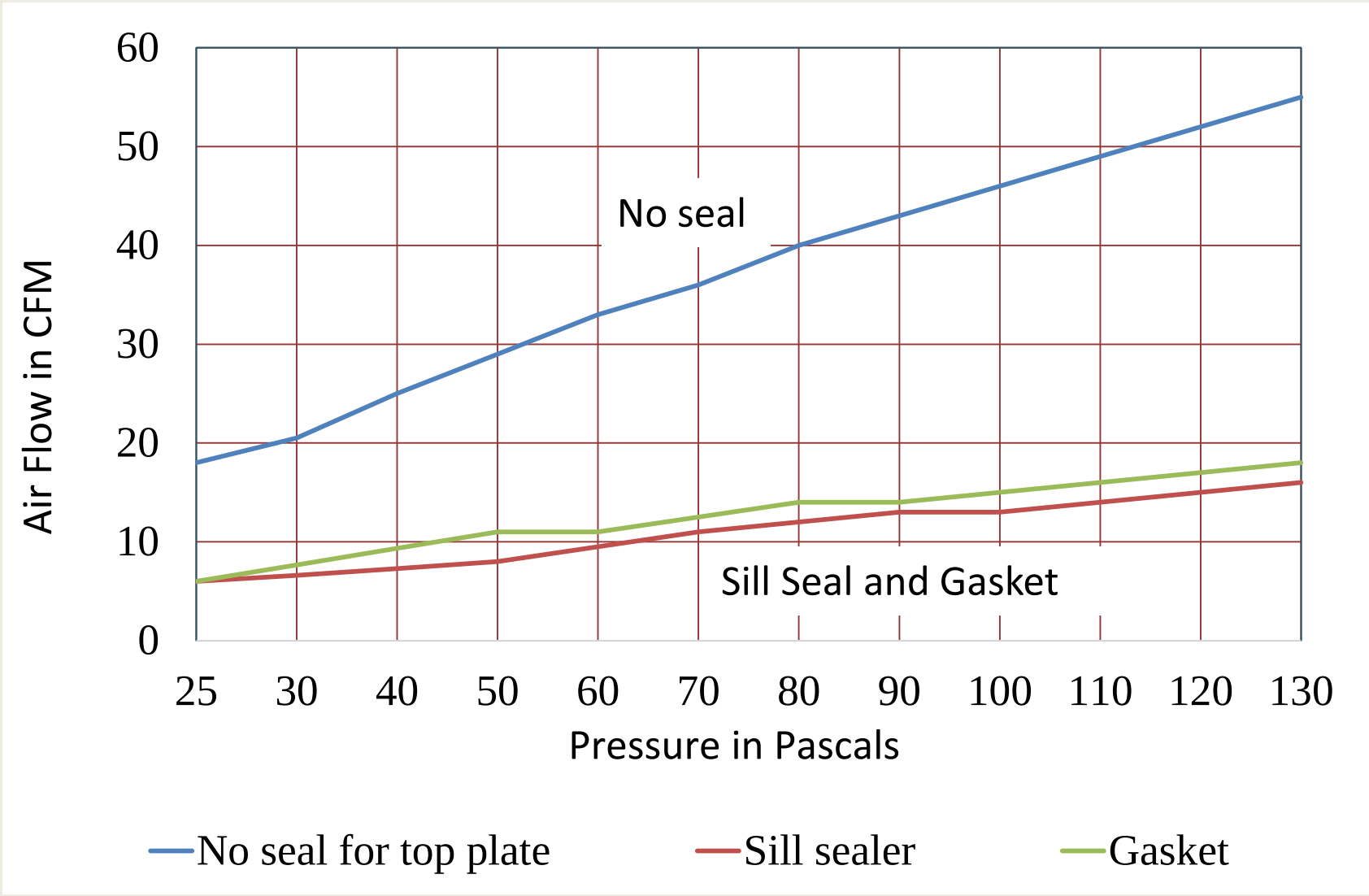
Example of Contractor Installation

- DeVere insulation

http://www.devereinsulationhomeperformance.com/2015/05/fiberglass-insulation.html

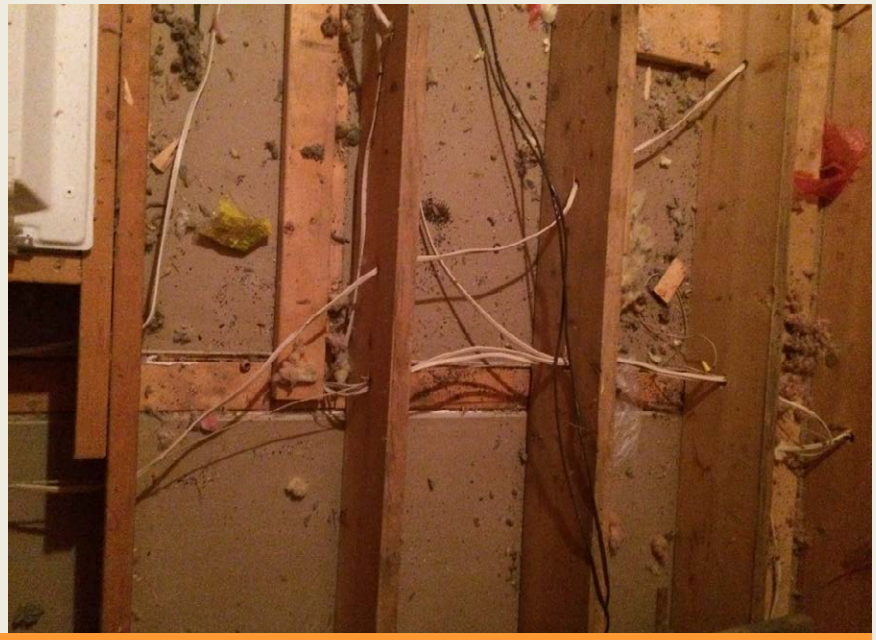
Our Box of Pressure

Lab Testing Results – Top Plate Sealing



Top Plate Sealing in Attic

- 16 feet x 25 feet (1/3 of attic area in house with divided attic)
- Stacked insulation away from top plates
- Cleaned the dust and debris (somewhat)
- Used spray foam (2 types) to seal

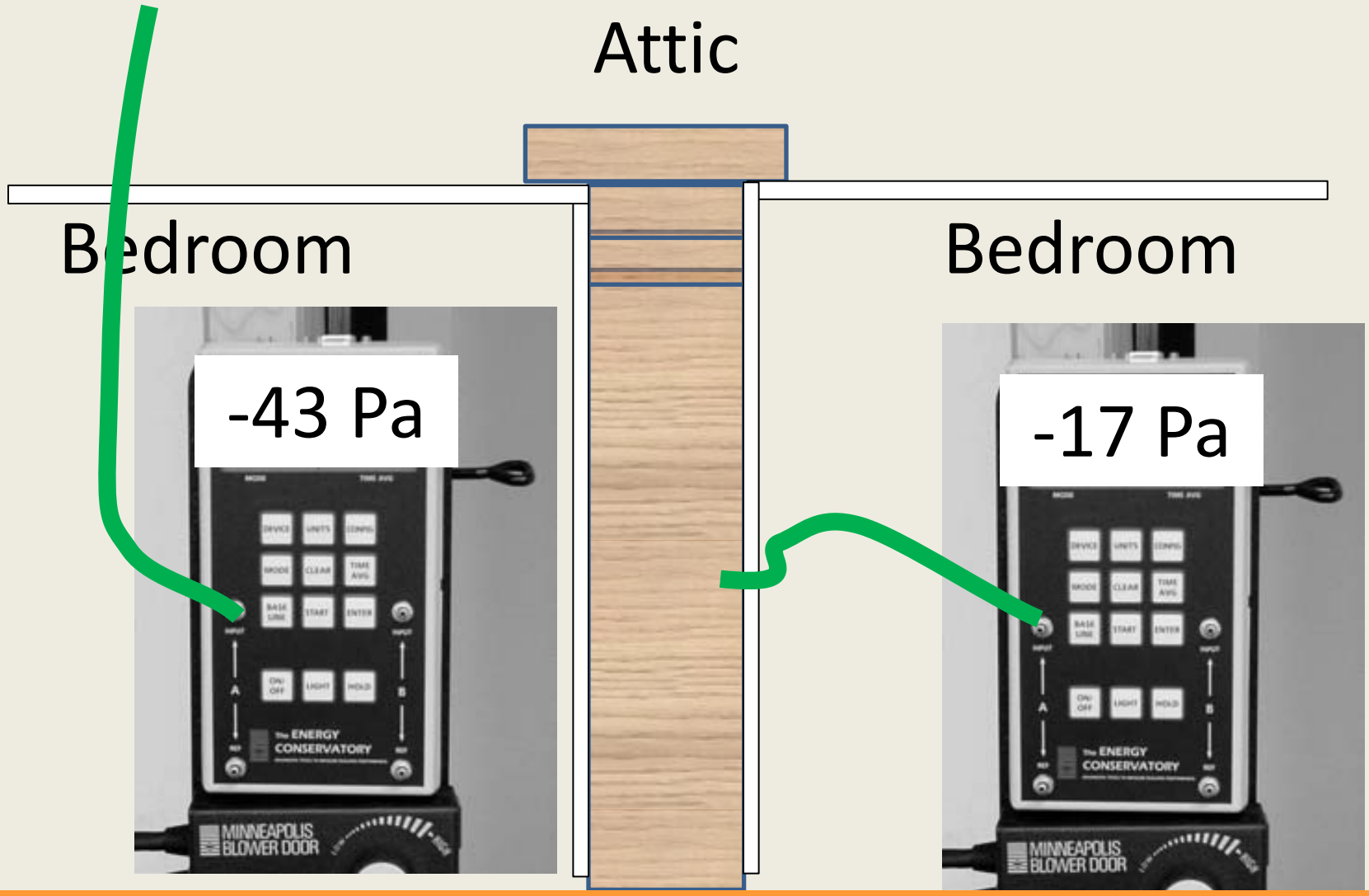


Air Flow Down the Drywall Gap

Crack was 0.025” wide in many places

Sealed Plates

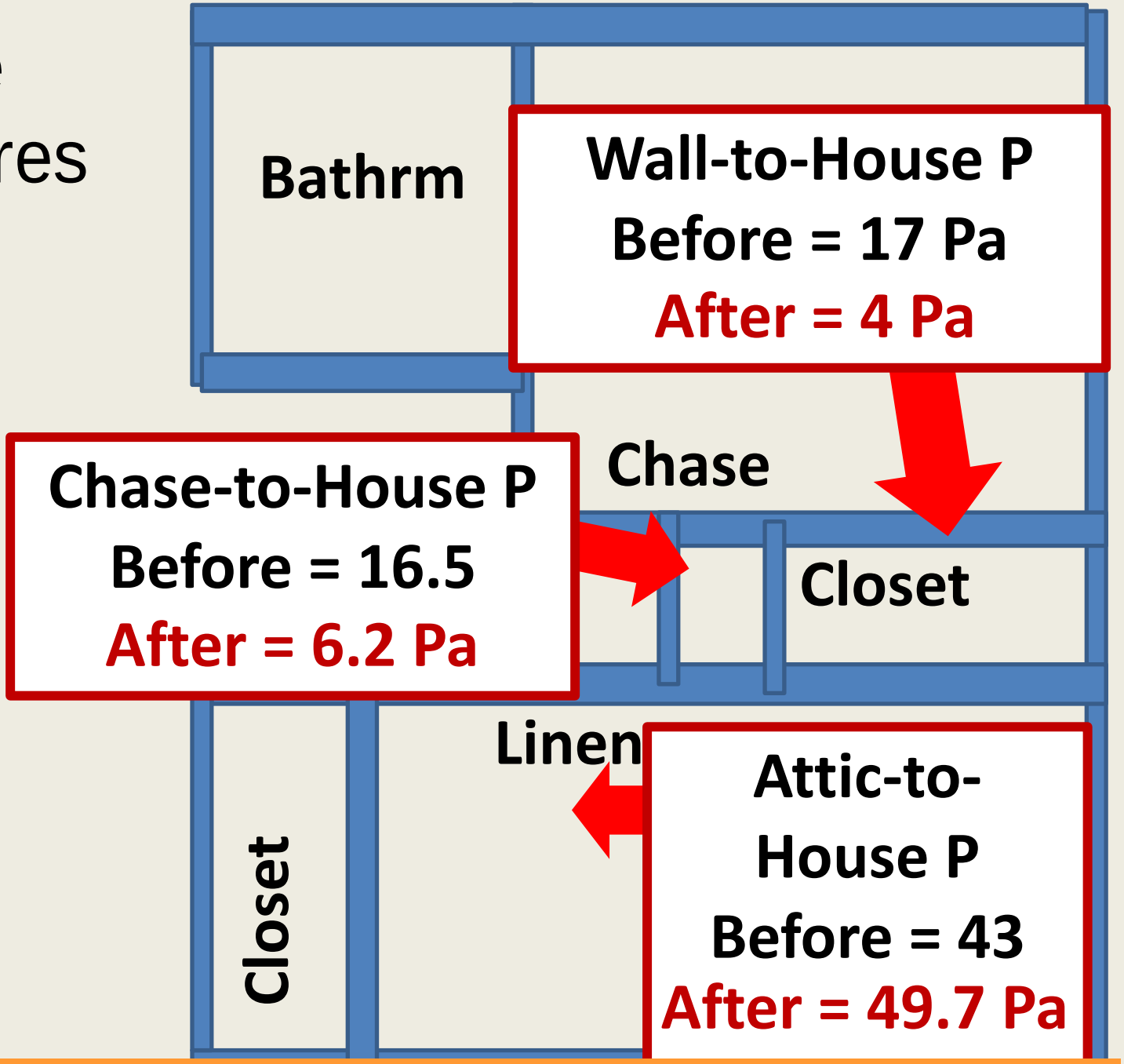
Zone Pressures – Interior Wall
House to Outside Pressure = -50 Pa BD Test



Zone Pressures

Tested ΔP between

- Attic and house
- Chase & house
- Inside wall and house

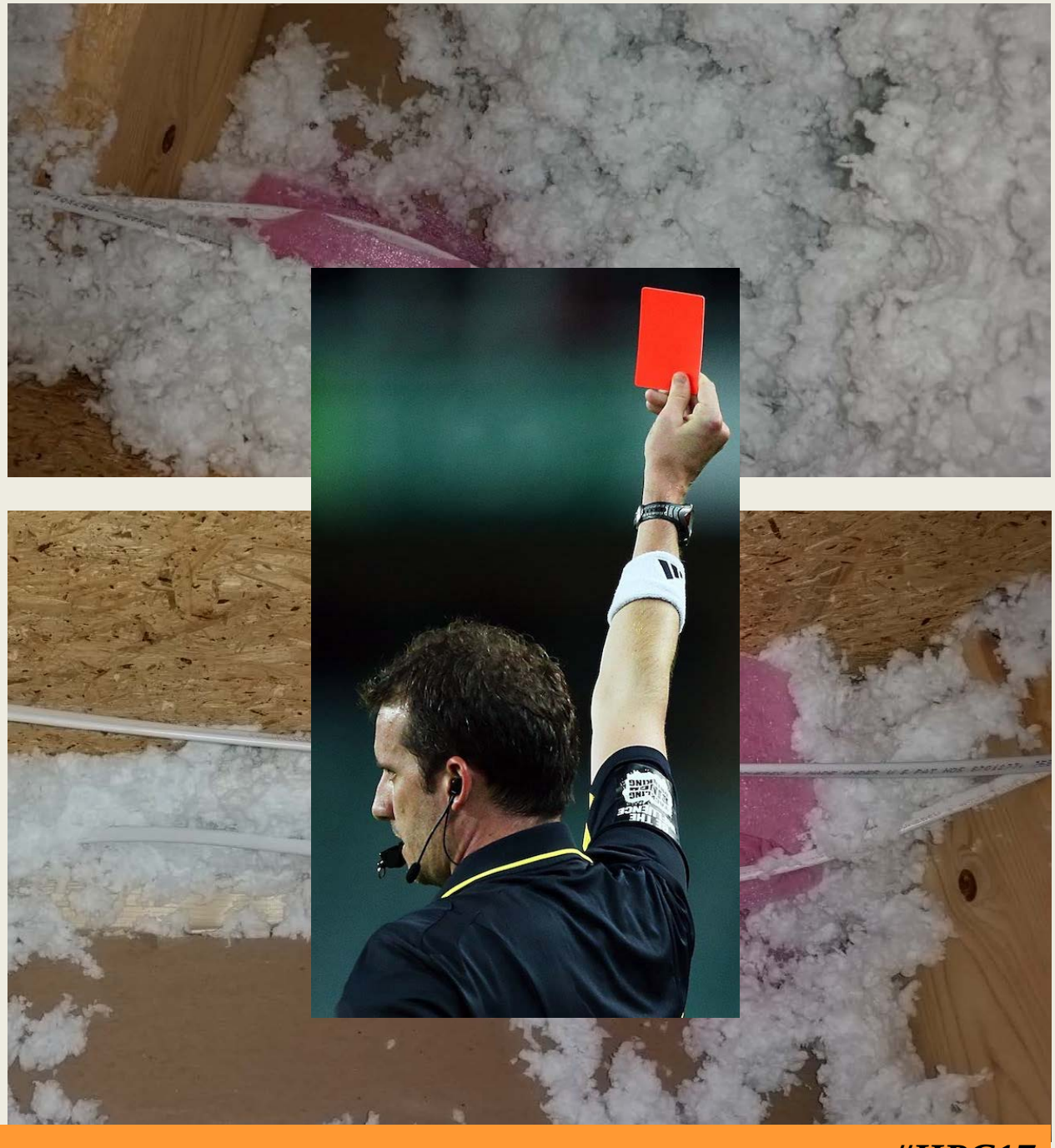


Air Leakage Results

- House air leakage before sealing = 2,440 CFM50
- House air leakage after sealing = 2,280 CFM50
- Reduction in air leakage = 160 CFM50
  - Reduction was about **0.8 CFM50** per foot of crack
  - About **6.6% of total house leakage**
  - If other attic spaces were sealed perhaps a **15% reduction** or more in air leakage rate

So Top Plate Air Sealing Works!?

Top Plate Gasket Now Serving as Insulation?

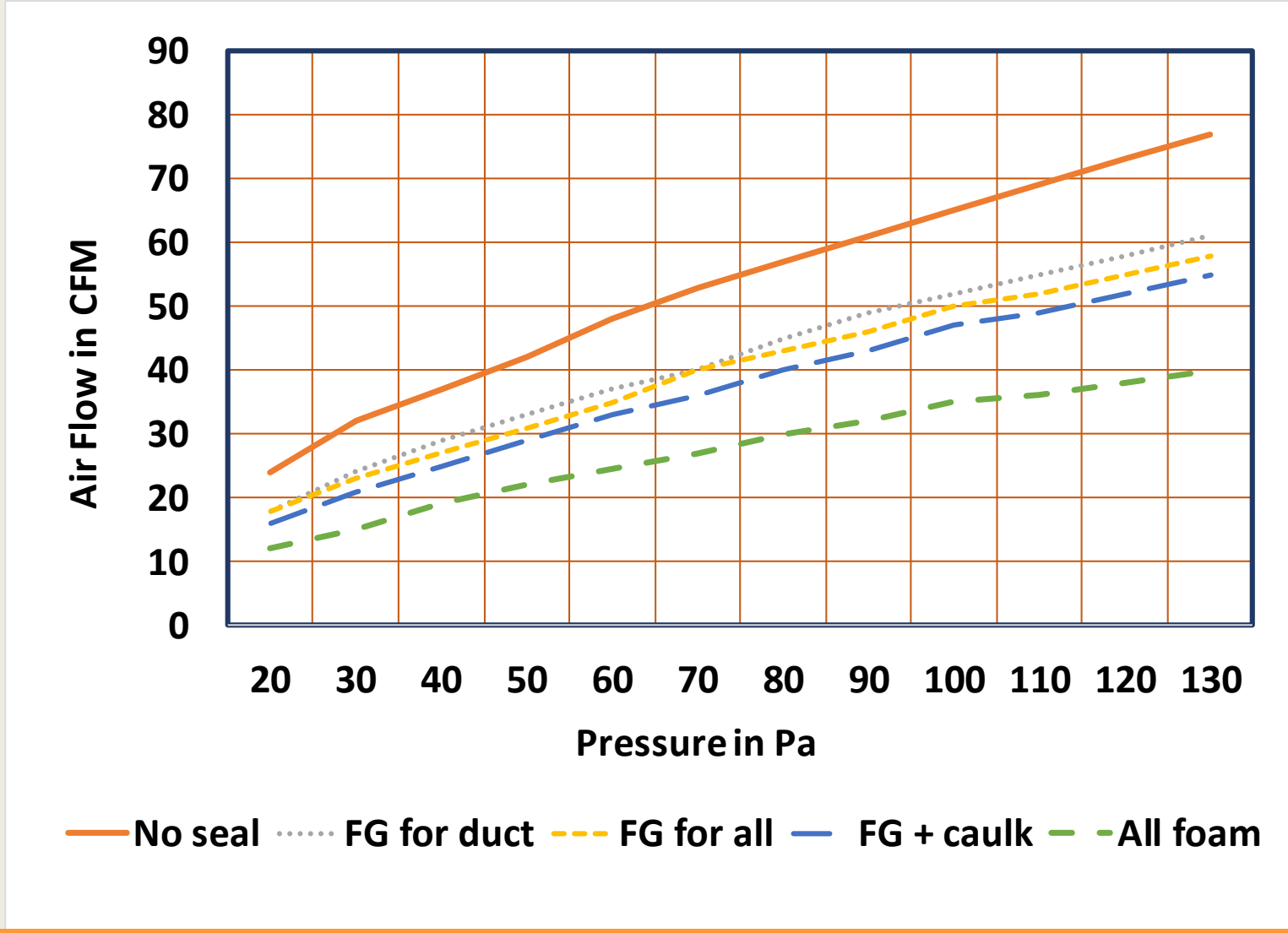


Sealing Chases

Chase Sealing Options Considered

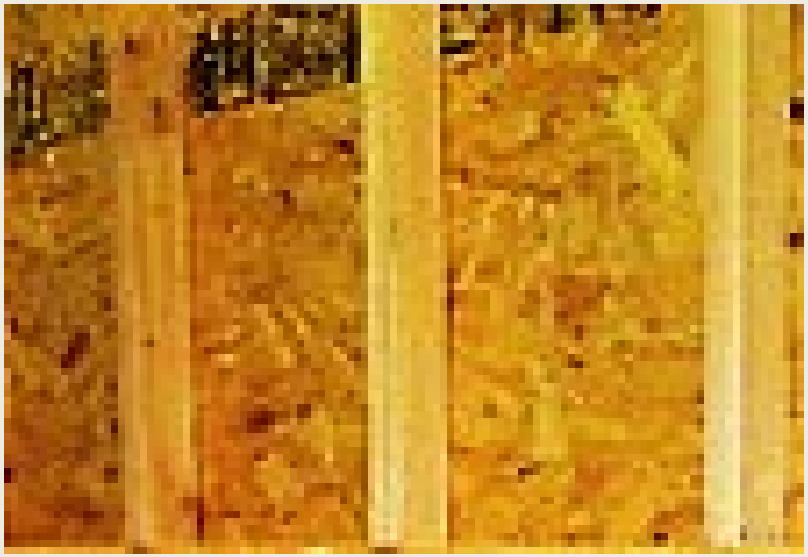
- No seal
- Fiberglass
- Fiberglass with caulked edge
- Foamed duct penetration
- Foamed cap edge

CFM at Different Pressures



Exterior Walls

- Continuous OSB
- Looks airtight to us
- But how about to an air molecule?



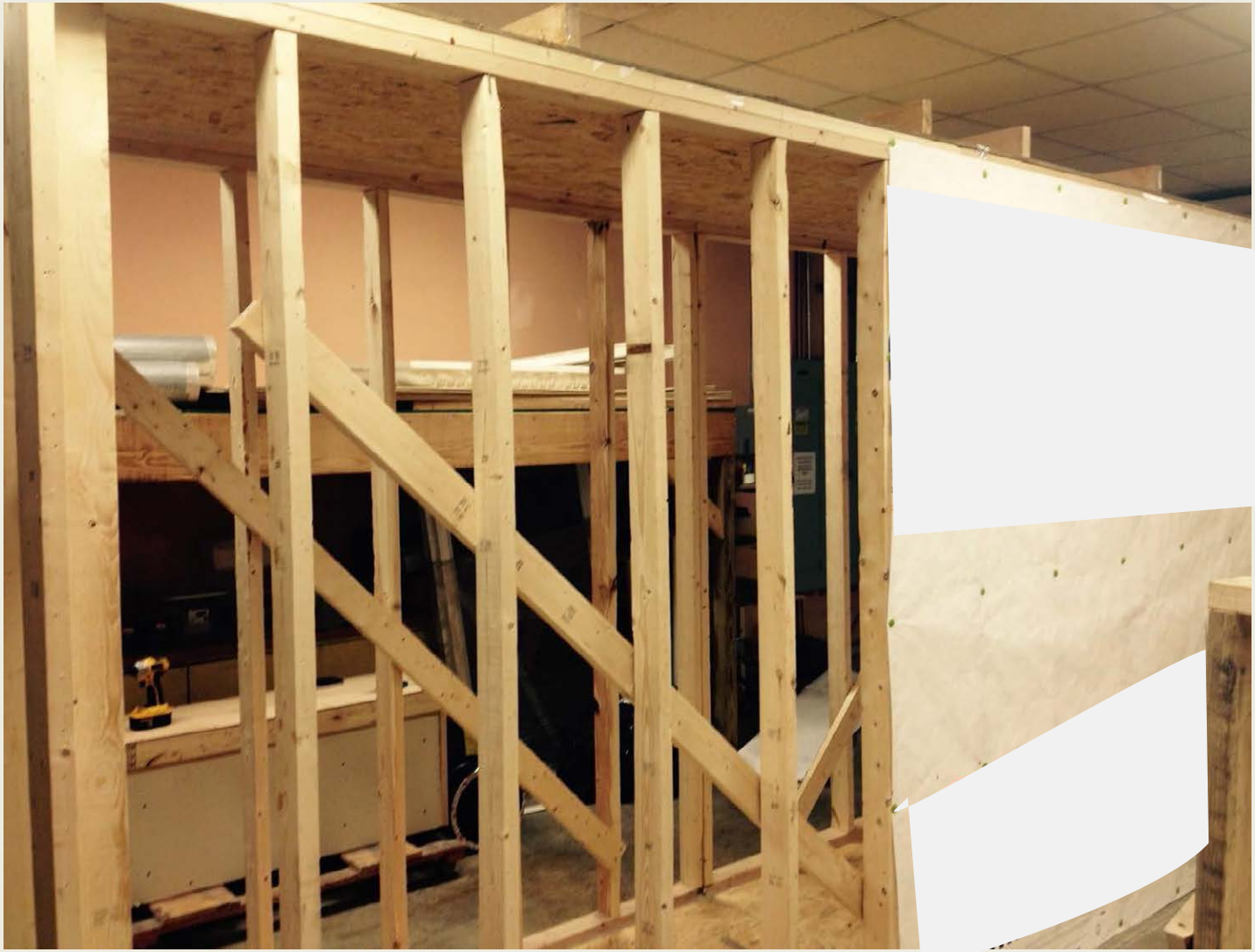
Tunnel of Pressure

Testing Process

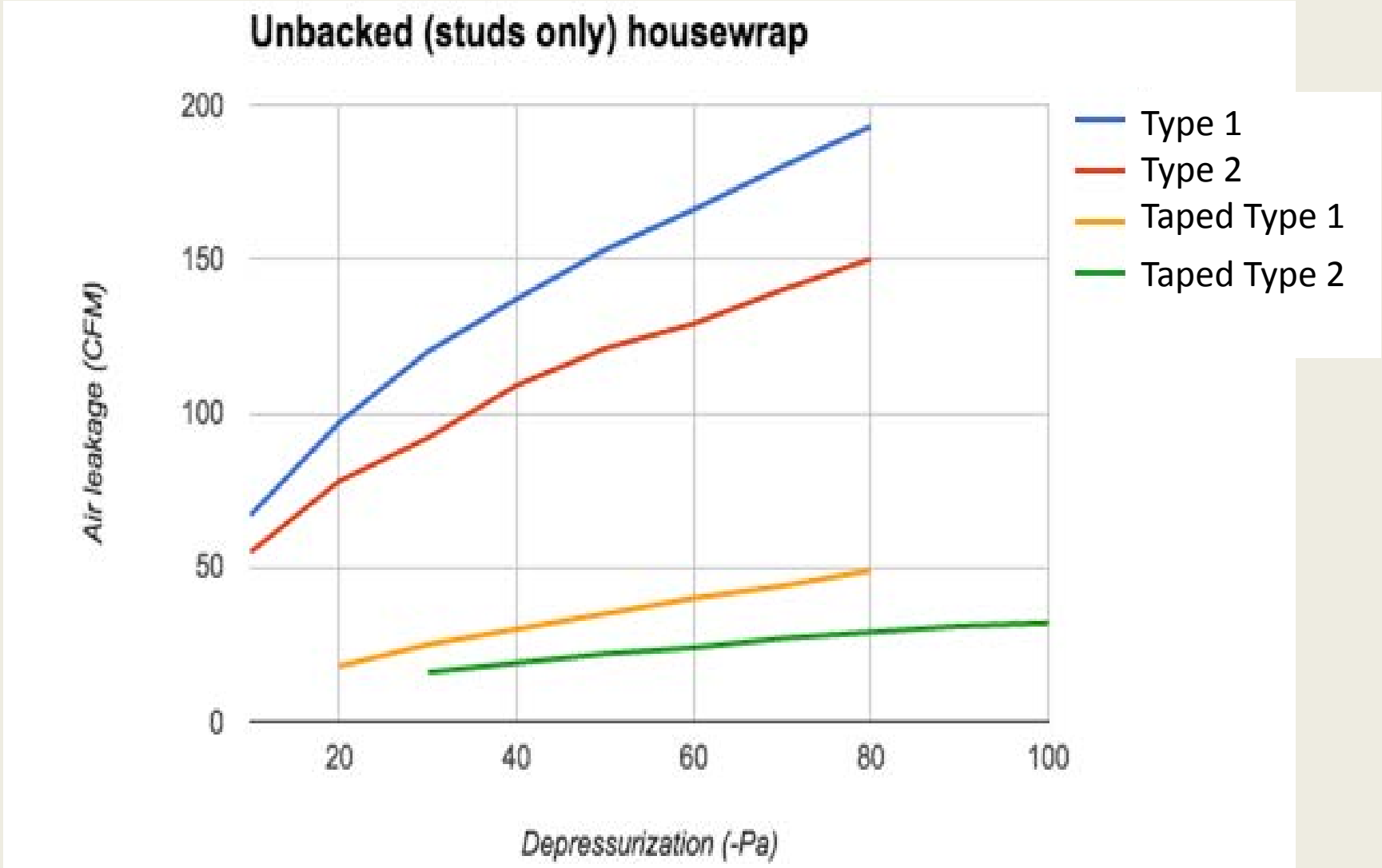
Measured Air Leakage for:

- Comparison of:
  - Sheathing tapes
  - Housewraps
- Taped vs. Untaped
- OSB backing vs. Stud (no) backing
- Whole-wall assembly with drywall on interior

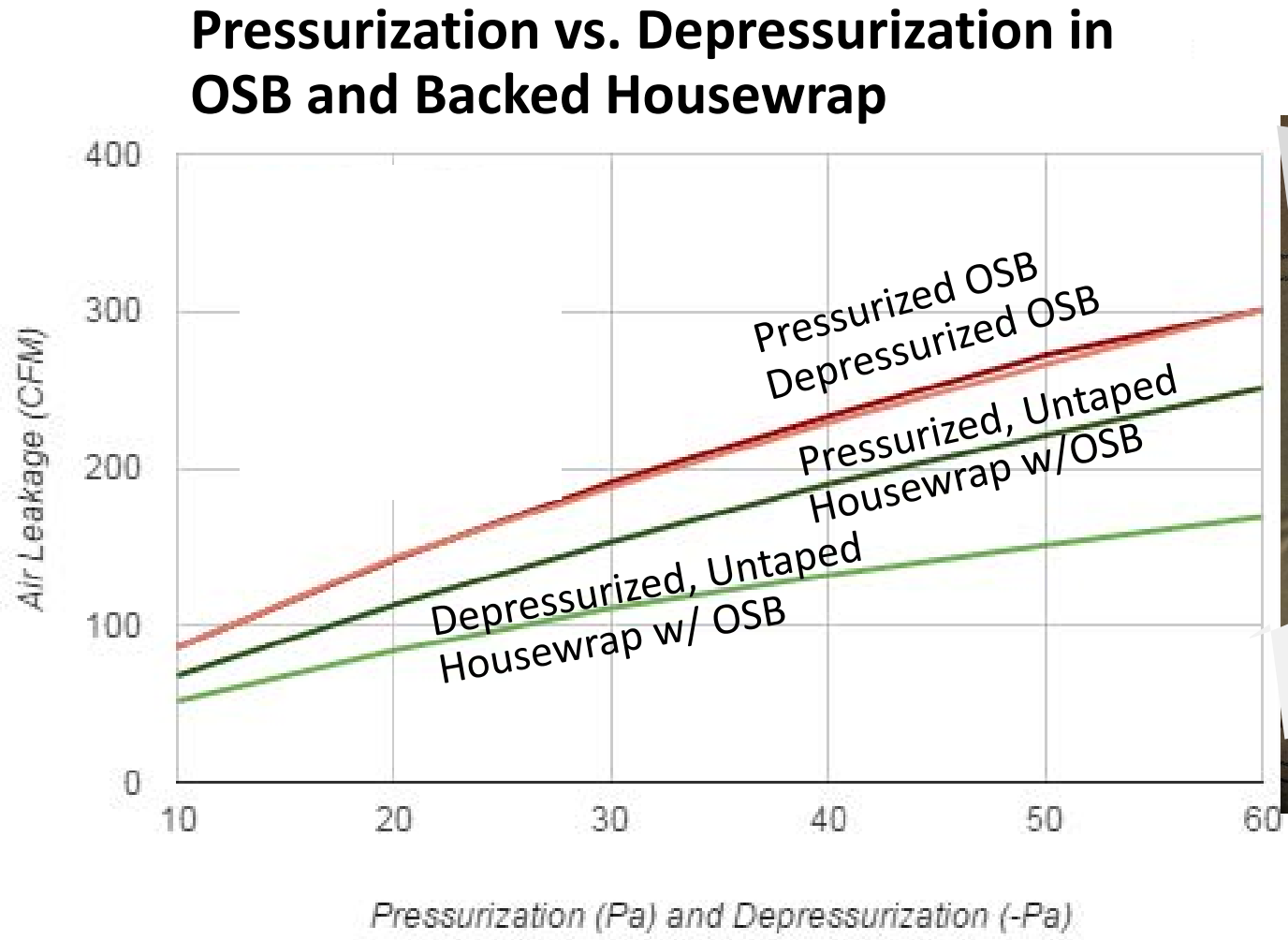
House Wrap Over Studs



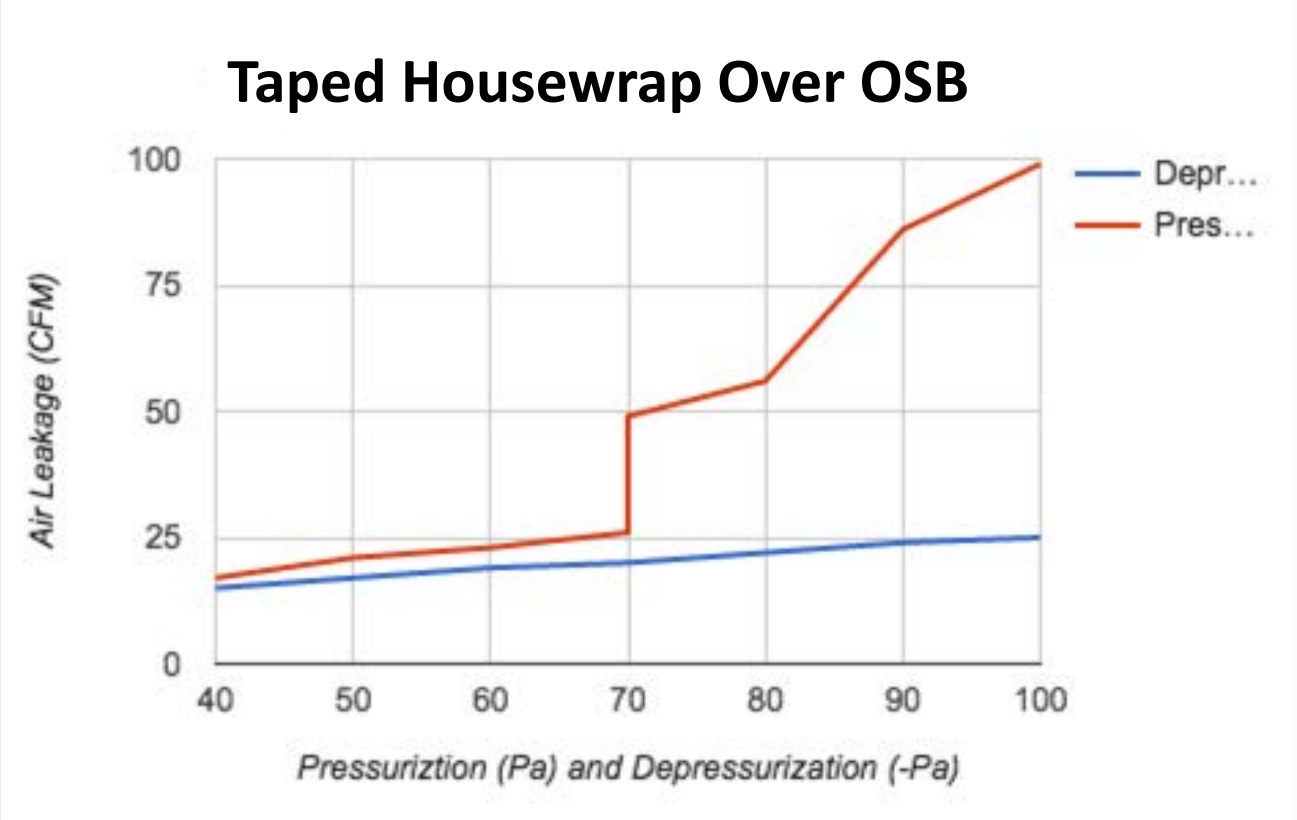
Housewrap on Bare Studs: 2 Products/ Taped vs Untaped



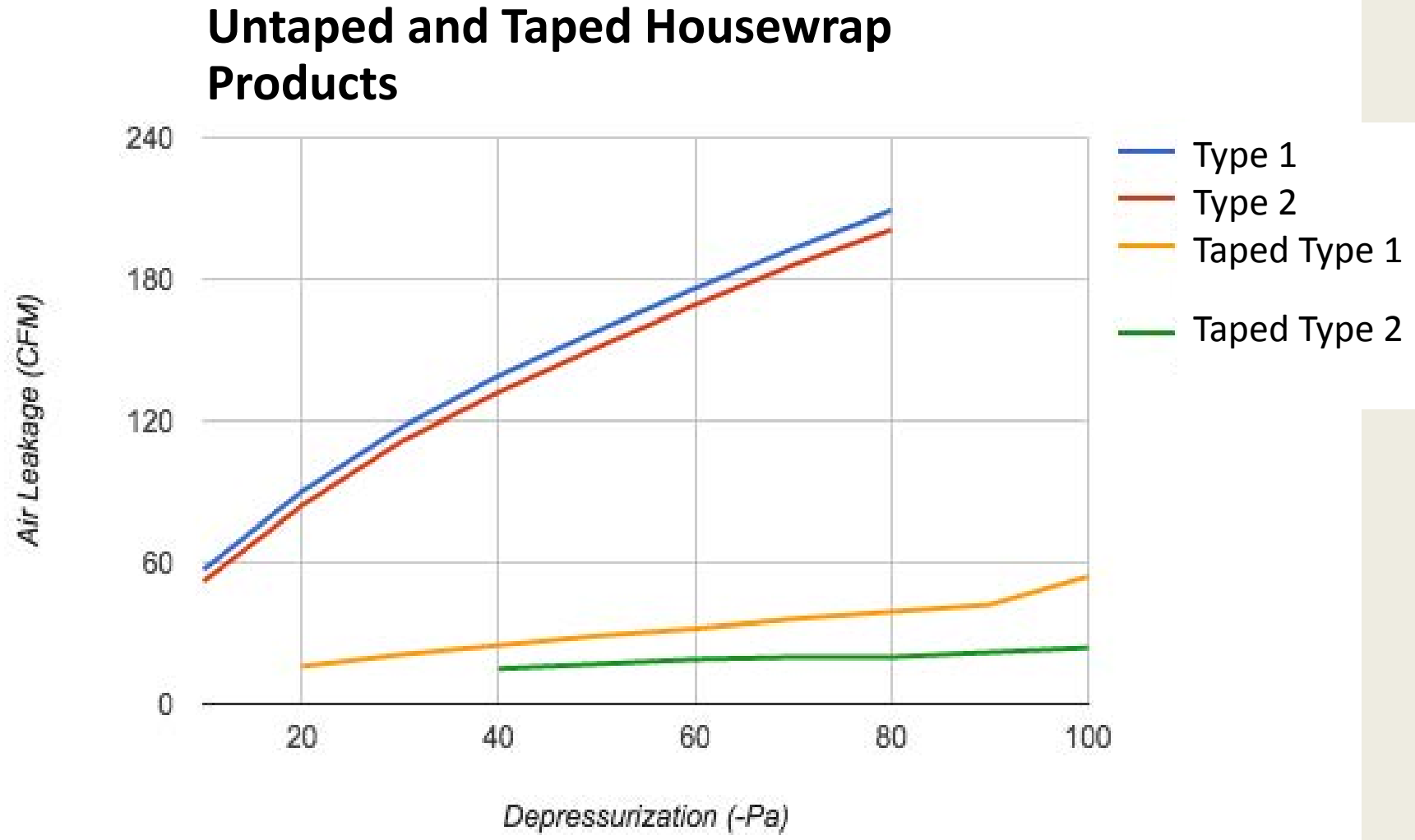
Pressurization vs. Depressurization



Housewrap – Depressurization vs Pressurization

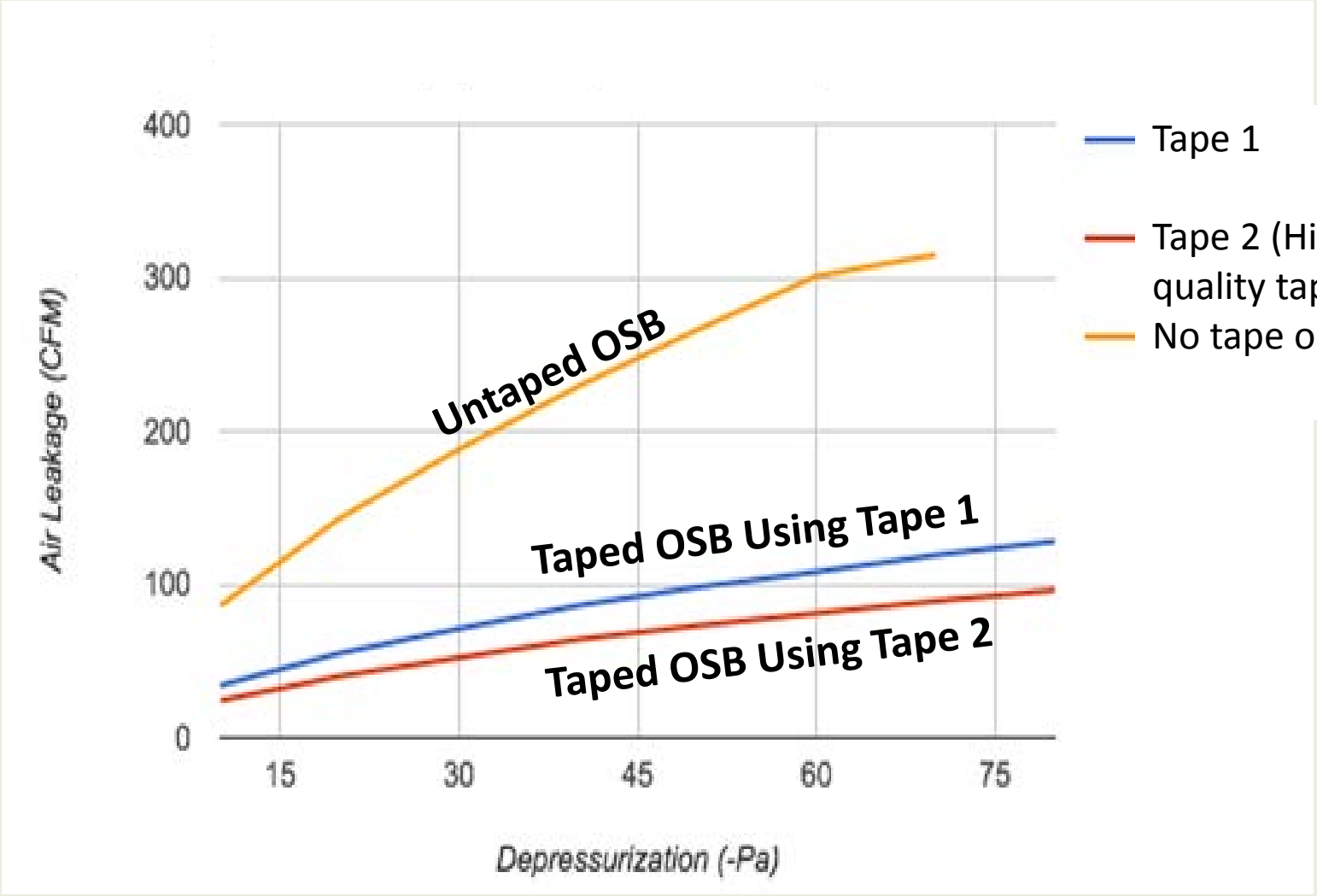


Housewrap on OSB: Comparison of 2 Brands



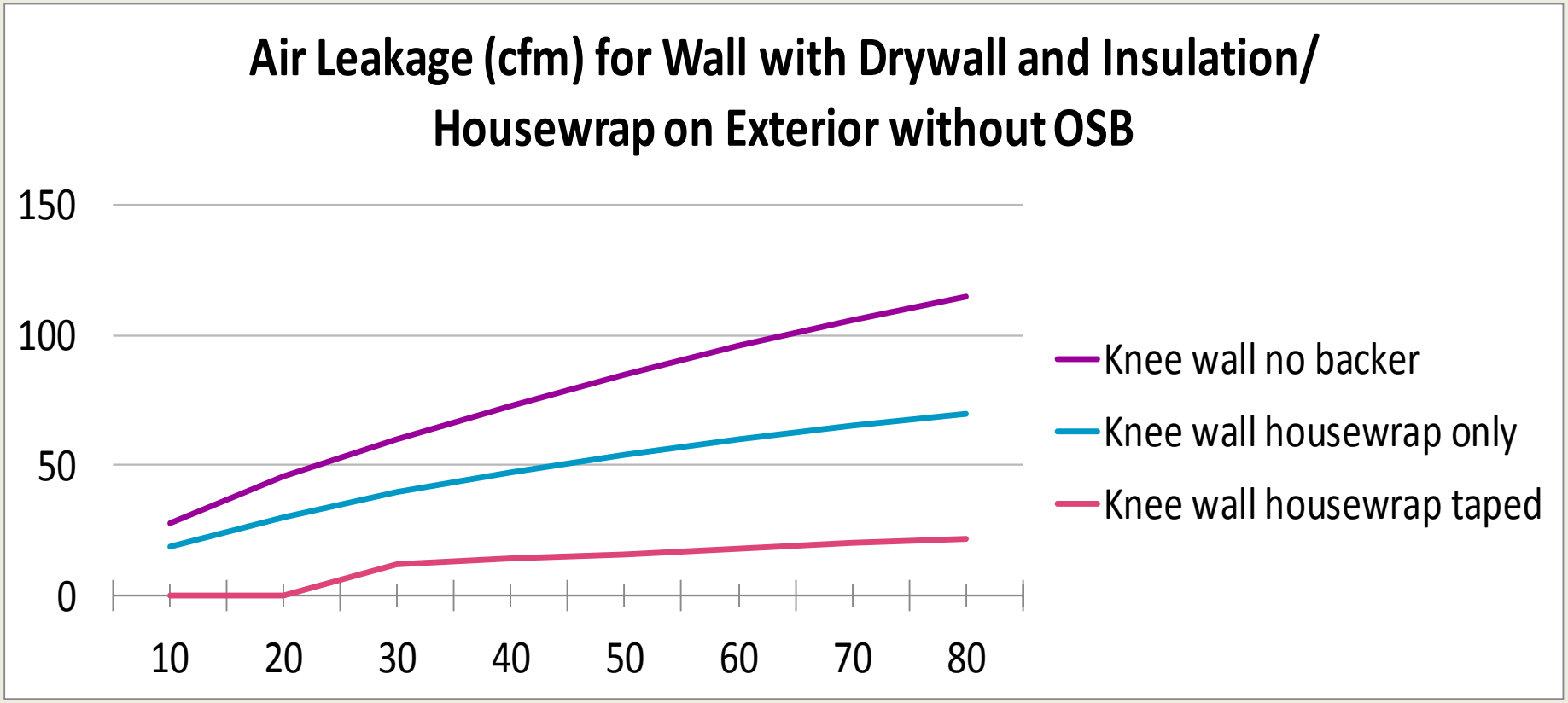
Sheathing Tape on OSB – Compared 2 Brands

Sheathing Tapes on OSB

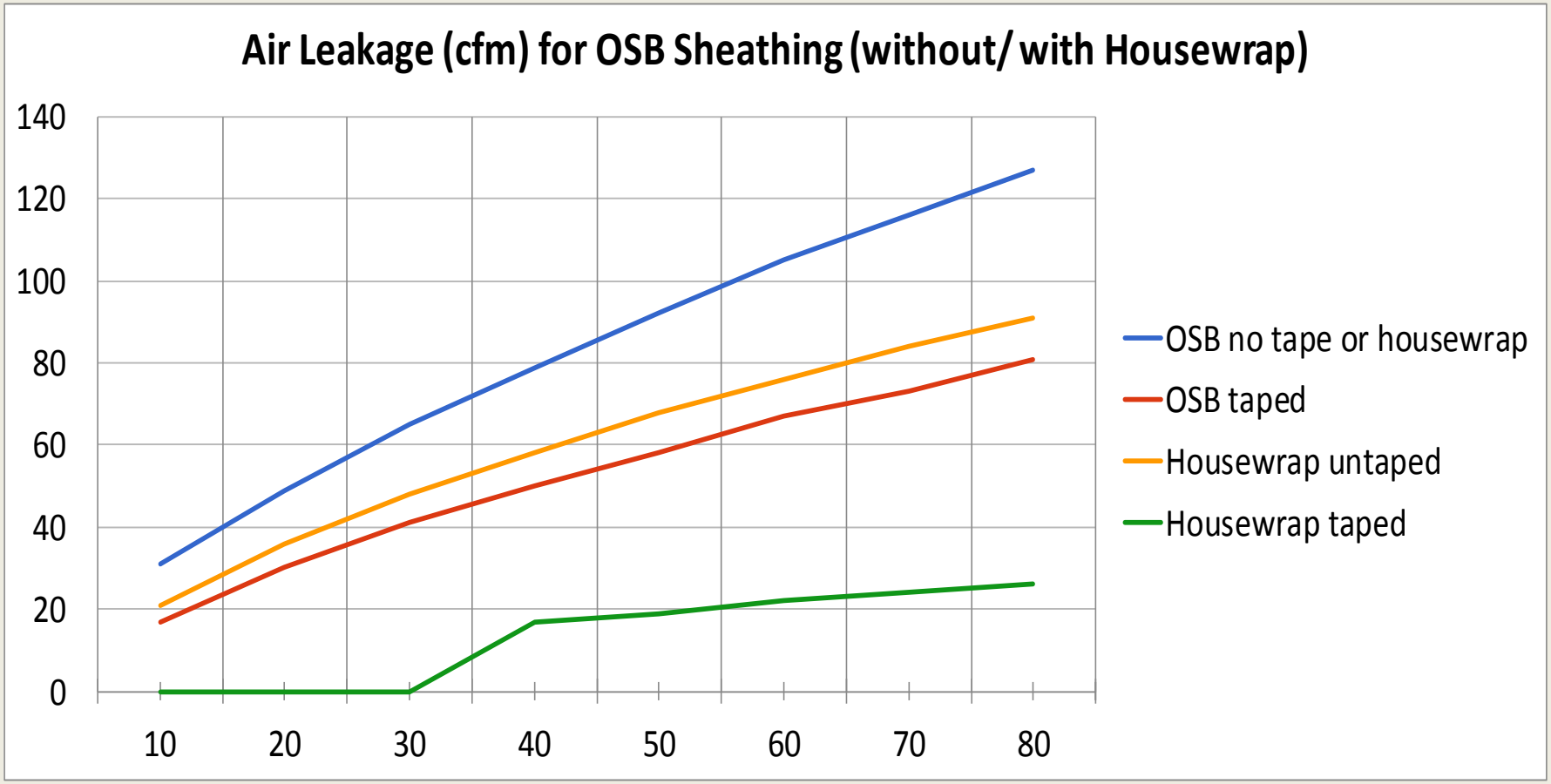


Drywall Added to the Interior

Leakage with Drywall/ Insulation Exterior Wall = Housewrap Only



Leakage with Drywall/ Insulation Exterior Wall = OSB with/ wo Hwrap



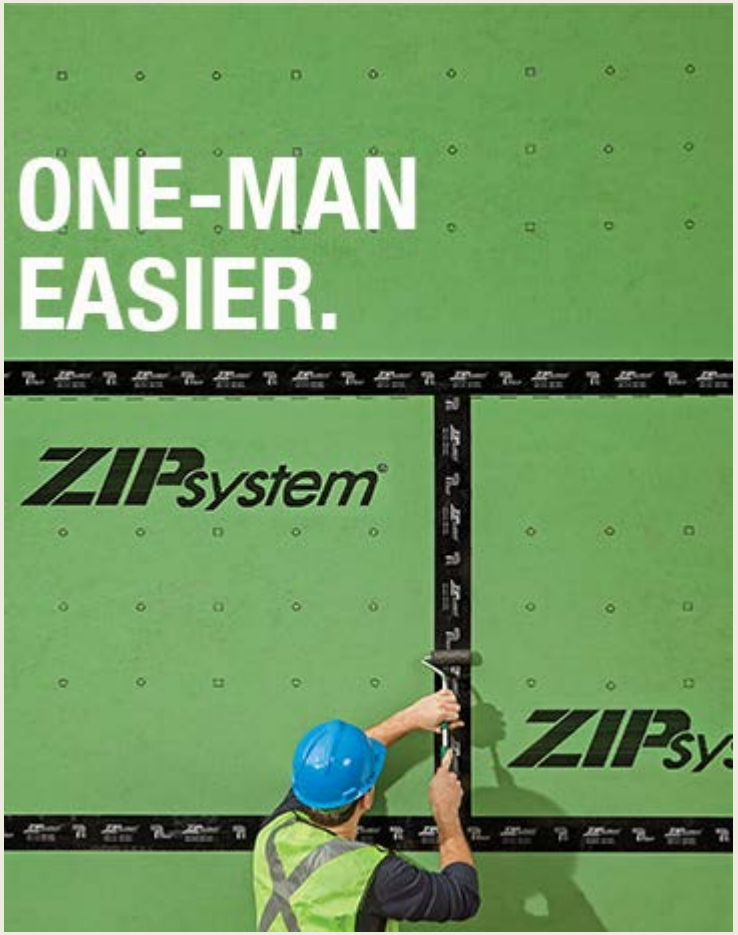
Housewrap Sealed?

Vertical and Horizontal Seams Sealed

Housewrap Sealed?

Housewrap Sealed?

Alternatives to Housewrap + Tape



DOE-Sponsored Energy Code Project

- Initial Survey of Energy Code Practices (250 new homes)
- Educational Programs (Current Stage)
- Final Survey (late summer, early fall)

2012 NC Code Briefly

- Insulation Backer Required
- Required Air Sealing
- 2 Options
  - Additional Air Sealing – All Mandatory
  - Blower Door Test – 5 ACH50

Insulation Backing Required

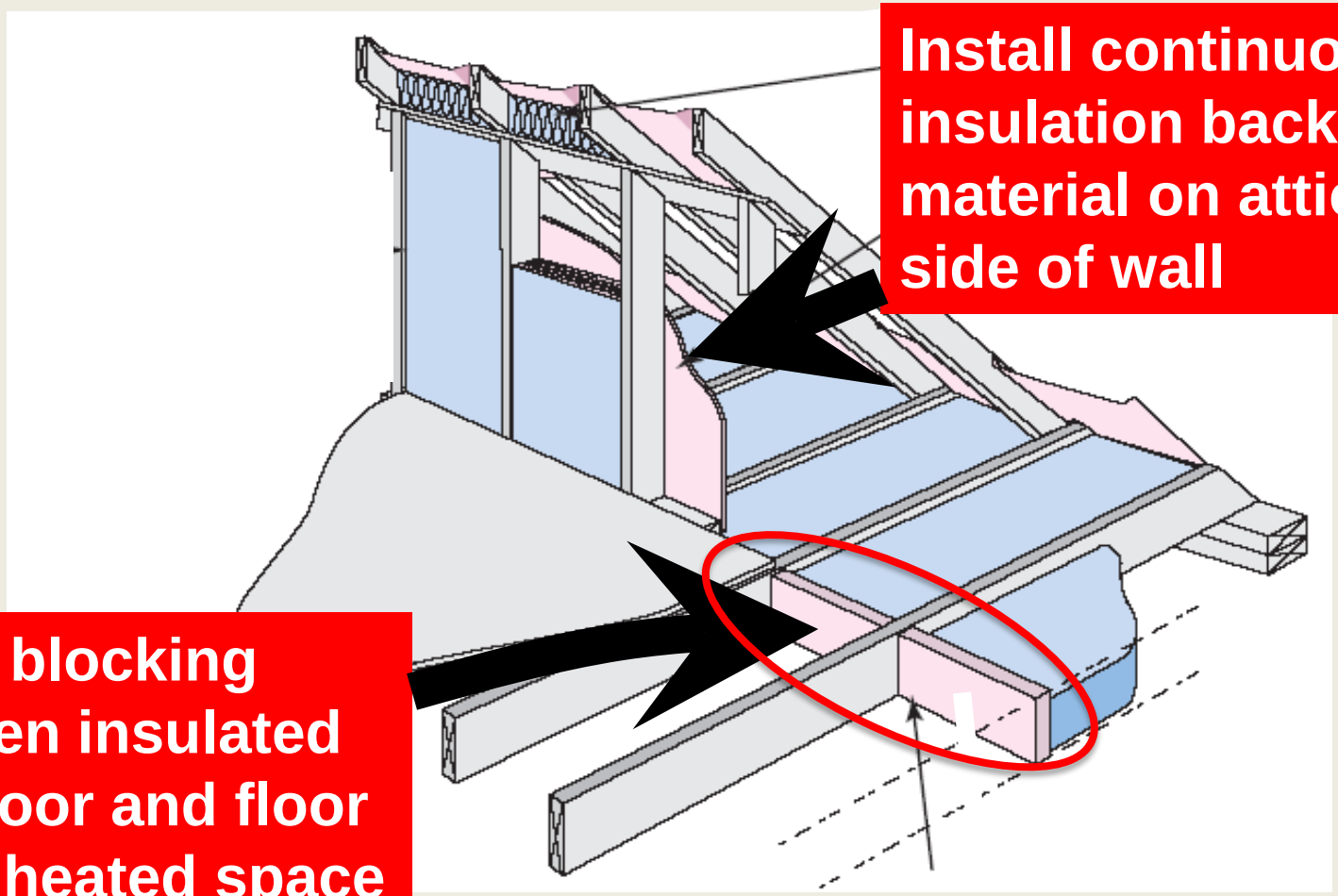
- Under the stair landing
- Behind tubs/ showers
- Behind fireplaces
- Behind knee walls

Required Air Sealing

- Chases
- Dropped Soffits
- Knee Wall Blocking
- Registers Sealed to Finish

Insulation Backing in the Field

Knee Walls – Blocking and Backing

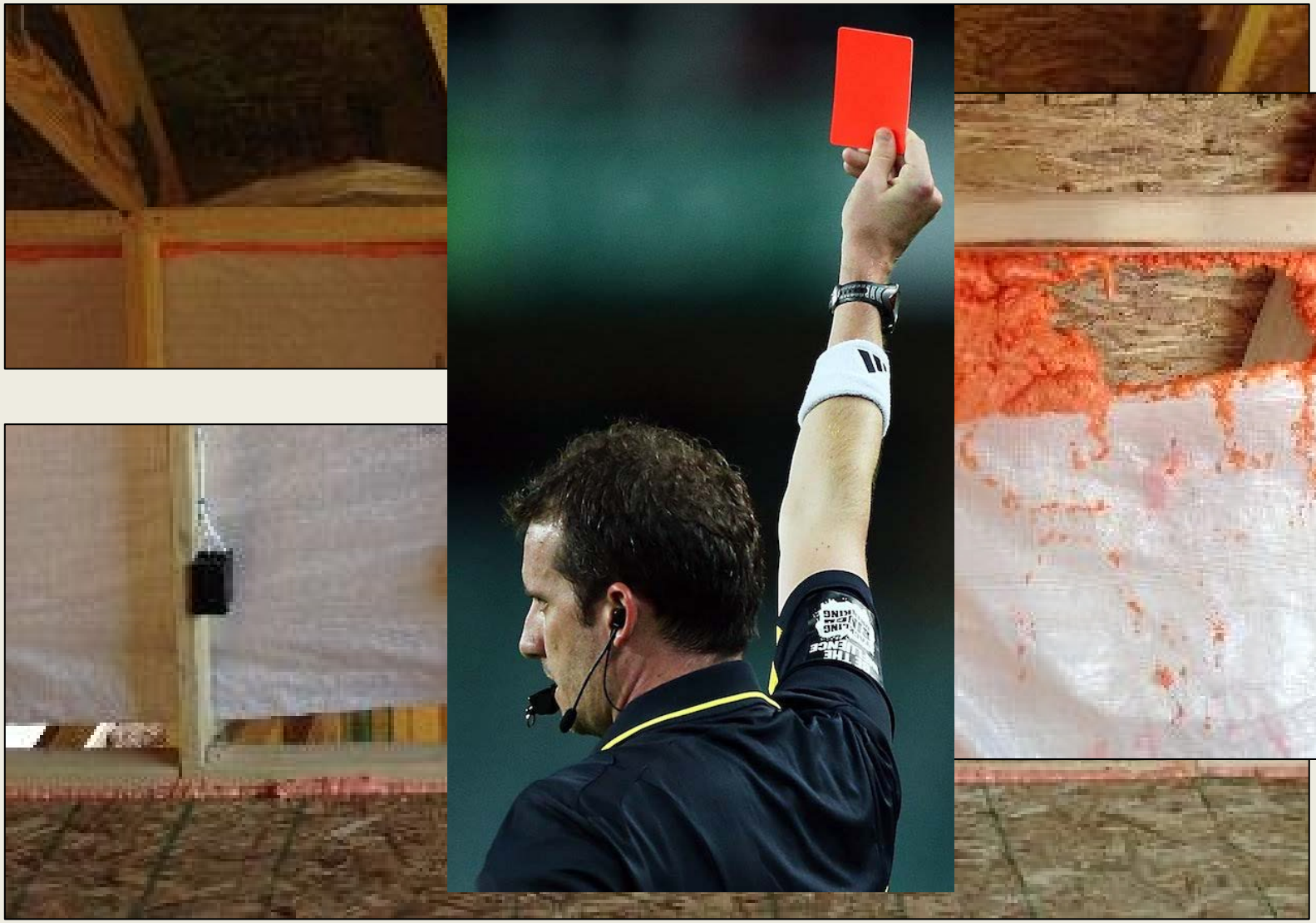


Install continuous insulation backing material on attic side of wall

Install blocking between insulated attic floor and floor under heated space

Insulation Backing in the Field – Many homes had gaps

How's This Insulation Backing?



MORE AIR LEAKAGE CONTROL

Two Options

- Air sealing table
- Blower door test

Sealed Top Plates:
Sill Sealer Visible in Attic

Air Sealing Table -- Bottom Plate Sealed?

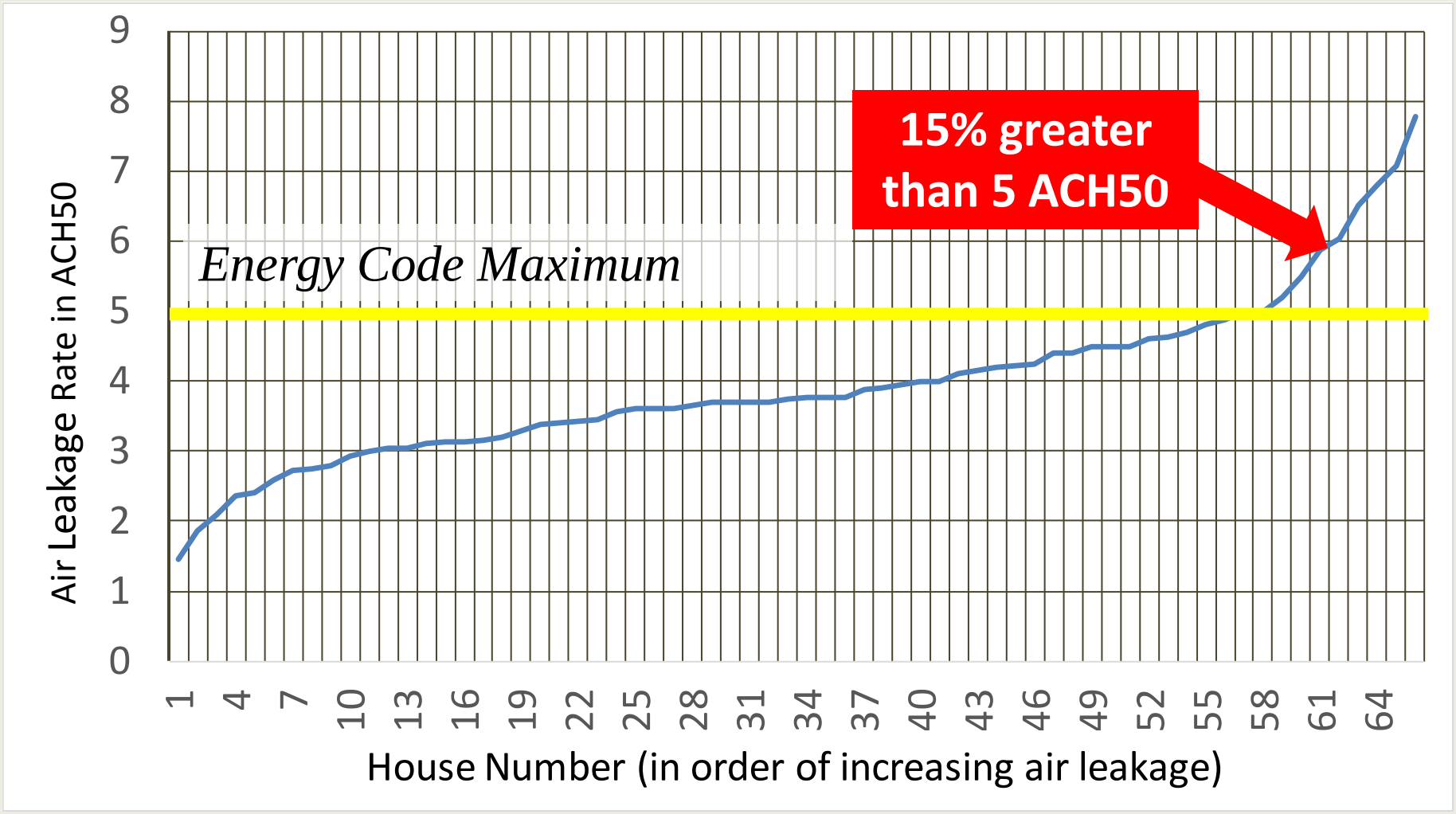
Garage sealed from conditioned space

Insulation contact air tight (ICAT) recessed lighting

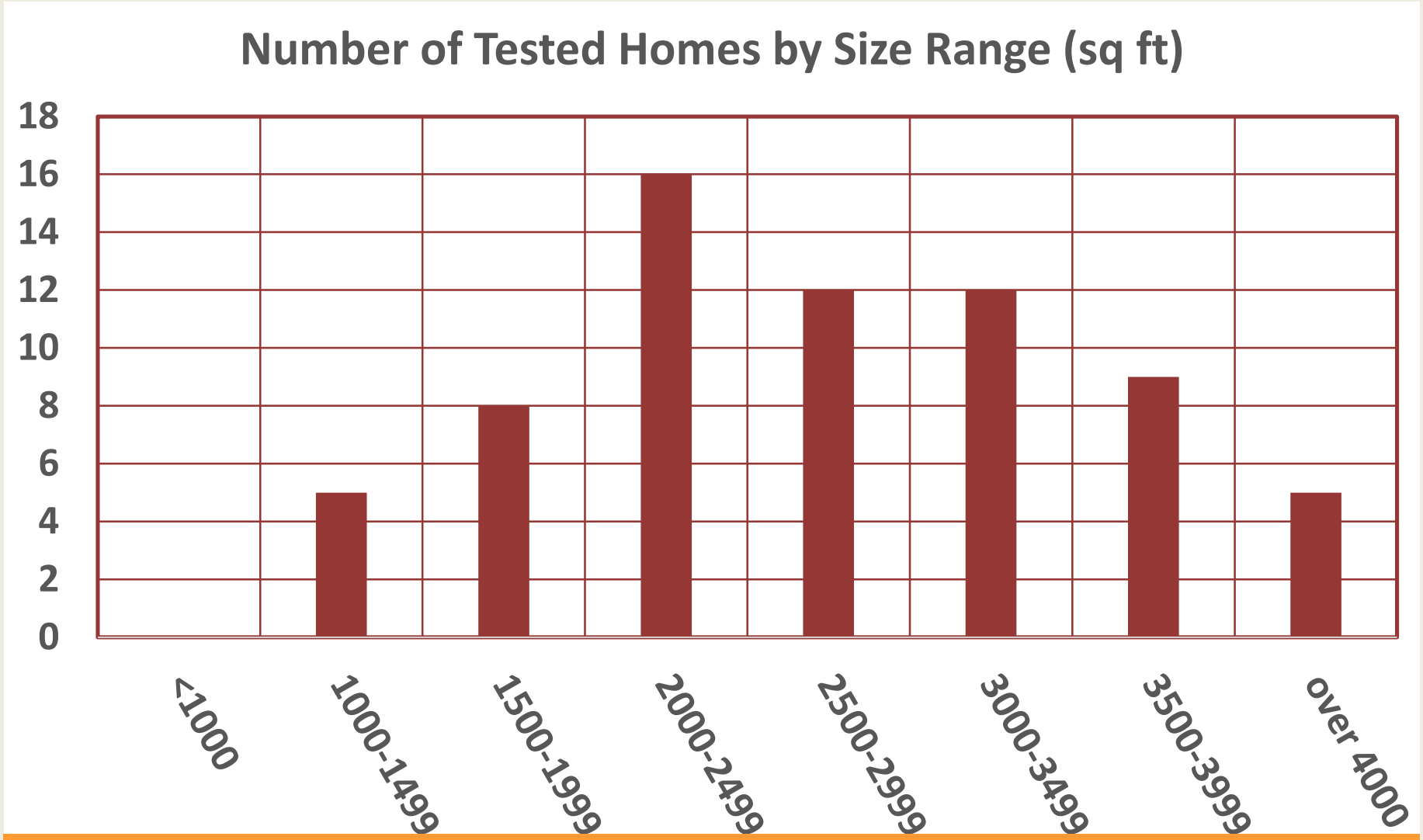
Option 2 -- Testing Option

1. 0.30 CFM50/Square Foot of Surface Area (SFSA) or
2. Five (5) air changes per hour (ACH50)

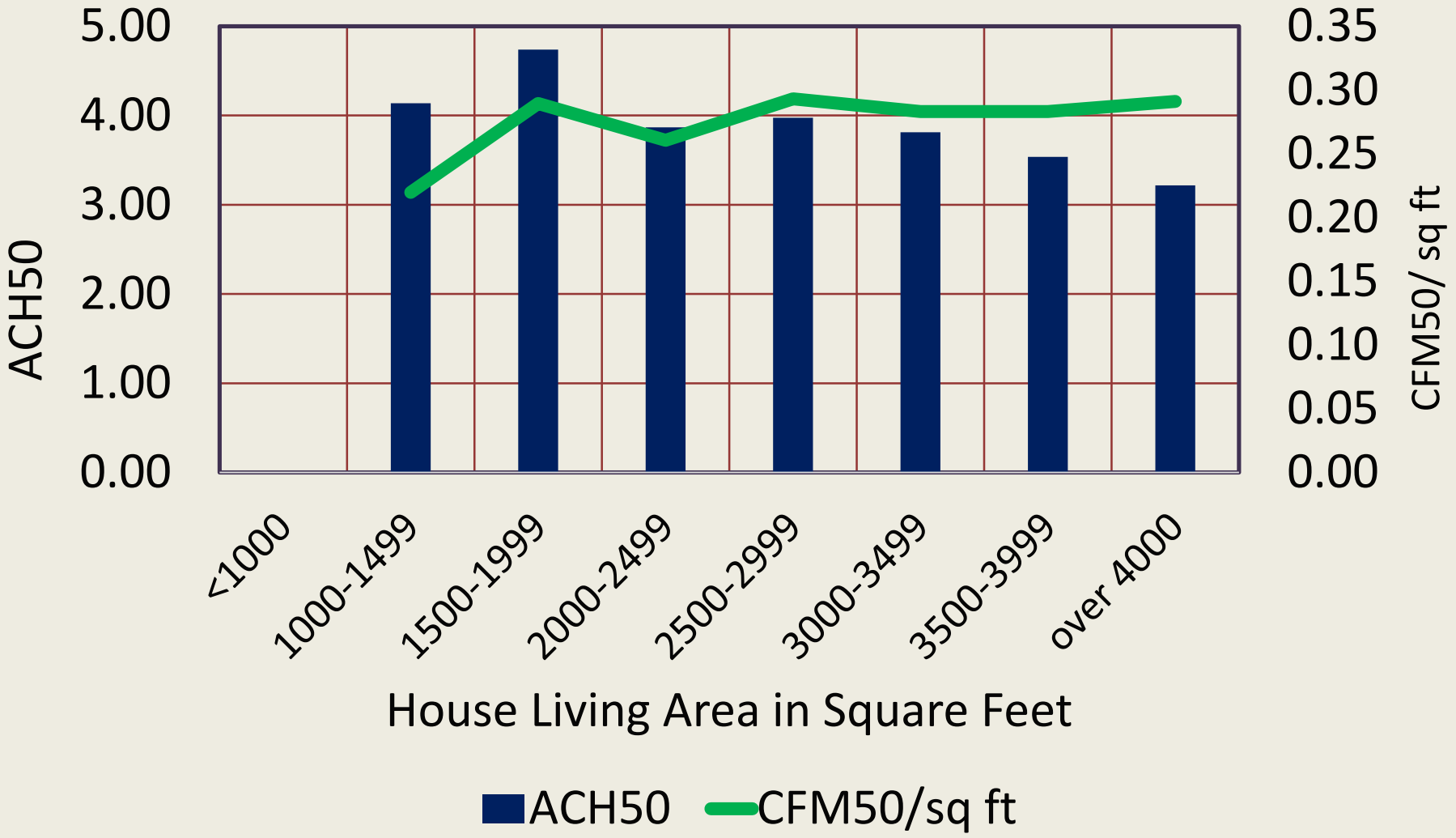
Results of Air Leakage Testing – 66 Homes



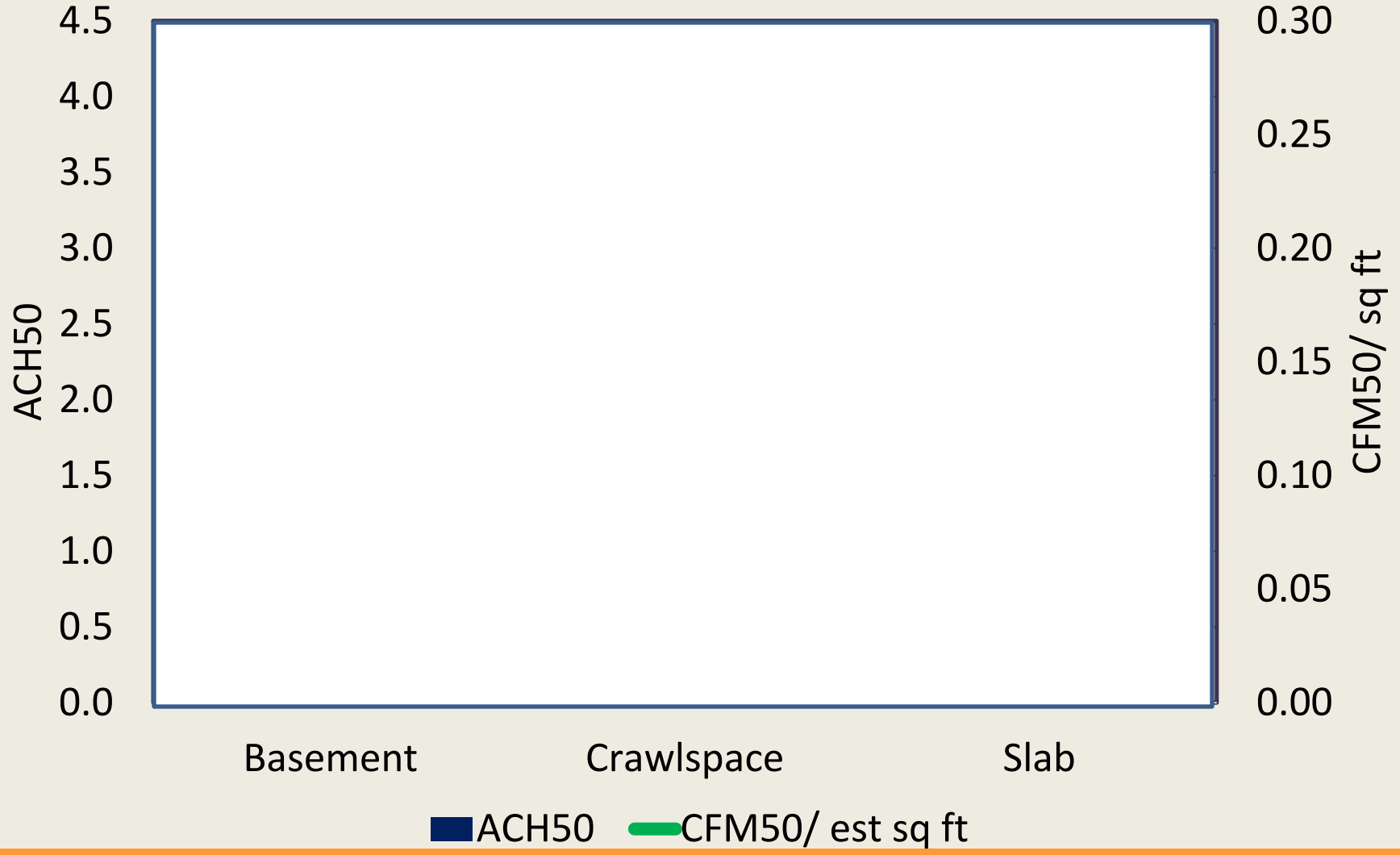
NC Survey Results for Air Leakage Tests



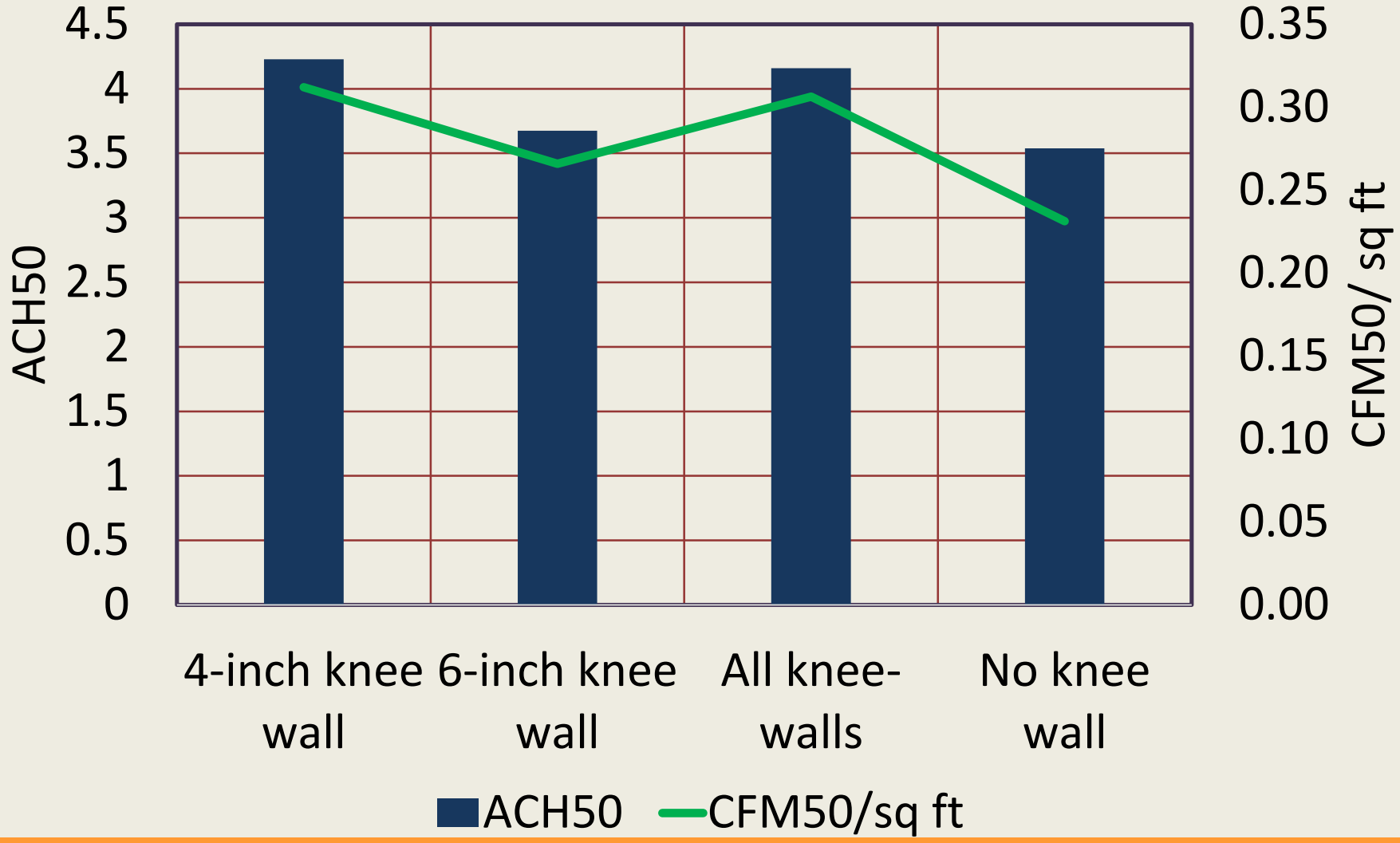
Air Leakage by House Size



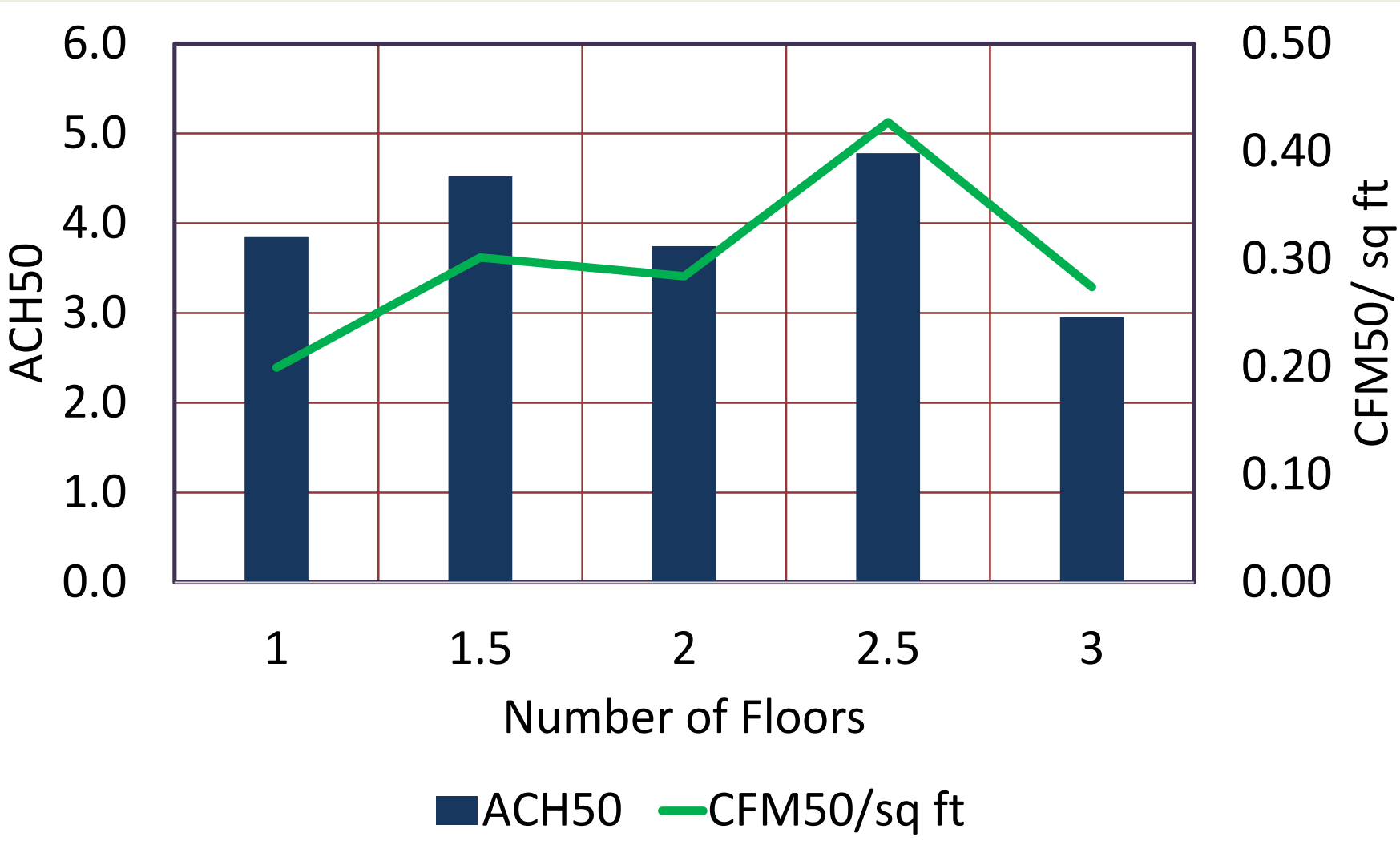
Air Leakage by Foundation Type



NC Study: Air Leakage and Knee Walls



Air Leakage and Number of Floors



Tightest Home

Air leakage = 1.45 ACH50
Total duct leakage = 4.6 CFM25/ 100 sq ft
Duct leakage to exterior = 0 CFM25/ 100 sq ft

Second Tightest

Air leakage = 1.87 ACH50
Total duct leakage = 5 CFM25/ 100 sq ft
Duct leakage to exterior = 1.1 CFM25/ 100 sq ft

Closed Crawl with Spray Foam

Spray Foam Roof Deck

Third Tightest

Air leakage = 2.1 ACH50
Total duct leakage = 4.8 CFM25/ 100 sq ft
Duct leakage to exterior = 1.7 CFM25/ 100 sq ft

Closed Crawl Space with Vinyl-Wrapped Batts

Third Tightest

Fourth Tightest

Air leakage = 2.4 ACH50
Total duct leakage = 7.8 CFM25/ 100 sq ft
Duct leakage to exterior = 4.8 CFM25/ 100 sq ft

Closed Crawl Space with Spray Foam Walls

Fiberglass Batts in Attic

Fifth Tightest

Air leakage = 2.4 ACH50
Total duct leakage = 2.7 CFM25/ 100 sq ft
Duct leakage to exterior = 1.6 CFM25/ 100 sq ft

Slab-on-Grade

Blown Fiberglass in Attic

Leakiest House

The following were “not okay”

- Knee wall backing (housewrap not sealed)
- Blocking under knee walls
- Sealed HVAC boots (to interior finish)
- Recessed lighting
- Sill plates
- Attic stair – no seal between jamb and framing
- Fan boxes in attic

Leakiest House

Air leakage = 7.8 ACH50
Total duct leakage = 8.2 CFM25/ 100 sq ft
Duct leakage to exterior = 2.8 CFM25/ 100 sq ft

Slab-on-Grade

Fiberglass Batts in Attic

Unsealed Items:

- Knee wall backing (housewrap)
- Blocking under knee walls
- HVAC boots (to interior finish)
- Recessed lighting
- Sill plates
- Attic stair –between jamb and framing
- Fan boxes in attic

Second Leakiest

Air leakage = 7.07 ACH50
Total duct leakage = 8.2 CFM25/ 100 sq ft
Duct leakage to exterior = 5.3 CFM25/ 100 sq ft

Slab-on-Grade

Fiberglass Batts in Attic

Unsealed Items:

- Blocking under knee wall
- Between garage and house

Third Leakiest

Air leakage = 6.8 ACH50
Total duct leakage = 5.3 CFM25/ 100 sq ft
Duct leakage to exterior = 4.6 CFM25/ 100 sq ft

Slab-on-Grade

Fiberglass Batts in Attic

Unsealed Items:

- Knee wall backing missing
- Recessed lights unsealed to finish
- HVAC boots (to interior finish)
- Semiconditioned storage room had substantial leakage

Breakdown of Insulation Quality

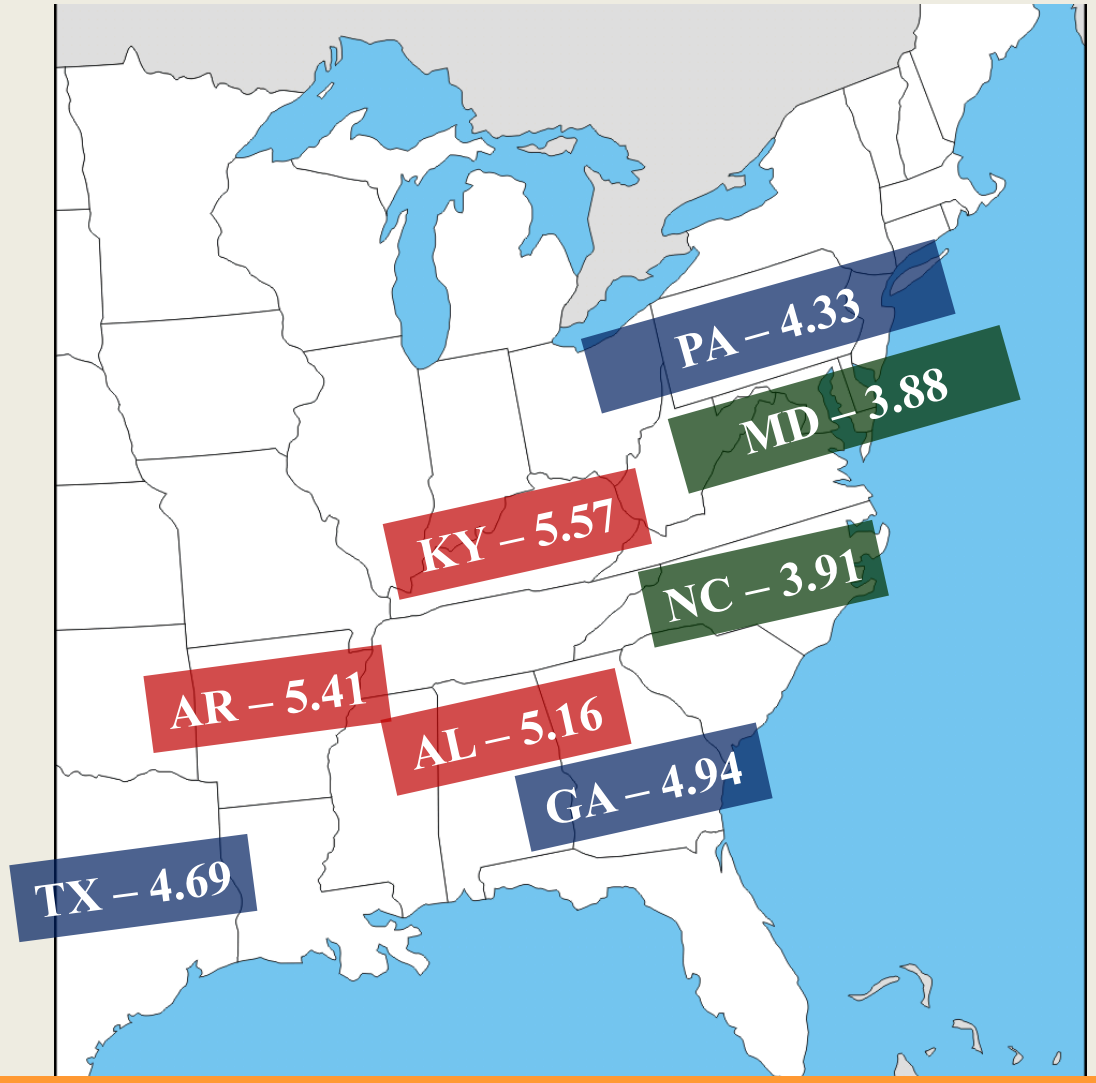
Location of Insulation	Quality 1	Quality 2	Quality 3	Total
Floor Insulation	45	36	1	**82**
Wall Insulation	39	43	0	**82**
Attic Insulation	99	38	6	**143**

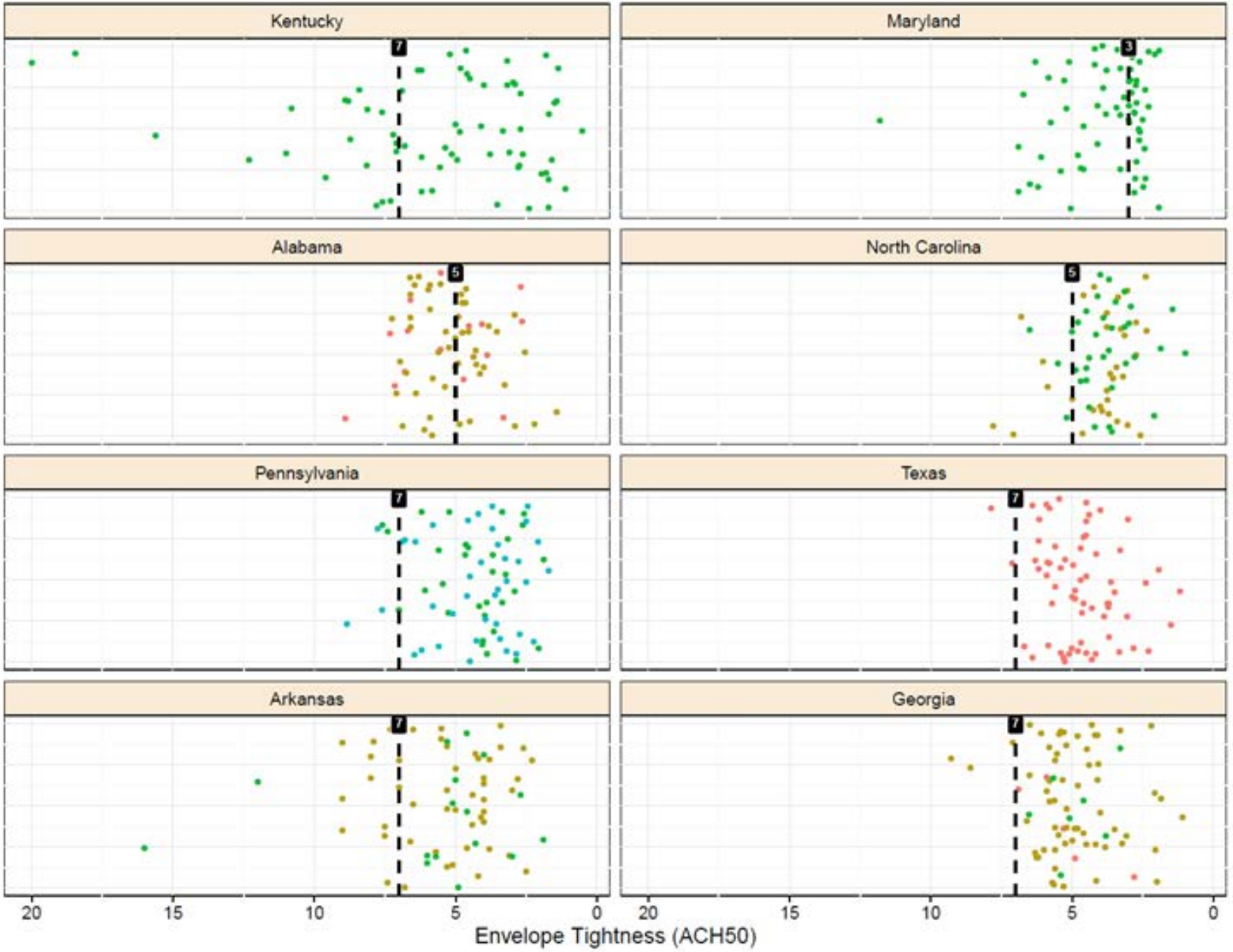
Less than Grade 1:

- 45% of floors
- 52% of walls
- 31% of ceilings/ attics

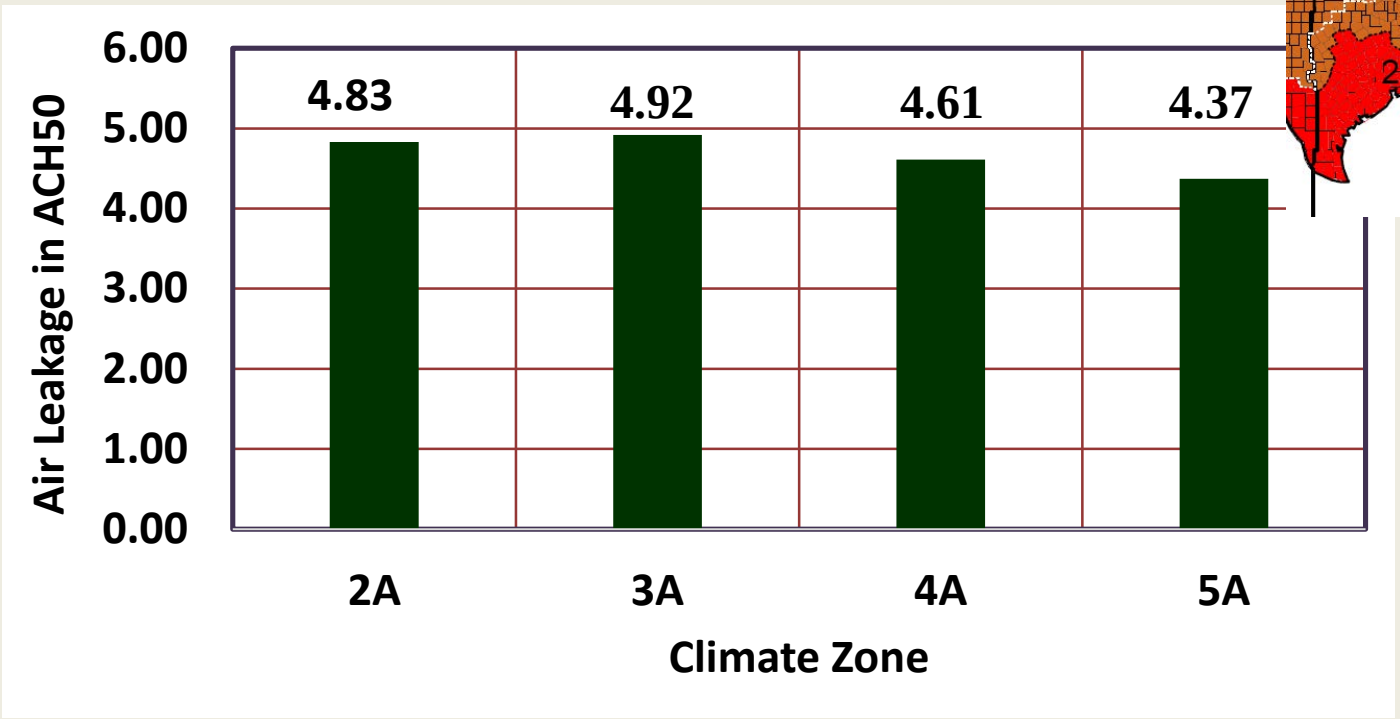
DOE Code Project Teams

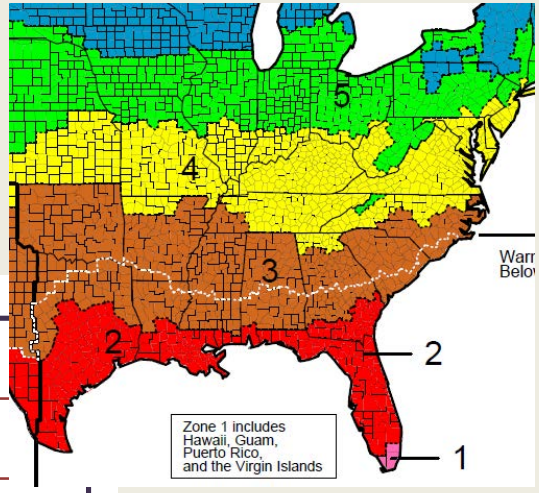
DOE Code Project Teams – Average ACH50




Kentucky
Maryland
Alabama
North Carolina
Pennsylvania
Texas
Arkansas
Georgia
7
3
5
5
7
7
7
7
20
15
10
5
0
Envelope Tightness (ACH50)
Climate Zone
CZ 2
CZ 3
CZ 4
CZ 5

Average Air Leakage by Climate Zone





	All States	AL	AR	GA	KY	MD	NC	PA	TX
2A	4.83	5.36		5.16					4.69
3A	4.92	5.10	5.31	4.92	9.28		4.03		
4A	4.61		5.69	4.91	5.57	3.90	3.80	4.28	
5A	4.37							4.37	

Air Leakage by State and Foundation

	All States	AL	AR	GA	KY	MD	NC	PA	TX
Slab-on-grade	4.81	5.15	6.13	4.87	4.94	4.20	4.02	6.15	4.69
Crawlspace	5.19	4.65	5.70	5.07	7.30	6.43	3.84		
Basement	4.19	4.89		5.28	5.00	3.57	3.51	4.09	
All Foundations	4.74	5.16	5.41	4.94	5.57	3.88	3.91	4.33	4.69

Note: Yellow = Leakiest and Blue = Tightest

Knee Walls and Air Leakage

	All States	AL	GA	KY	NC	TX
4 inch Knee Wall	4.98	4.97	6.47	7.28	4.23	4.65
6 inch Knee Wall	5.31	5.61	4.84	18.45	3.67	
All Knee Walls	5.02	4.99	5.33	7.94	4.16	4.65
No Knee Wall	4.61	5.32	4.87	4.62	3.54	5.37
% Greater	8.9%	-6.2%	9.3%	71.8%	17.5%	-13.5%

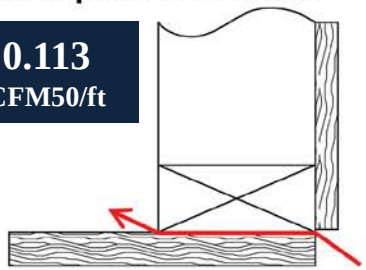
Number of Homes	All States	AL	GA	KY	NC	TX
No Knee Wall	384	34	62	49	27	31
With Knee Walls	137	31	10	17	40	24

Examples of Other Studies – Prioritizing Air Leakage Measures

- Characterization of Air Leakage in Residential Structures by D. Wolf of Owens Corning
  - Study on different air sealing measures (Next Slide)
- Matt Braman and Bruce Manclark report
  - 2014 ACEEE Summer Study on Energy Effic. in Bldgs
  - 50 homes sealed top plates/ 40 homes with no treatment
  - Average reduction in air leakage of 15%
- David Treleven, Advanced Energy
  - Statistical study on air leakage effectiveness in 944 homes
- Martin Halladay, Green Building Advisor, (Aug/13)
  - Getting the Biggest Bang for Your Air-Sealing Buck

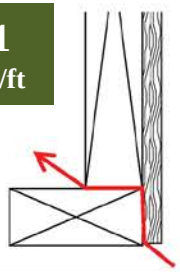
Bottom plate-to-subfloor

0.113 CFM50/ft



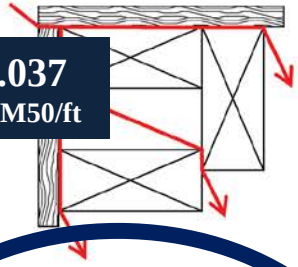
Band joist-to-plate

0.171 CFM50/ft



Outside corner

0.037 CFM50/ft

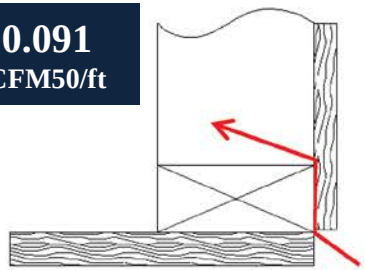


Light switch

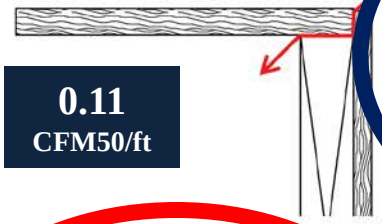
1.4 CFM50

Plate-to-sheathing

0.091 CFM50/ft



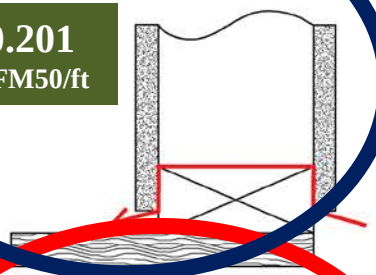
Band joist-to-subfloor



0.11 CFM50/ft

Garage wall base

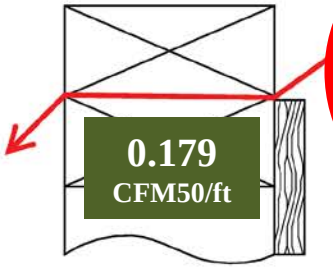
0.201 CFM50/ft



Electrical outl

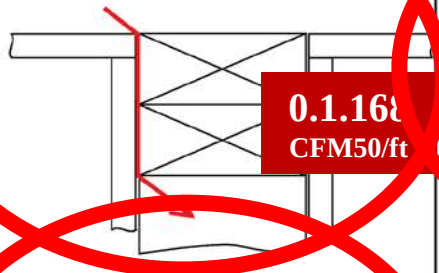
2.62 CFM50

Double top plate



0.179 CFM50/ft

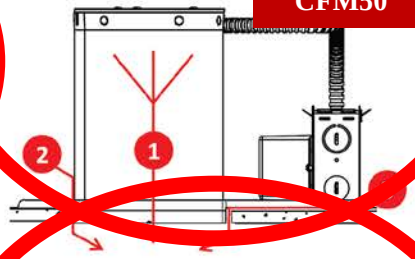
Drywall-to-top plate



0.1.168 CFM50/ft

Recessed light

9.1 CFM50

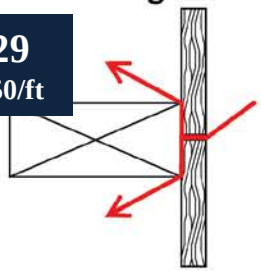


Electrical outlet (ext.)

2.79 CFM50

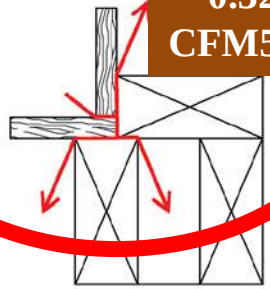
Vertical sheathing-to-stud

0.129 CFM50/ft



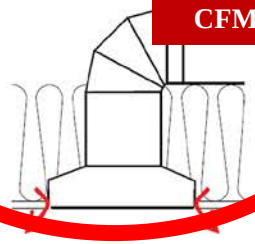
Inside corner

0.325 CFM50/f



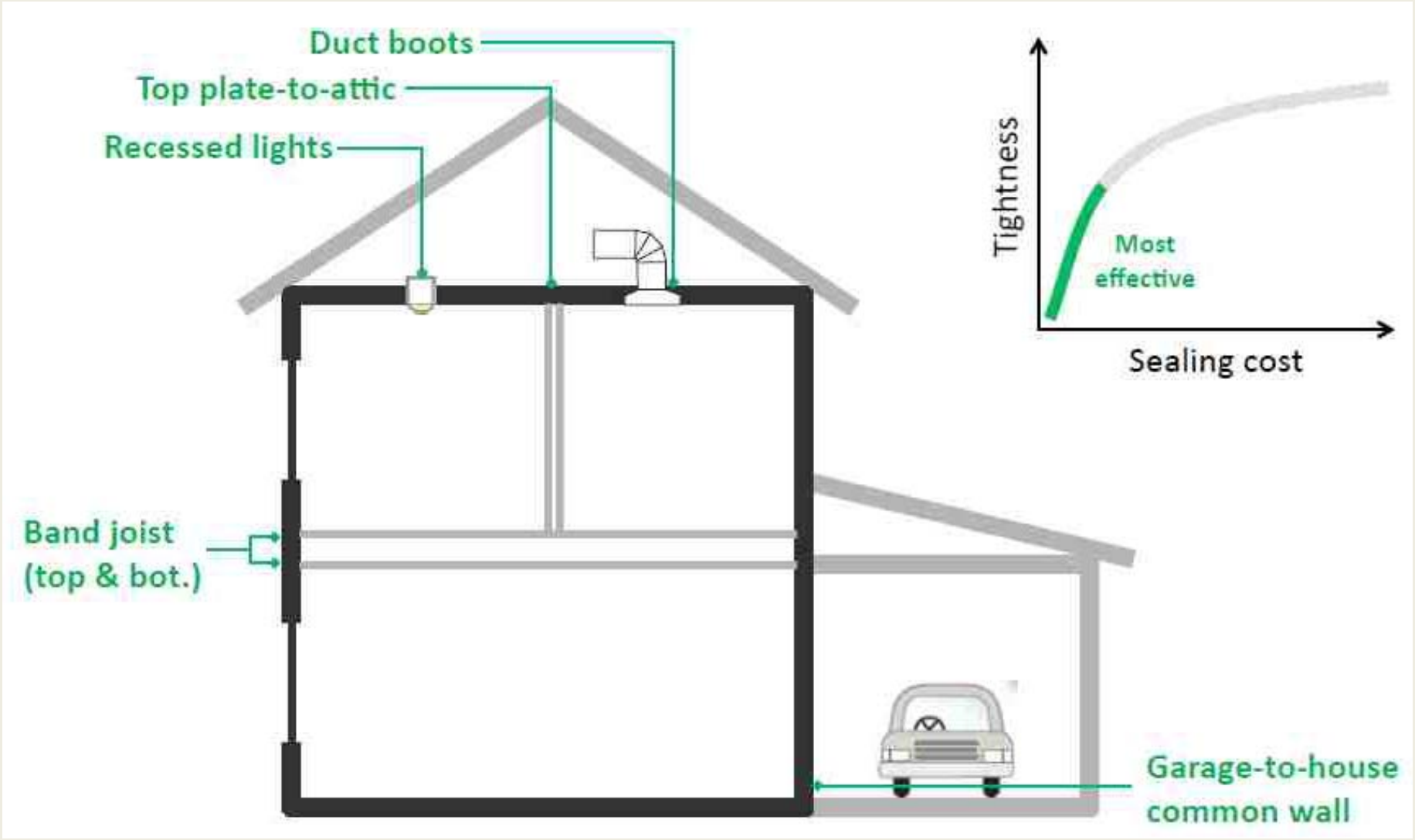
Duct boot

7.7 CFM50



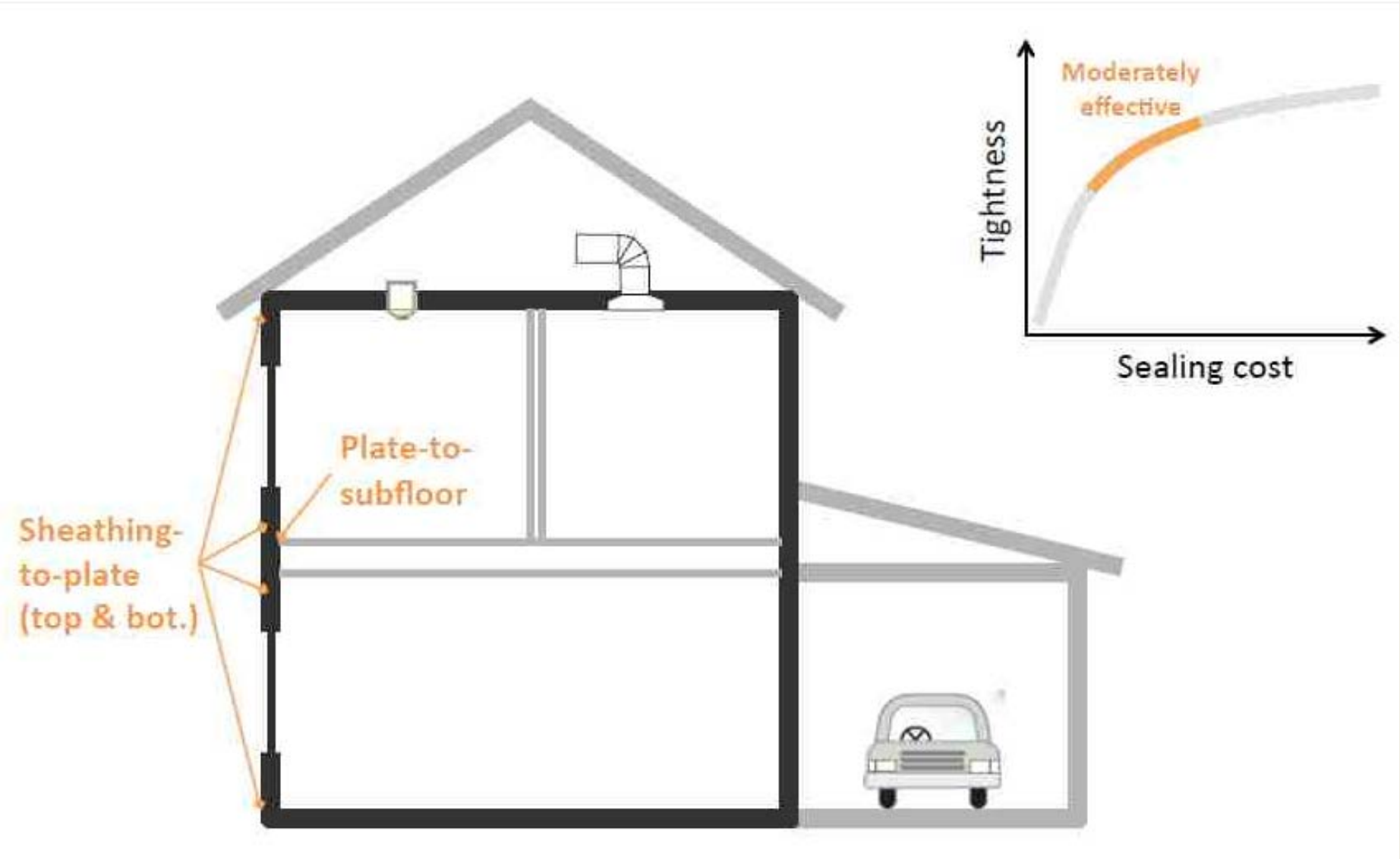
Wolf and Tyler, Owens Corning

Highest Priority Joints to Seal



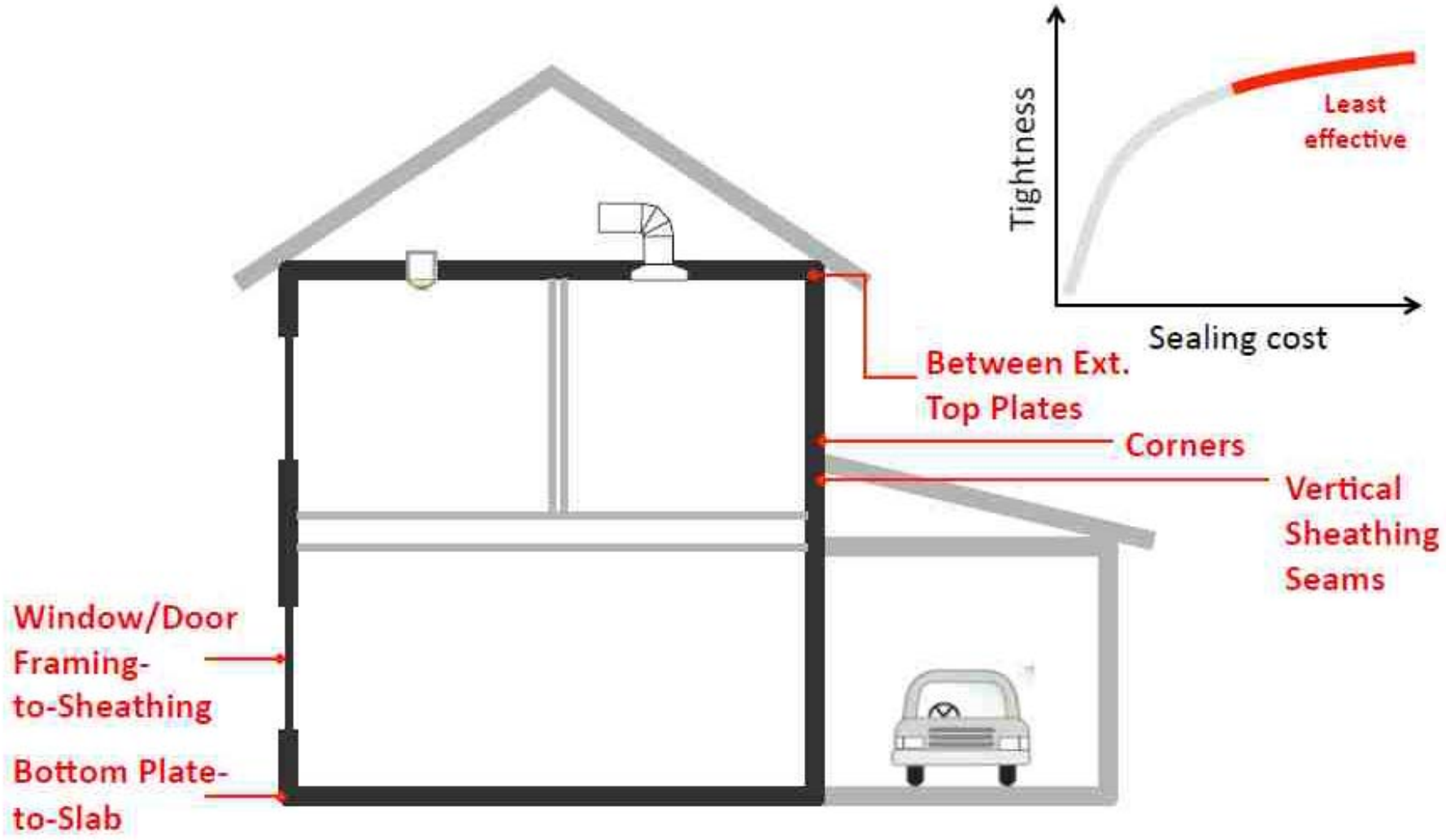
http://www.greenbuildingadvisor.com/blogs/dept/musings/getting-biggest-bang-your-air-sealing-buck

Moderate Priority Joints to Seal



http://www.greenbuildingadvisor.com/blogs/dept/musings/getting-biggest-bang-your-air-sealing-buck

Least Effective Joints to Seal



http://www.greenbuildingadvisor.com/blogs/dept/musings/getting-biggest-bang-your-air-sealing-buck

Questions? Comments! Opinions$

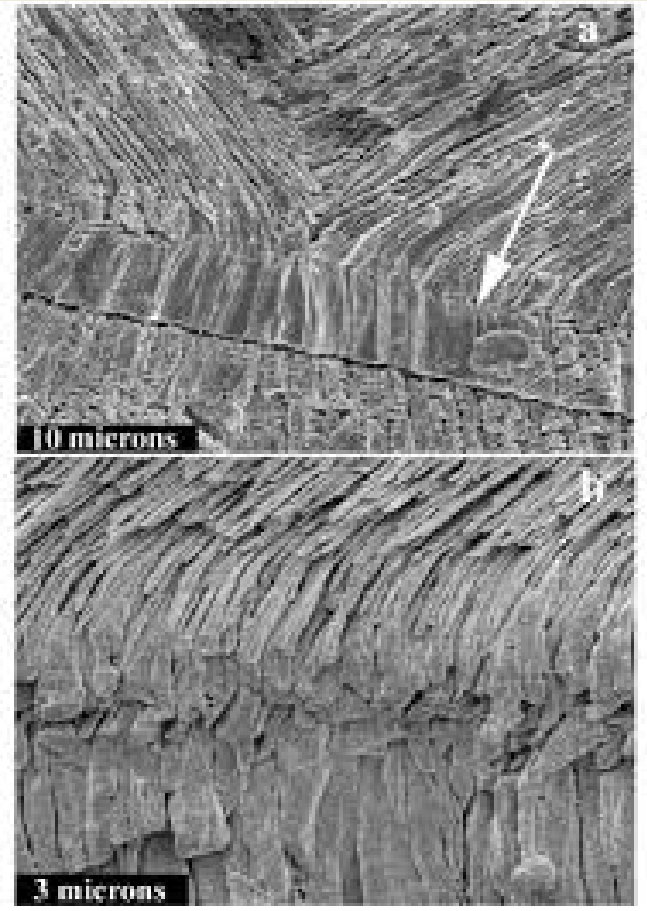
Air Leakage and Number of Stories

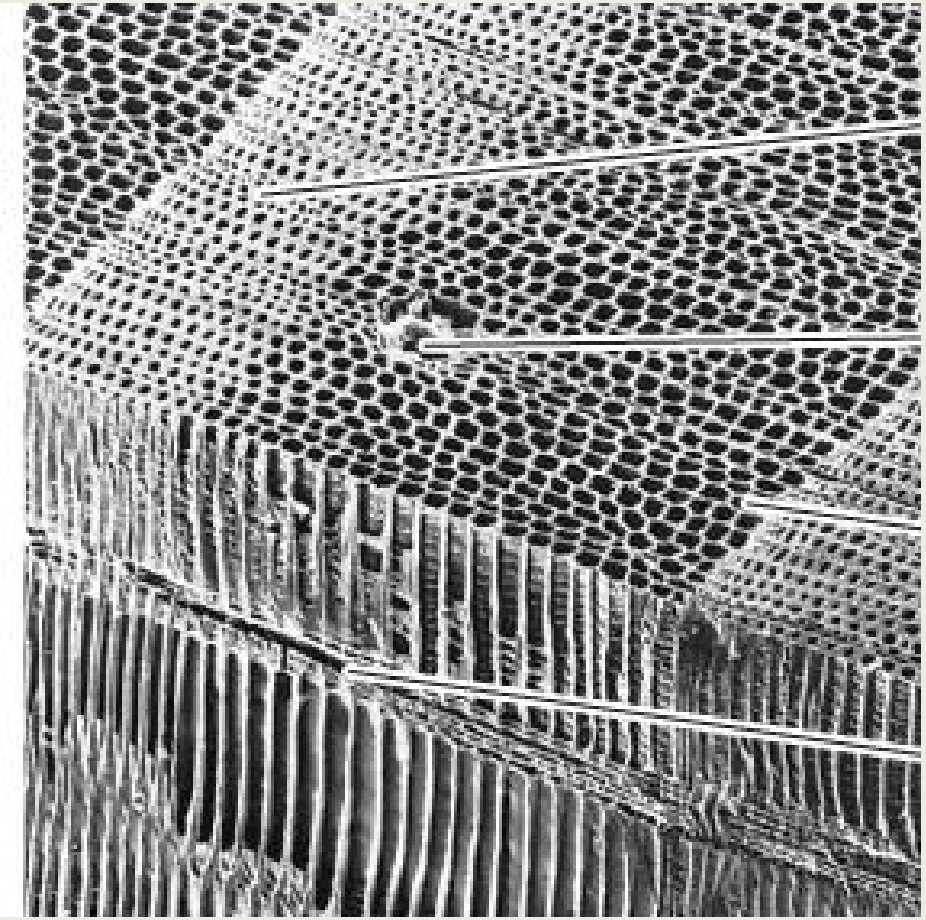
	All States	AL	AR	GA	KY	MD	NC	PA	TX
1	5.16	5.04	6.85	5.06	5.51	7.27	3.84	5.95	4.68
1.5	4.41					4.70	4.52		2.30
2	4.61	5.32	5.30	5.00	5.67	3.85	3.74	4.05	4.93
2.5	3.42					3.29	4.78		
3	4.53	2.90		4.54		4.85	2.95	4.98	4.10

Number of Homes	All States	AL	AR	GA	KY	MD	NC	PA	TX
1	125	29	6	5	40	2	12	5	26
1.5	16	0	0	0	0	2	13	0	1
2	223	35	1	30	26	29	37	37	28
2.5	24	0	0	0	0	22	2	0	0
3	51	1	0	14	0	7	3	17	9

Air tight?

Wood Is Not Smooth and Not Solid to Air





1772 CFM50
5,455 sq ft


1772 CFM50
5,455 sq ft

Tightest

But Even Lionel Messi is Human