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

“This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 code/energy hours** of credit toward **Building Officials and Residential Contractors** continuing education requirements.”

For additional continuing education approvals, please see the continuing education credit section in the conference agenda booklet.

Highly Permeable Membranes Allow Vapor Diffusion and Stop Heat

Scott D. Wood, Senior Building Scientist

SCOTT D. WOOD
Senior Building Scientist

YOUR PRESENTER

Scott D. Wood is a member of the VaproShield team, providing lab evaluations on competitor and VaproShield's products.

He provides technical support answering company's client inquiries, and assists in development--updating product literature and creating VaproShield's AIA presentations.

As president of Scott Wood Associates he provides a level I and II Building Science Thermography course. His extensive background in building science and infrared thermography has supported the excellent presentations and papers he has provided domestically and internationally.

Course Description

- Low permeance vapor barriers, once thought to improve performance, may in fact increase interior condensation and trap moisture within the wall assembly. Due to the problems with impermeable water-resistive barrier (WRB) installation many architects are now incorporating highly vapor open WRB systems in their designs. But many still believe too much permeability is bad for a wall assembly.
- Studies show that highly permeable WRB systems increase substrate drying, reduce the wet time of absorptive claddings allowing permeable WRB membranes to enhance the wall assembly performance. This presentation investigates the current research on vapor open systems and discusses how more permeability enhances wall assembly performance.

Learning Objectives

At the end of the this presentation, participants will be able to:

- Define what water vapor permeance is and how it is tested
- Understand wall assembly drying mechanisms using vapor diffusive drying in conjunction with air tightness
- Show the benefits of permeable assemblies
- Illustrate the differences between vapor tight and highly permeable WRB membranes in relation to water intrusion of a wall assembly

Disclaimer

This Presentation reflects the opinion of the author based on professional experience. The author reserves the right to modify opinions should additional (factual) information be made available that is contrary to the opinions expressed herein.

Overview

Water Vapor Transmittance

- What is Water Vapor Transmittance?
- Procedures: ASTM E96, ASTM E398, ASTM F1249

Water Hold Out Air Tight

- Water Vapor Transport but Air Tight
- Surfactants
- Water Holdout Testing

Energy Loss - Convection

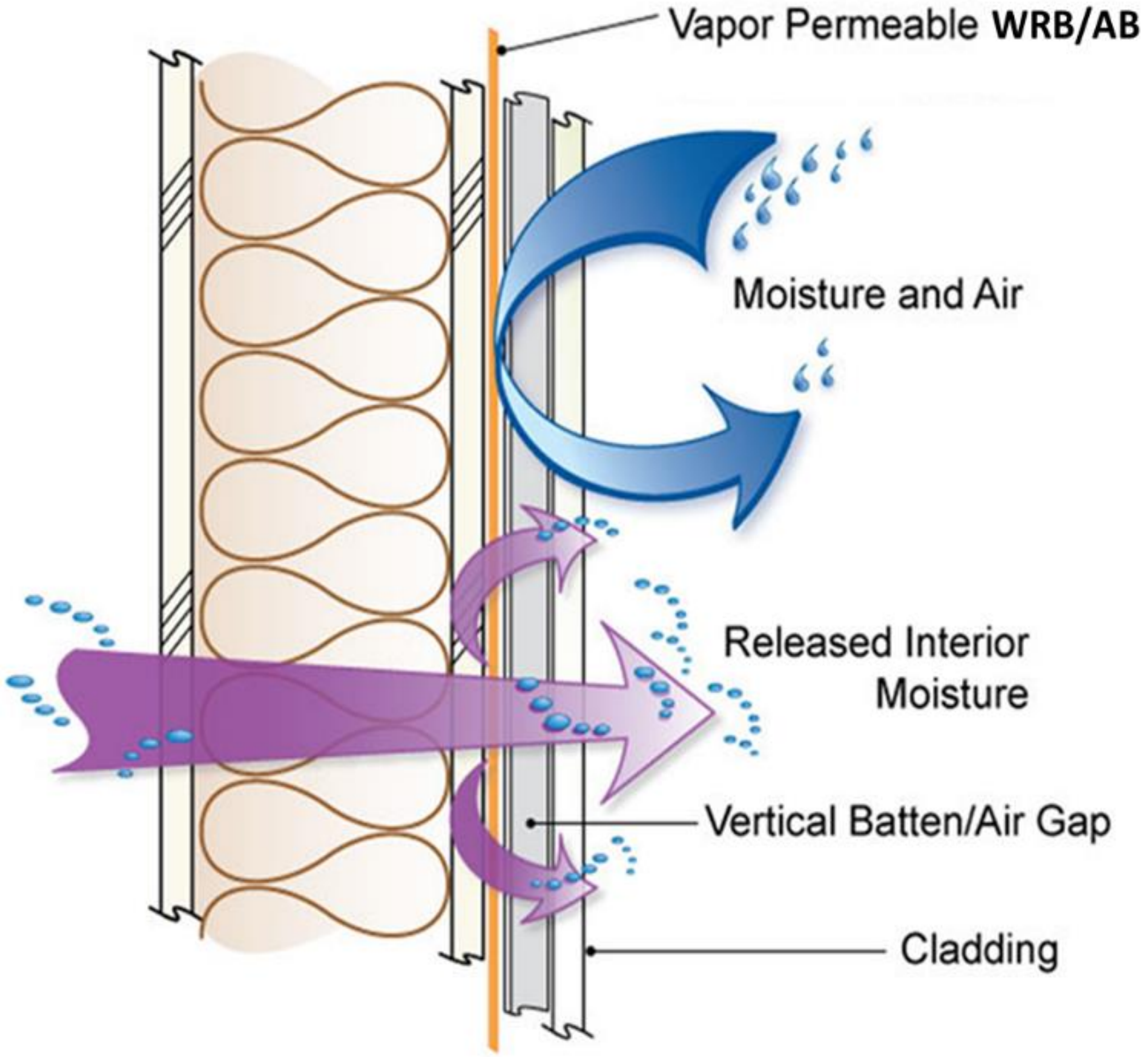
Drying Capacity

- Vapor Diffusive Drying Test

Vapor Barriers vs. Vapor Open

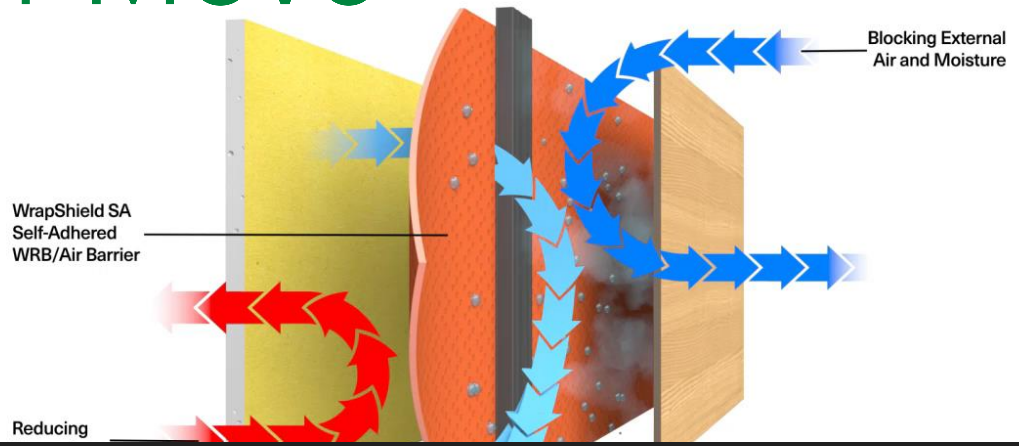
Cladding

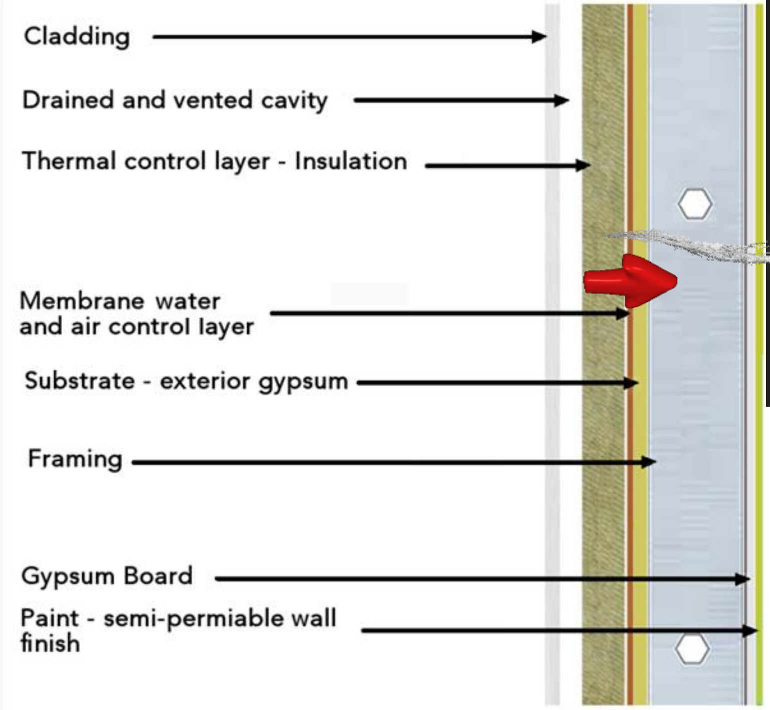
- The Perfect Wall
- Rainscreen



How Does Water Vapor Move

- Vapor Diffusion: Through materials
- Air Flow: Through holes

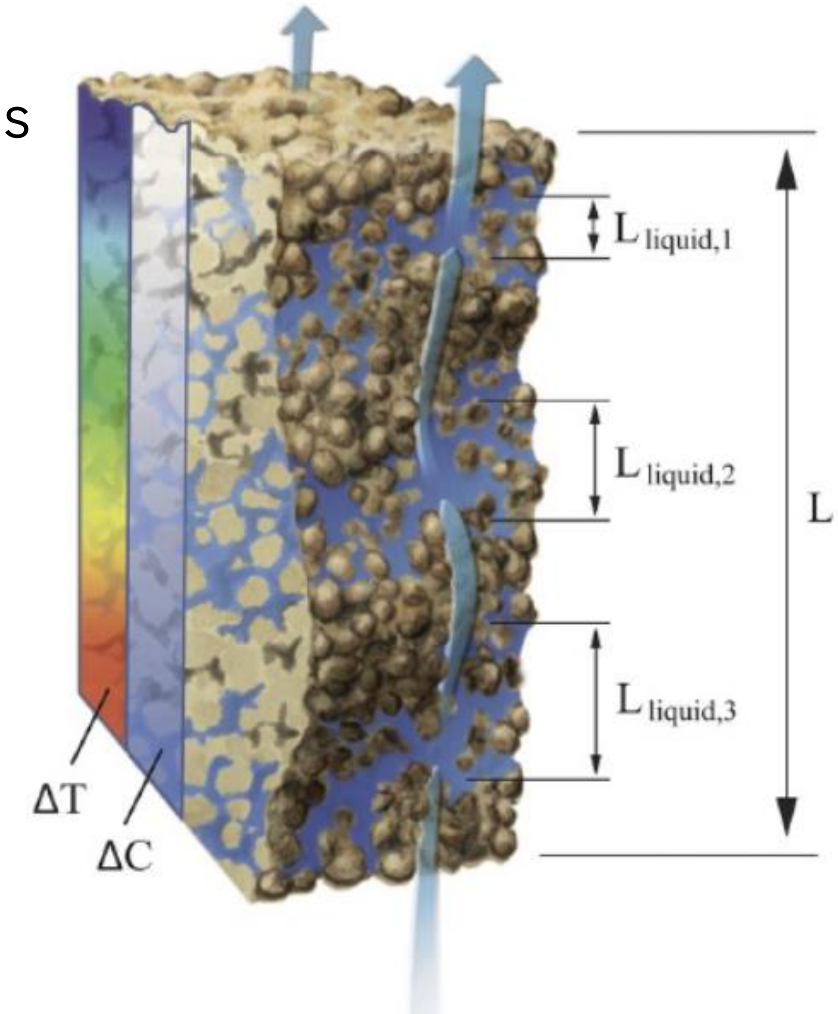




What is Permeance? "Vapor Movement"

- Measurement of water vapor through materials
  - ➢Weight of Water
  - ➢Per Time
  - ➢Through a given Area
  - ➢At a specific Pressure

- US perm:
  1 grain / hour • ft^2 @ 1 inch of mercury
- Metric permeance:
  ng / Pa • s • m²



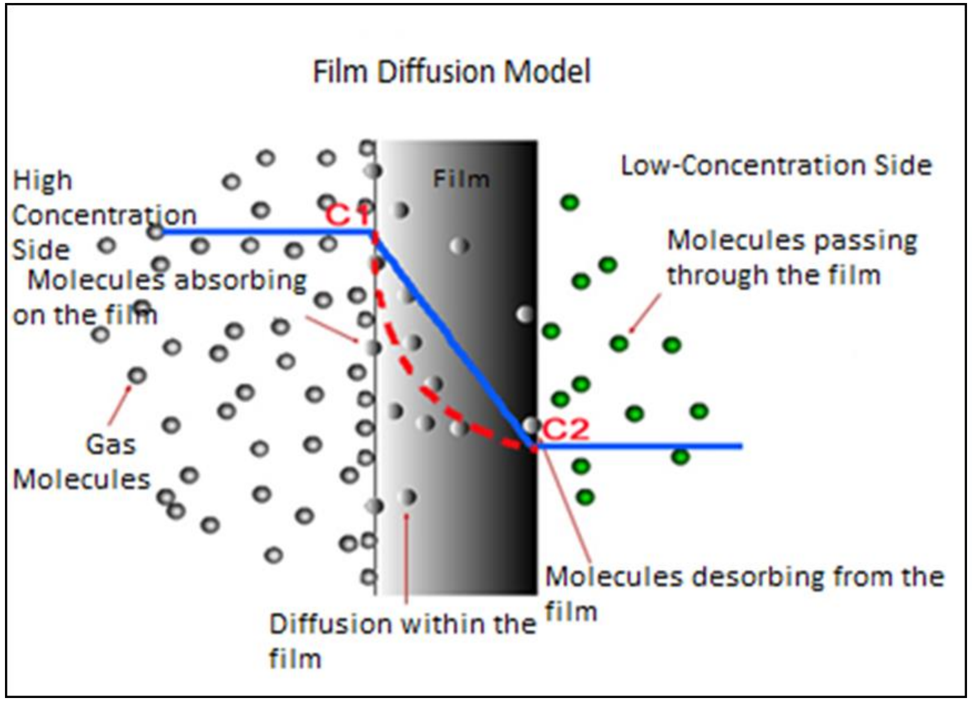
WATER RESOURCES RESEARCH, VOL. 48, 2012 *Pore scale mechanisms for enhanced vapor transport through partially saturated porous media*

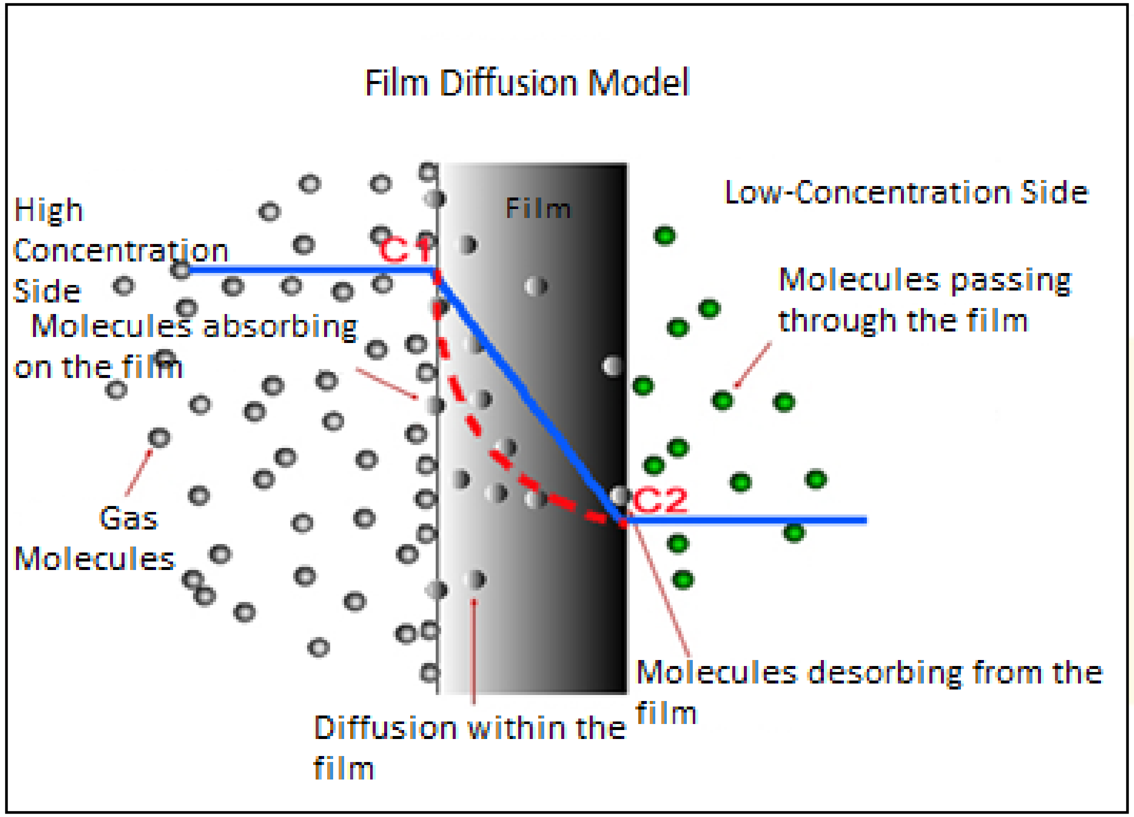
Water Vapor Movement & Hygroscopic Material

- **Adsorption:** Gas to liquid
- **Absorption**: liquid to solid

Adsorption

Absorption





Adsorption (hygroscopic material)

- ASHRAE Handbook of Fundamentals
- Adsorption provides a Hygric Buffer
- 16-20% correlates to a 80-90 %RH

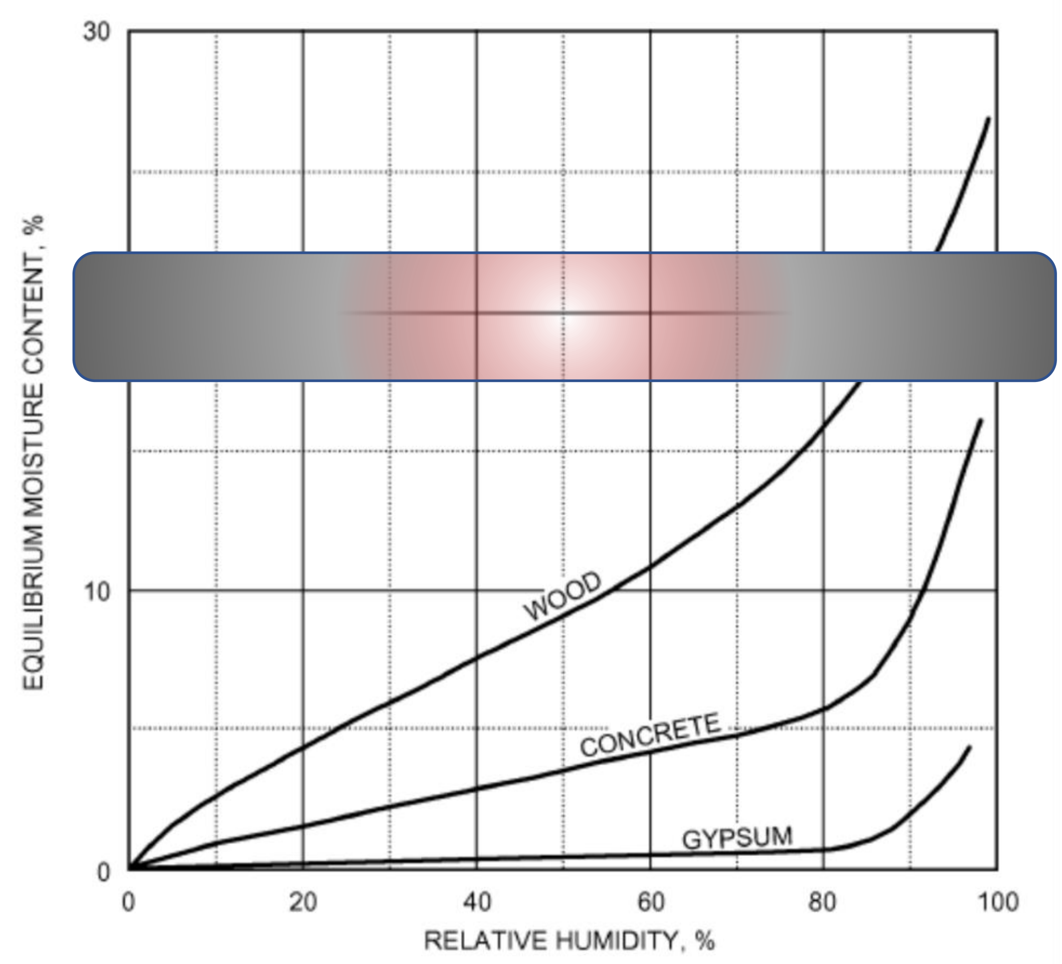


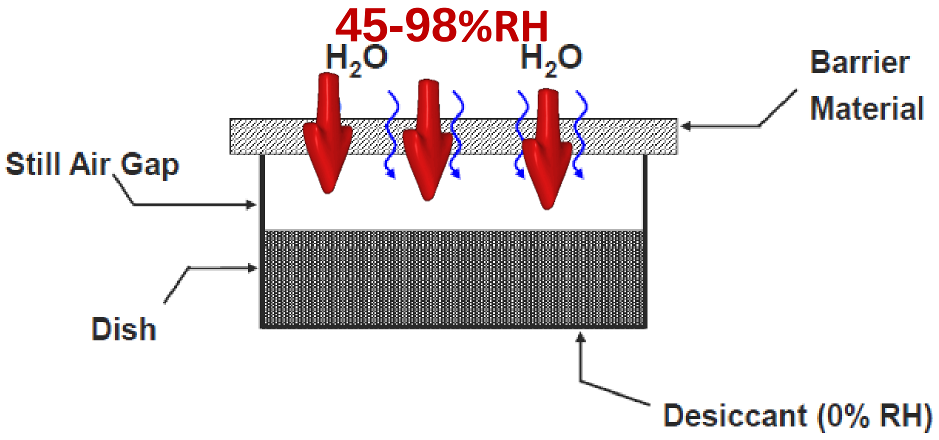
Fig. 1 Adsorption Isotherms for Wood, Concrete and Gypsum

ASTM E96

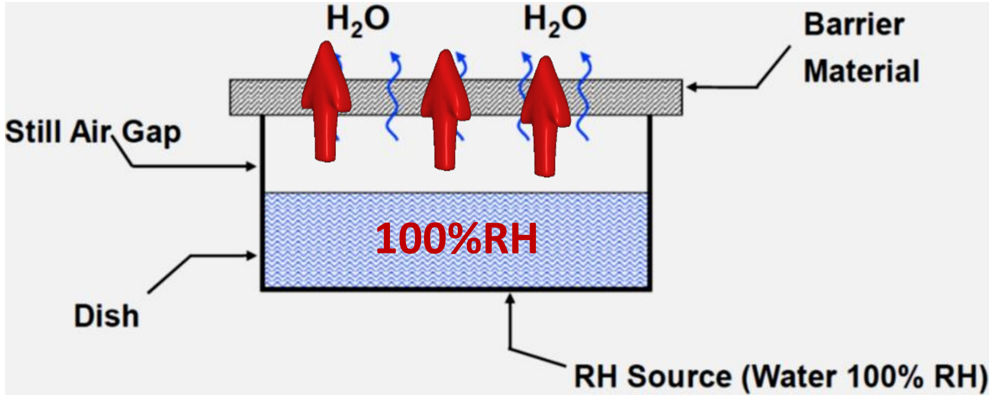
- Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials

ASTM E-96 Water Vapor Transmission (WVT)

- Procedure A – Desiccant method (Dry Cup)

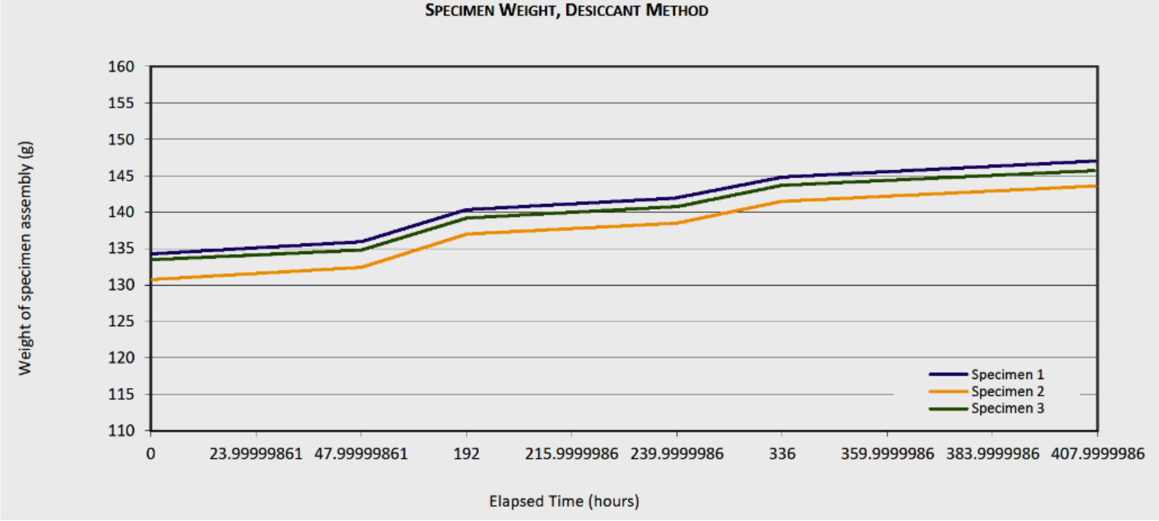


- Procedure B – Water method (Wet Cup)



ASTM E-96 Water Vapor Transmission (WVT) adopted in 1941

- Equipment/Operator Variability
  - ASTM reports 20% lab-to-lab
  - Size and type of cup
  - Sample sealing mechanism
  - Amount of water/desiccant
  - Sample distance from desiccant or water level (Edge effects)
  - Environmental controls
  - Sampling (weighing/plotting)

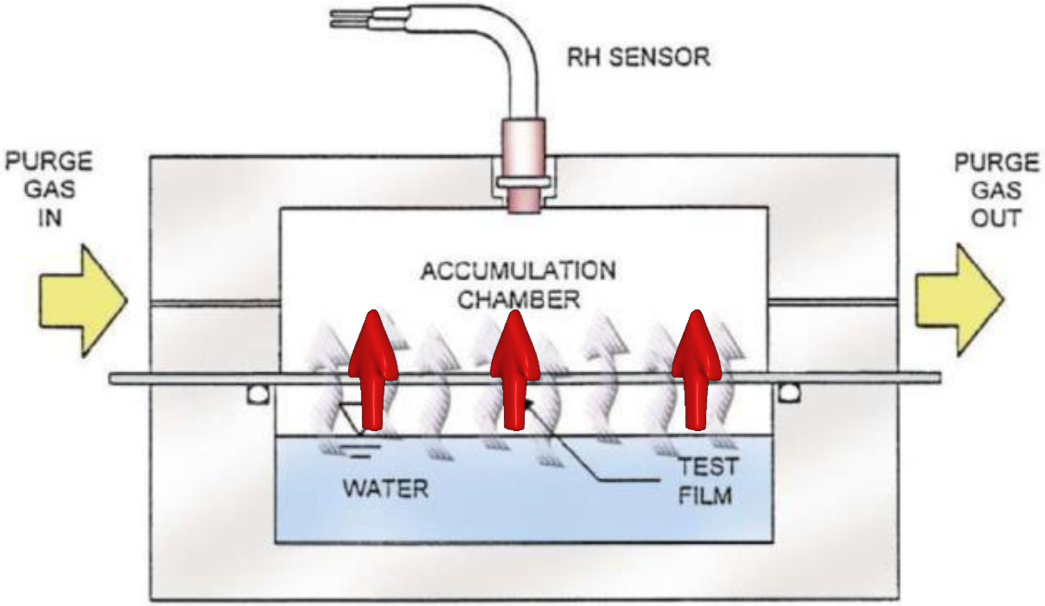


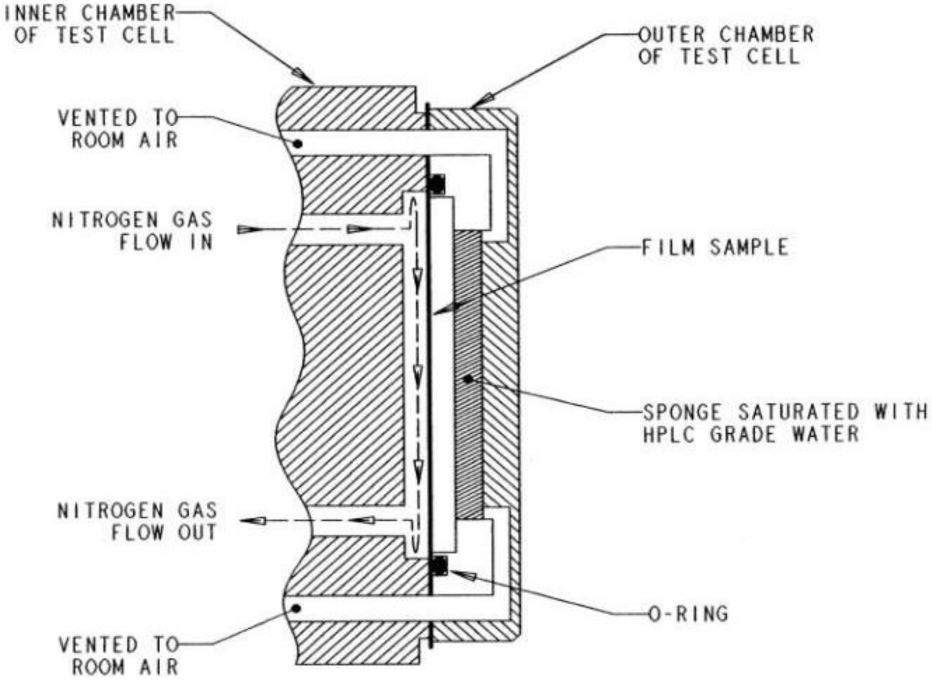
ASTM E398

- Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement

ASTM E398

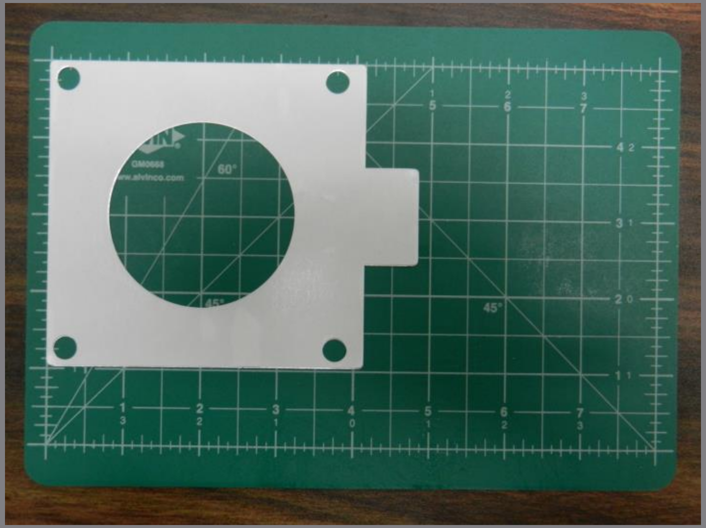
- **ASTM E398** Water Vapor Transmission Rate of Sheet Materials Using Dynamic **Relative Humidity** Measurement





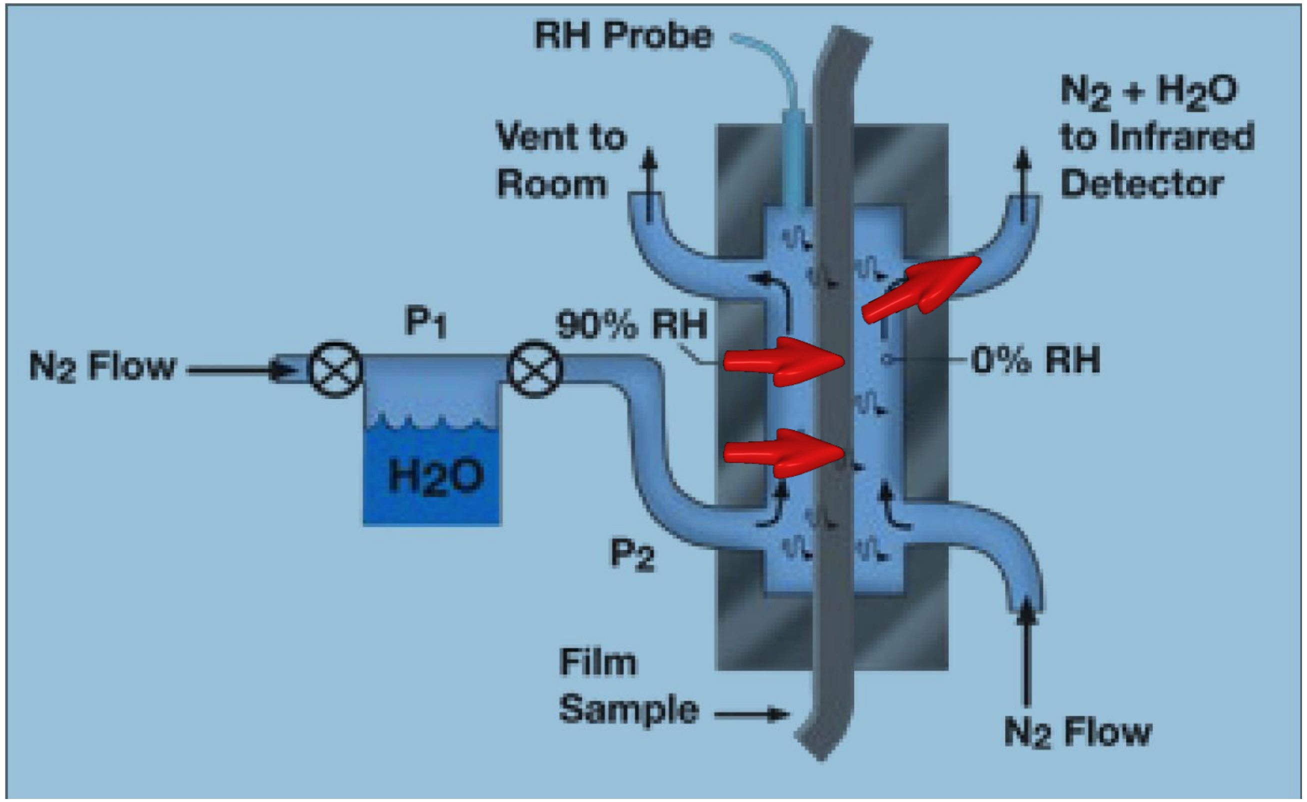
ASTM F1249

- Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor



ASTM F1249

- **ASTM F1249** Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated **Infrared Sensor**



WVTR Testing E398 and F1249

- ASTM E398 - Similar to the ASTM E96 Water Method
  100% RH always on the high vapor pressure side
- ASTM F1249 – Similar to the ASTM E96 Desiccant Method
  0% RH always on the low vapor pressure side

Comparisons

	E96 	E398  F1249 
Temperature Range	room or 15-55°C (60-130°F)	8-50 °C (46-122 °F)
Relative Humidity	room or 45-98%	5-90%
Average Run Time	8-24 hours – days	6-8 hours - days
Sample Size	30 cm^2	5 cm^2 - 30 cm^2
Number of Samples	1-6	2 per module

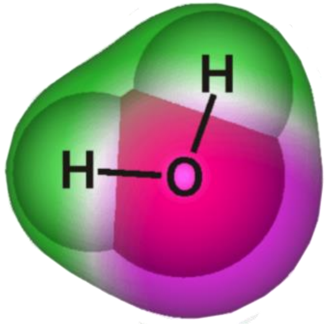
Water Tight, Air Tight, Water Vapor Open?

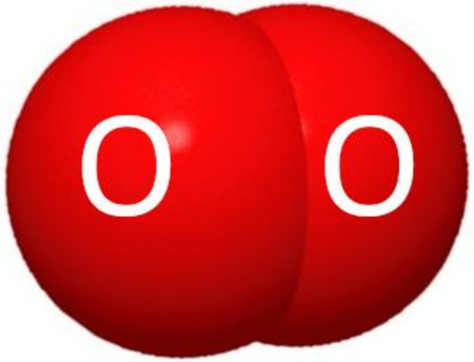
Not leaking water and air?

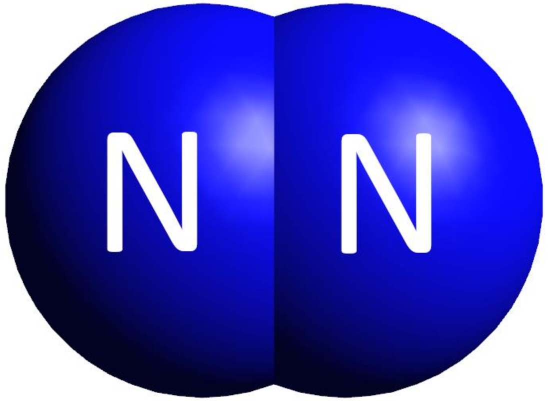
- Air contains: 78% Nitrogen, 21% Oxygen
- N_2 (3.16 Å), O_2 (2.96 Å), H_2O (2.7 Å)
- Water vapor in the air is a gas, **invisible to the eye**

- Water Vapor Transmission is measured through solids

  US PERM= grains/ft^2•hour•inchHg

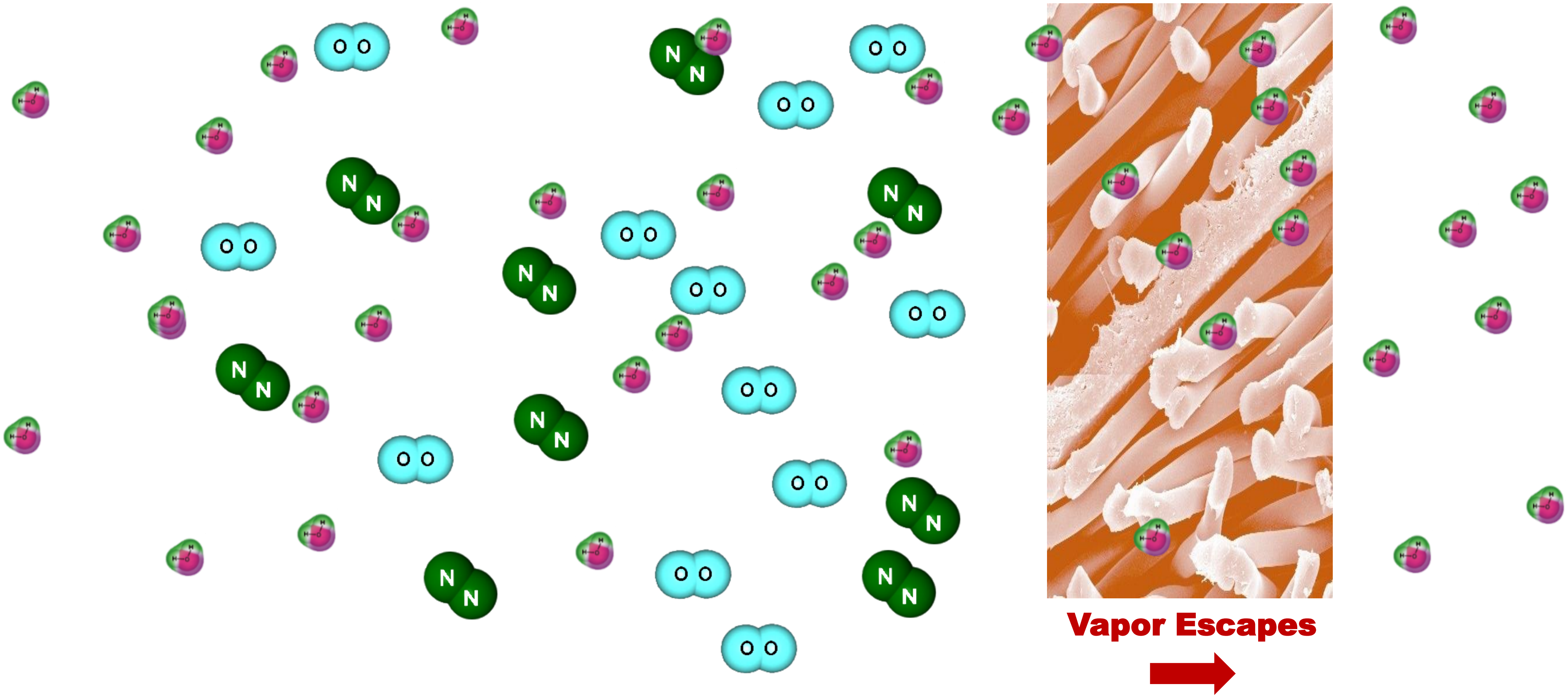






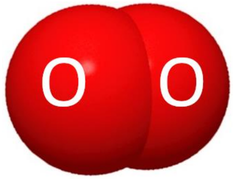
Water & Air Tight Breathable Membranes

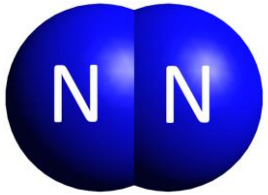
- "Air" (O_2 & N_2) is 1.5 times LARGER than H_2O

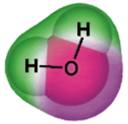


Amount of Vapor in the Air

- x10^{23} atoms of "Air" in 1x1 ft^2
- x10^{21} atoms of "Water" in 1x1 ft^2

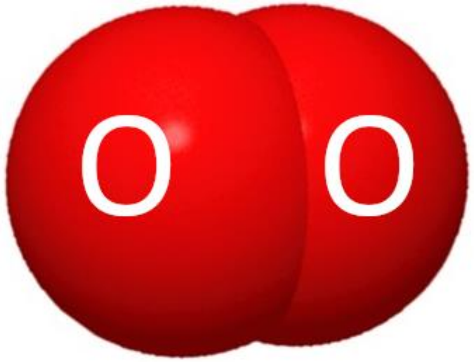


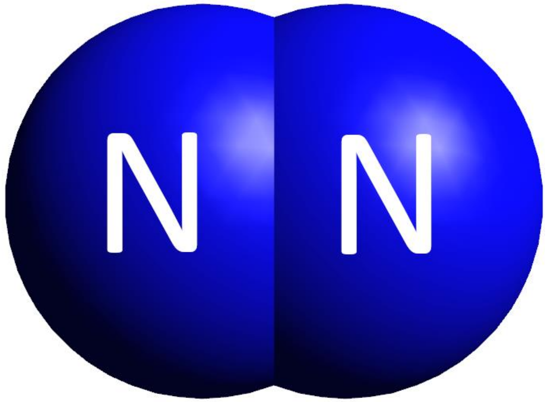




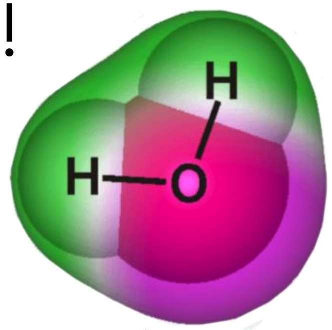
80-95% difference

Amount of Vapor in the Air





- $\times 10^{23}$ atoms of "Air" in 1x1 ft^2
- Dependent on relative humidity: 1-4% is water vapor Even at that percentage that's a lot of water in the AIR!



- Air transported moisture during the heating season provides 90 times greater intrusion via air then vapor permeance.

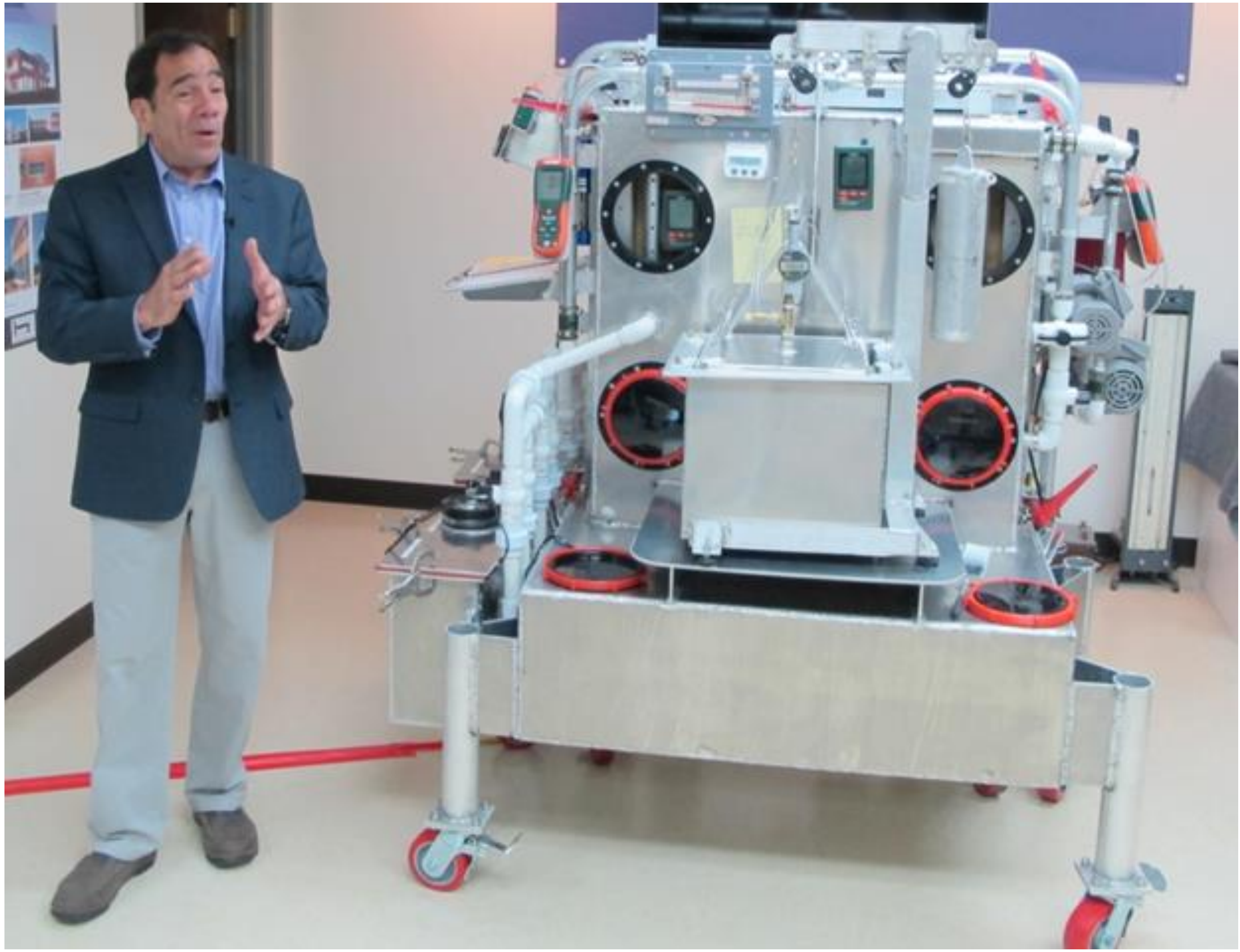
Air Barriers and Air Permeability

- The IECC and ASHRAE 90.1 dictated the air leakage rate allowed by air barrier materials

0.004 cfm/ft² (0.02 L/s m²) @ 75 Pa

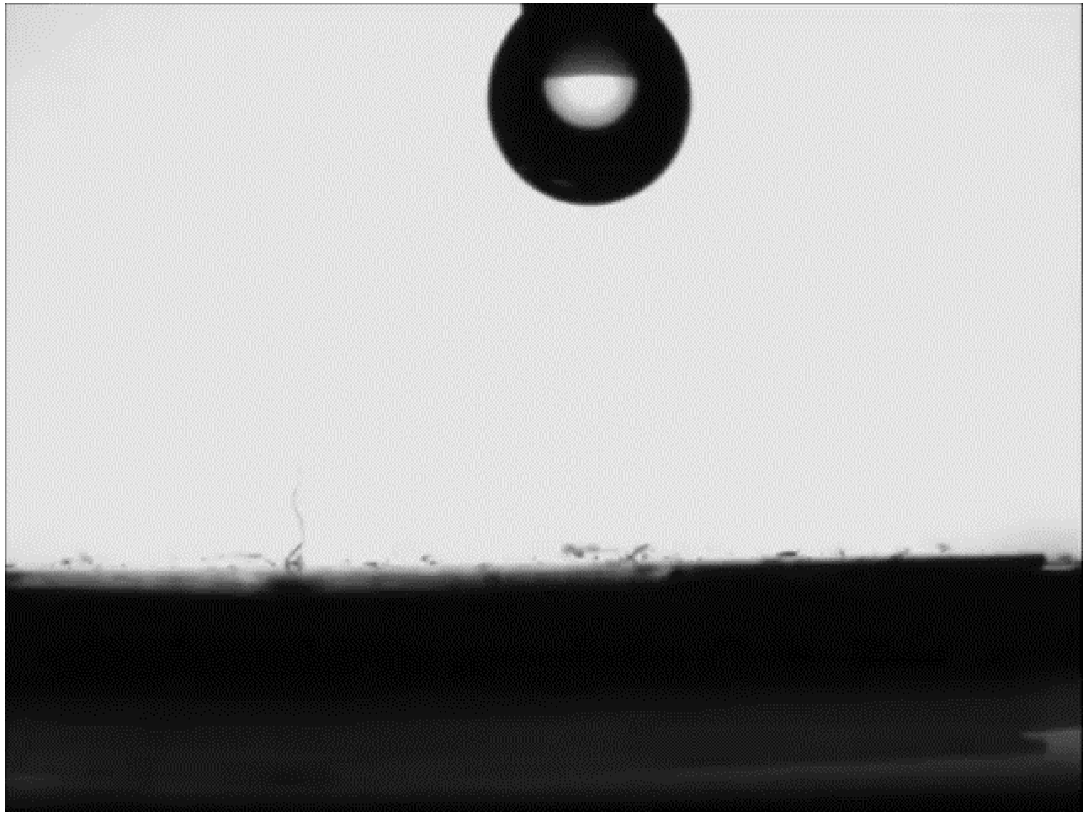
- Whole-building air leakage testing is becoming a requirement in many code jurisdictions

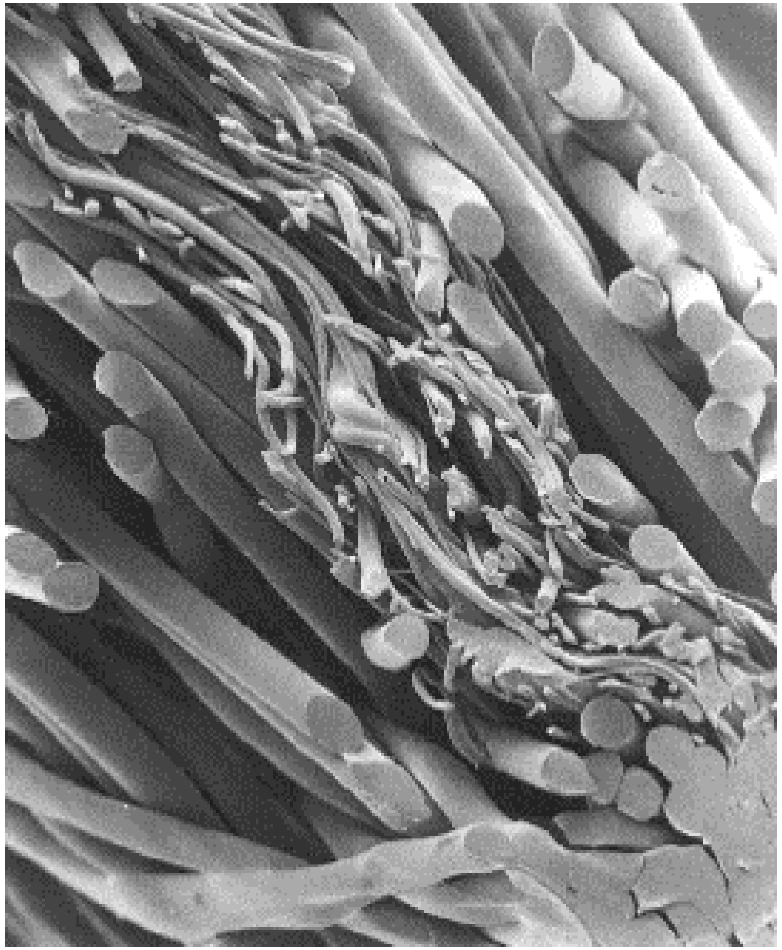
0.4 cfm/ft² (2.0 L/s m²) @ 75 Pa



Building Wraps are Hydrophobic

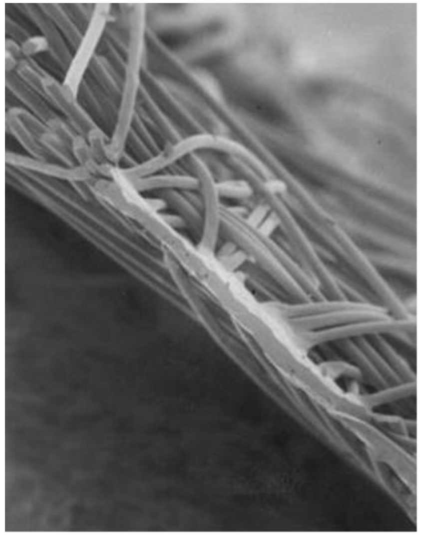
- But doesn't Vapor Open "Leak"?
- Failure is typically due to bulk "leaks"

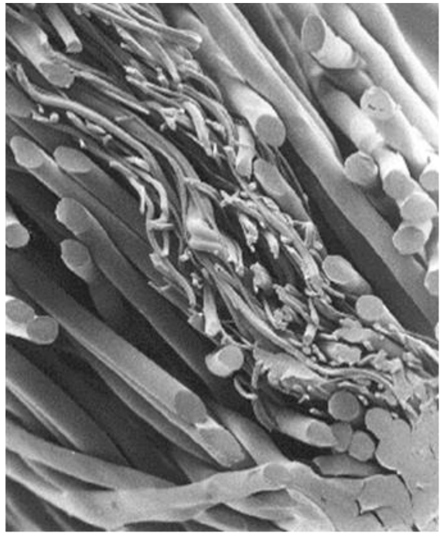




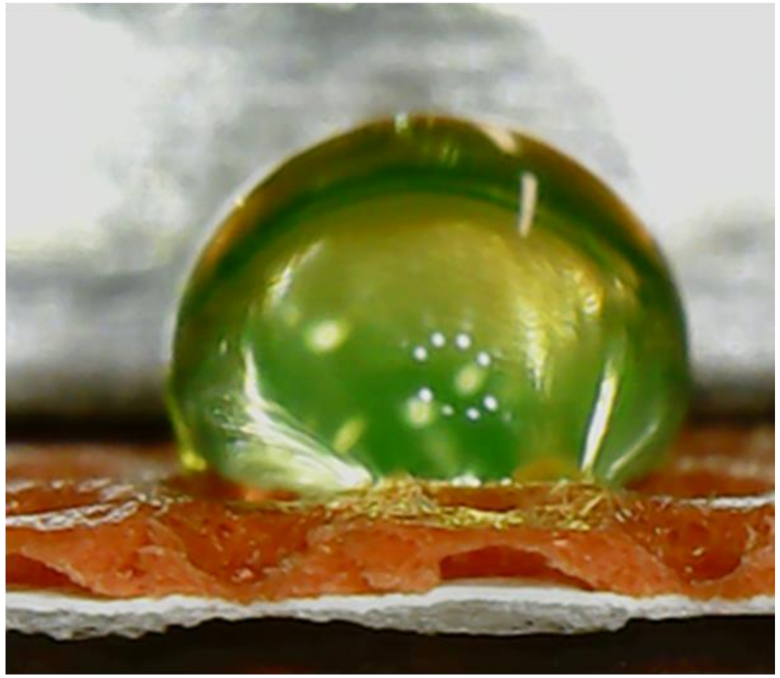
Building Wraps

- Spunbond:



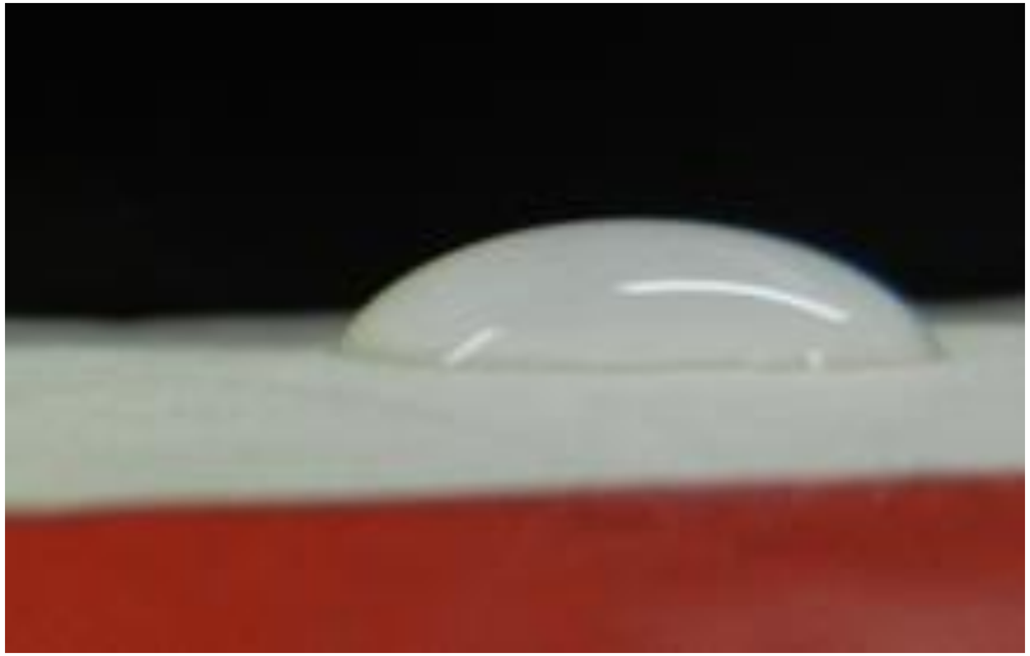


- Woven:

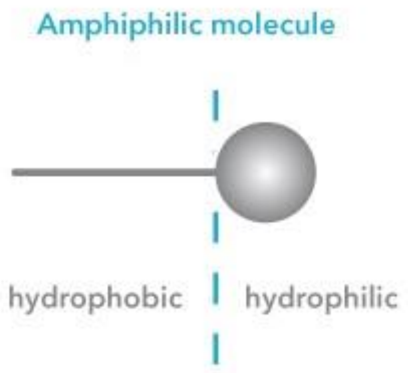


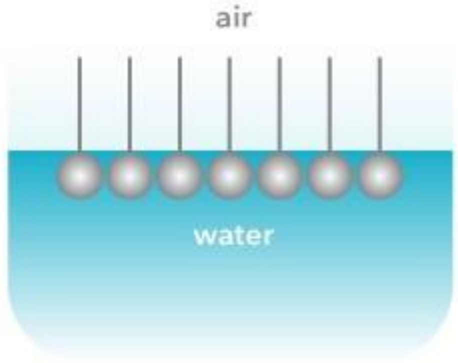
Surfactants and Vapor Permeable Building Wraps

- Surfactants make water more wettable
  Reduces water's hydrogen bonding at the air-water surface



Surfactants





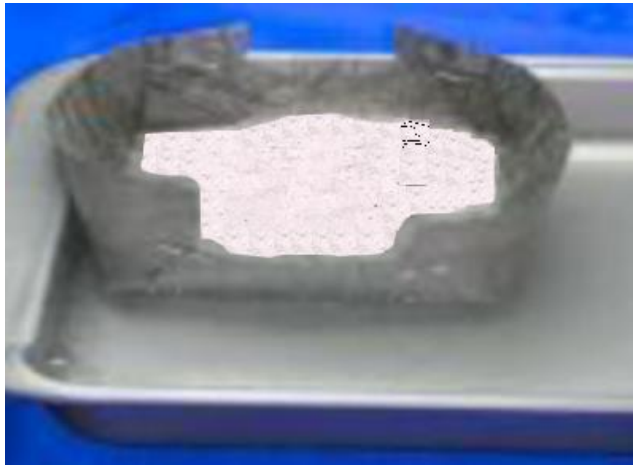
- Amphiphilic molecules
- Align at the air-water interface
  decreases the surface tension of the water

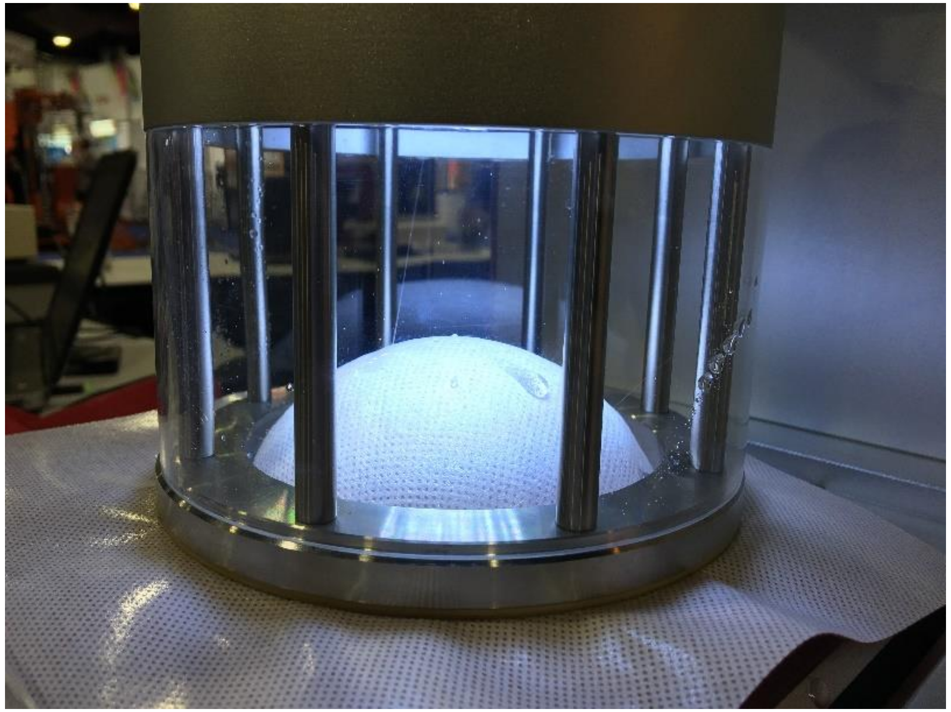
Surfactant type	Example	Use
Anionic	Alkyl sulfates, soaps, Calsoft®, Texapon®	50 % of overall industrial production, laundry detergent, dishwashing liquids, shampoos
Cationic	Quaternary ammonium salts	Used together with nonionic surfactants but not with anionic, softeners in textiles, anti-static additives
Nonionic	Ethoxylated aliphatic alcohol, polyoxyethylene surfactants, Triton™ X-100, Span®, Tergitol™	45 % of overall industrial production, a wetting agent in coatings, food ingredient
Zwitterionic	Betaines, amphoacetates	Expensive, special use e.g. cosmetics

Water Holdout Tests

- ‘Boat test’ (ASTM D779)
- ‘Ponding test’-Canadian Construction Materials Center (CCMC 07102)
- Hydrostatic Pressure Test (AATCC Test method 127
- Hydrostatic Pressure Test EN 20811

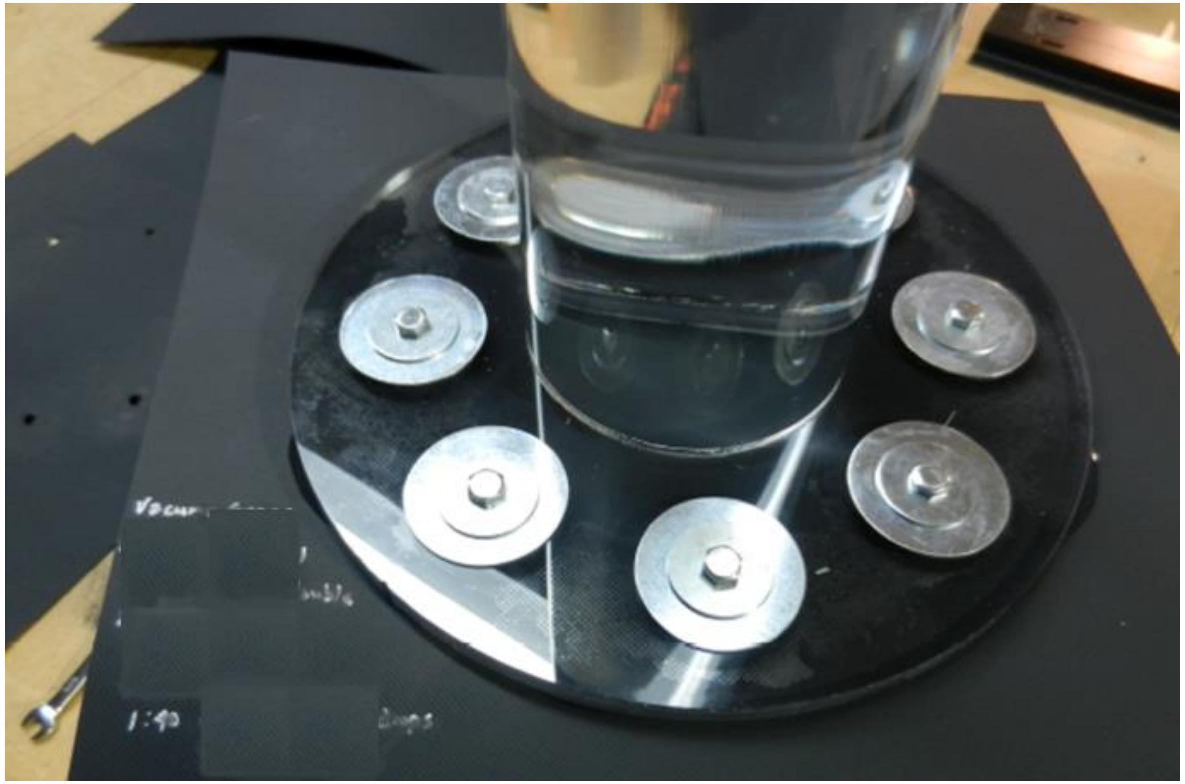
- Indicator material in a “boat” 60 min
- 2.5 cm (1”) water column 2 hours
- 55 cm (22”) column 5 hours





Water Holdout
"AATCC Hydrostatic Pressure Test"

- 550 mm Water Head
  <4 drops at 5 hours



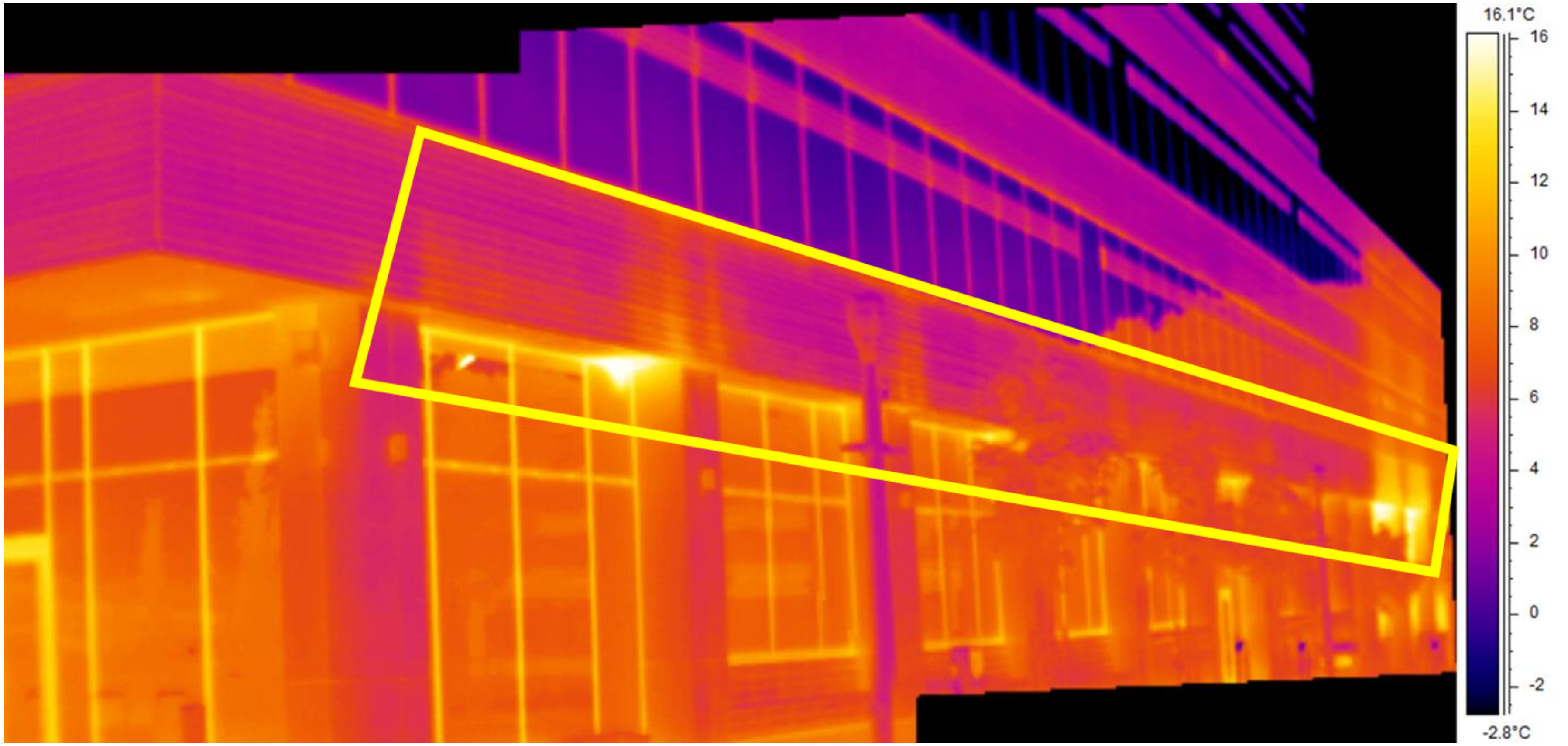
Some Membranes Fail Water Hold Out

Water Vapor Permeable Air Tight?

- **Infrared Thermography**

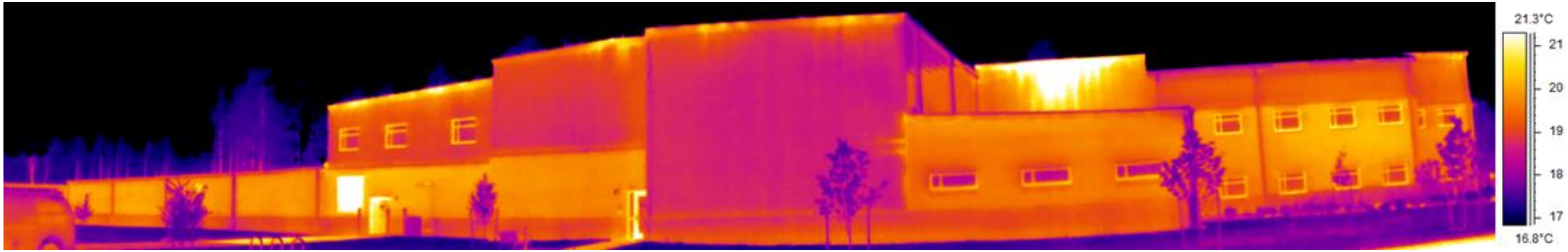
Water Vapor Permeable **Air Tight**

- Increased Heat transfer and Energy to heat and cool
- Forced Convection



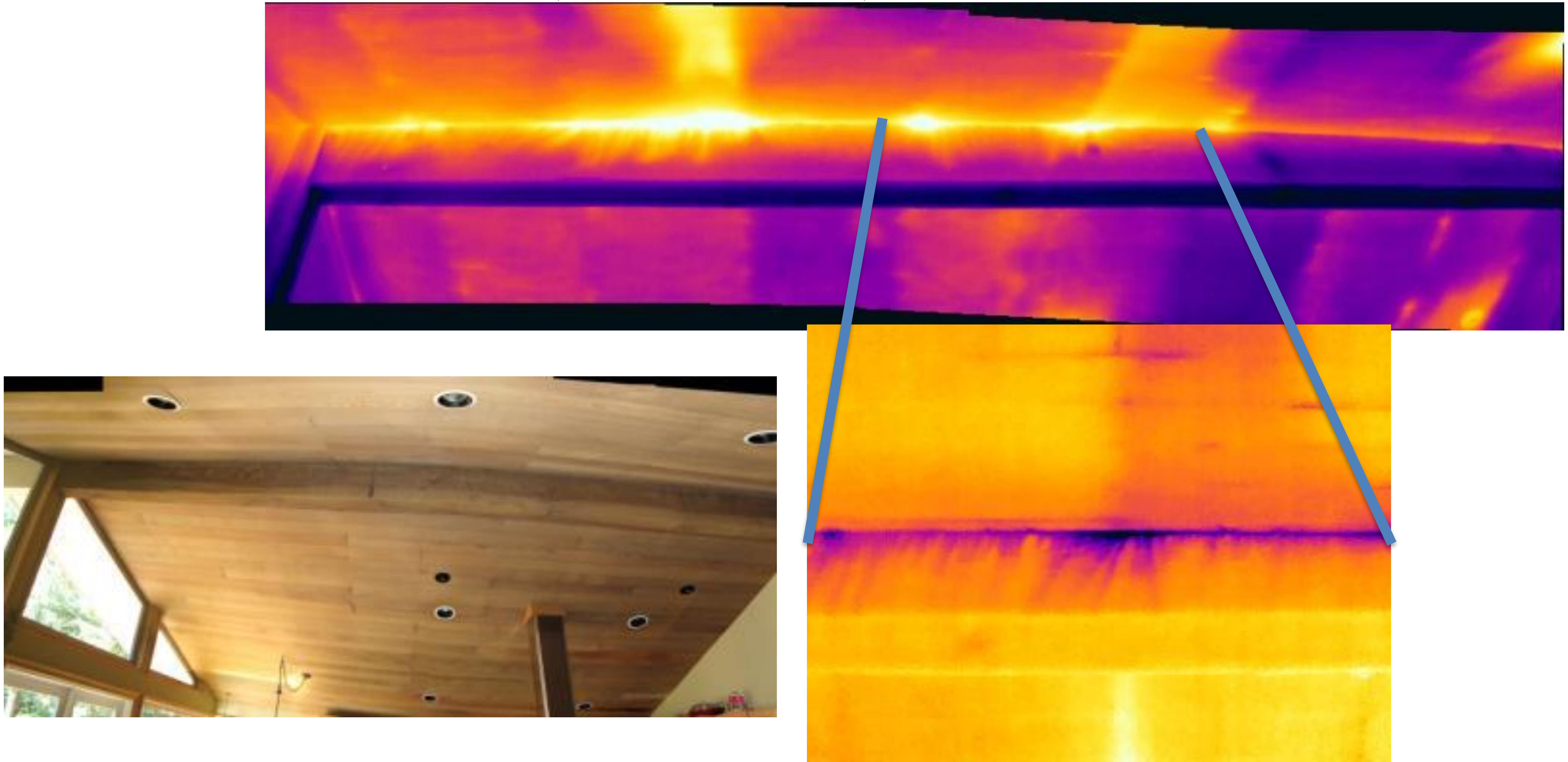
Water Vapor Permeable **Air Tight**

- Infrared Thermography Testing

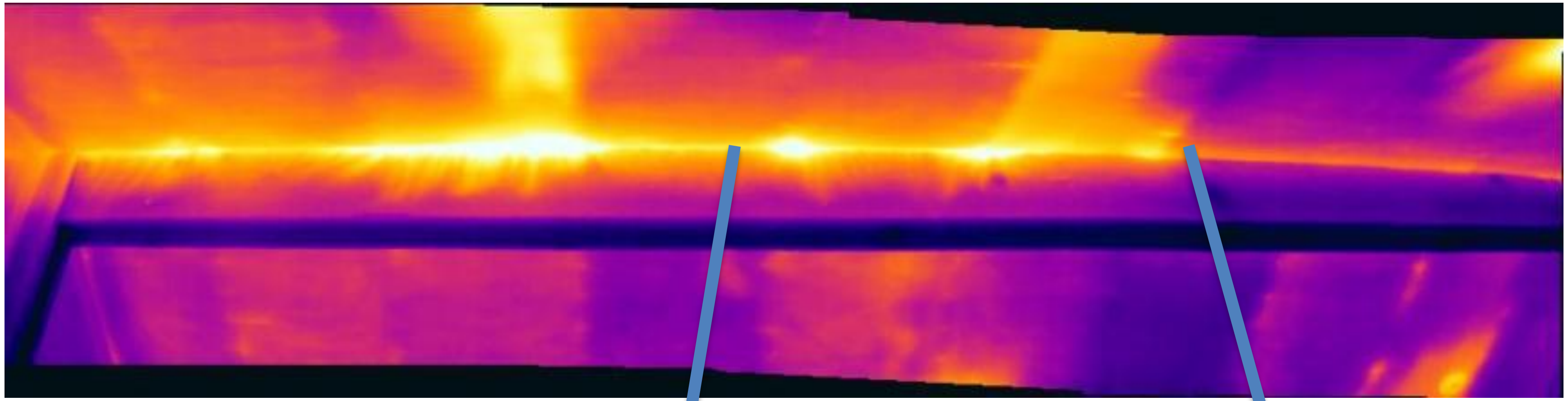


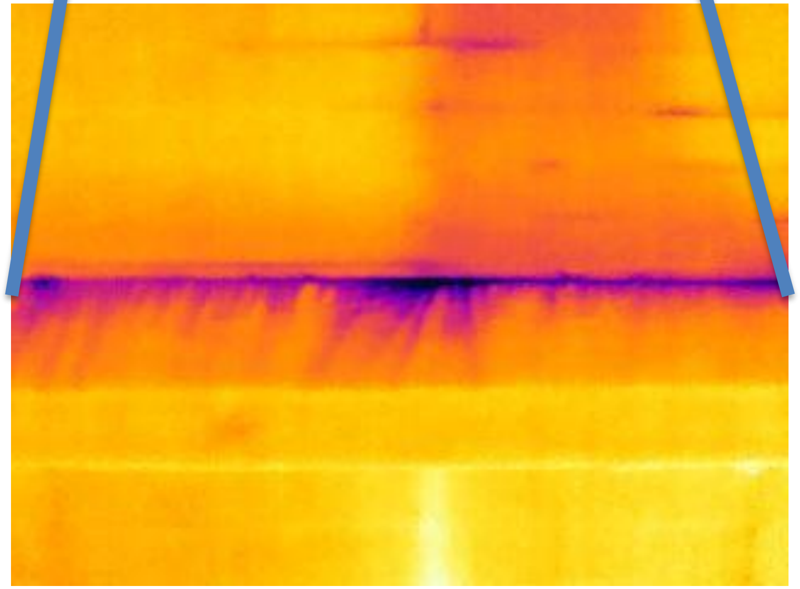
Water Vapor Permeable **Air Tight**

- Natural Convection (Stack Effect)



Warm or Cold



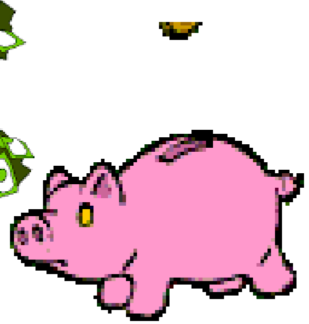


Energy Loss - Air Leaks

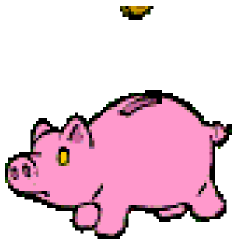
- Studies have shown that air barriers can reduce air leakage by up to 83 percent
- Energy consumption for heating & cooling savings of 3-36%

Seal tight,
Ventilate right!

Jack Hébert, founder of the Cold Climate Housing Research Center

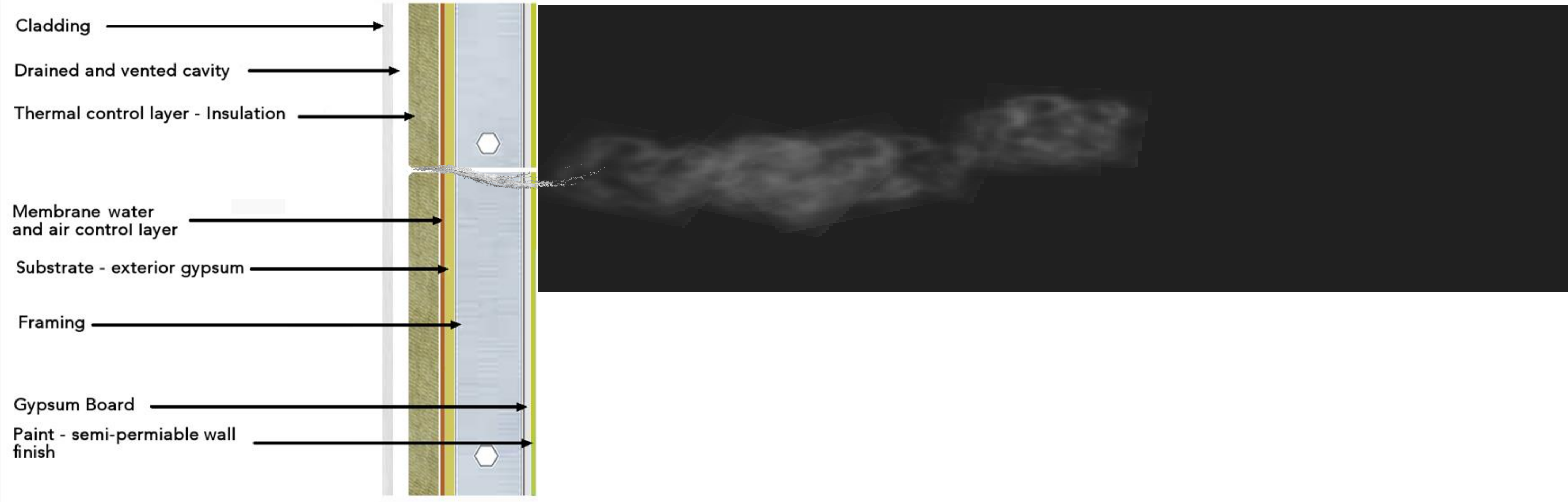


Energy Savings



- Air Flow: Moisture and Heat Movement

"Seal Tight, Ventilate Right"



Energy Savings and Moisture Transfer Calculator

- Uncontrolled heat, air, and moisture transfer through the building envelope has a significant impact on energy usage.
- Air movement accounted for greater energy losses than any other component of the building envelope and responsible for over 4 % of all the energy used in the United States.
- With the addition of air barrier systems ROI < 5 years

"Seal Tight, Ventilate Right"

Energy Loss – Air Leaks

- Energy-cost savings in buildings with an air barrier range from 3% to 36%

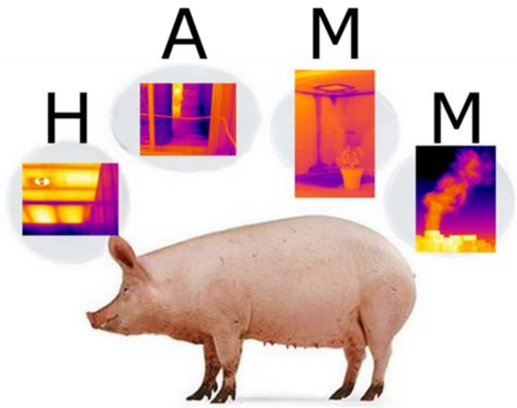
ORNL Energy Savings & Moisture Transport Calculator:
https://airleakage-calc.ornl.gov/#/

Duluth Area:

- Primary School (74,000ft^2): $25,912 [82,683 – 21,141gal/year]
- Residential (20,000ft^2): $1,157 [7,000 – 2,300gal/year]
- Retail (25,000ft^2): $14,096 [47,638 – 14,084gal/year]

abaa air barrier association of america U.S. DEPARTMENT OF ENERGY Office of Science NIST National Institute of Standards and Technology U.S. Department of Commerce

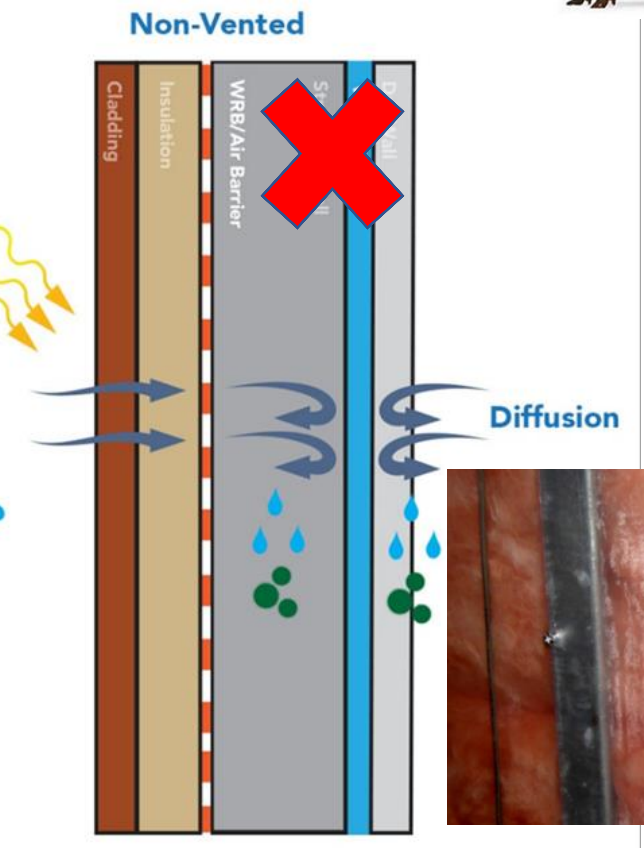
Building Enclosure

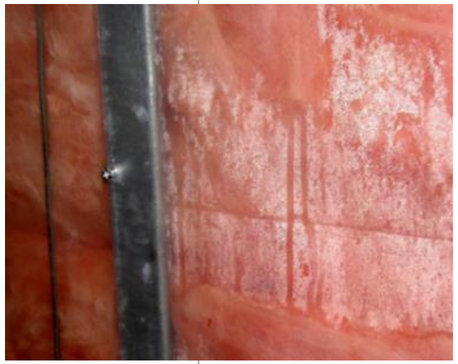


The building enclosure has four "controlling" functions.

Heat, Air, Moisture liquid, Moisture vapor
In order of importance, they include:

- Rain Control
- Air Control
- Vapor Control
  Not Vapor Barrier
- Thermal Control

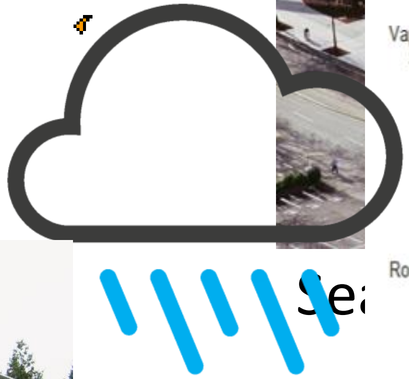


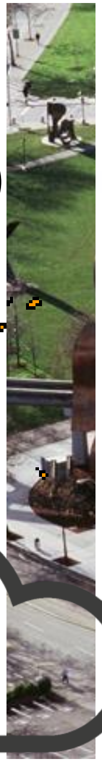


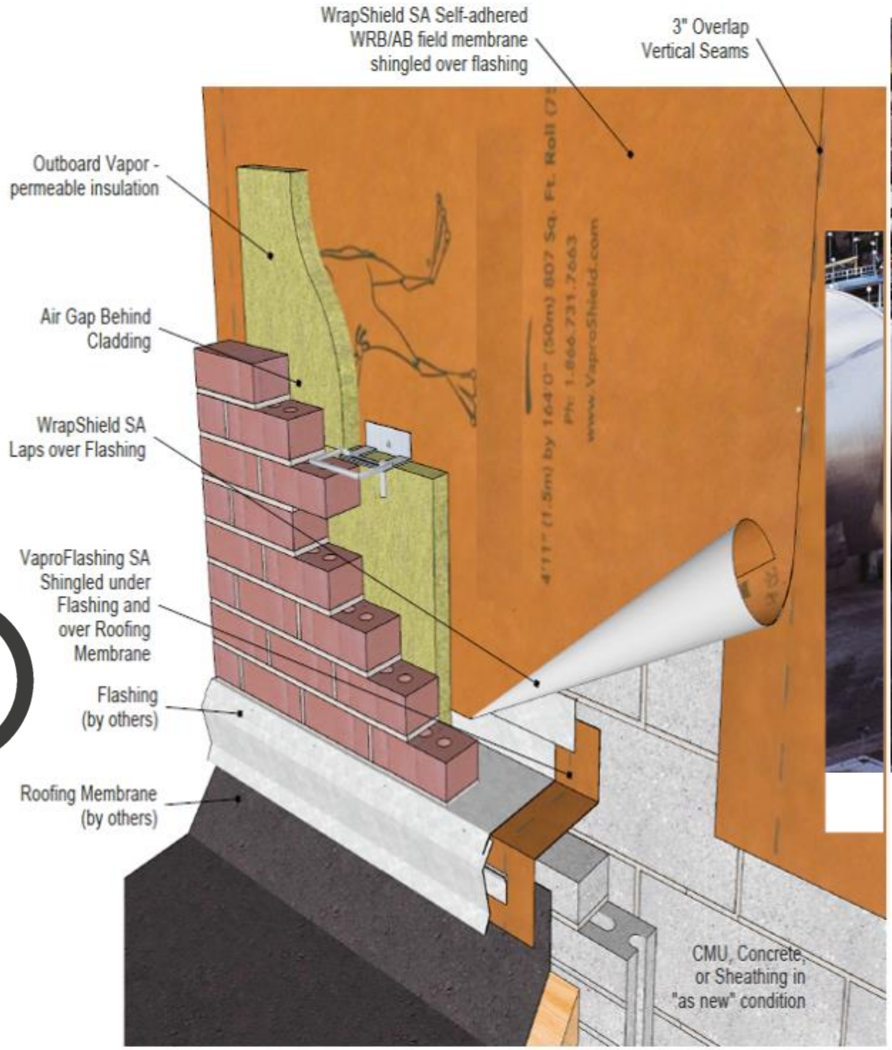
The Exterior "Shell" Provides:

1. Aesthetics
   (Ugly buildings don't usually last)
2. Protection from UV
3. Protection from Water
   and Heat

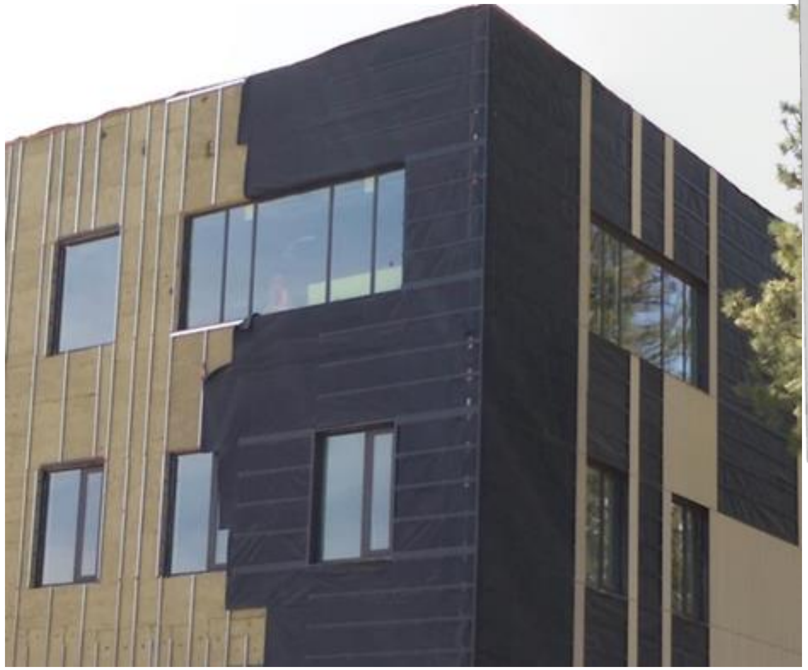
   But it may leak:
   Heat, Air, Water

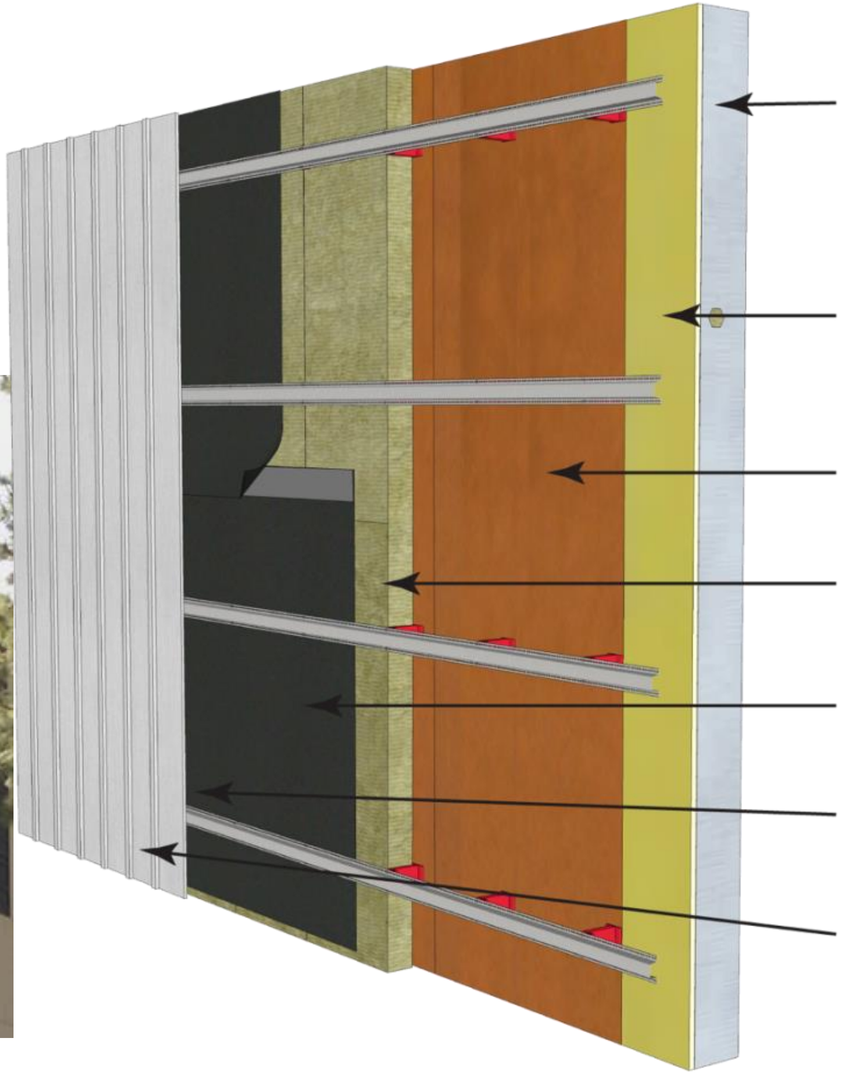






UV Stable Vapor Open WRB/AB



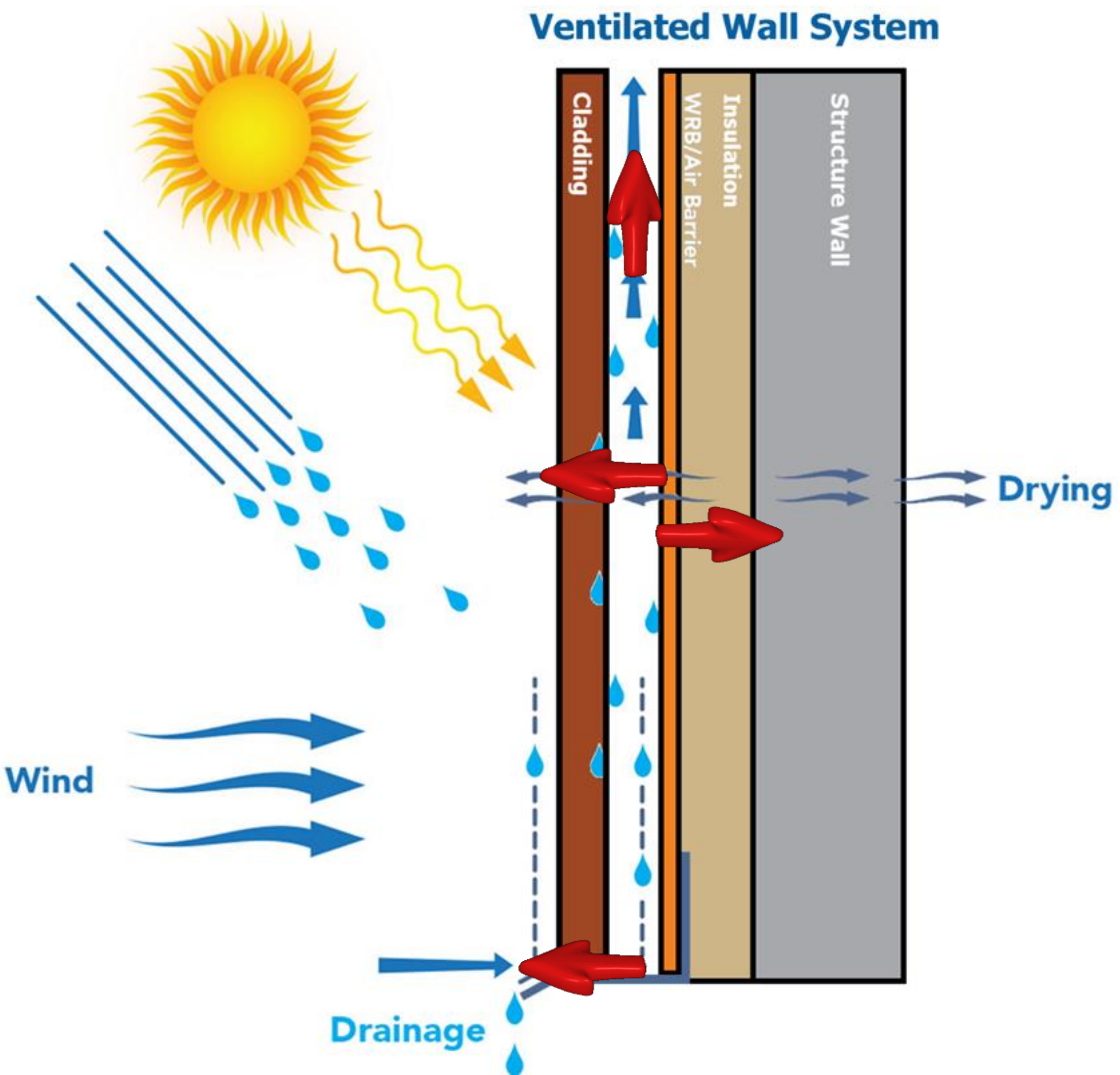


Water Resistive Barrier/Air Barrier (WRB/AB)

A sensible line of defense to keep out Water an Air. Vapor Open?

When a Rainscreen design is used with a water vapor permeable system it provides:

Drying



Vented Rainscreen

Claddings Typically have Low Permeance

- Enhances cladding drying
  Allows drying to both sides

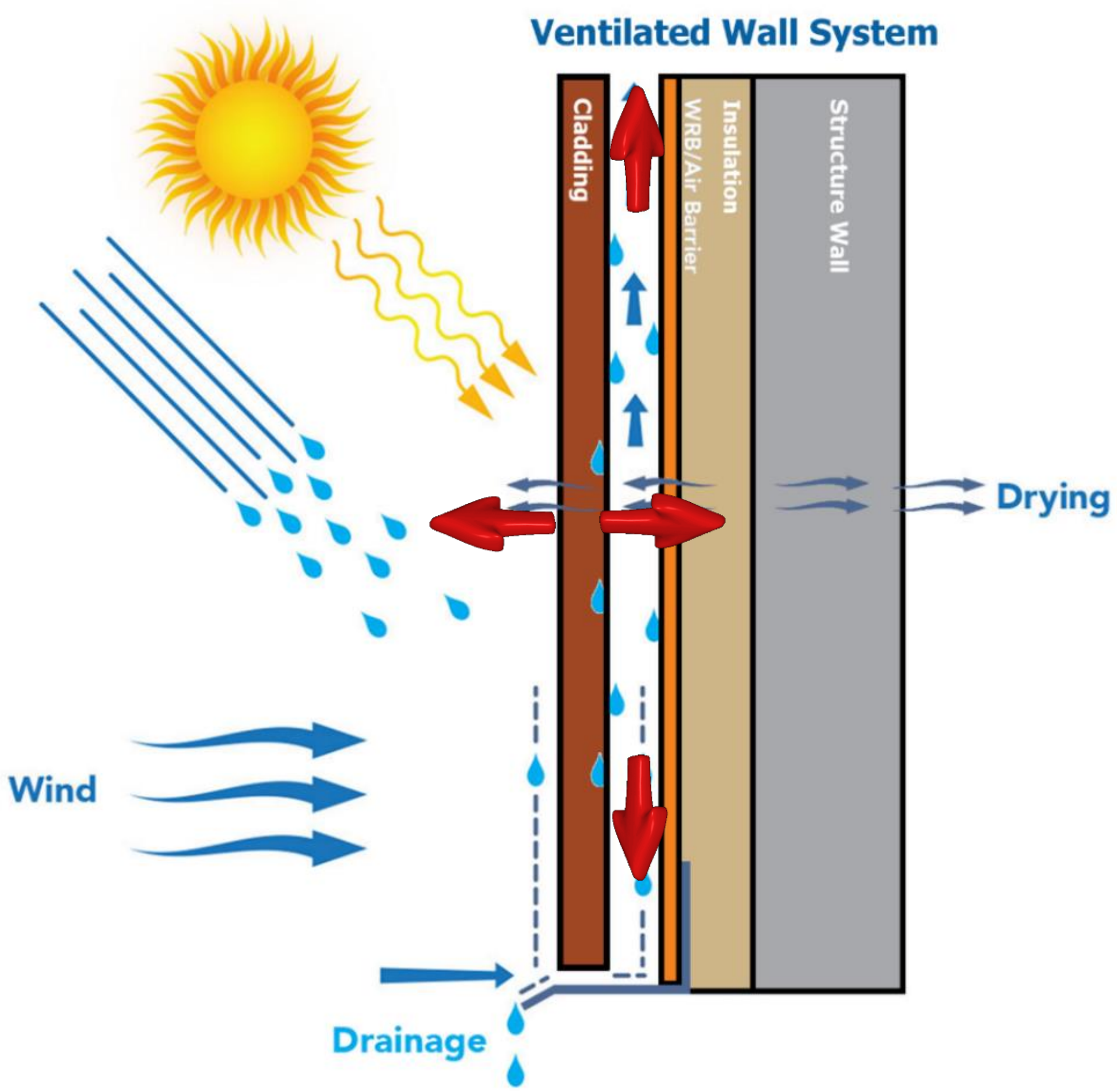
Minimum 0.5 – 1.0 mm ($^1/_{16}$") – prevents capillary suction, allowing draining

7-10 mm or greater ($^1/_4$"-$^3/_8$") – allows venting

- Mitigates reverse vapor drive
- Increases drying

Air Gap

- Insulation – Reduces heat transfer from the cladding to interior



Vapor Open WRB/AB High Drying Capacity

- 14 WRB materials were evaluated for diffusive drying
  - 3 fluid applied WRB
  - 11 membranes some with primer as per manufacture

Vapor Open WRB/AB High Drying Capacity

- 1′x1′ plywood samples were saturated with water
- WRB/AB installed on ½ of the plywood
- Samples placed in drying chamber

50 Air Change Hour (ACH)

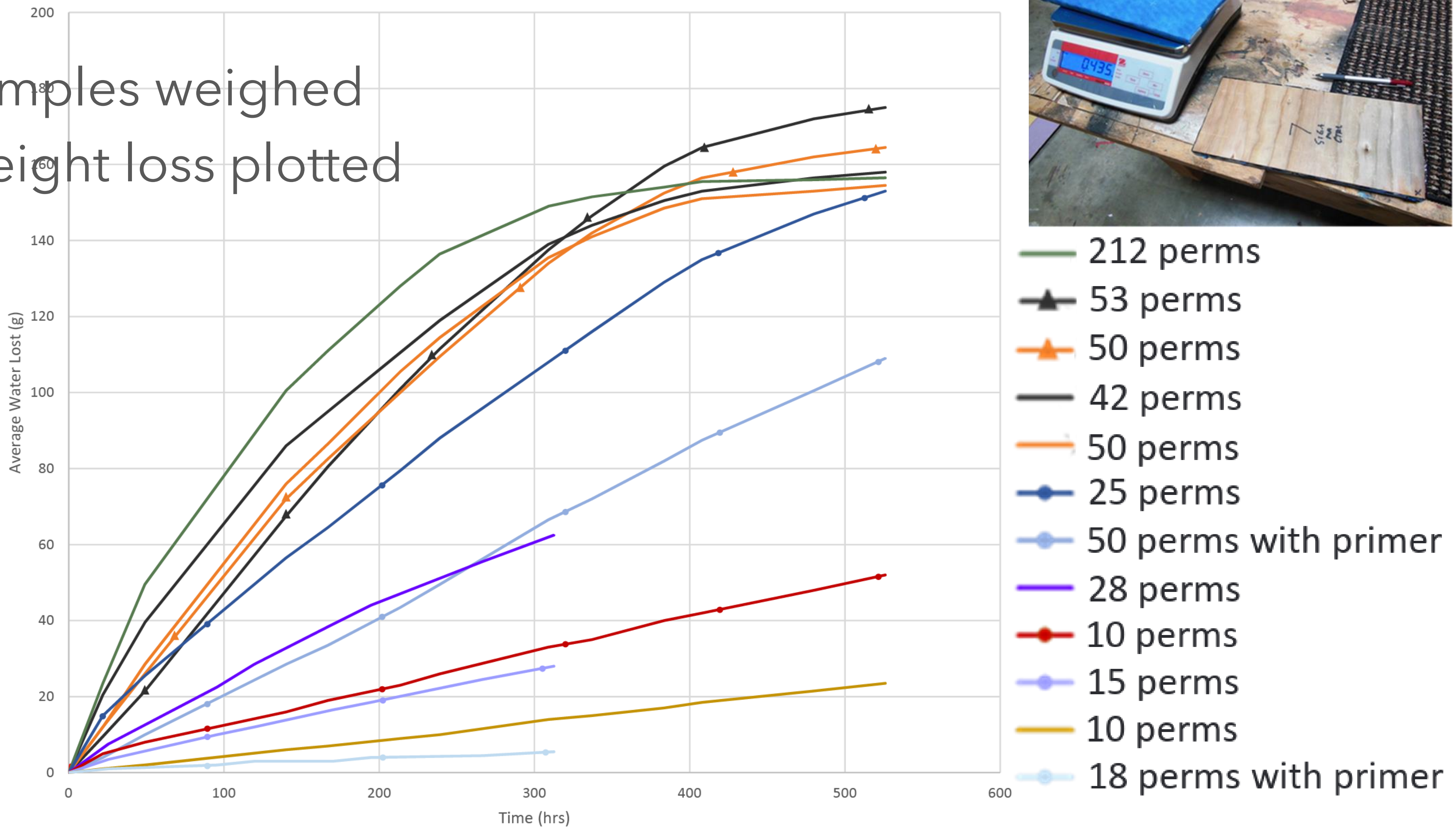
21.7 °C (71 °F) ± 5%

54% RH ± 8%

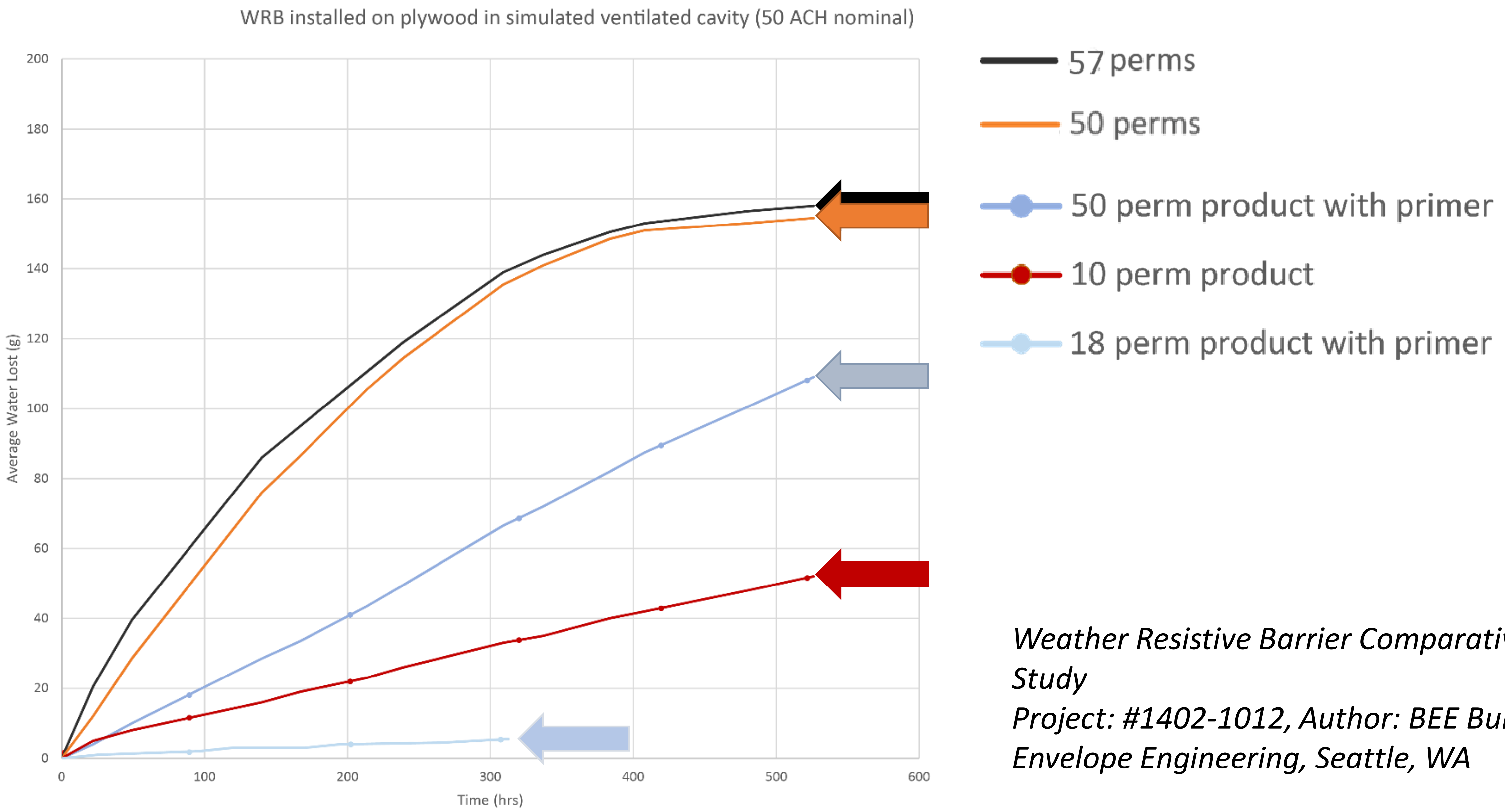
Vapor Open WRB/AB Advantages: High Drying Capacity

- Samples weighed
- Weight loss plotted

WRB installed on plywood in simulated ventilated cavity (50 ACH nominal)

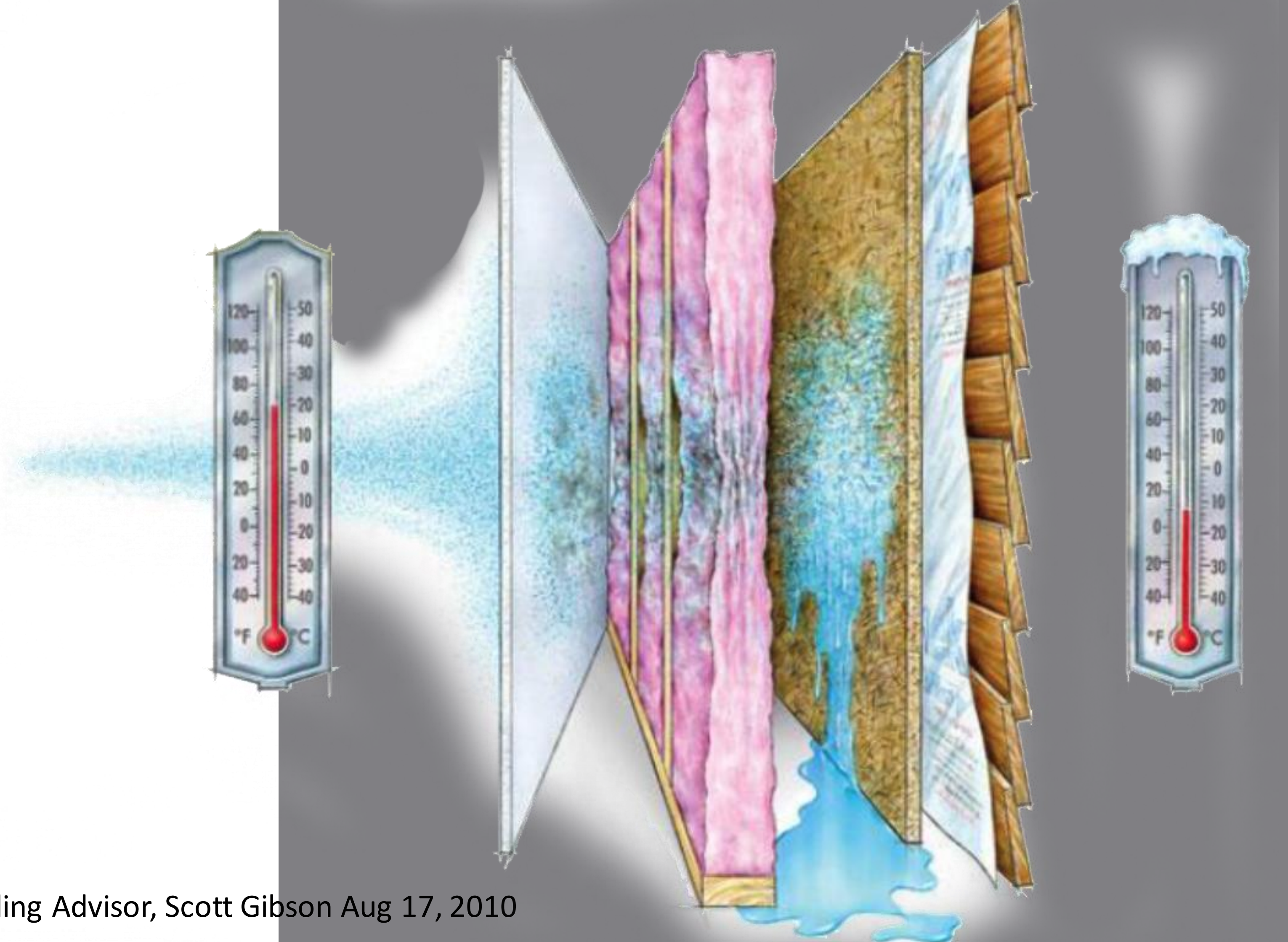


Vapor Open WRB/AB High Drying Capacity



Weather Resistive Barrier Comparative Drying Study
Project: #1402-1012, Author: BEE Building Envelope Engineering, Seattle, WA

Surface Condensation



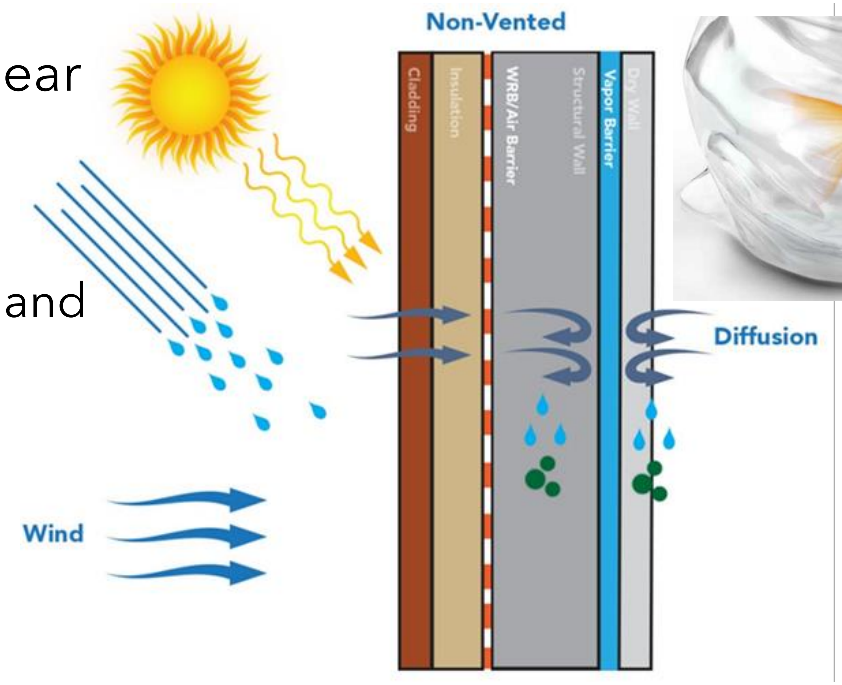
Green Building Advisor, Scott Gibson Aug 17, 2010

Energy Flow Reduced

- Insulation in exterior walls increased human comfort, long before energy was a concern
- In the 1930's, professionals; Larry Teesdale (researcher at the U.S. Forest Products Laboratory), Tyler Rogers (architect) and Frank Rowley (professor of mechanical engineering at University of Minnesota) contributed papers on why paint was pealing on insulated buildings

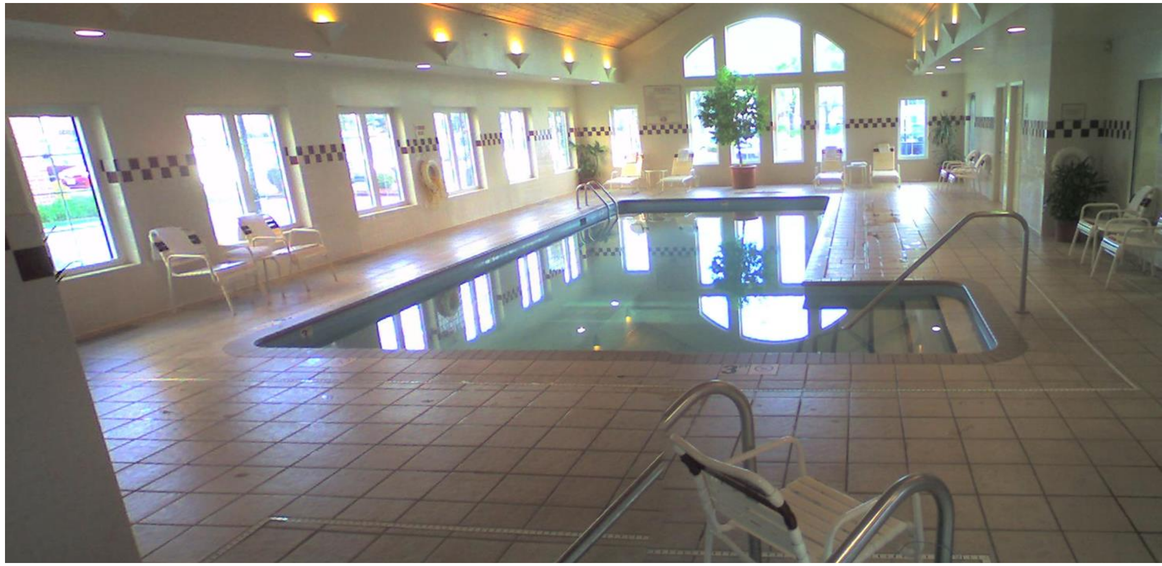
Energy Flow Reduced

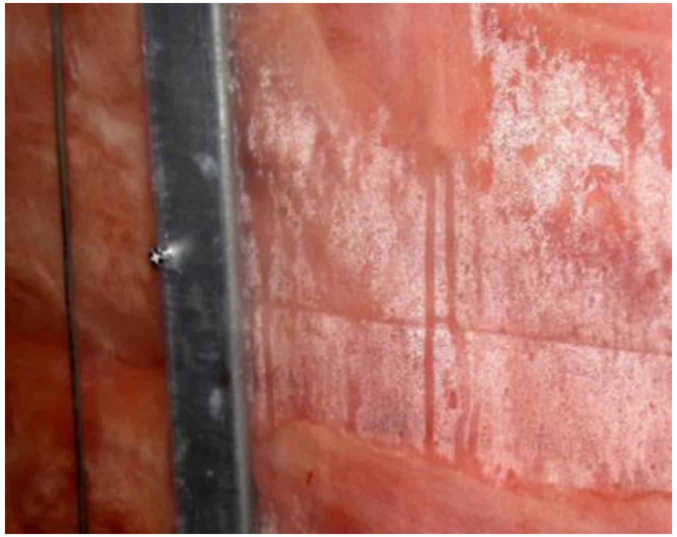
- Insulation and moisture vapor diffusion were blamed.
  A vapor barrier was suggested as the fix.
- The 1948 building code requirements for vapor barriers were the result of technical errors and politics, not scientific research.
- Building science places vapor diffusion near the bottom of moisture causing issues.
- Vapor diffusion is still confusing.
  - ➢ Vapor Barriers can block Heat, Air, Water and Vapor!
  - ➢ Vapor diffusion is through solids
  - ➢ Air movement is through holes



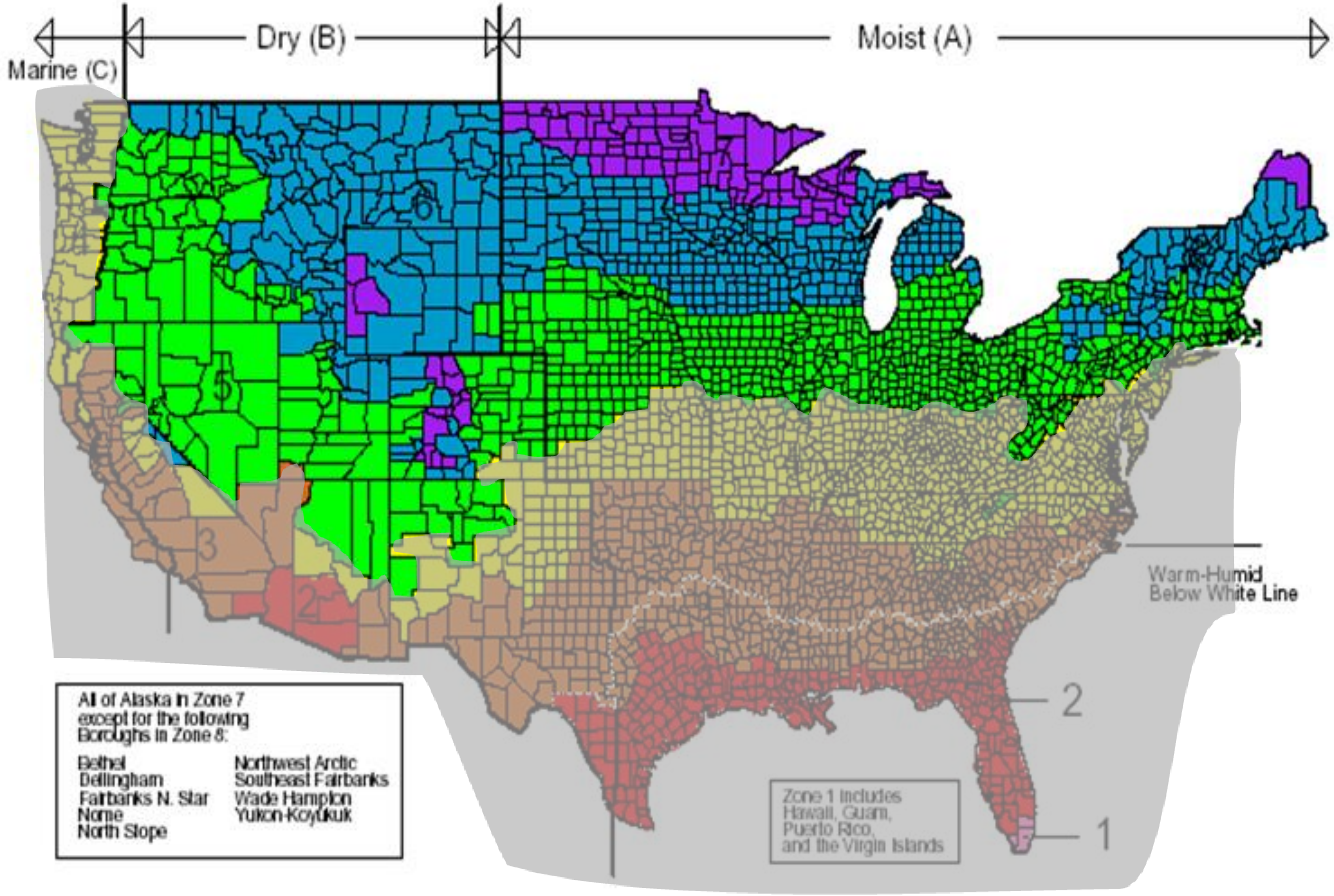
When should Vapor Diffusion be controlled?

- High vapor pressures: greenhouses, natatoriums or saunas
- Cold climates in Zones 7 and 8
- "Solar Driven Moisture"
  High reservoir cladding (brick veneer)
  if not properly vented





IRC IECC Vapor "Retarders" Not R



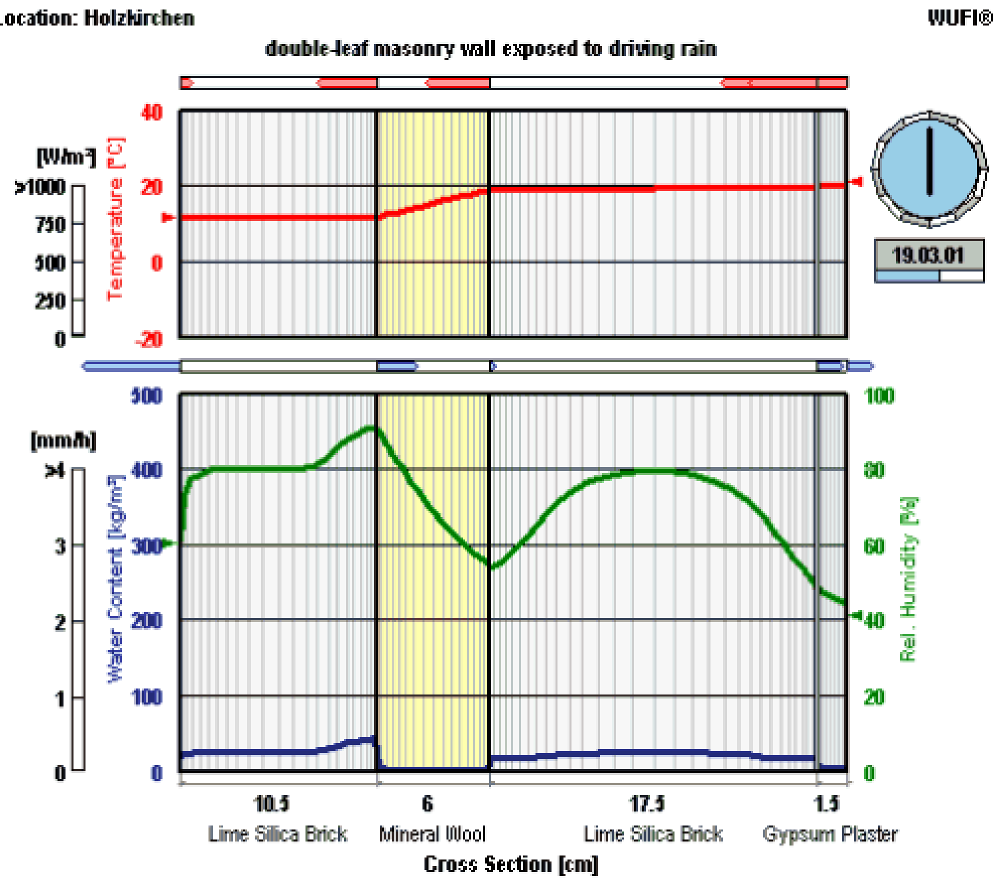
No Vapor Retarder!

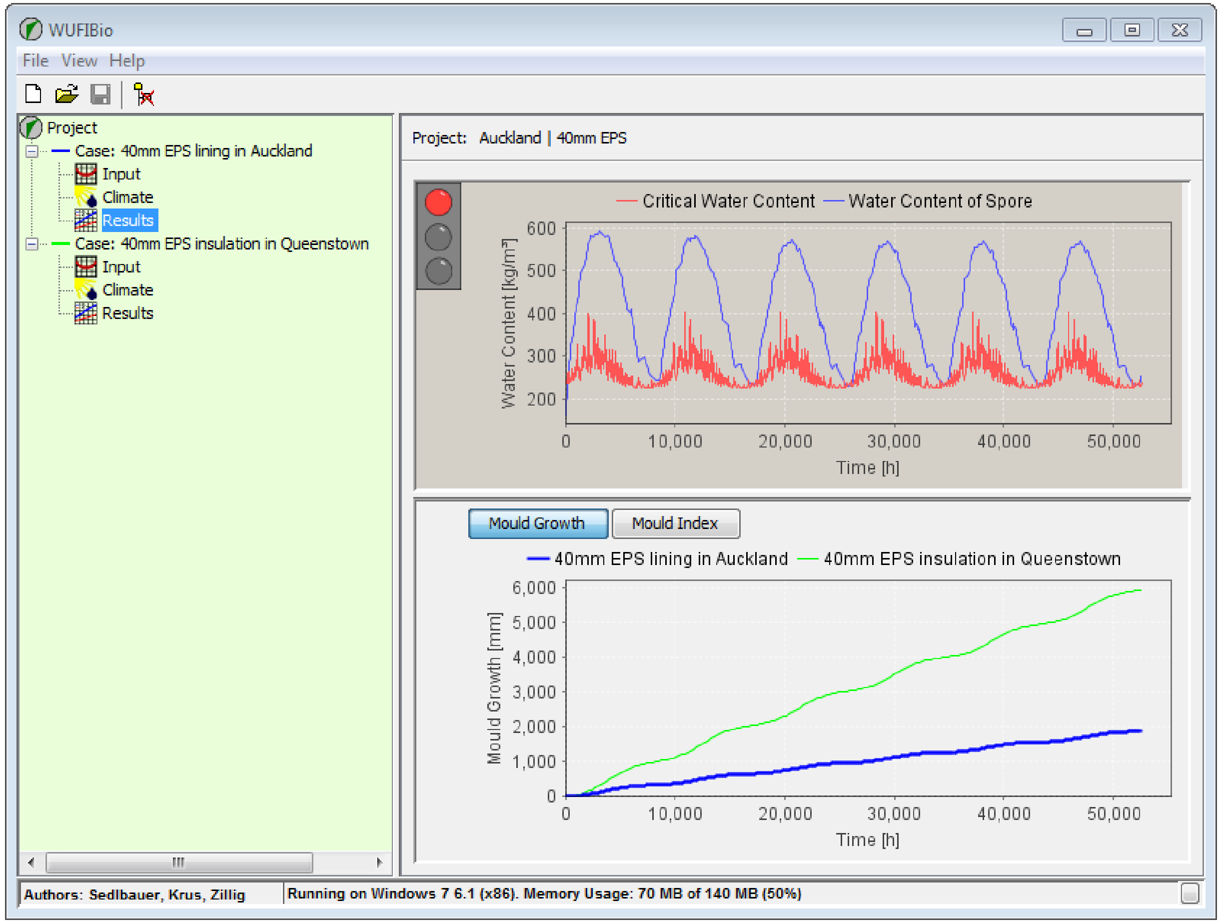
2021 Table R702.7(2) Vapor Retarder Requirements for Climate Zones 1-8

"A vapor retarder shall be provided on the interior side of frame walls..."

Climate Zone	CLASS I (<0.1 perm)	CLASS II (0.1-1 perm)	CLASS III (1-10 perm)
1,2	Not Permitted	Not Permitted	Permitted
3,4 except Marine 4	Not Permitted	Permitted with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls	Permitted
4 Marine, 4-8	Permitted if no exterior Class I	Permitted with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls	Refer to Table R702.7(3)

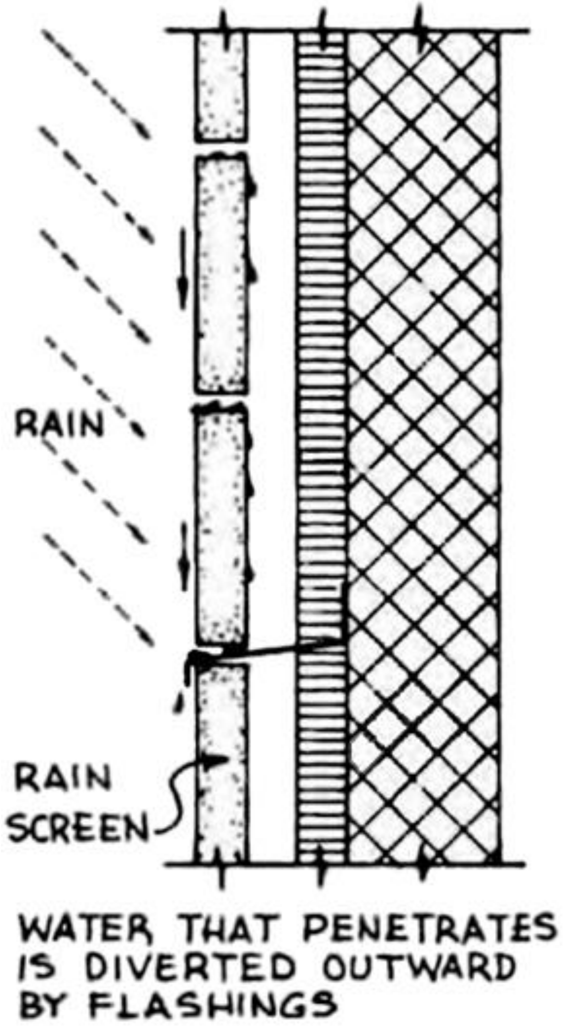
Hygrothermal Modeling



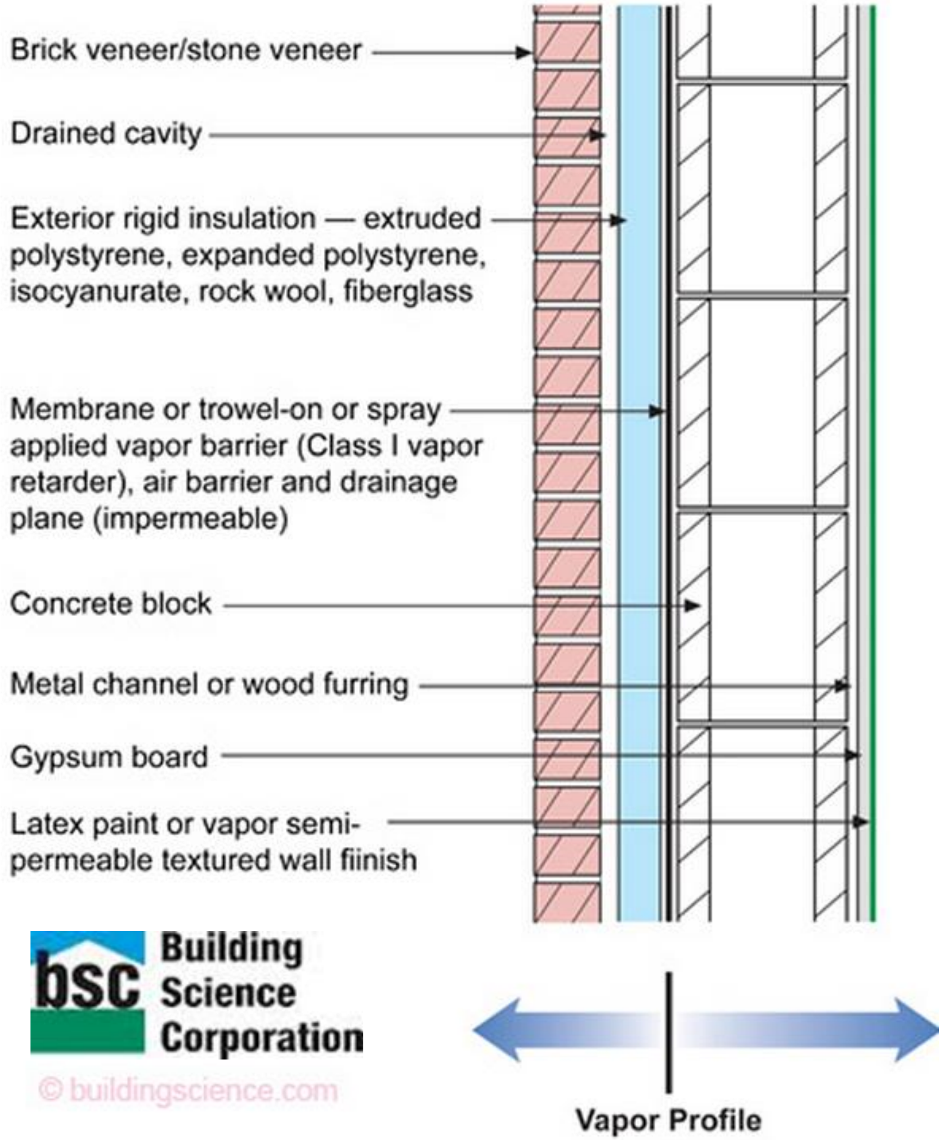


The "Old" Perfect Wall

1964 Hutcheons'

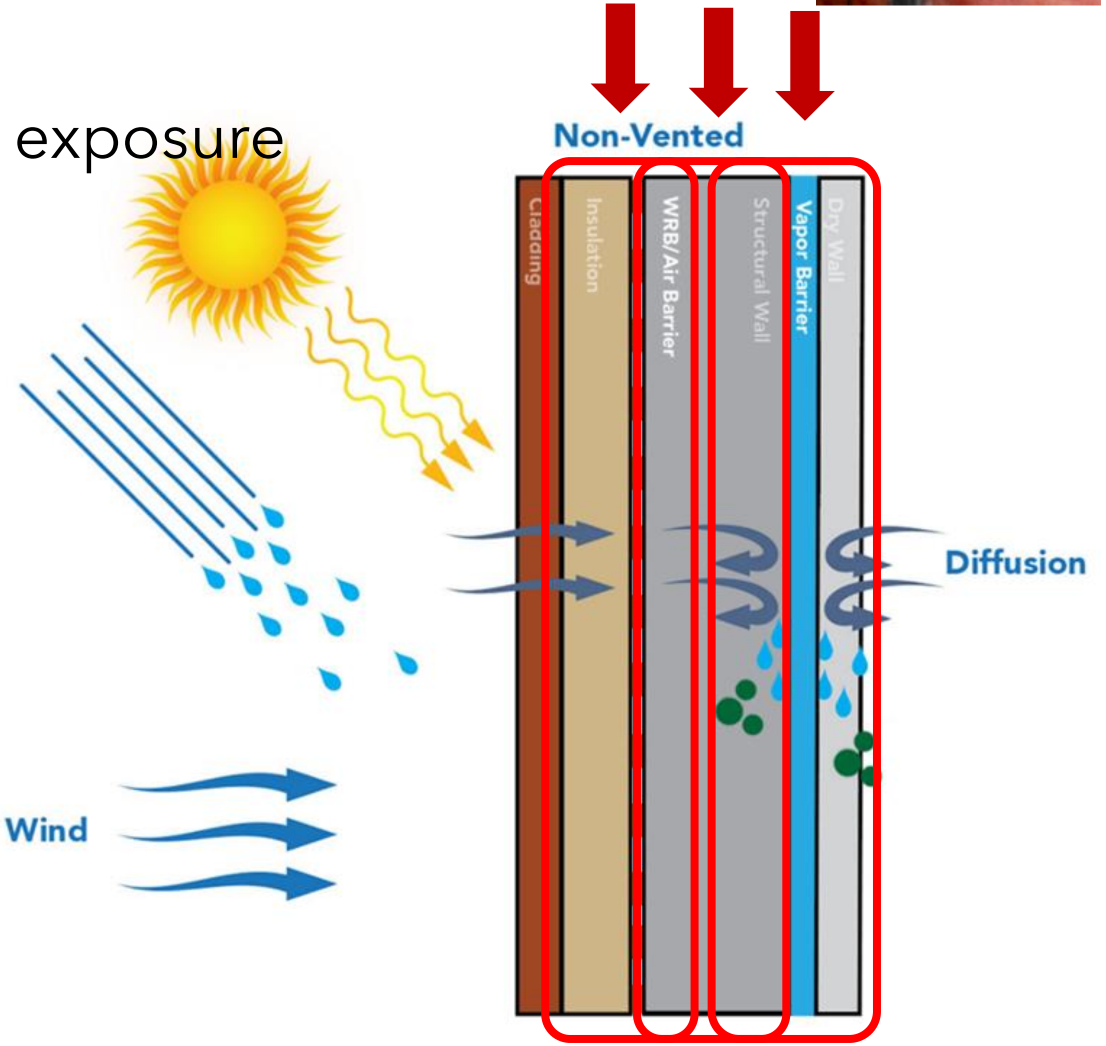


2010 Dr. Joes'



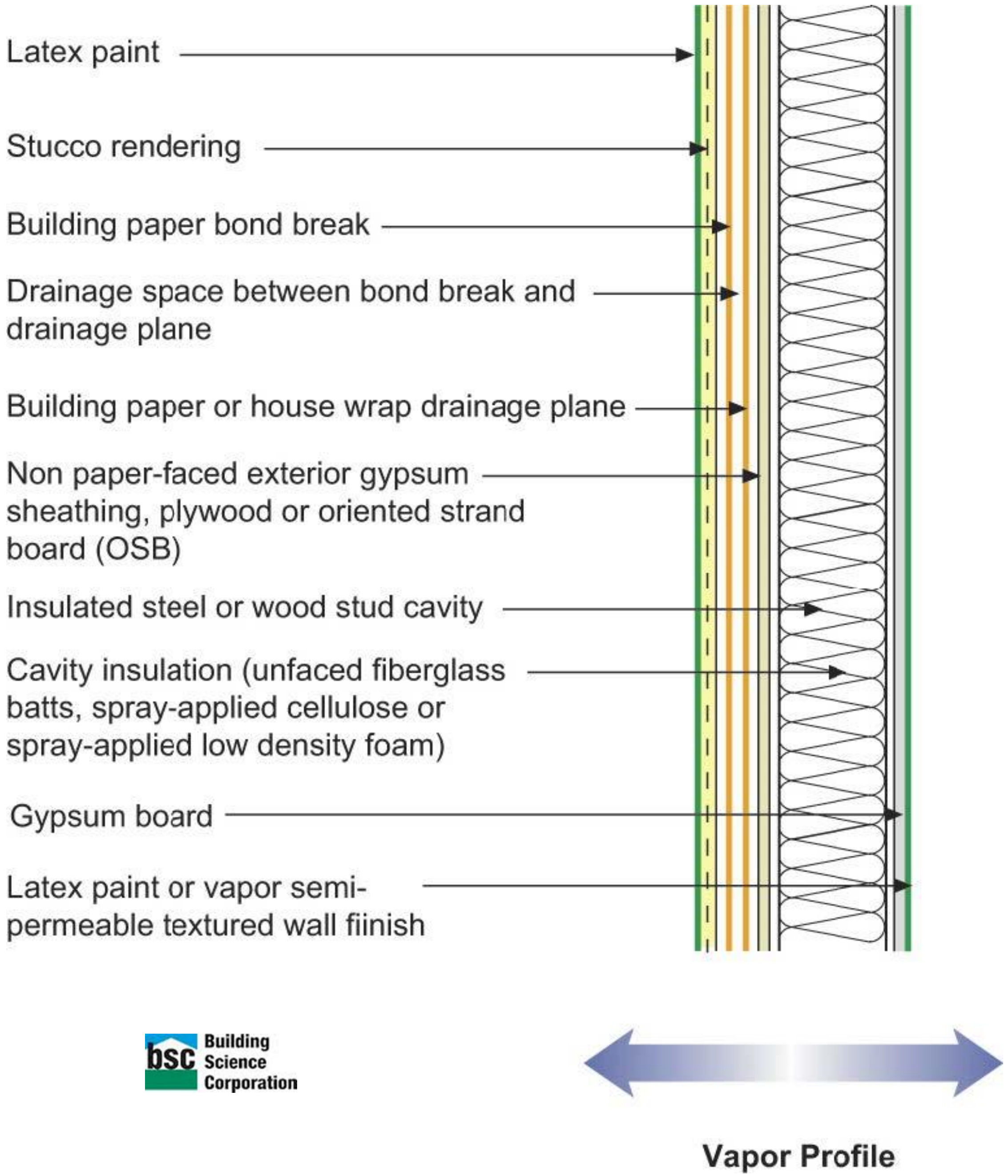
Vapor Closed System Disadvantages

- Air tight plus thermally insulated = reduced energy for drying
- Can't dry well
- Vapor barriers block drying = longer exposure
- Vapor diffusion only one way



The "New" Perfect Wall

- Vapor is controlled by the wall layers and should not block vapor diffusion, allowing the building to breath and dry out



2011.04.15 BSD-106: Understanding Vapor Barriers

Building Enclosure With A Vented Rainscreen

Controls:

Rain Control:

Deflection/Drainage: Rainscreen (Cladding), Roof, WRB, Flashing

Air Control:

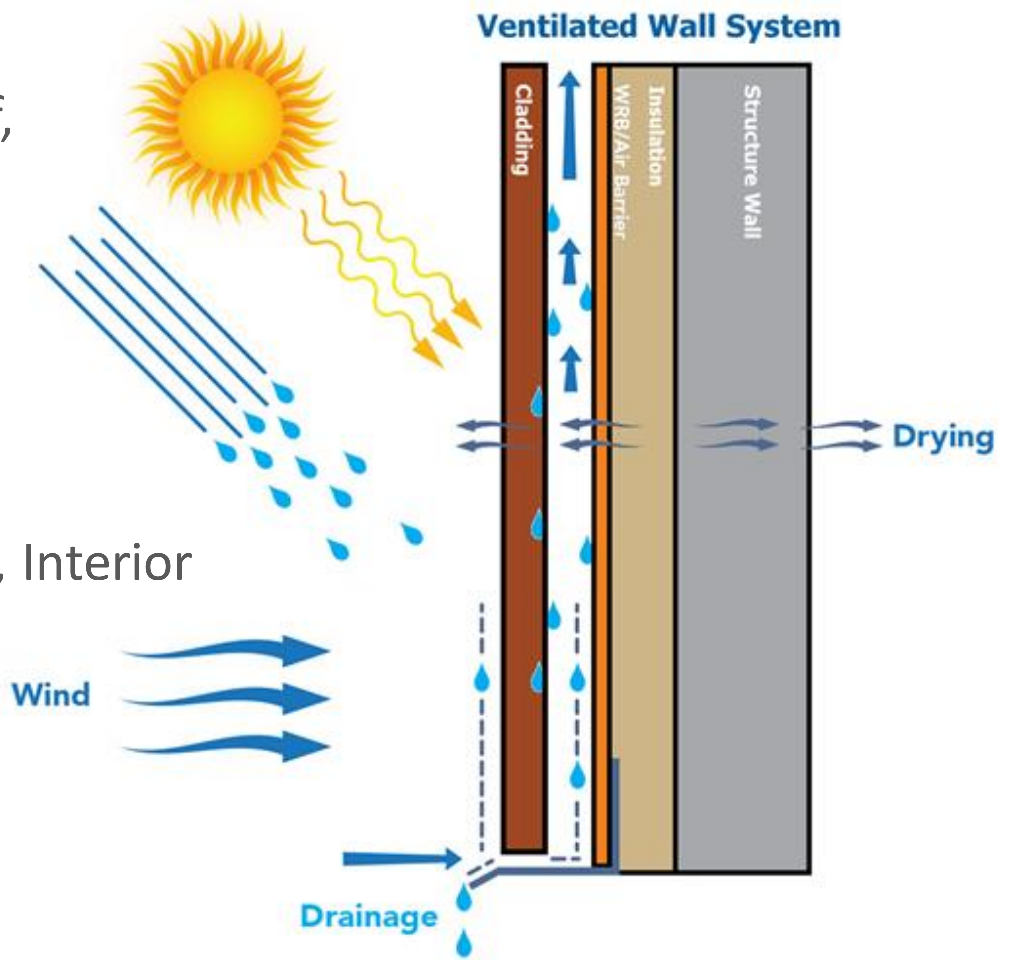
Rainscreen (Wind break), Continuous Air Barrier

Vapor Control:

Rainscreen (Vented) Wall Assembly Components, Interior Paint

Thermal Control:

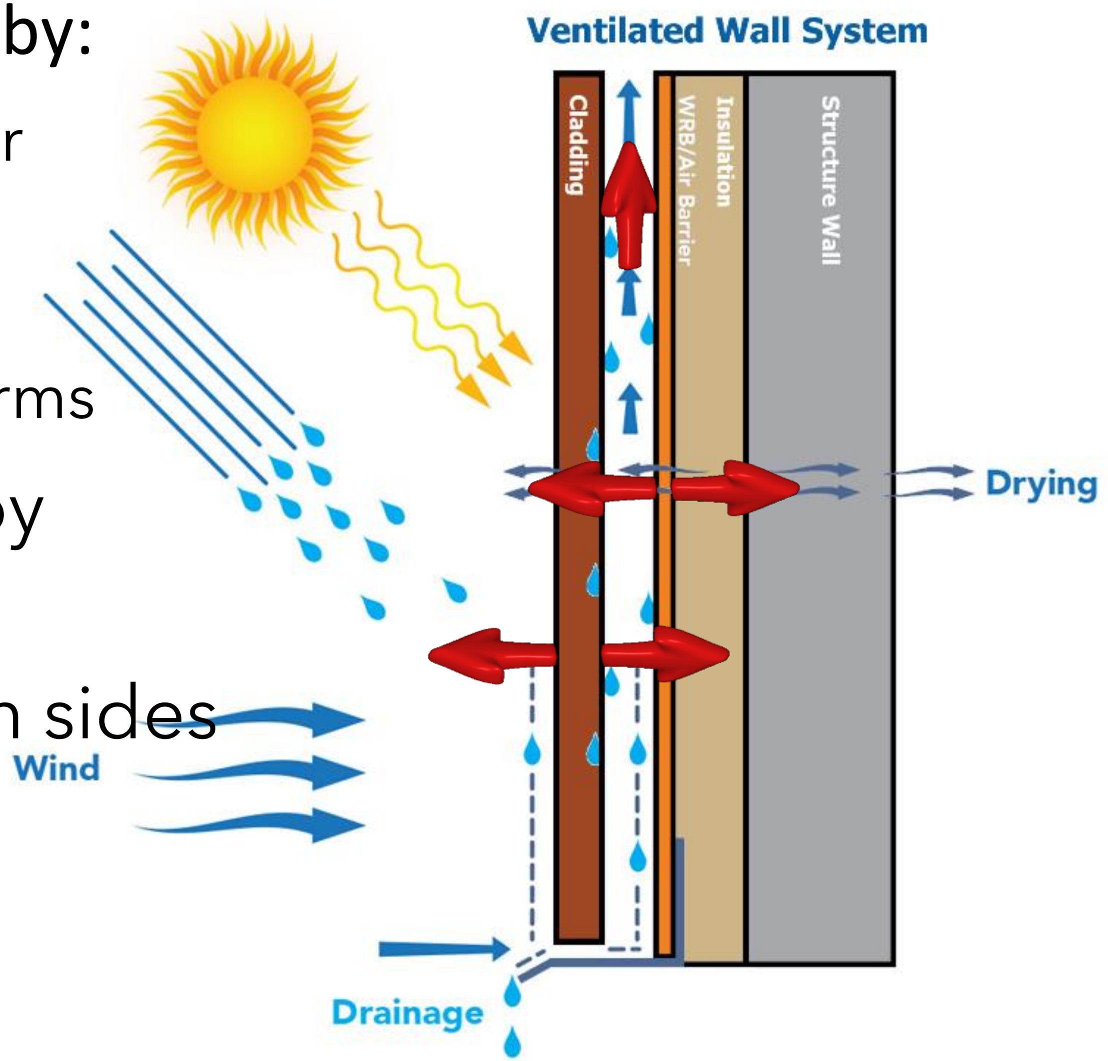
Rainscreen (Gap) Insulation



Vapor Open Advantages

Vented rainscreen increases drying by:

- Allows diffusion/drying with Vapor open WRB/AB
- 50 perms or greater
  Water diffuses faster at higher perms
- Prevents reverse vapor drive by Venting
- Allows Cladding to dry to both sides



Summary

Water Vapor Permeance

- ASTM E96, ASTM E398, ASTM F1249

Water hold out and Air tight

- Hydrostatic water column
- Water vapor transport but air tight

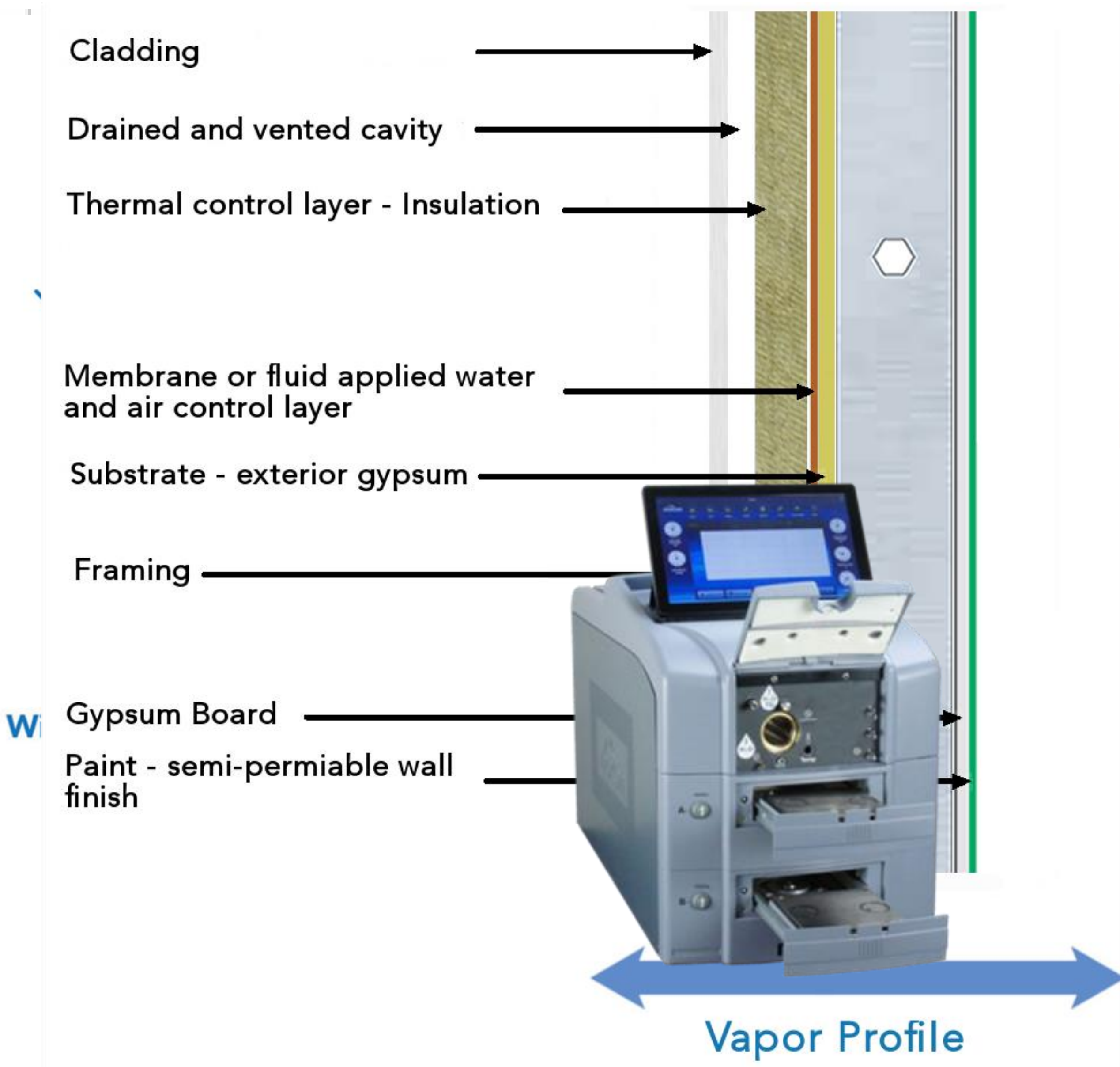
Drying Capacity

- Drying tests 50 perms greater

Vapor Barriers or Vapor Open

Cladding

- The “Real” Perfect Wall
- Rainscreen



ARE HIGHLY PERMEABLE MEMBRANES TOO PERMEABLE?

THANK YOU FOR YOUR TIME

VAPRO SHIELD®

Breathable Membrane Systems for Roofs & Walls