ENERGY DESIGN

conference & expo

Building Science Fundamentals

Hygrothermics and the principle of continuous control layers

PETER YOST

BUILDING - WRIGHT

In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

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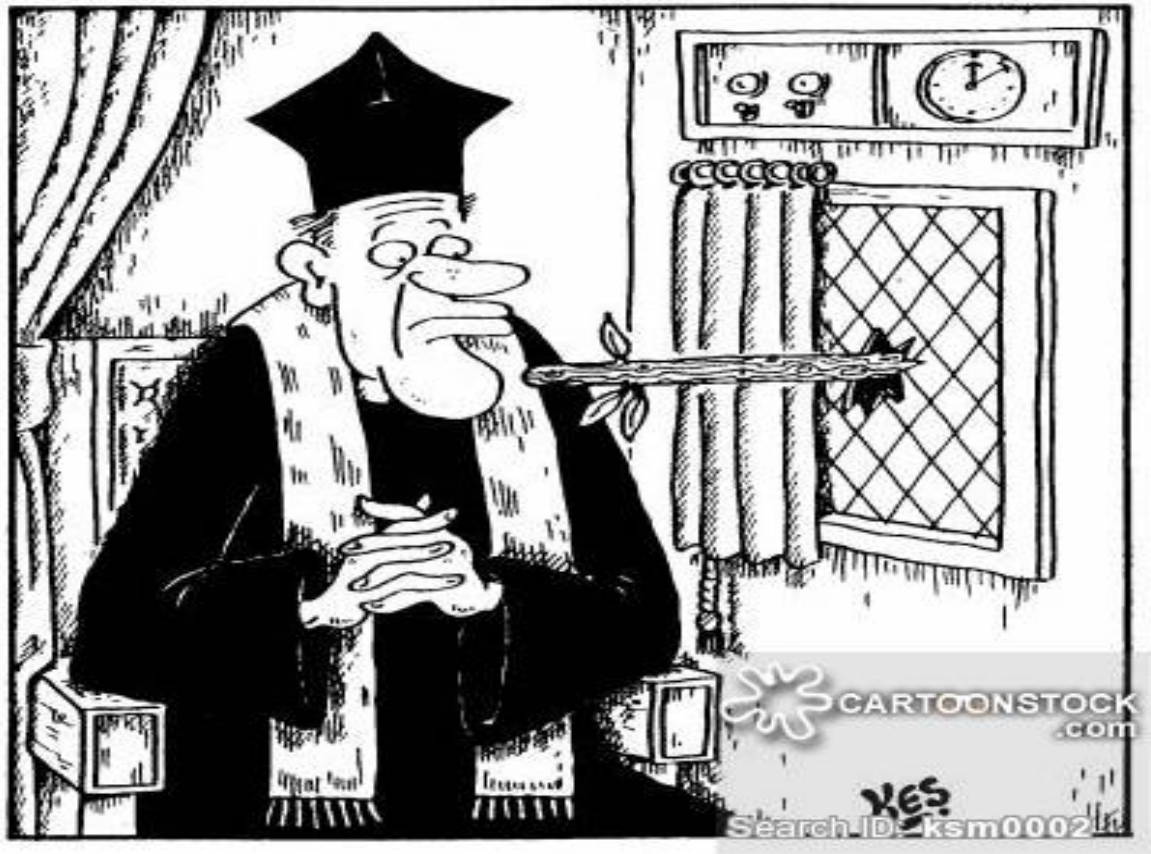
Building Science Foundation:
The Core of Durability
(and risk reduction)

Full Disclosure



Father James doubted that Pinocchio had made a full and truthful confession.

Premises

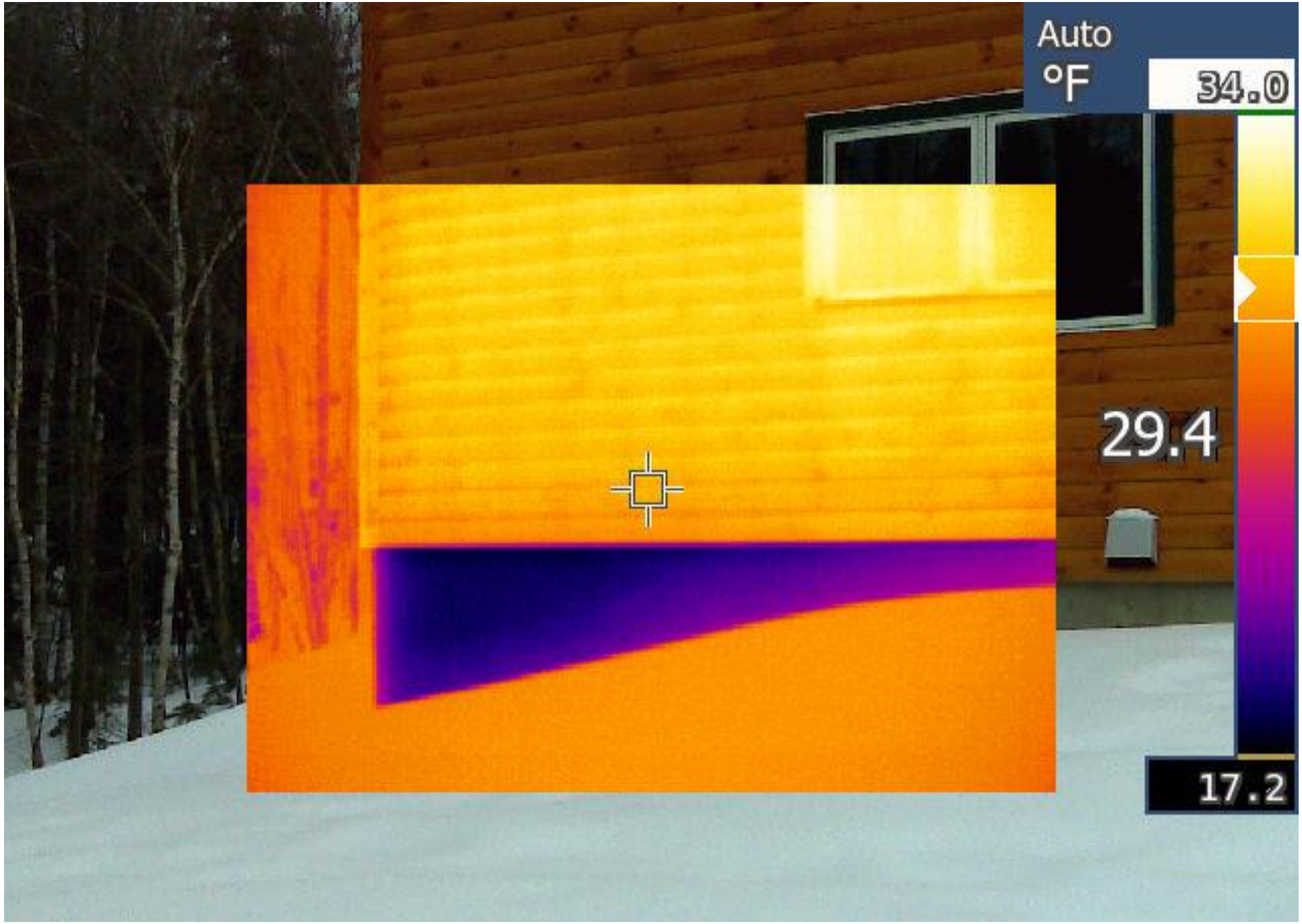
- Things get wet, heat dries them out.
- Energy efficiency measures reduce heat loss.
- Energy & moisture must be managed with equal intensity.
- Do this, and buildings are durable; don’t and not-so-much…

Just Three Things

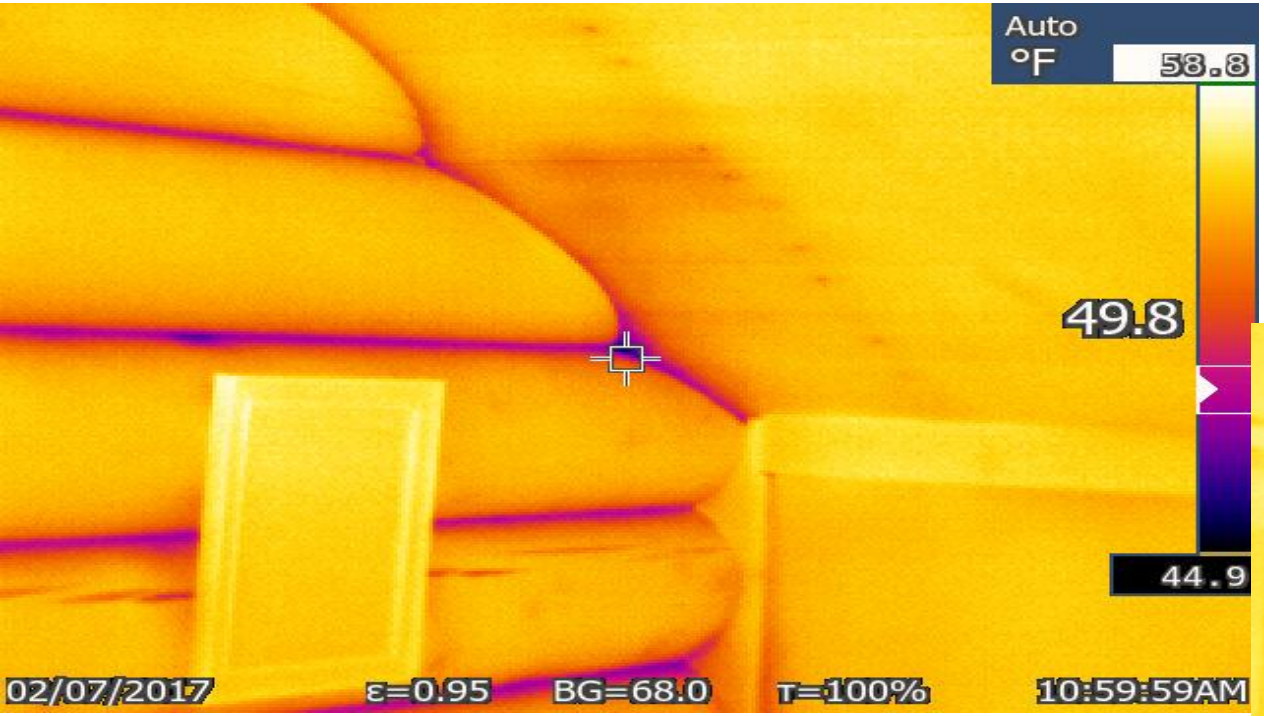
- How does heat get around?
- How does water get around?
- How are the two related?

Heat moves in 3 ways

- Radiation
- Conduction
- Convection
- **25% - 40% of heat loss in a typical home is air leakage.**

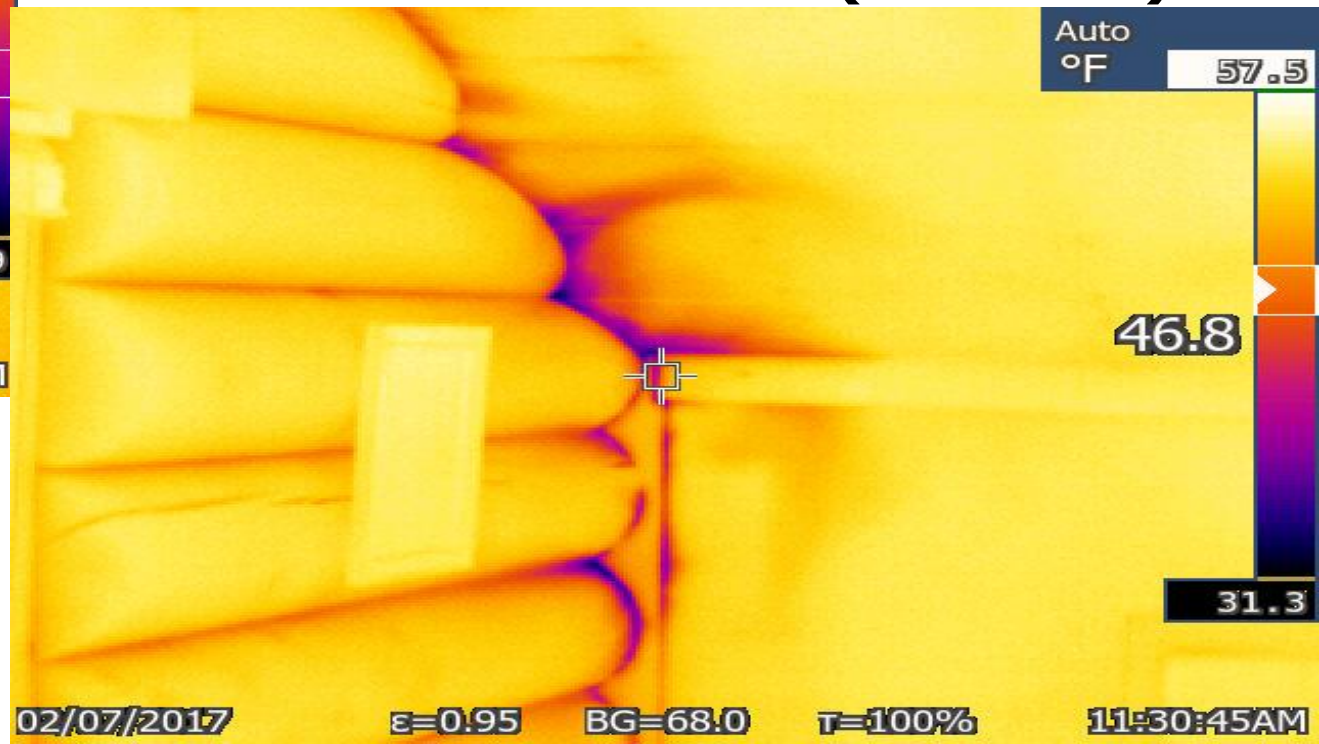

Auto
°F
34.0
29.4
17.2

Combining IR & Blower Door

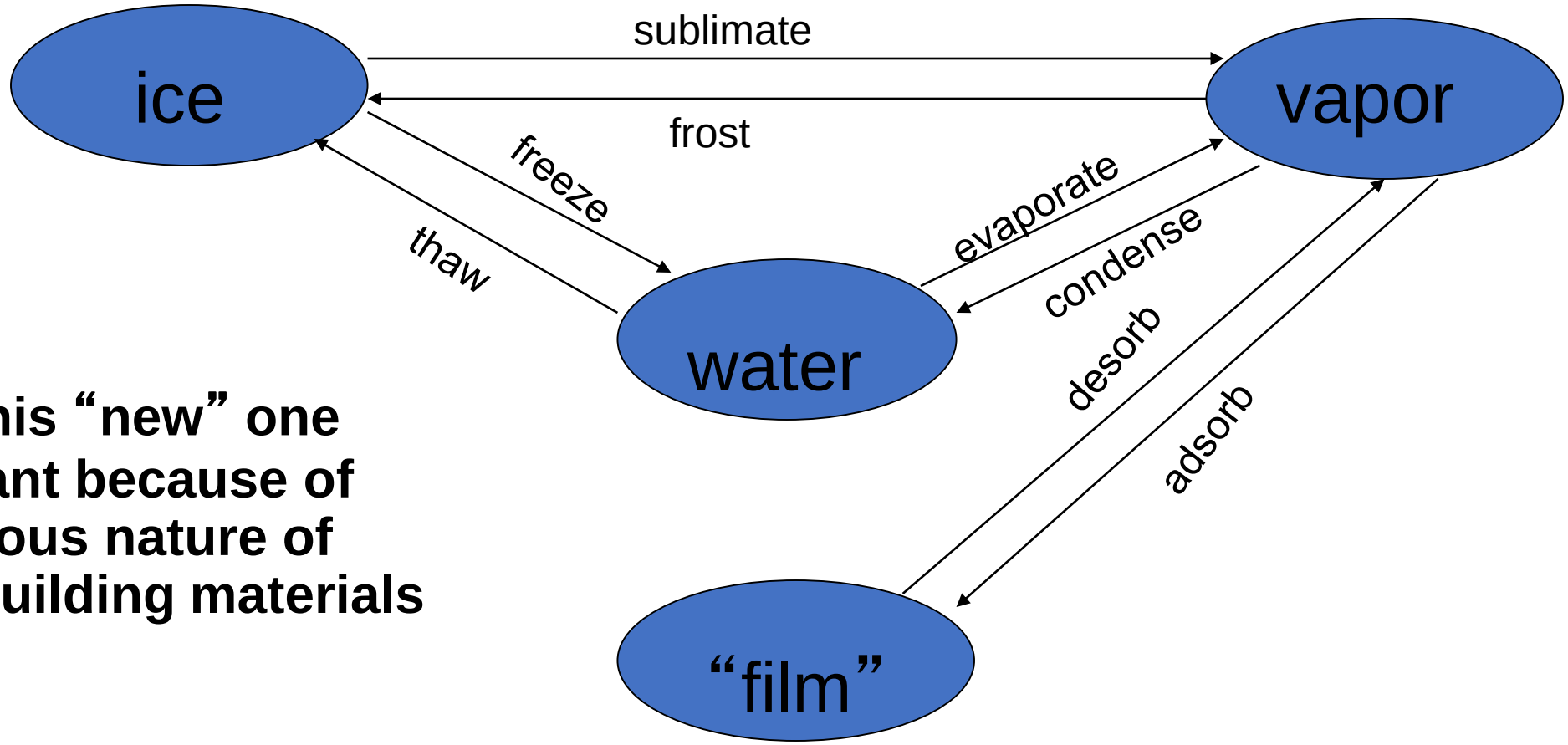


Blower door off

Blower door on (-50 Pa)



Dealing With Water

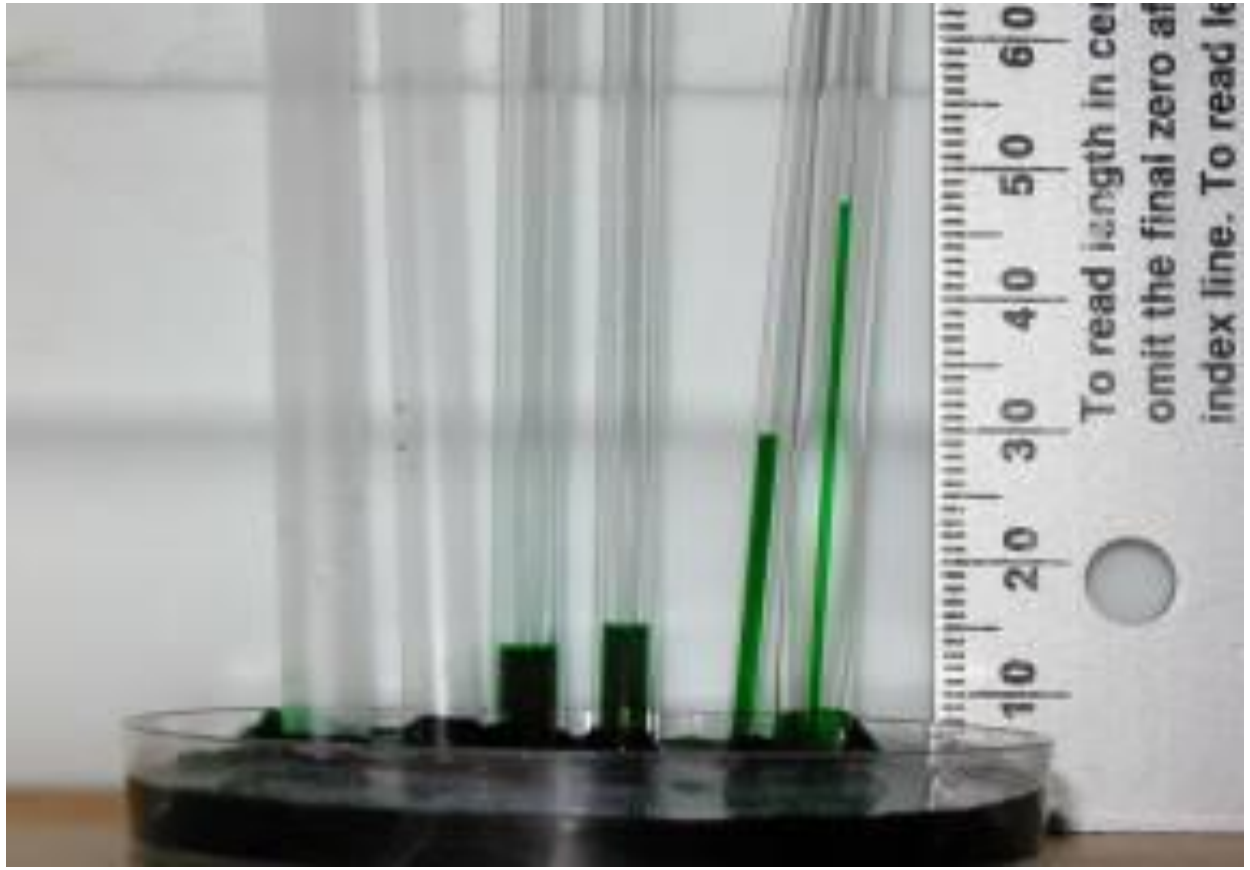


***with this “new” one important because of the porous nature of many building materials**

Moisture Flows – 4 Ways: Gravity – Priority #1

- Tempered by:
  - Lateral cohesive movement
  - Wind-driven rain
- Can involve LOTS of water—from an outside or inside source

Moisture Flows – 4 Ways: Capillarity – Priority #2



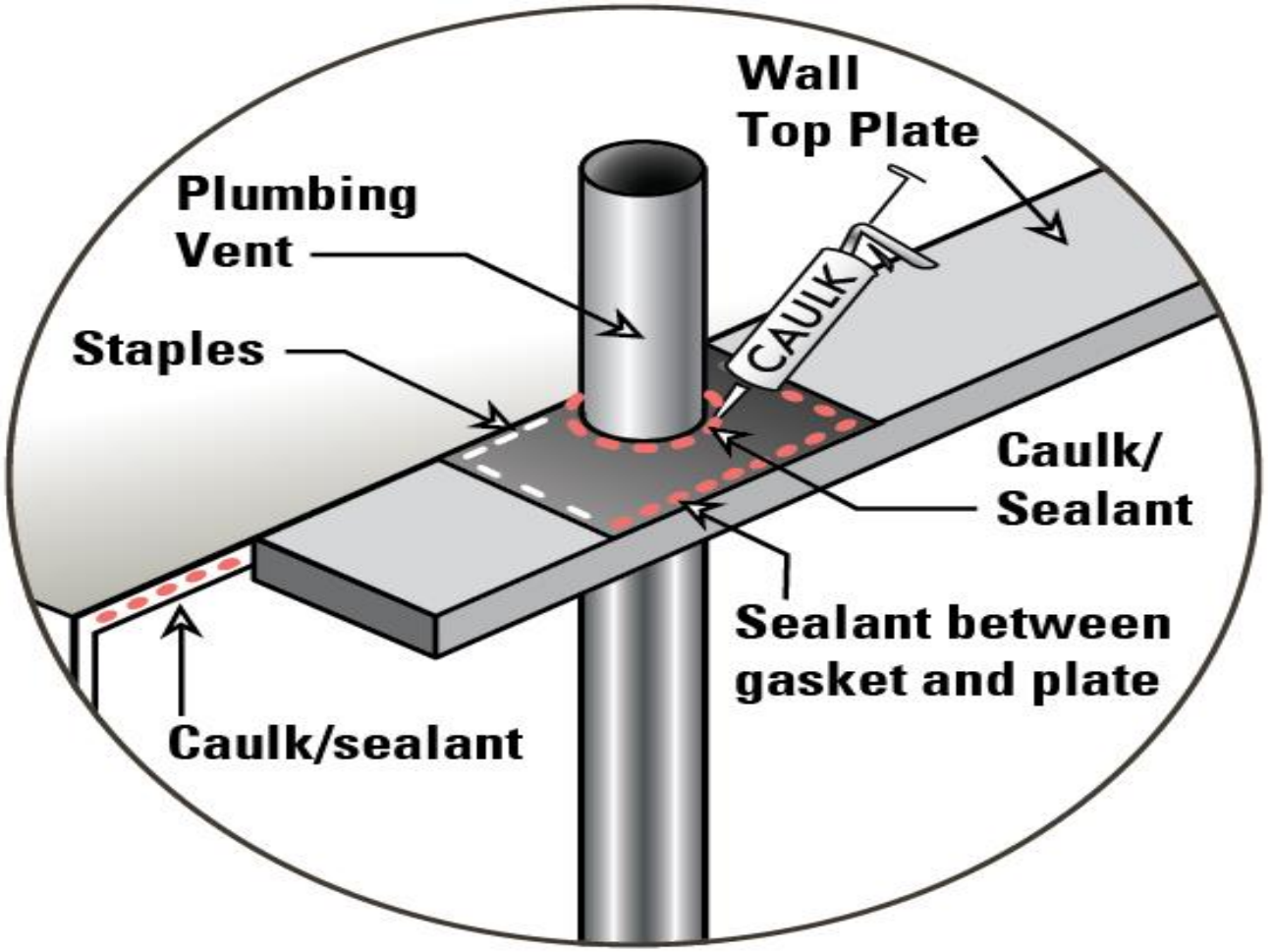
Capillary Breaks

18.0%

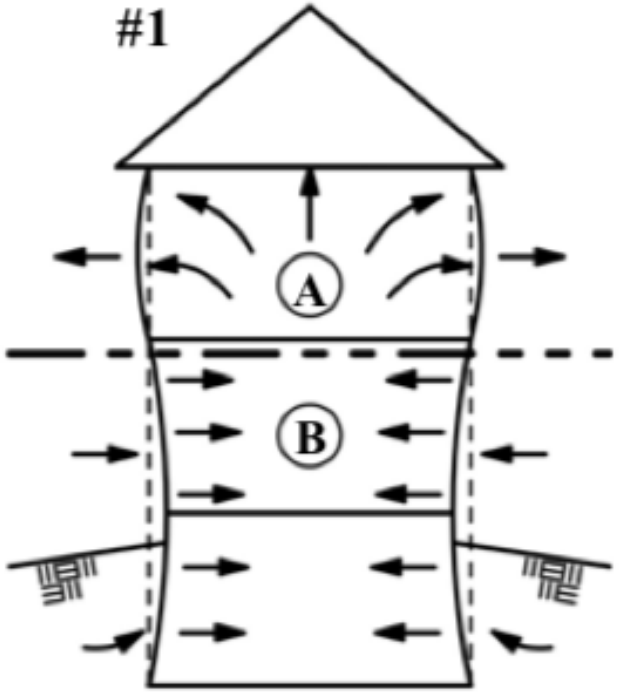
12.8%

Moisture Flows – 4 Ways: Air Leakage – Priority #3

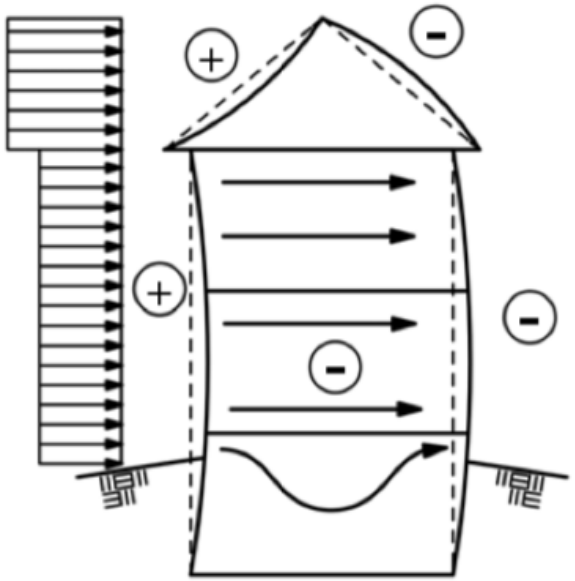
Moisture Flows – 4 Ways:
Air Leakage – Priority #3



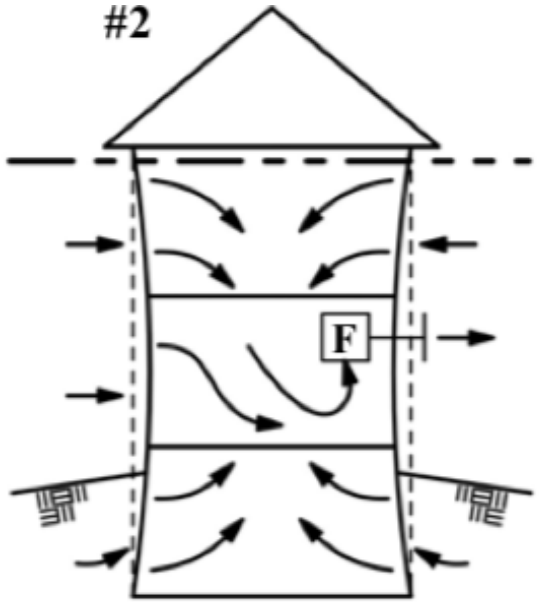
Air leakage driving forces



Stack effect



Wind



Fans (exhaust)

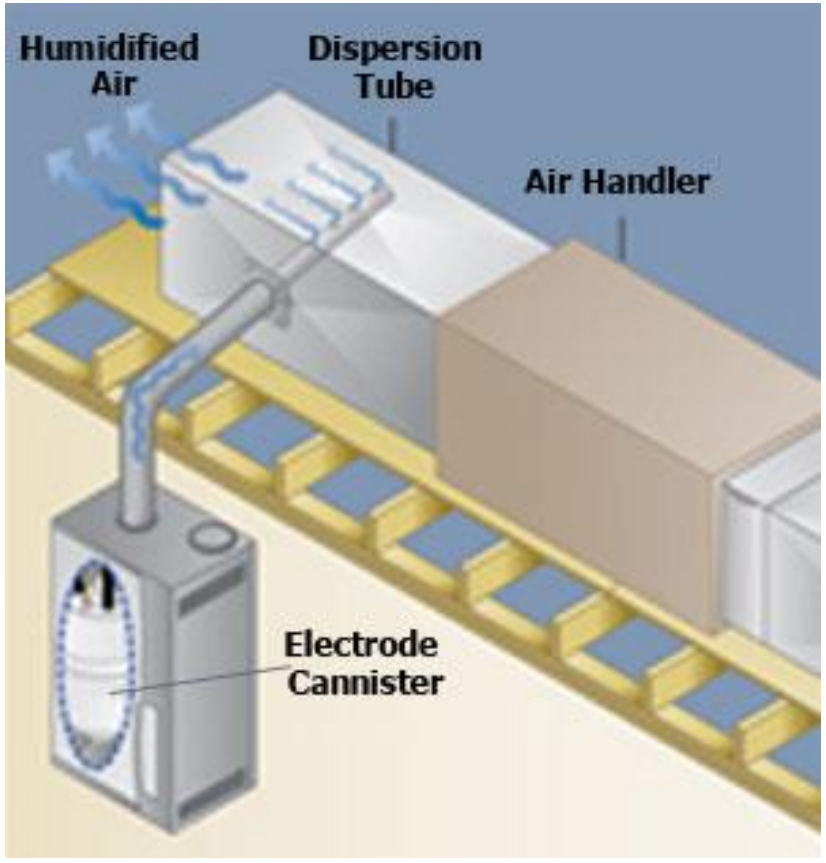
Moisture Flows – 4 Ways: Diffusion– Priority #4

Russ Chapman, Sierra Pacific Windows, SEON

Special situations: humidifiers

Scroll wheel

Steam

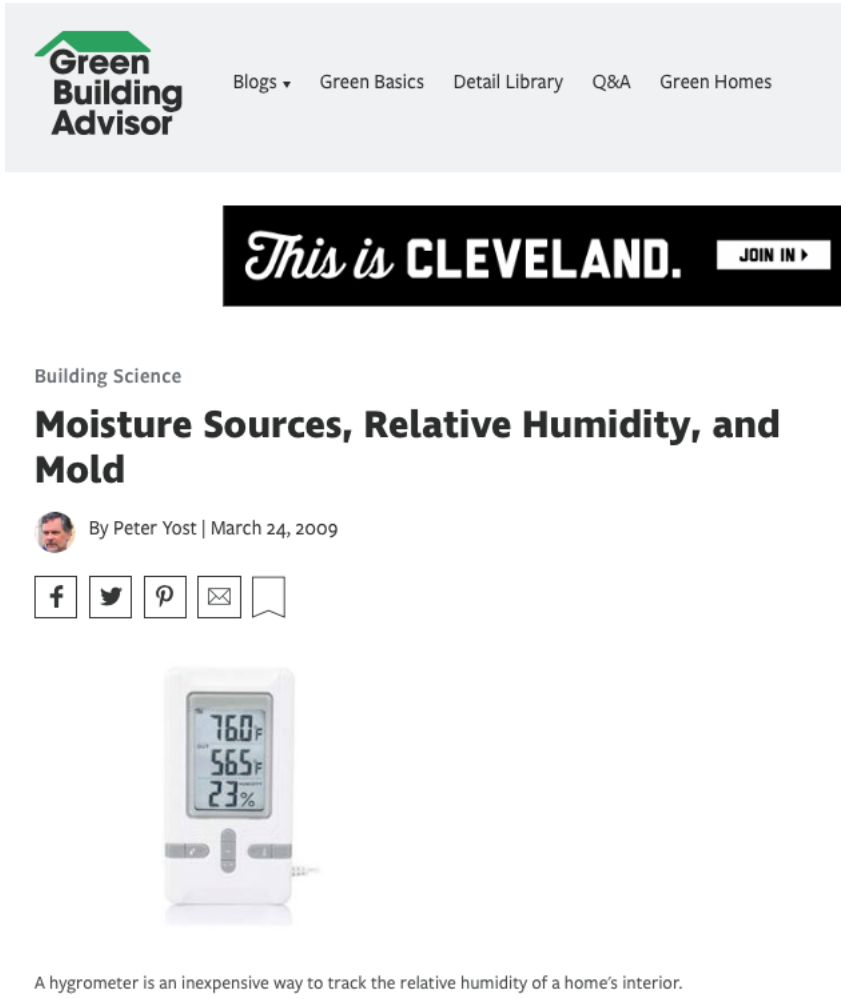


Household Sources of Moisture

Source	**Quantity (pints)**
Showering	**.5 (5 - min shower)**
Clothes drying	4 - 6/load
Cooking (dinner)	1.2 (+1.5 gas)
5 house plants	1/day
1 cord “green” wood	600 - 800/season
4 people	.5/hour
Building materials	**6 - 17/day**
Ground moisture	0 - 100/day

Source: Minnesota Extension Service (also, see GBA blog…)

https://www.greenbuildingadvisor.com/article/moisture-sources-relative-humidity-and-mold

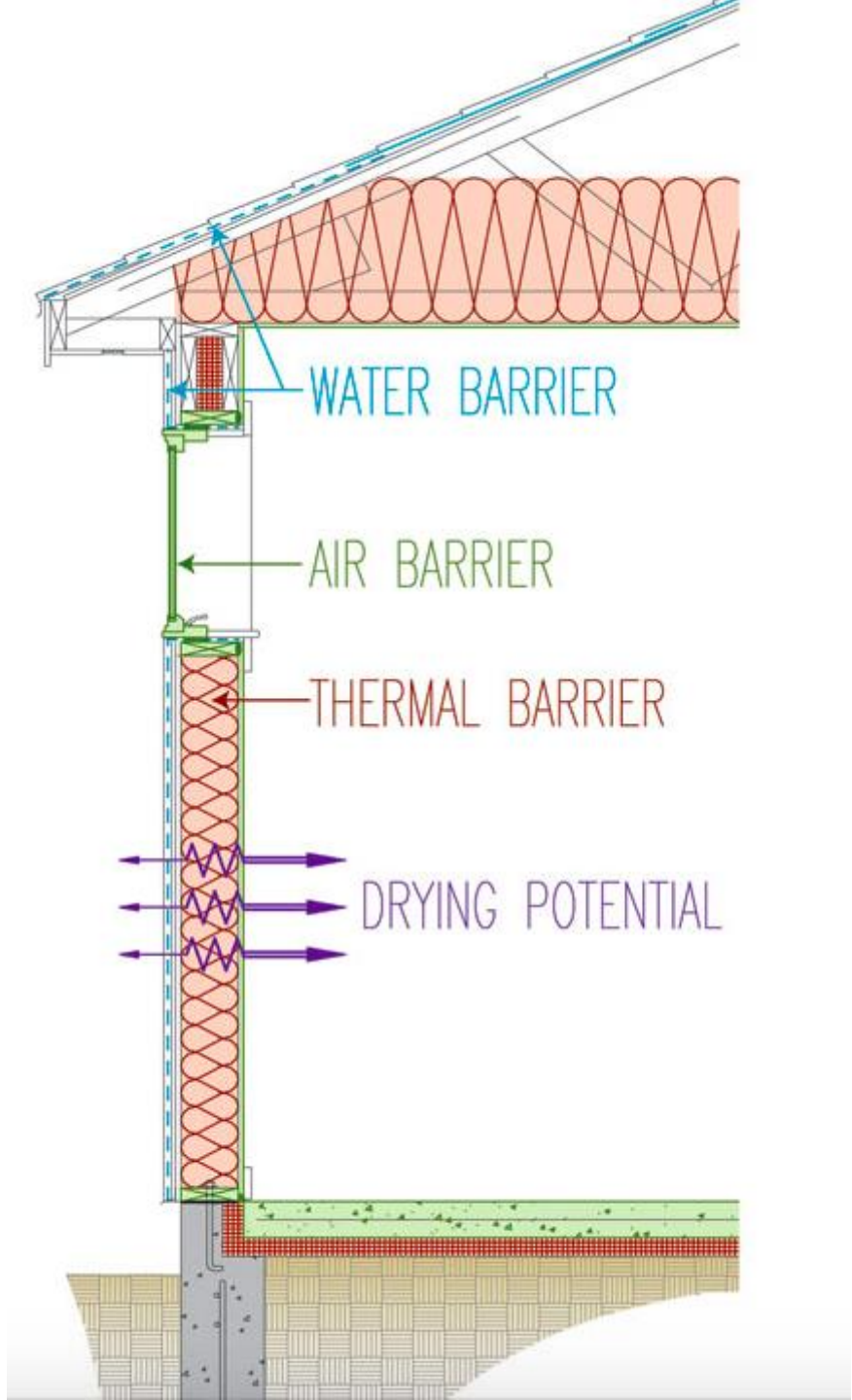


Prioritizing moisture worries…

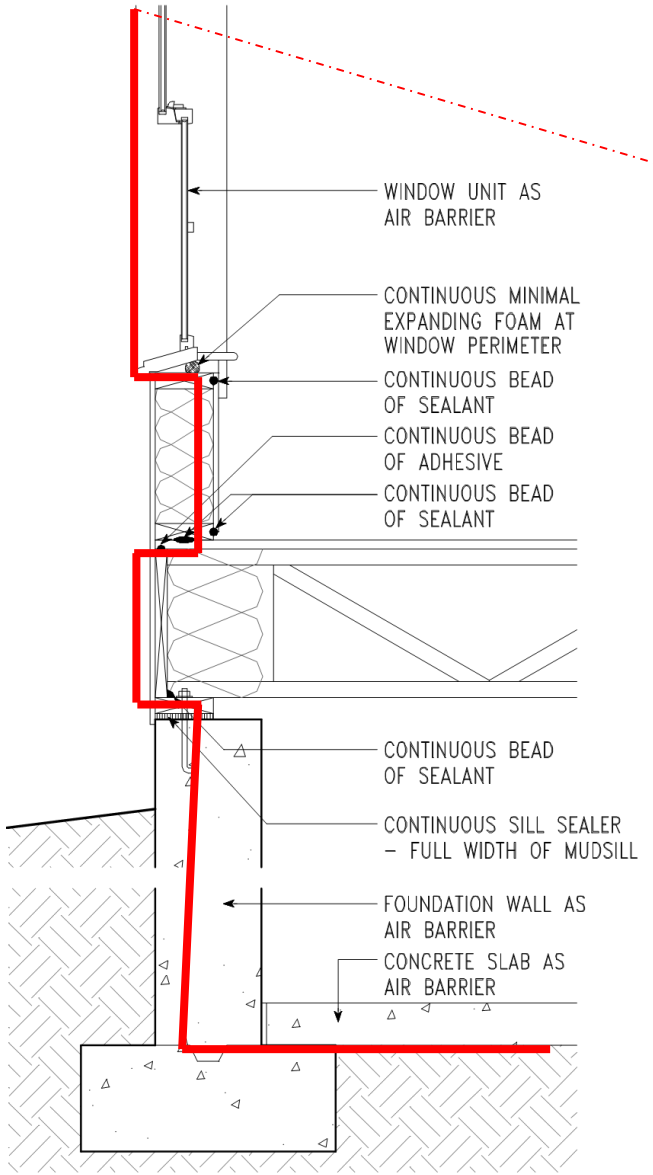
- Bulk water (liquid)
- Capillary water (liquid)
- Air-transported moisture (vapor)
- Diffusion (vapor)

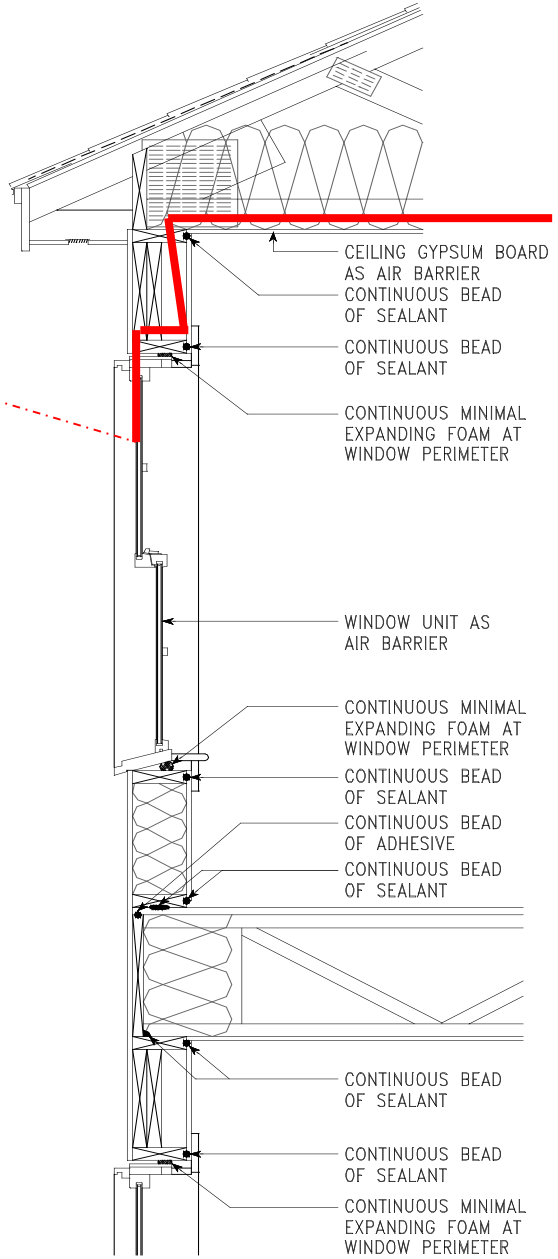
Continuous control layers

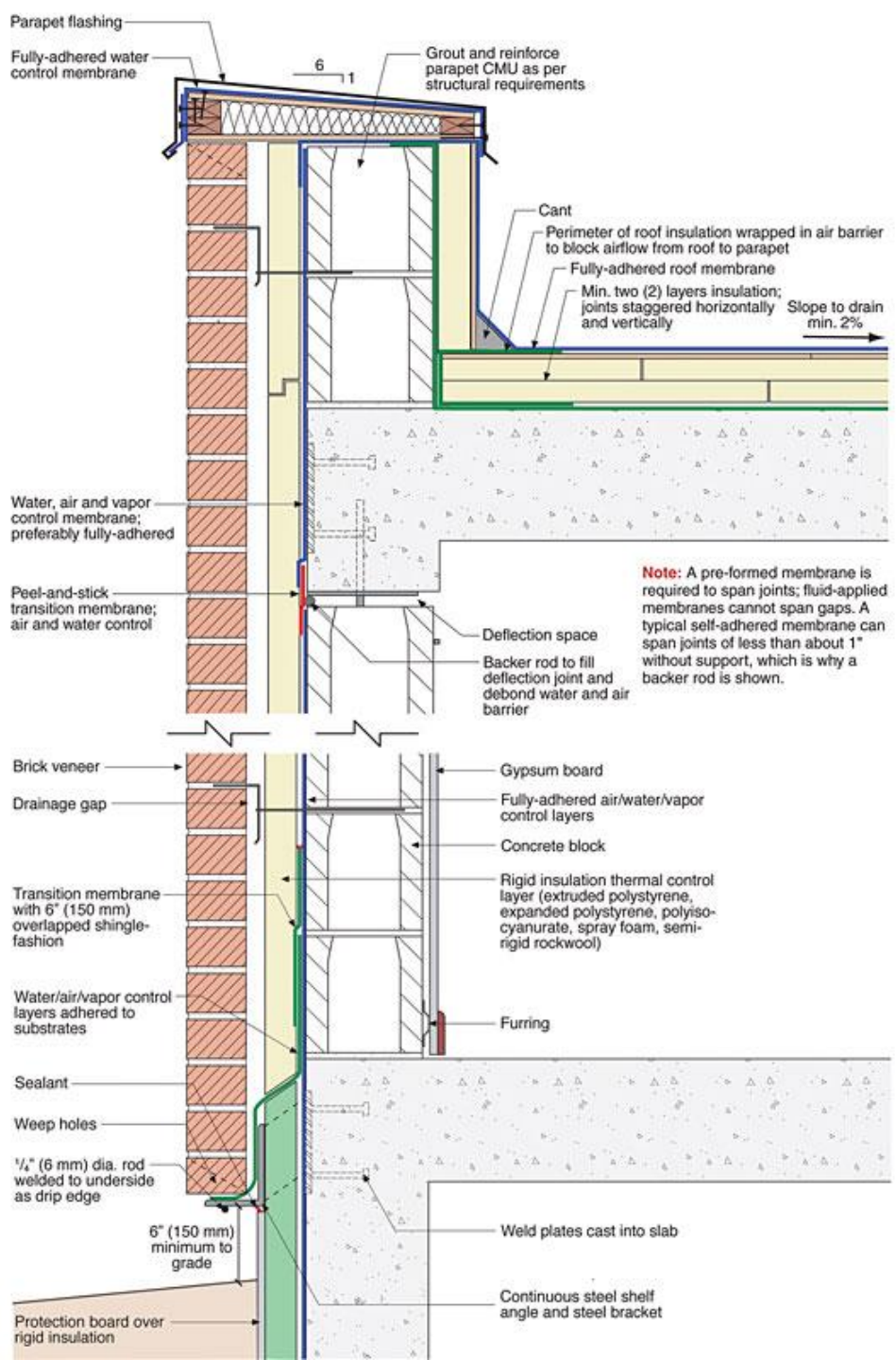
- 1 – Water
  - Bulk
  - Capillary
- 2 – Vapor
  - Air leakage
  - Diffusion (more about drying than wetting)
- 3 – Thermal
  - Bridges
  - Cavities



The “Pen” Test







Source: *High Performance Enclosures*, Building Science Press, Dr. John Straube, 2012.

Continuous bulk water management

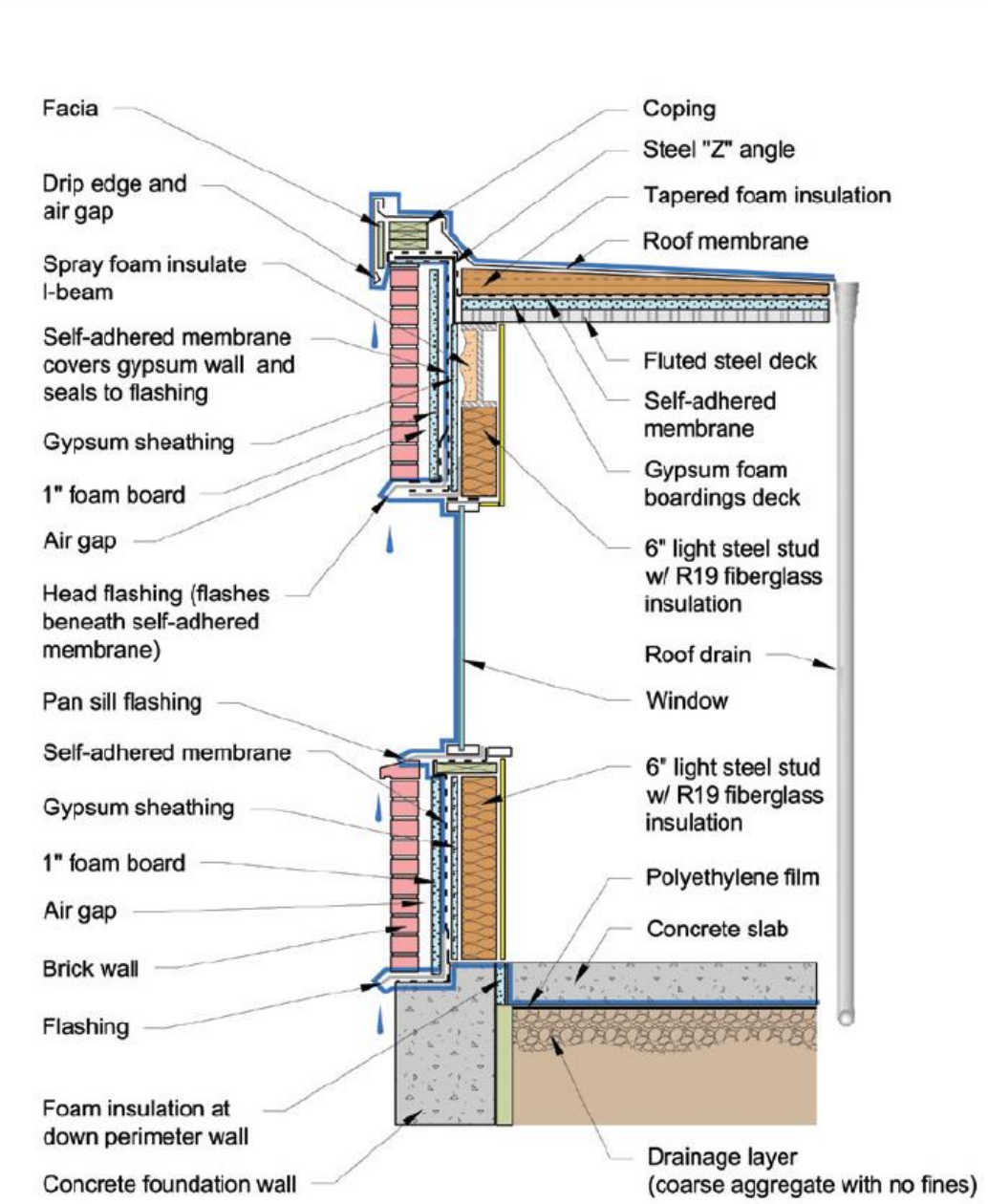
Barrier vs Screen Assemblies

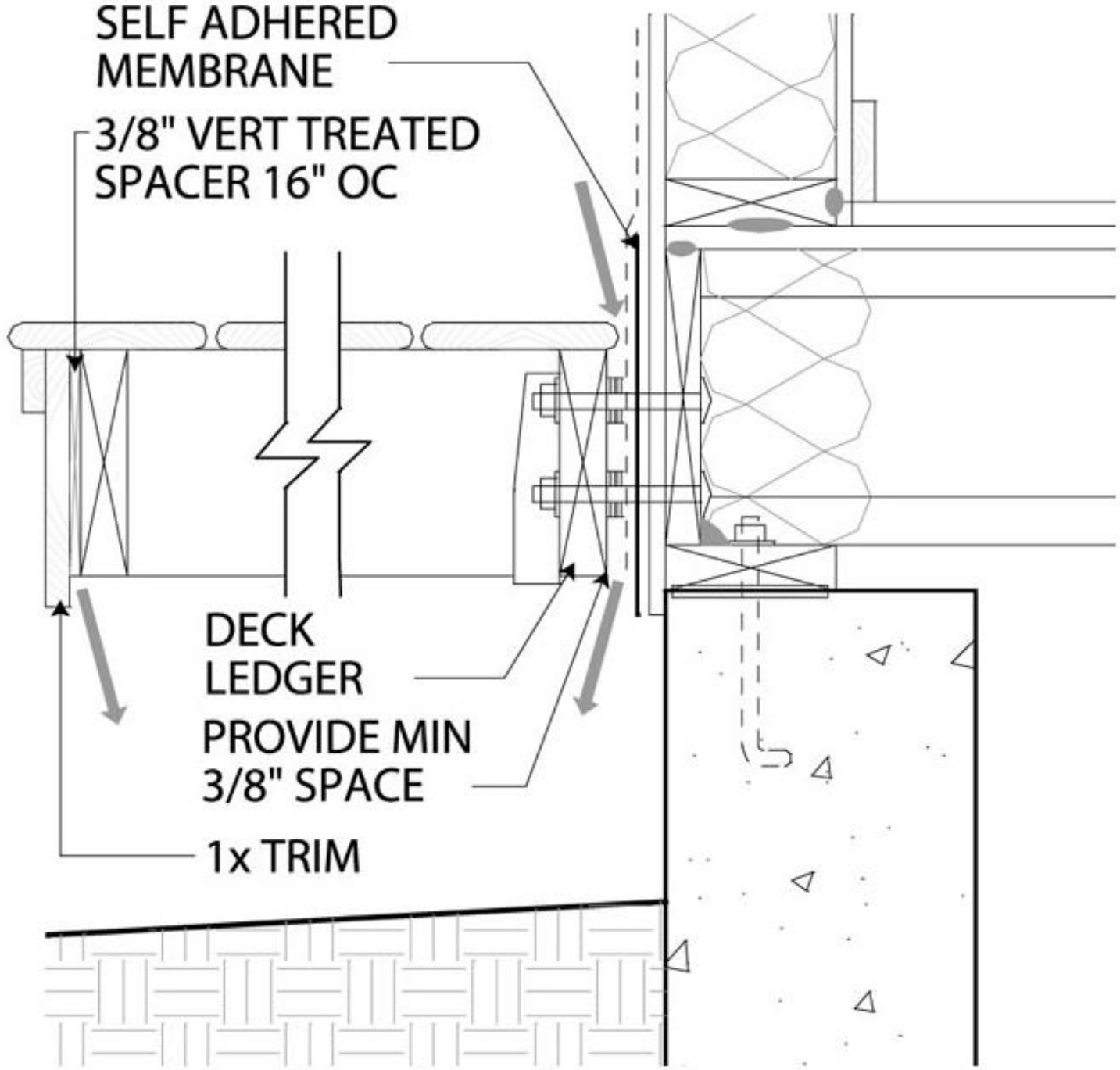
- Barrier: Cladding is drainage plane
  - Sealants are key to “face-sealing” penetrations
  - Sealants are exposed
  - Sealants can and must be inspected, repaired and replaced
- Screen: Concealed drainage plane is primary line of defense
  - Sealants and PSA tapes are key to connecting WRB to flashings at openings and penetrations
  - Sealants and tapes are buried
  - Sealants and tapes cannot (easily) be inspected, repaired and replaced
  - Sealants and tapes must last life of assembly

EPA Moisture Control Guide

www.epa.gov/iaq/moisture

Figure A-1 The Blue Line Traces the Elements of the Capillary Break in the Rainwater Control System for a Section Through a Building




SELF ADHERED
MEMBRANE
3/8" VERT TREATED
SPACER 16" OC
DECK
LEDGER
PROVIDE MIN
3/8" SPACE
1x TRIM

Principles of bulk water management

- Physics first
  - Weatherlap first
  - Mechanically support
- Chemistry second
  - Liquid sealants
  - PSA tapes
- Anything not vertical is a “roof”

Continuous air control layer

AIR BARRIER CONTINUITY: A QUICK GUIDE TO SEALING AIR LEAKAGE PATHWAYS IN BUILDINGS

Contents

https://www.buildinggreen.com/sites/default/files/usace_airbarriercontinuity.pdf

Air Barrier Continuity: A Quick Guide to Sealing Air Leakage Pathways in Buildings

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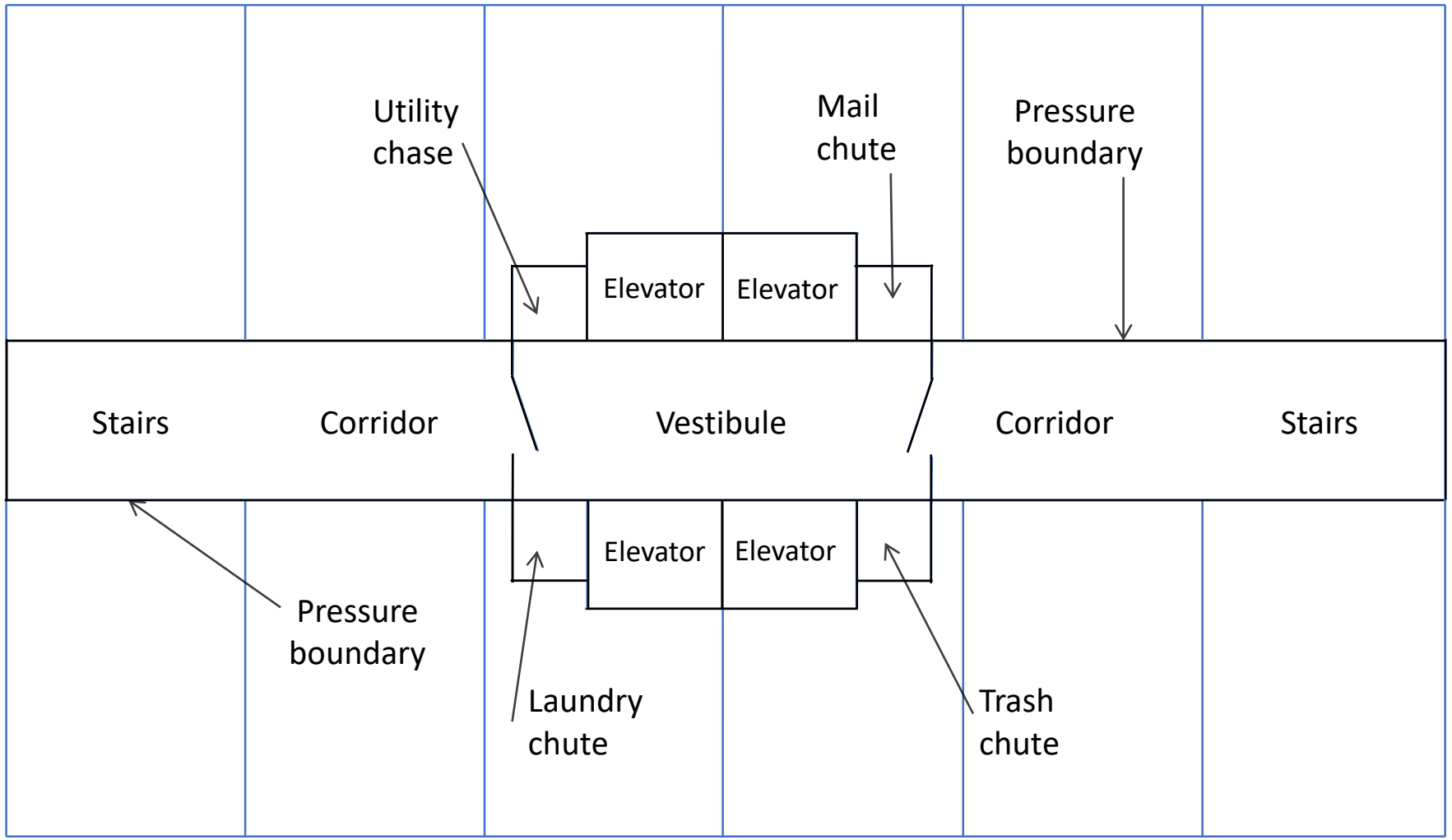

Utility chase
Mail chute
Pressure boundary
Elevator
Elevator
Stairs
Corridor
Vestibule
Corridor
Stairs
Elevator
Elevator
Pressure boundary
Laundry chute
Trash chute

Primary Air Barrier Components

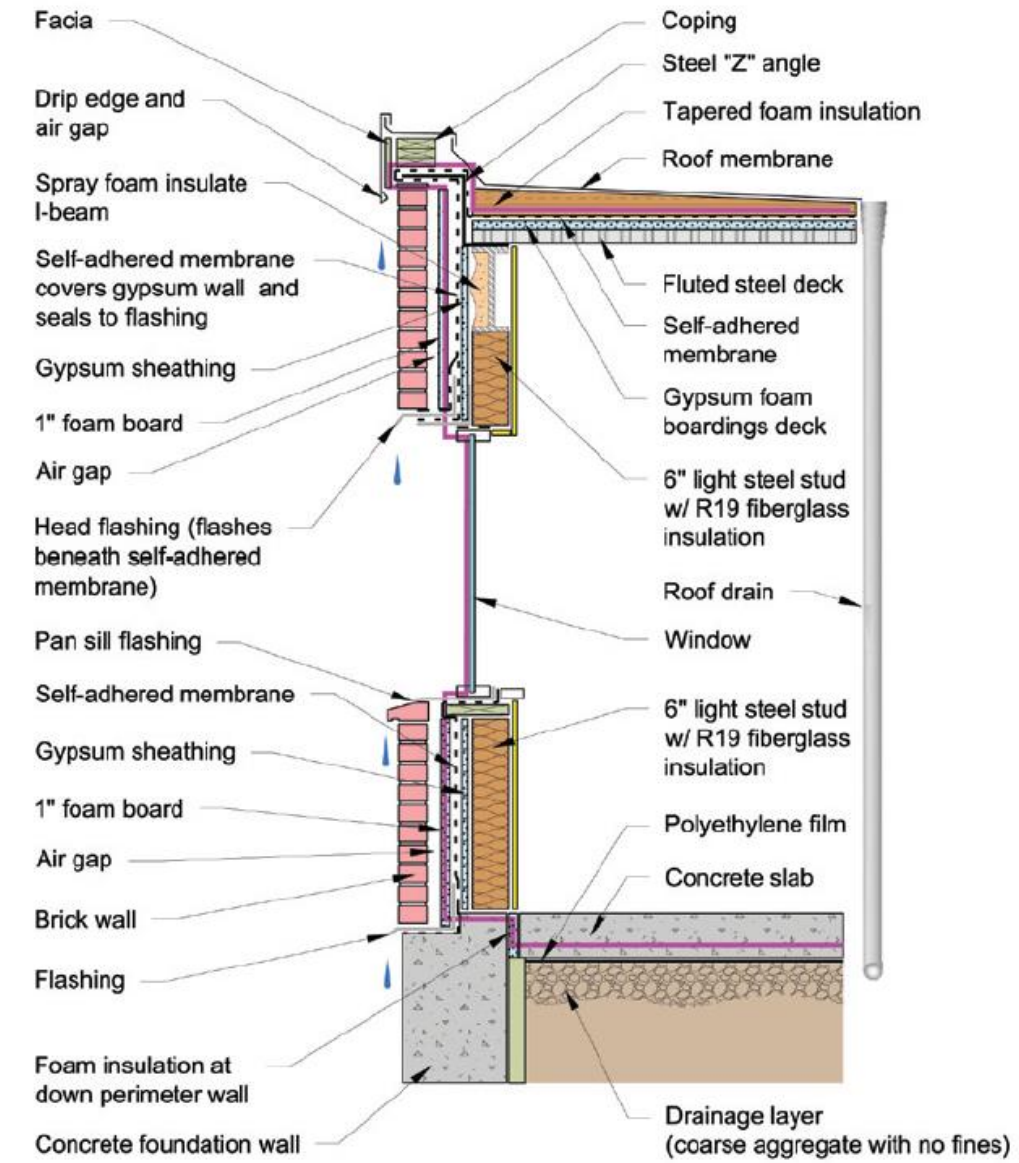
- Field
  - Sheet good/membrane
  - Rigid sheathing
  - Fluid-Applied
- Connection
  - PSA tapes
  - Mesh/Mastic
- Systems

- Field examples
  - SBPO (Spun-bonded polyolefin)/Henry Blueskin
  - ZIP system
  - DOWSIL
- Connection examples
  - Acrylic, Butyl, Modified bitumen
- System examples
  - Huber 4-component ZIP system

EPA Moisture Control Guide

www.epa.gov/iaq/moisture

Figure A-3 The Purple Line Traces the Air Barrier Components

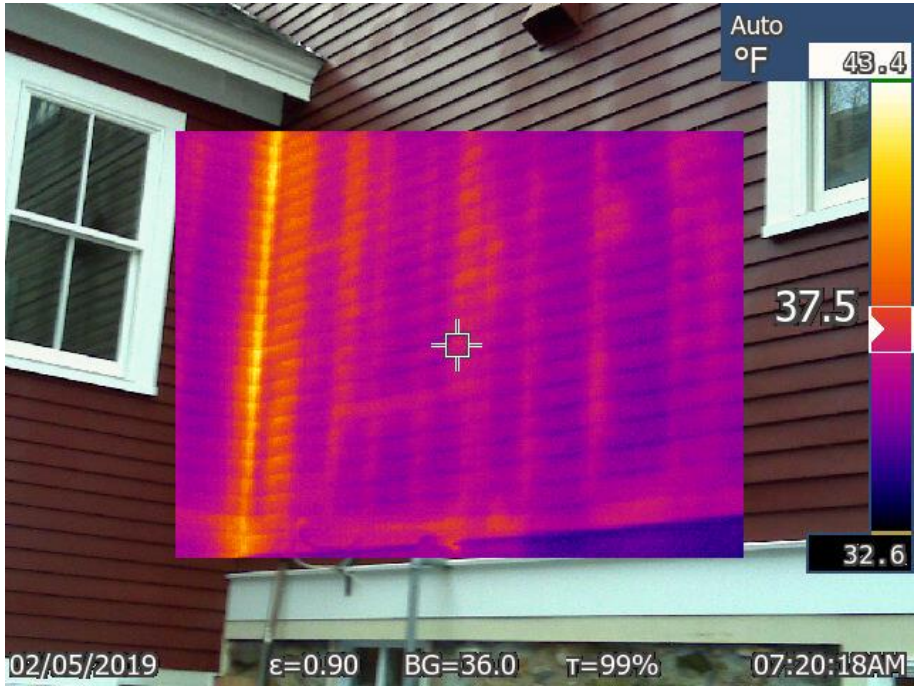


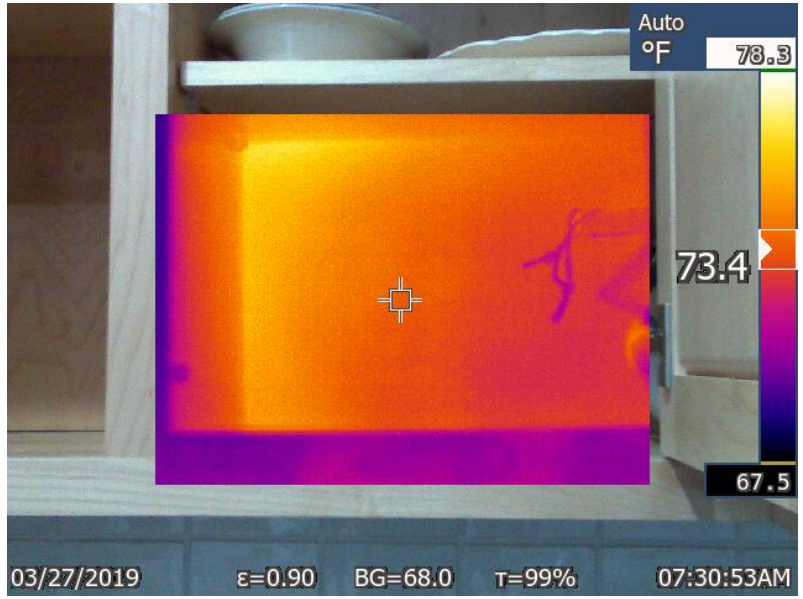
Airtightness proof positive: blower door test

Thermal Control Layer

- Exterior vs. cavity insulation
- Connection to air control layer
- Thermal breaks vs. thermal bridges
- Opaque assemblies vs. glazing (special case)

Thermal Bridges





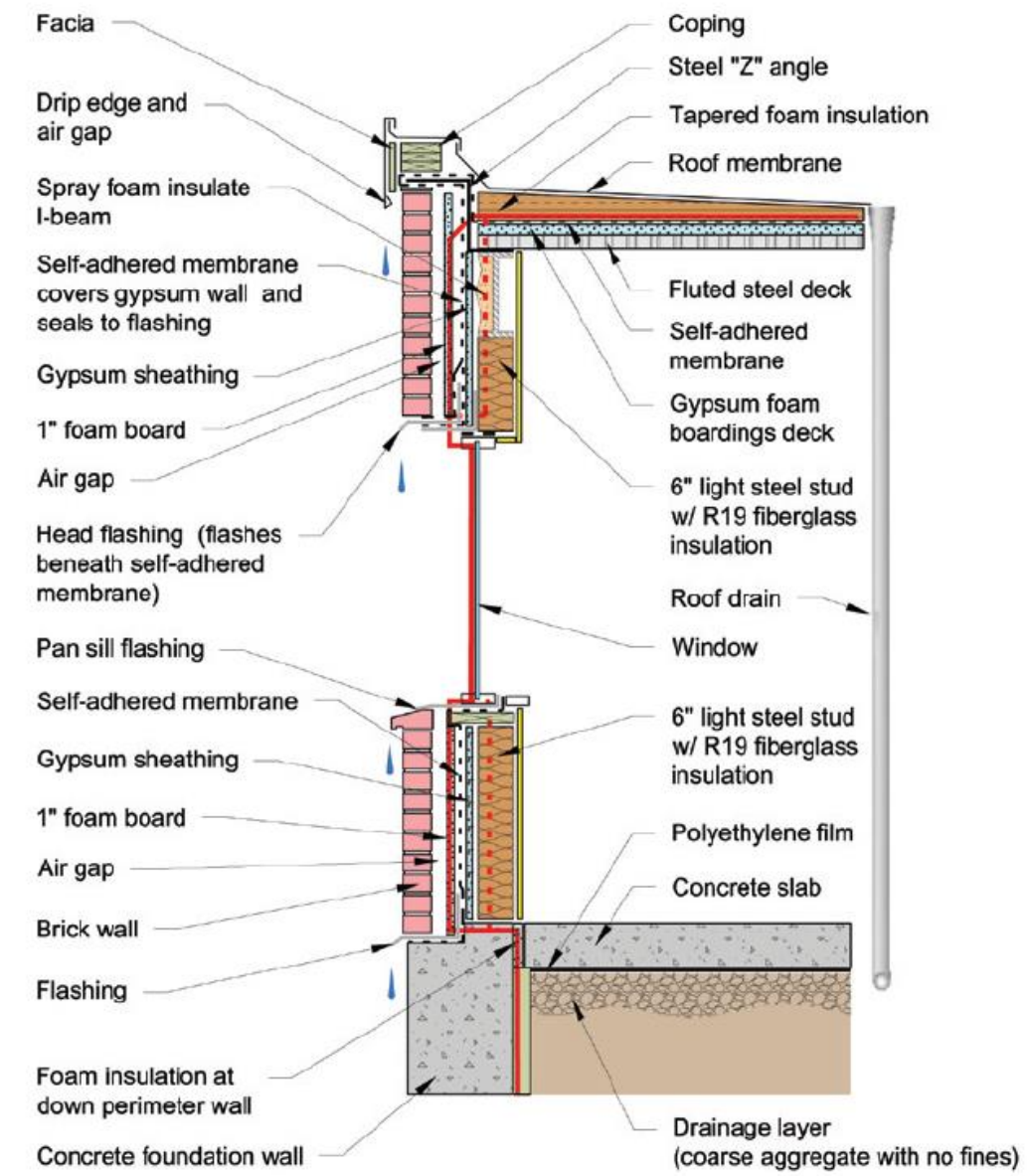
Thermal bridges…

Breaking Thermal Bridges

- Materials
  - Stainless steel
  - Fiberglass
  - Poylester-reinforced nylon
- Intermittent rather than continuous structural support
- Maintain plane
- Ladder constructions stuck on later, when you can
- Push spaces in or pull them out of the condition boundary

EPA Moisture Control Guide

Figure A-2 The Red Line Traces Continuity of the Insulation Layer



Vapor Control/Profile
(not vapor retarder)

How many discrete components or layers make up a “typical” building assembly?

In order for this assembly to dry, which components layers do you need to know the vapor permeability of?

Vapor Profile:
If/When a building assembly gets wet, will/how will it dry?

Vapor Profile Considerations

- The weakest form of wetting (diffusion) is our last resort for drying (diffusion).

- So, we need to know vapor permeance of our enclosure materials not because assemblies get wet by diffusion, but because that is how, finally, they will dry (or not).

- To determine direction and extent of an assembly's drying potential, need to know vapor permeability of ALL layers of your assemblies.

Vapor Profile

1. Determine vapor permeability of each component of assembly
2. Categorize each component (Class I, II, III, vapor open)
   A. Class I: < 0.1 perms
   B. Class II: 0.1 – 1 perms
   C. Class III: 1 – 10 perms
   D. “Vapor open:” > 10 perms
3. Assess direction and extent of vapor drive: interior/exterior temperature difference, interior/exterior relative humidities
   (remember always high to low)
4. Identify/assess drying direction & potential

Representative Vapor Permeability Info

Material	Dry Cup	Wet Cup	Comments
Plywood	.75	3.5	Semi-permeable
OSB	.75	2	Semi-
Fiberboard (AI)	14.5	15	Permeable
Thermo Ply	0.5	0.6	impermeable
XPS	1	1	Semi (but with skin, im-)
EPS	5	5	Semi-
6-mil poly	.06	.06	Impermeable
Kraft paper	1	5 - 10	Semi- (variable)
MemBrain™	1	10+	Variable, by design
Tyvek®	14	?	permeable
Latex paint (primer + 1 coat)	3.6	6	Semi-

Hold on: Exactly what is a perm?

- 1 grain H2O moving through
- 1 square foot of building material
- In 1 hour
- At 1 inch of Hg pressure difference
- 7000 grains H2O = 1 lb H2O
- 1 inch Hg vapor pressure difference?

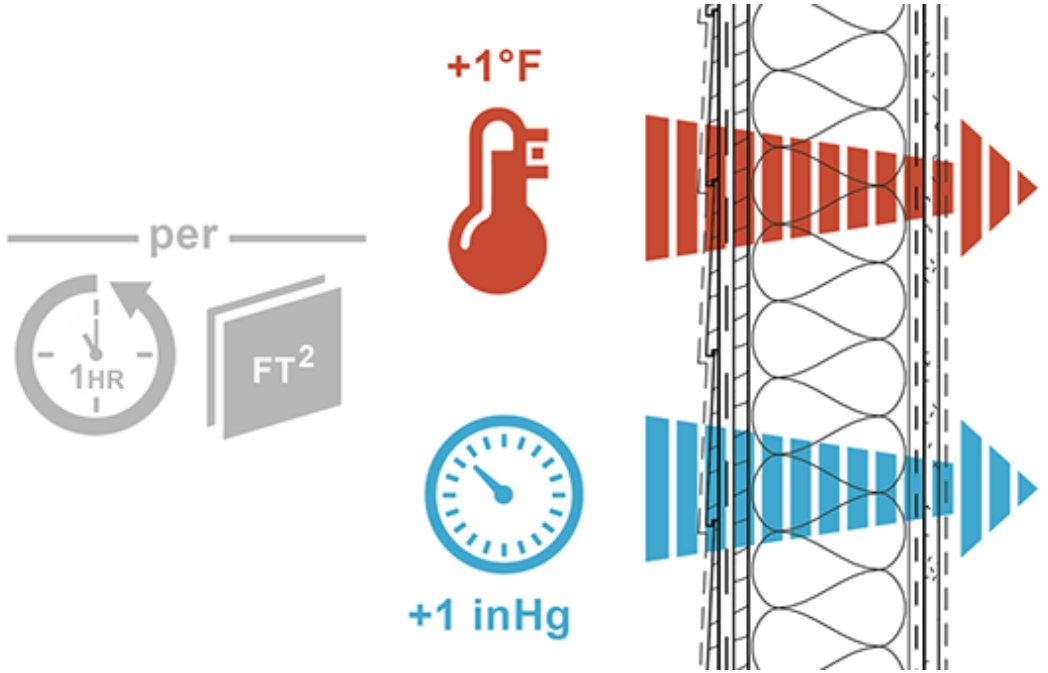
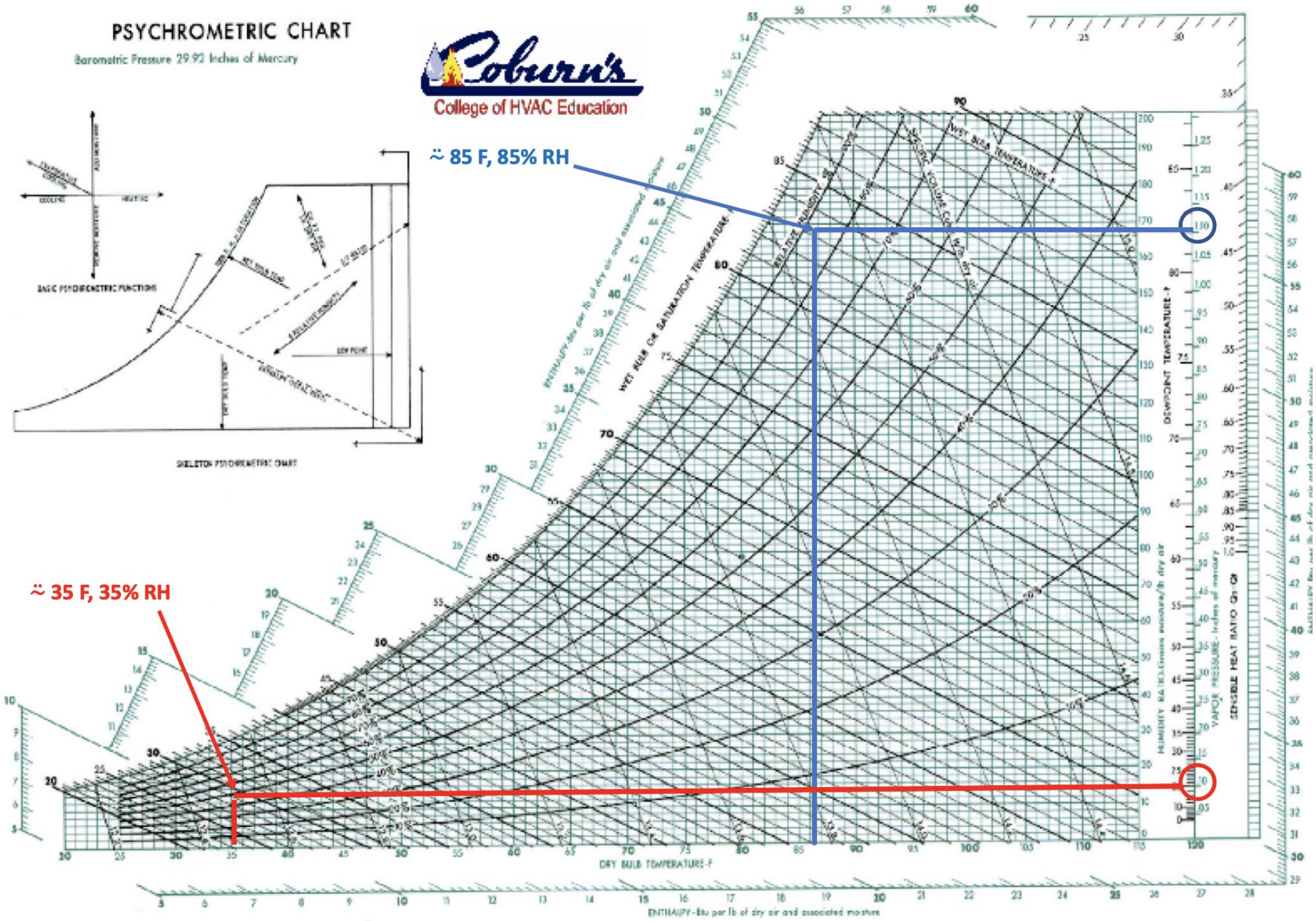


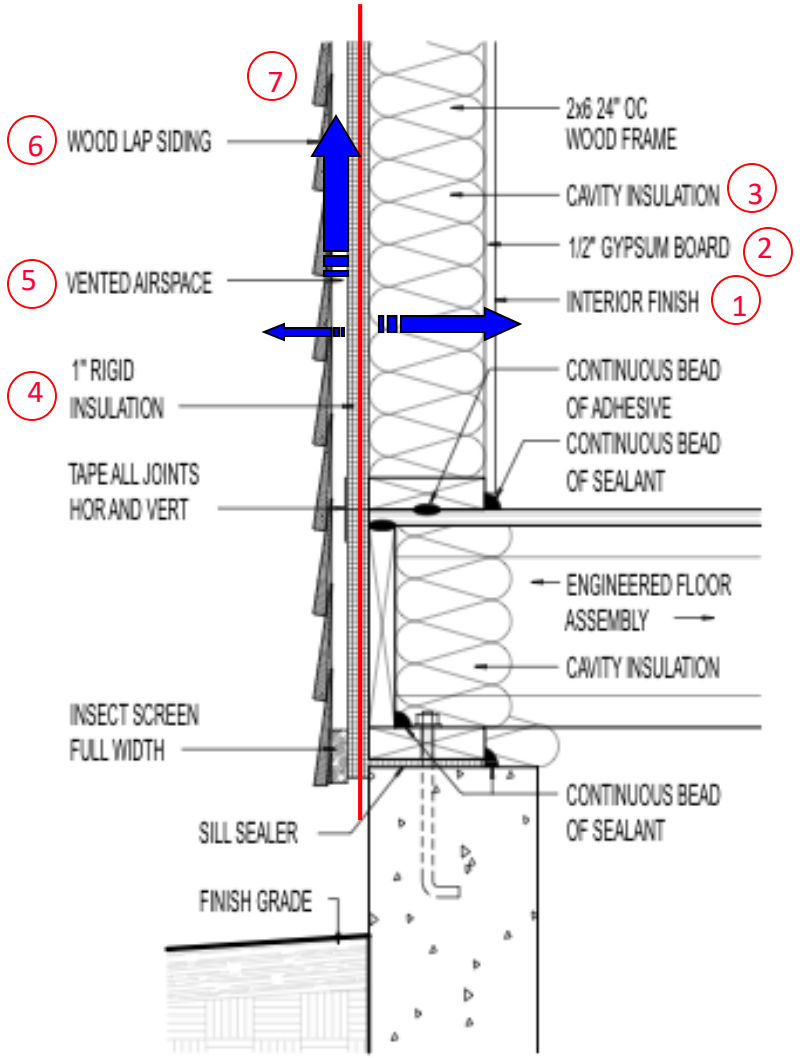
Image credit: danieloverbey.blogspot.com


PSYCHROMETRIC CHART
Barometric Pressure 29.92 Inches of Mercury
Coburn's
College of HVAC Education
≃ 85 F, 85% RH
≃ 35 F, 35% RH
BASIC PSYCHROMETRIC FUNCTIONS
SKELETON PSYCHROMETRIC CHART
DRY BULB TEMPERATURE-F
ENTHALPY-Btu per lb of dry air and associated moisture
WET BULB OR SATURATION TEMPERATURE-F
DEWPOINT TEMPERATURE-F
SENSIBLE HEAT RATIO Gs/G
VAPOR PRESSURE-Inches of mercury

Vapor Profile: Example 1

1. Latex paint - 17 perms
2. Wall board - 40
3. Cellulose - 75
4. XPS - 1
5. Air space - “300”
6. Wood siding - “35”
7. Oil-based paint - 0.6

Least permeable - 4. XPS



WALL SECTION // WOOD LAP SIDING // 1" RIGID INSULATION

GreenBuildingAdvisor.com

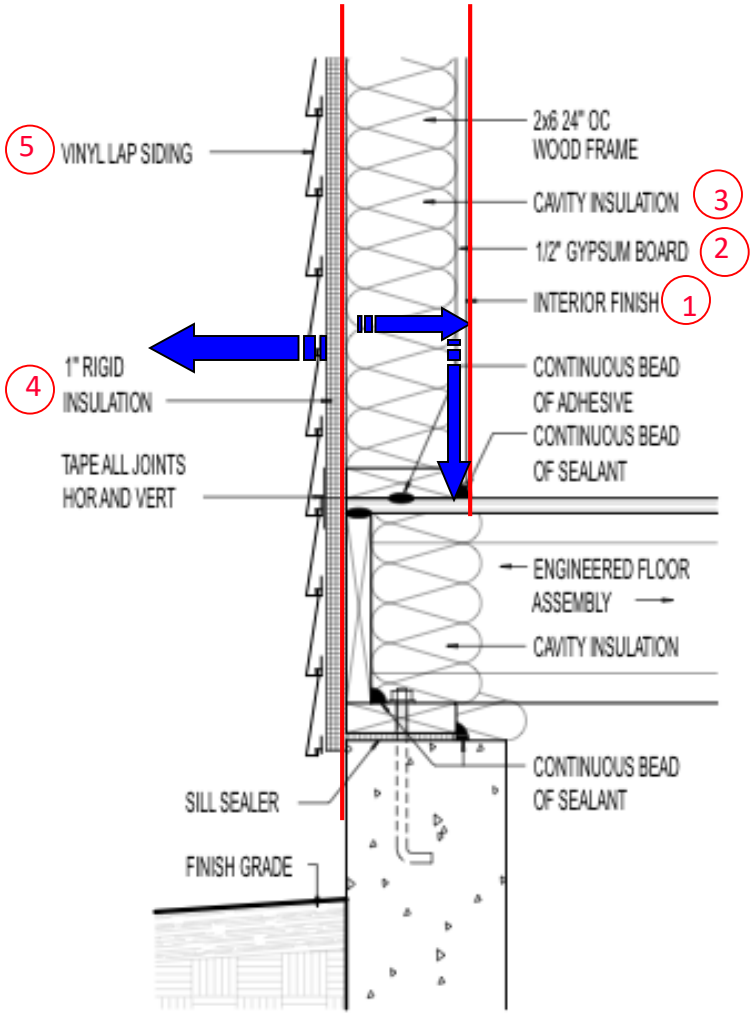
Scale: 1 1/2" = 1'-0"

2-00002

Vapor Profile: Example 2

1. Vinyl wallpaper - < 0.1 perms
2. Wall board - 40
3. Cellulose - 75
4. Foil-faced polyiso - > 0.1
5. Vinyl siding - “60”

Least permeable - 1 & 4



WALL SECTION // VINYL LAP SIDING // 1" RIGID INSULATION

GreenBuildingAdvisor.com

Scale: 1 1/2" = 1'-0"

2-00008

Principal Resource – Vapor Profile: GBA Building Science blog…

Building Science

The nuts and bolts of building

2
Helpful?
+ -

Vapor Profiles Help Predict Whether a Wall Can Dry

To avoid moisture problems in walls, think about the permeability of all the wall's components — not just the "designated" vapor retarder

POSTED ON AUG 5 2010 BY PETER YOST

Today's walls, roofs, and floors are better insulated, tighter, and made with a much greater variety of components than they used to be, making them a lot more susceptible to moisture problems when they get wet. Compared to the old days, today's walls and ceilings are more complicated and can be very slow to dry.

Poorly crafted building codes are blamed for many examples of confusion, and the confusion over vapor retarders and vapor barriers is no exception. To design and build energy efficient and durable building assemblies, following the code is not enough. We need a new approach — such as the vapor profile.

Image 1 of 3

Why did this roof rot? Inadvertent vapor barriers in this 10-year old house had terrible consequences. The moisture came from air leaks through can lights (the Romex wire is the hint). Foil-faced foam on the inside and peel and stick

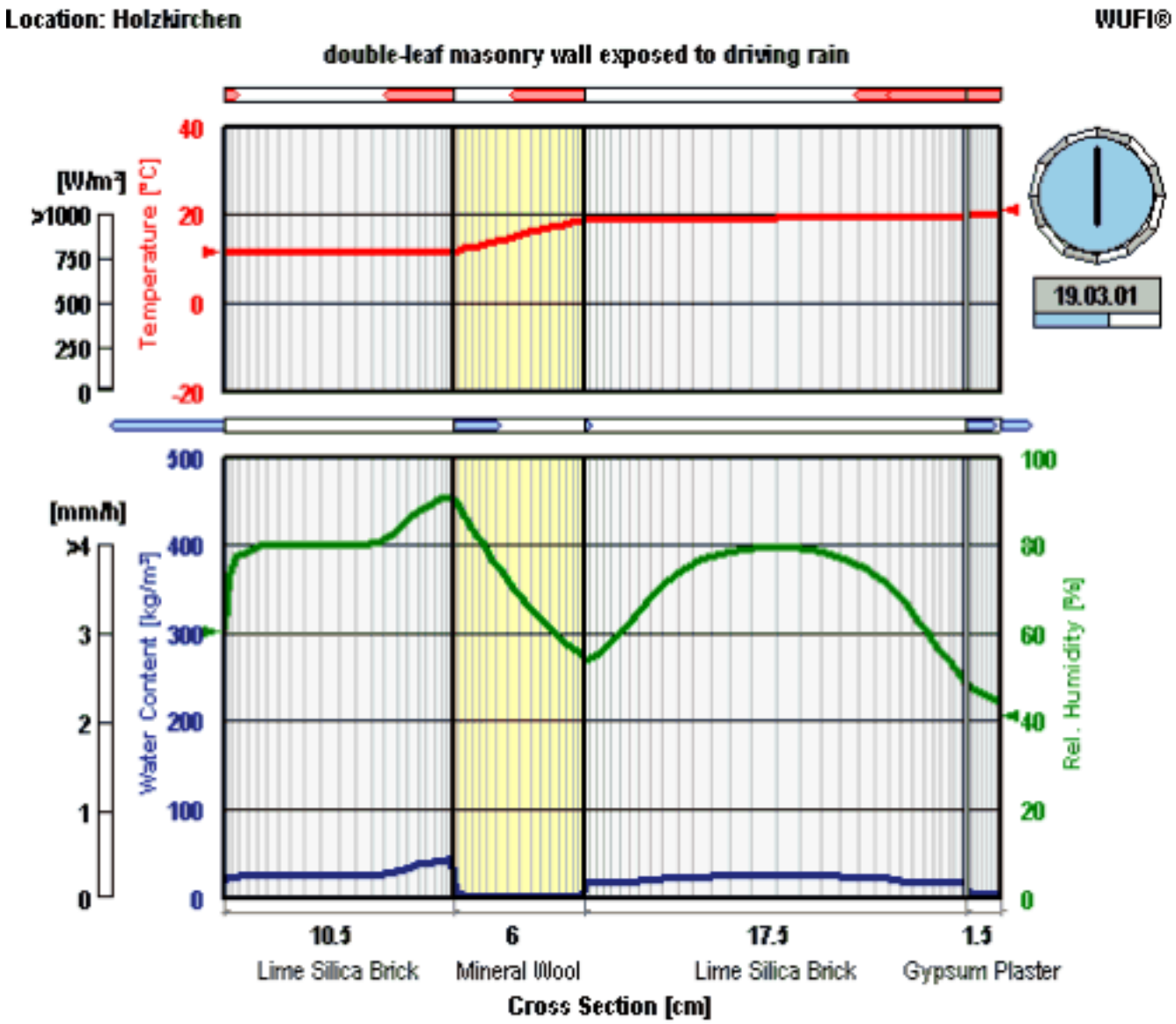
What is a vapor profile?

A vapor profile is an assessment of the vapor permeabilities of each component in a building

Areas of Focus for the BE Protection Systems

- Below-grade walls, Above-Grade walls, Roofs
- Underlayments
- Claddings
- Penetrations (connecting/weatherlapping flashings to WRB)
- Margins
- Transitions

WUFI – hygrothermal modeling



Building science summary

- Manage energy & moisture with equal intensity.

- Manage all types of moisture but generally in this order of priority:
  - Bulk water
  - Capillary water
  - Air-transported vapor
  - Vapor diffusion

- Who cares about this stuff? Believe or not, building owners do…

2015 Model Energy Code: Insulation, venting, VRs?

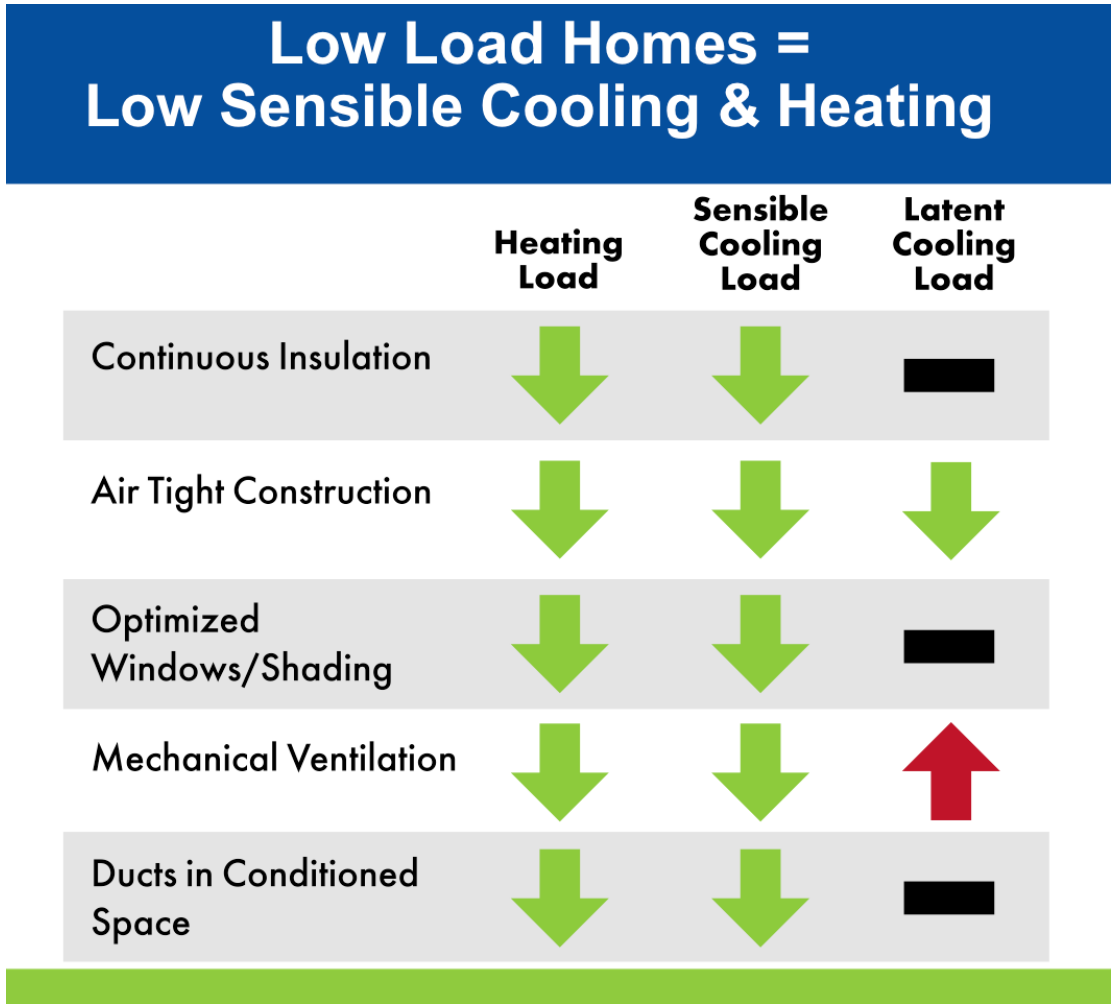
TABLE R702.7.1 CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a]
Marine 4	Vented cladding over wood structural panels. Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 2.5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 3.75 over 2 × 6 wall.
5	Vented cladding over wood structural panels. Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 7.5 over 2 × 6 wall.
6	Vented cladding over fiberboard. Vented cladding over gypsum. Insulated sheathing with *R*-value ≥ 7.5 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 11.25 over 2 × 6 wall.
7 and 8	Insulated sheathing with *R*-value ≥ 10 over 2 × 4 wall. Insulated sheathing with *R*-value ≥ 15 over 2 × 6 wall.

TABLE R702.7.1 CLASS III VAPOR RETARDERS

5	Vented cladding over wood structural panels. Vented cladding over fiberboard. Vented cladding over gypsum.
	Insulated sheathing with *R*-value ≥ 5 over 2 × 4 wall.
	Insulated sheathing with *R*-value ≥ 7.5 over 2 × 6 wall.

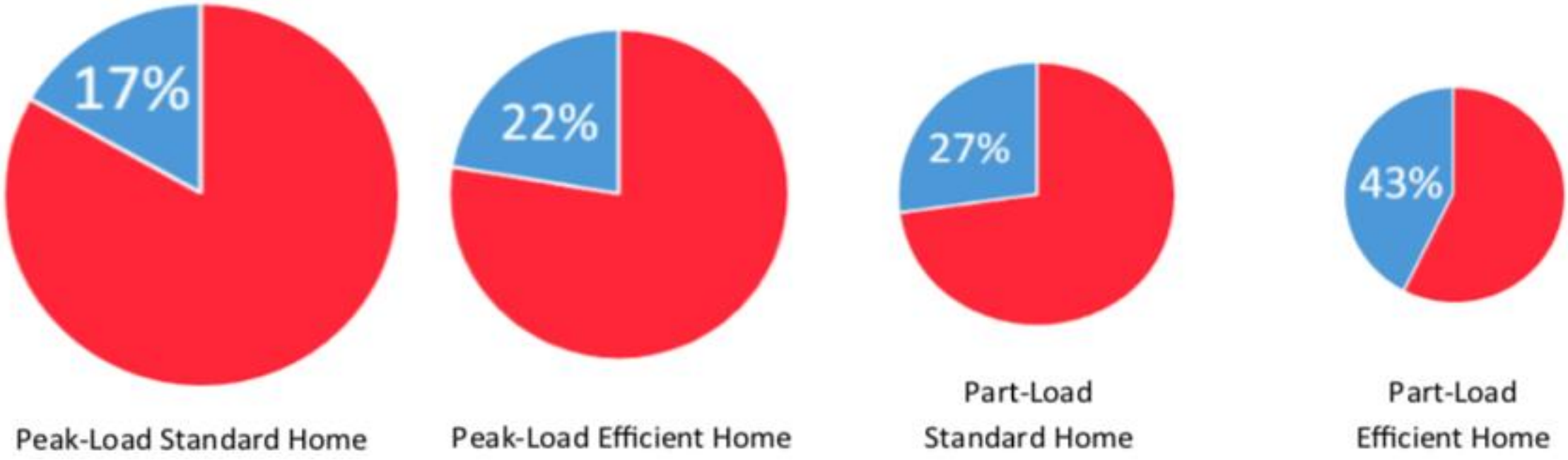
High Performance HVAC(D?)



Ultra·Aire™
WHOLE HOUSE VENTILATING DEHUMIDIFIERS

Latent Loads Increase as a Percentage of Total Loads at Part-Load Conditions.

PREPARED BY Home Innovation RESEARCH LABS



Summary – Action Items

Worry/work in this order:

1. Bulk water management
2. Capillary breaks
3. Air leakage
4. Vapor diffusion (INCLUDING interior sources of moisture from those darn occupants…)
5. Manage each with continuous control layers

Hygrothermal Balance