Residential Air Sealing: The Importance of Air Barriers and Evolving Code Requirements

Theresa A. Weston, PhD.
DuPont Building Innovations

EEBA Conference, September 27, 2012

Learning Objectives

- Understand the physics of air and moisture movement through the building envelope and the role of air, water and vapor barriers
- Describe the air barrier functions, benefits, and performance requirements for effective air leakage control in residential structures.
- Understand how to manage the balance between wetting and drying (prevent wetting/ promote drying) for effective moisture management
- Explain recent trends in air barrier codes

Agenda

Air Leakage – Why is it important?

Fundamentals of air leakage

Water Management: Air Barriers vs. Water-resistive barriers vs. Vapor Barriers

Air Sealing Code requirements

Industry Status & Trends

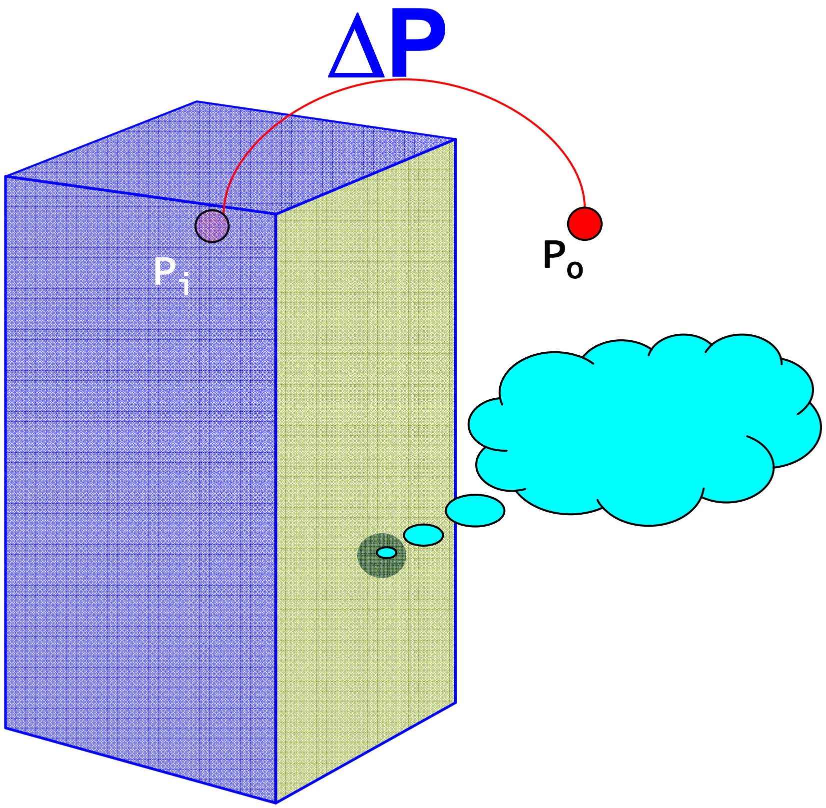
Home For Sale by Owner
110 W. King Place, Nome, Alaska

This 2,009 square foot superinsulated energy-efficient and low maintenance home includes a 364 square foot heated garage with cement floor. It's one of Nome's finest houses, located on a 7,700 square foot lot (55 x 140), in an extremely convenient location. It's less than a five-minute walk from downtown, from Nome's Safeway store, and from nine of Nome's

surrounds.

“In 1993, the home was re-sheathed in “a housewrap” with all joints carefully glued with acoustic sealant (thirty tubes of it!), providing extreme protection from wind. (Although the 1993 addition increased floor space by 30%, our heating bills actually dropped.)”

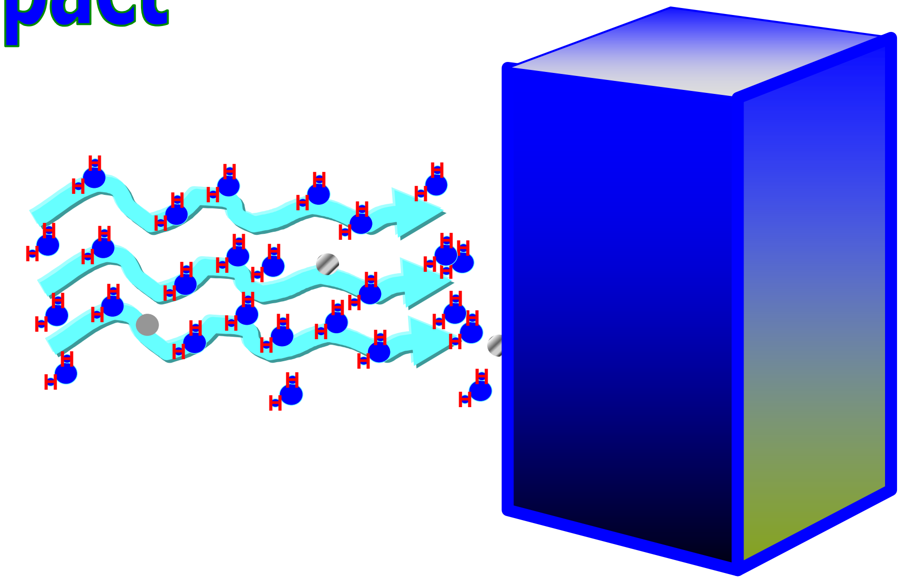
What is Air Leakage?
Unplanned/**Un**predictable/**Un**intentional Airflow



Air Leakage needs BOTH:

1. **A Driving Force** (Δ Pressure)
2. **A Pathway** (Unintended Opening)

Air Leakage Impact



Transport of:		Impact on Buildings
Heat	→	Energy Efficiency
Moisture	→	Energy & Durability
Contaminants	→	IEQ & Comfort

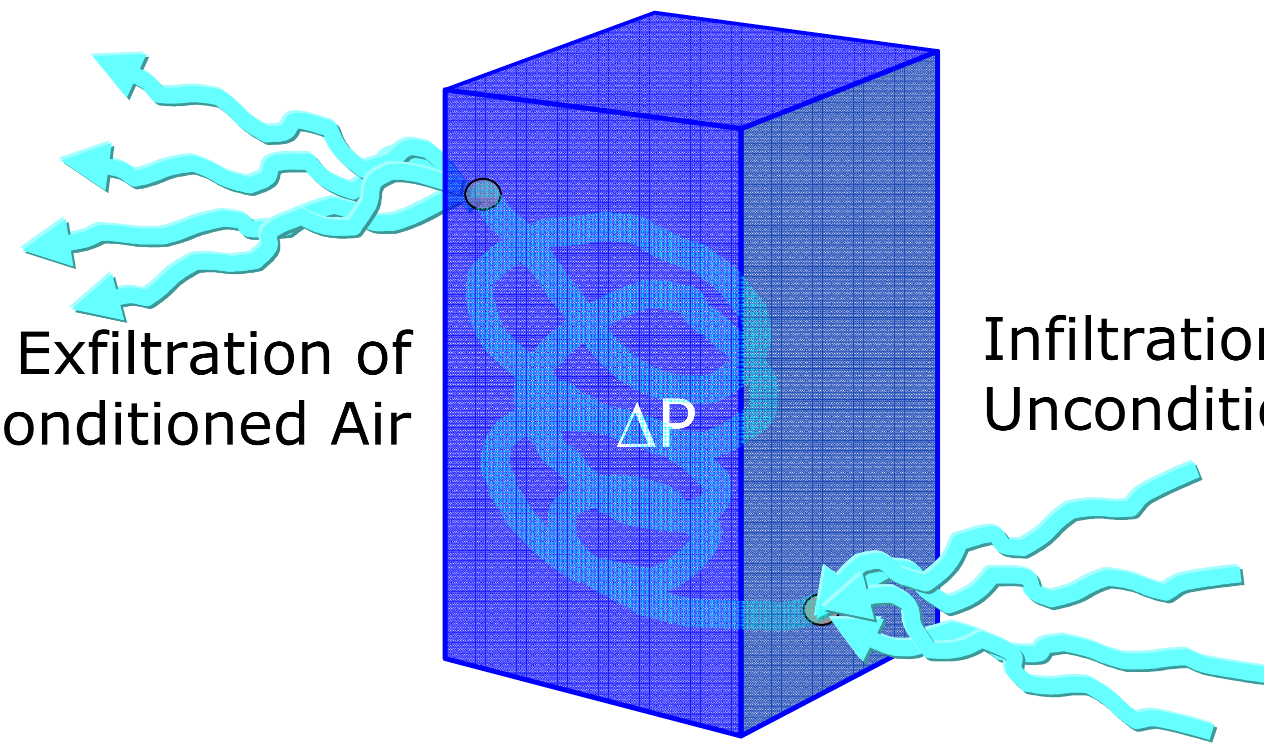
Direct Air Leakage Impact on the HVAC Energy Use

Heat → Energy Efficiency

Moisture → Envelope Durability & Performance

Contaminants → Occupant Safety & Comfort

up to 40%*

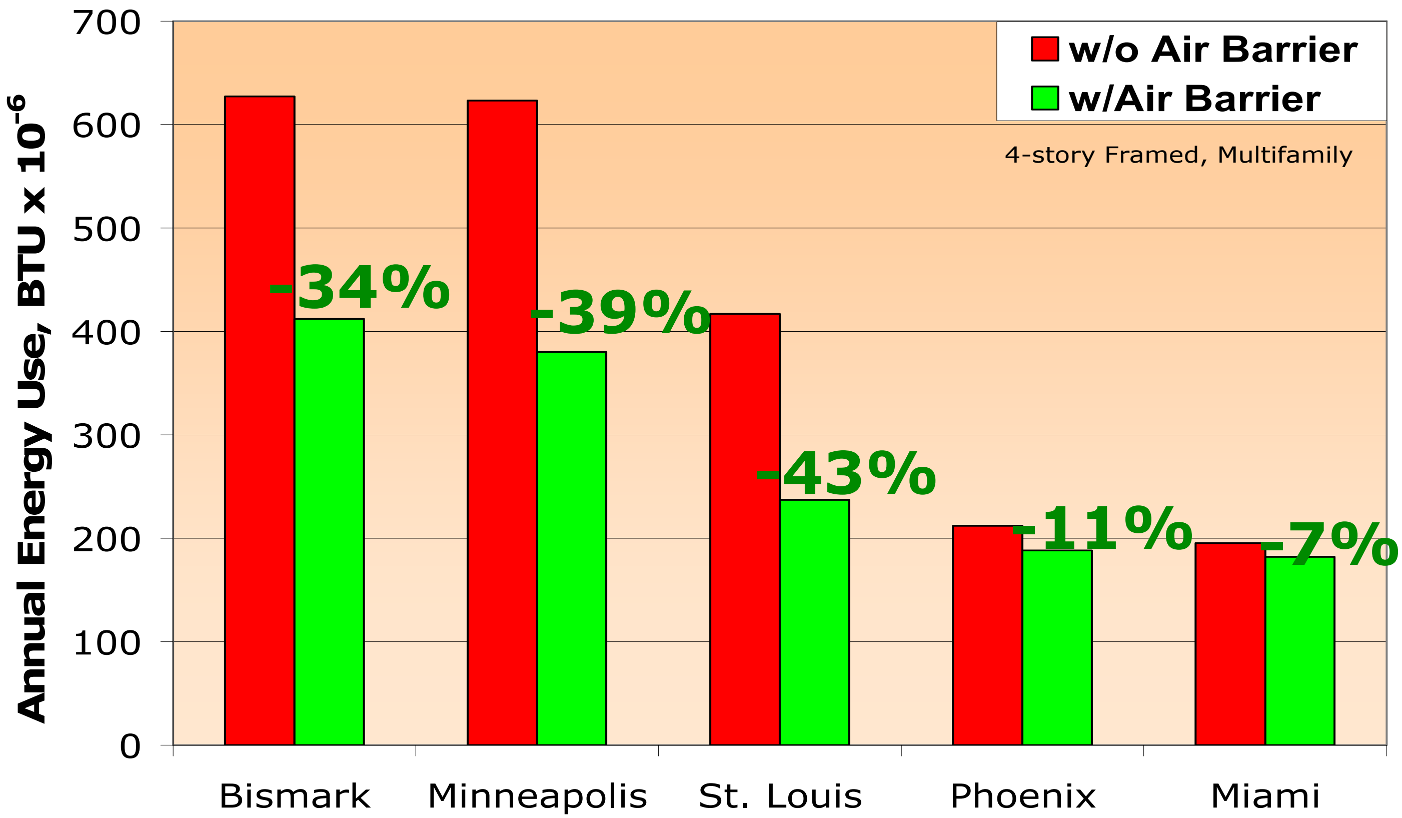


Exfiltration of Conditioned Air

Infiltration of Unconditioned Air

*Source: NIST Report "Investigation of the impact of Commercial Building Envelope Airtightness on HVAC Energy Use", *S. J. Emmerich, Tim McDowell, W. Anis*

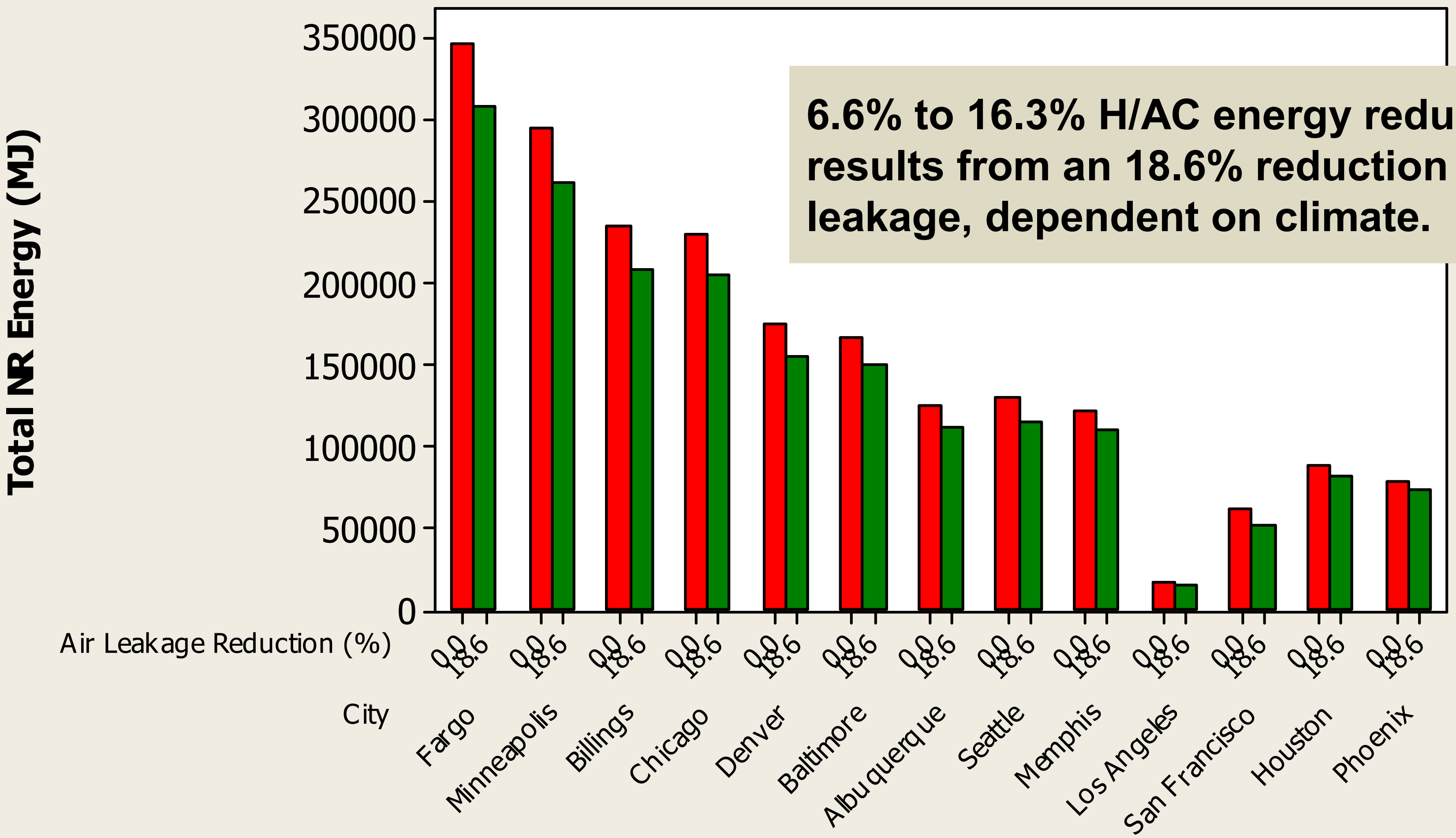
Direct Air Leakage Impact on HVAC Energy Use:
Percent energy savings due to reduced infiltration/exfiltration



Source: NISTIR 7238, "Investigation of the impact of Commercial Building Envelope Airtightness on HVAC Energy Use", *S. J. Emmerich, Tim McDowell, W. Anis*

Residential H/AC Energy Efficiency from Air Leakage Reductiom

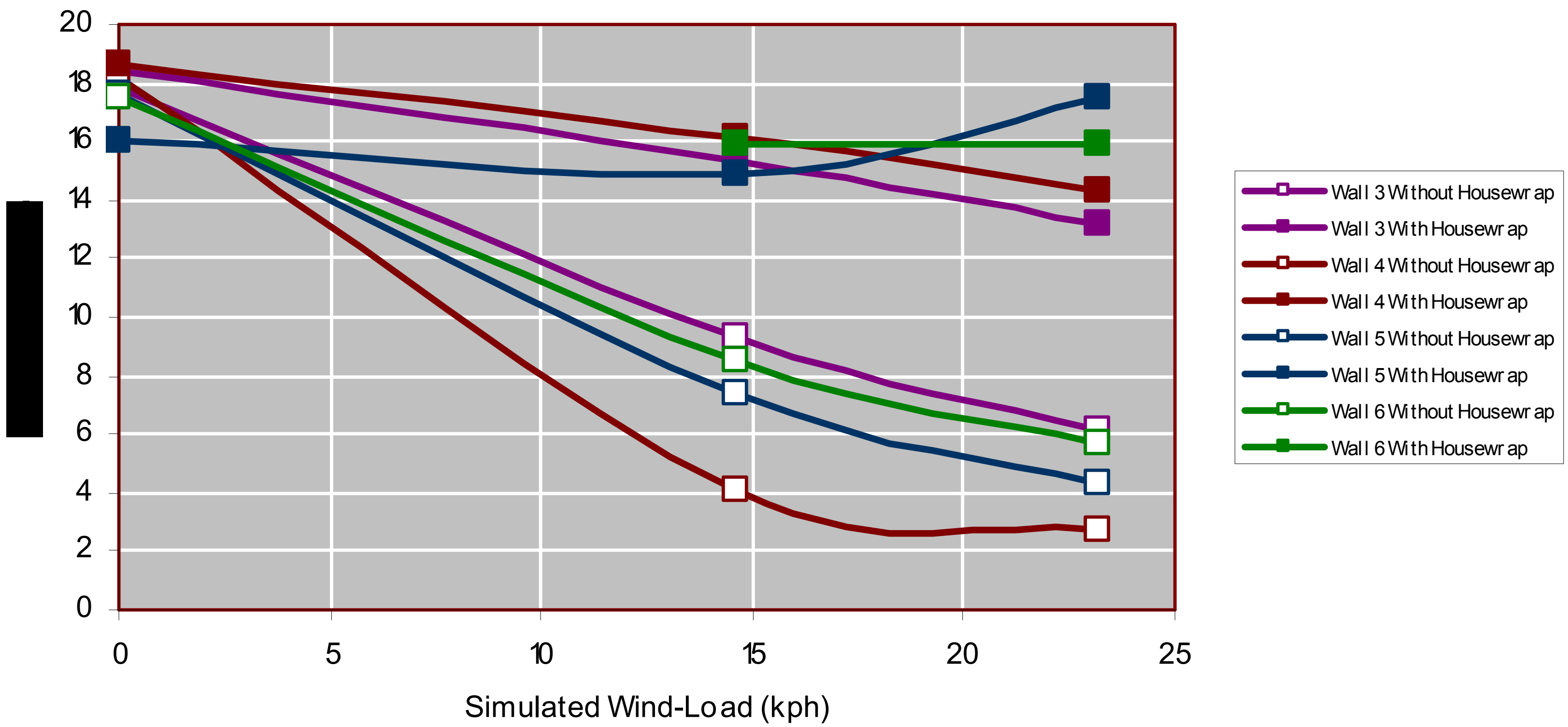
Energy-10 Simulations (House 2846 sq ft, Gas Heat)



6.6% to 16.3% H/AC energy reduction results from an 18.6% reduction in air leakage, dependent on climate.

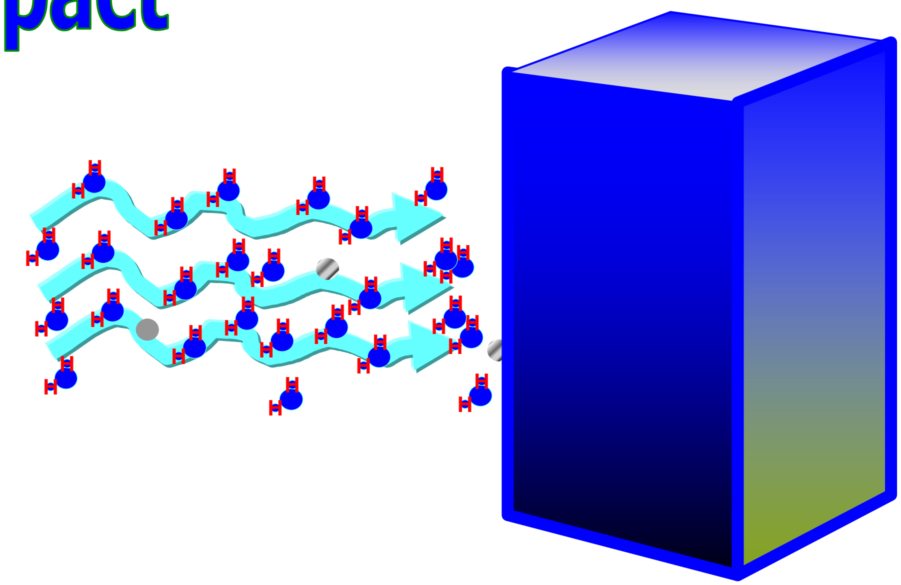
Indirect Air Leakage Impact on Energy Use:
Wind Degradation of Thermal Insulation Performance

Measured Effective R-value under Simulated Wind-Load (R-19 Walls).
Data from Jones, 1995



Source: Impact of Airflow on the Thermal Performance of Various Residential Wall Systems utilizing a calibrated hot box, Thermal Envelopes VI/ Heat Transfer in Walls -- Principles

Air Leakage Impact



Transport of:	Impact on Buildings
Heat →	Energy Efficiency
Moisture →	Energy & Durability
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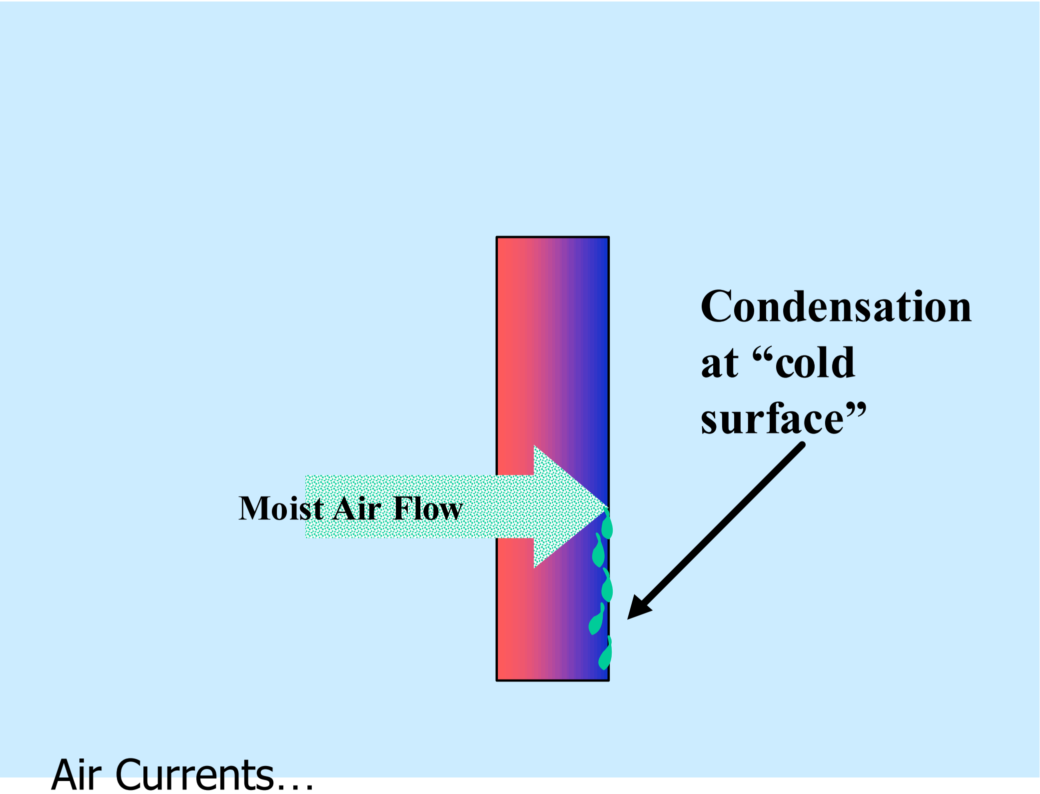
Water Carried by Air Leakage



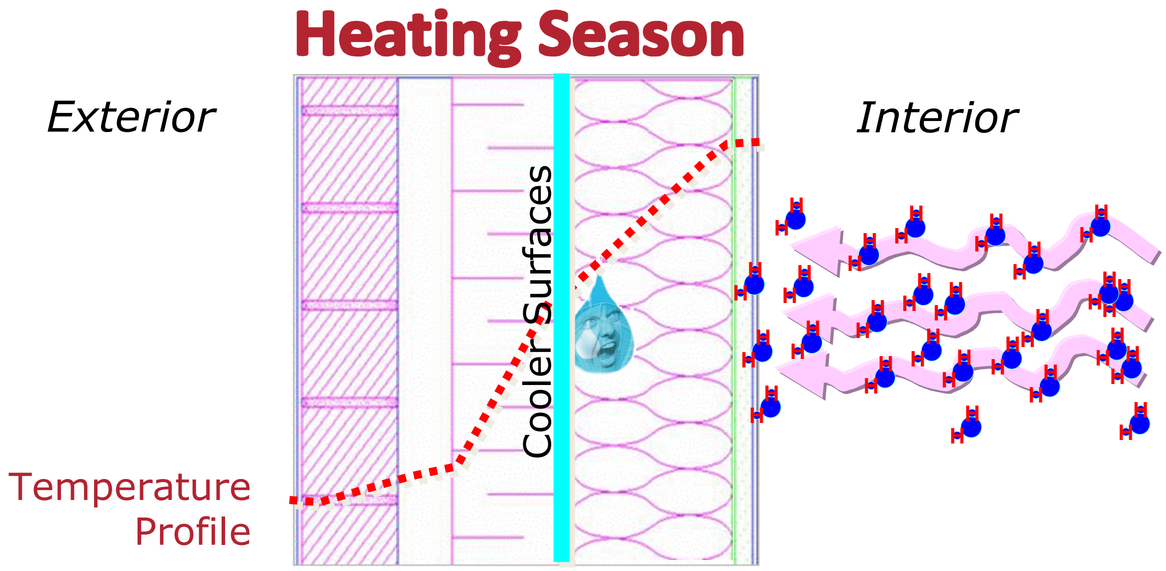
Air Currents…

- …account for 90x more moisture vapor entering a wall cavity than diffusion.
- …reduce the effectiveness of the insulation.
- …reduce overall comfort
- …can place unnecessary stress on HVAC System

Wintertime Condensation

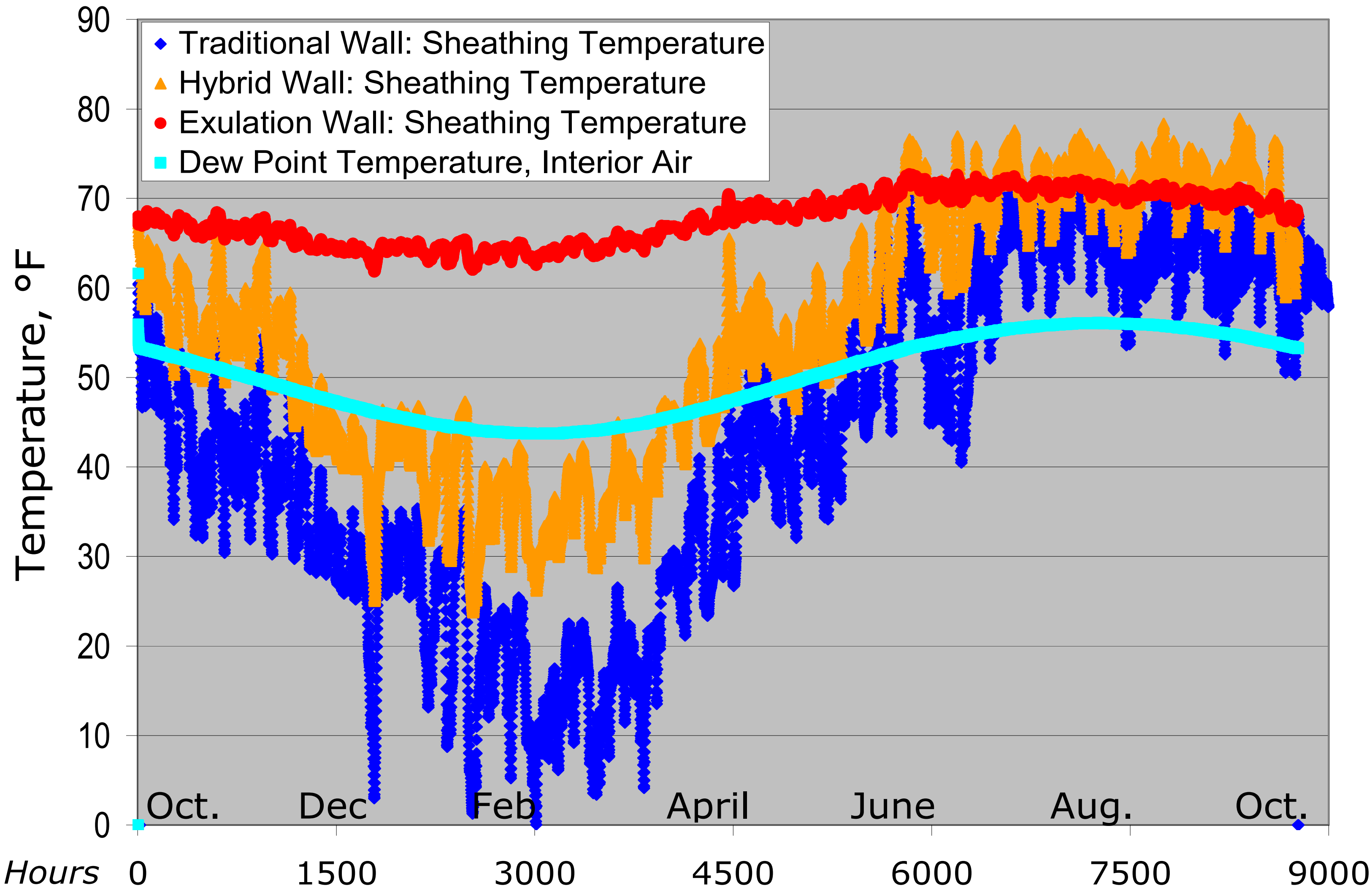
Air leakage condensation potential can be estimated by determining the hourly dew point of the interior air, and the temperature of the potential condensation plane:

» When the temperature of the condensation plane is below the dew point of the interior air, condensation would occur if air exfiltration reaches the condensation plane.

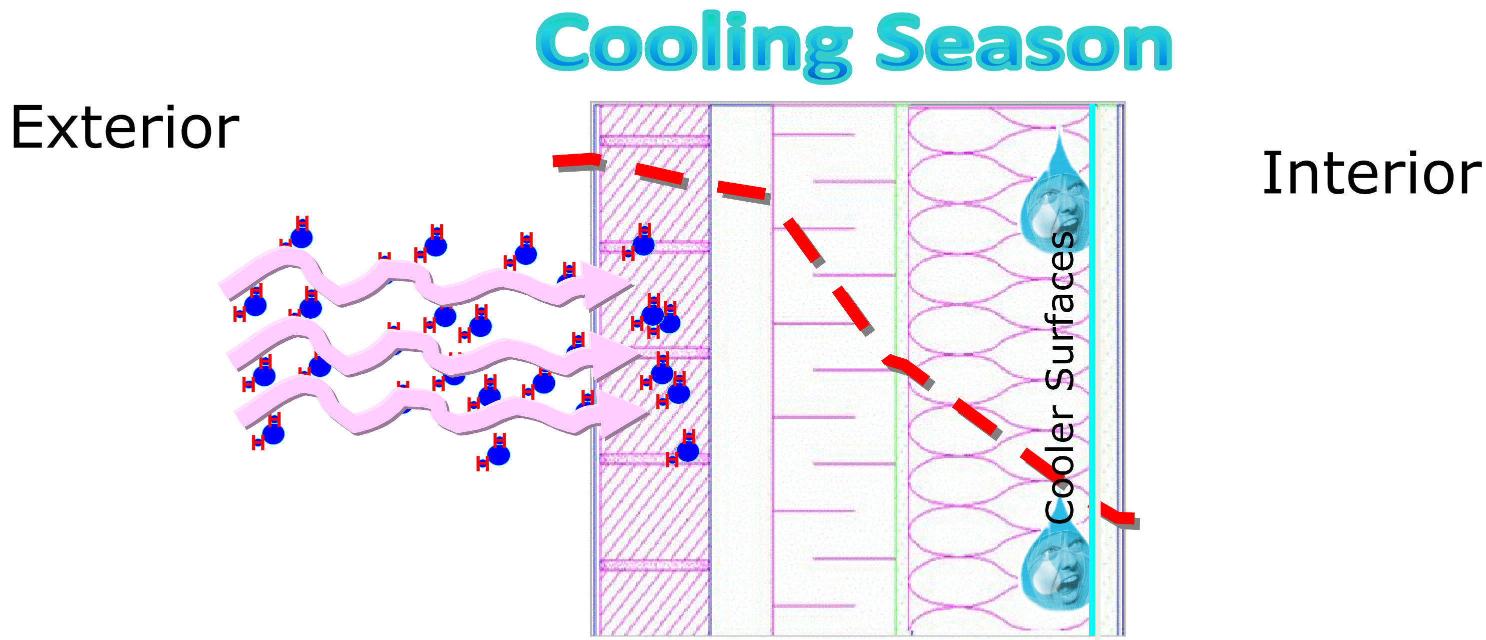


Interior, moisture-laden air **Ex**filtration could lead to condensation on cooler exterior surfaces, *e.g. if the temperature of the sheathing is below the dew point of the interior air*

Air Leakage Condensation Potential:
Chicago Example --*Heating Season, Air Exfiltration*



Summer Time Air Leakage Condensation Potential



Exterior, moisture-laden air **In**filtration could lead to condensation on cooler interior surfaces, *e.g.* if the temperature on the back of interior Vapor Retarder is below the dew point of the exterior air

Typical Problem Causes in Hot, Humid Climates

Shortly after construction was completed, a seven-story, four-star hotel in Charleston, South Carolina, developed severe moisture and mildew problems. The investigators attributed the problems to rainwater intrusion through the hotel's exterior brick veneer (Figure 1-6). Following that diagnosis, the hotel owner spent over $10 million on renovations, including a completely redesigned and reconstructed building envelope.

The summer after the renovations were completed, the moisture and mildew problems returned. They returned because the investigators had focused on the envelope leaks and overlooked the significant secondary source of interior moisture (outside air infiltration).

In areas like Charleston, where hot, humid conditions persist, IAQ problems are largely due to a combination of the following factors:

brick veneer (Figure 1-6). Following that diagnosis, the hotel owner spent over $10 million on renovations, including a completely redesigned and reconstructed building envelope.

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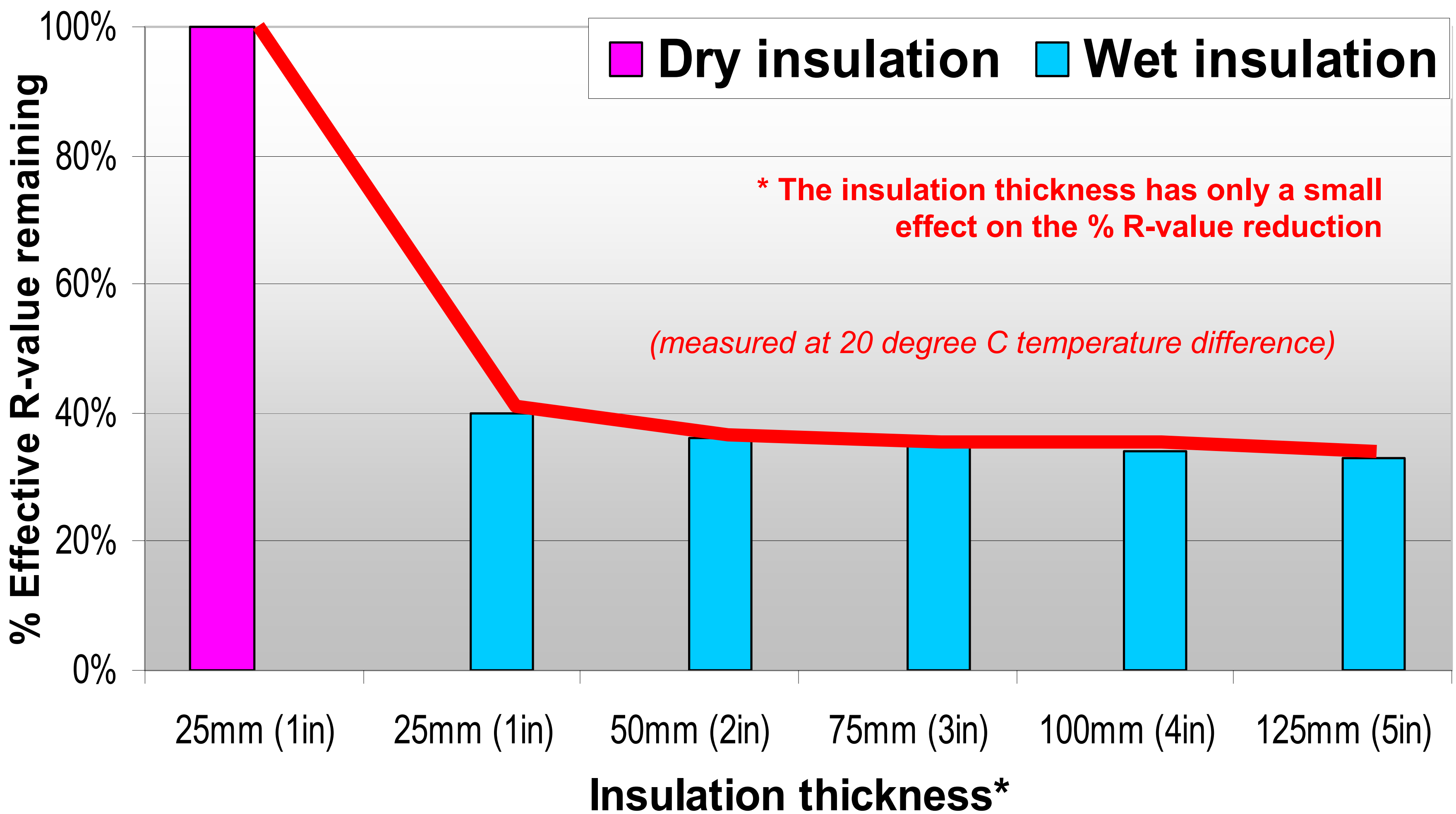
problems shortly after it was built.

From "Preventing Moisture and Mildew Problems in Hospitality Industry Buildings" -CH2M HILL

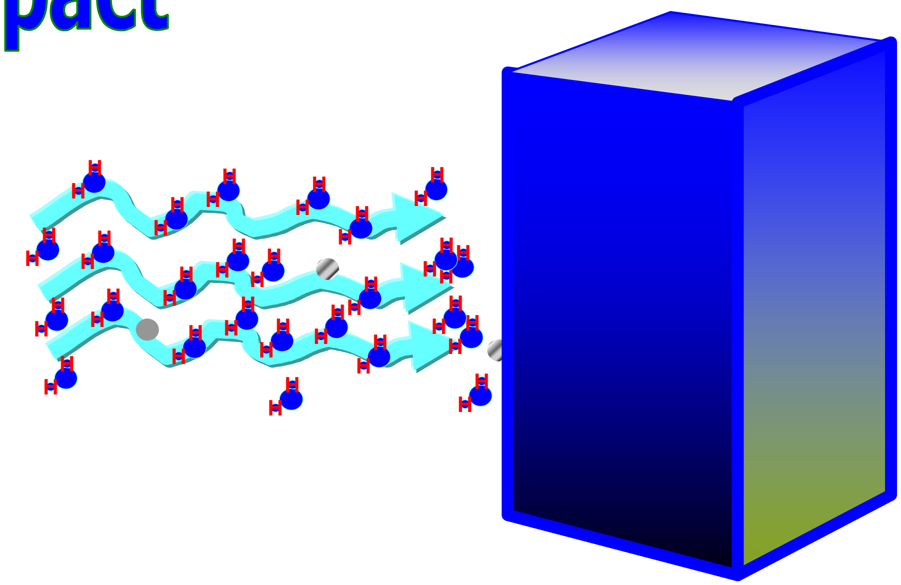
Indirect Air Leakage Impact on Energy Use:

Moisture Impact on Thermal Insulation Performance



Source: Controlling the Transfer of Heat, Air & Moisture through the Building Envelope M.C. Swinton, W.C. Brown, G.A. Chown

Air Leakage Impact



Transport of:	Impact on Buildings
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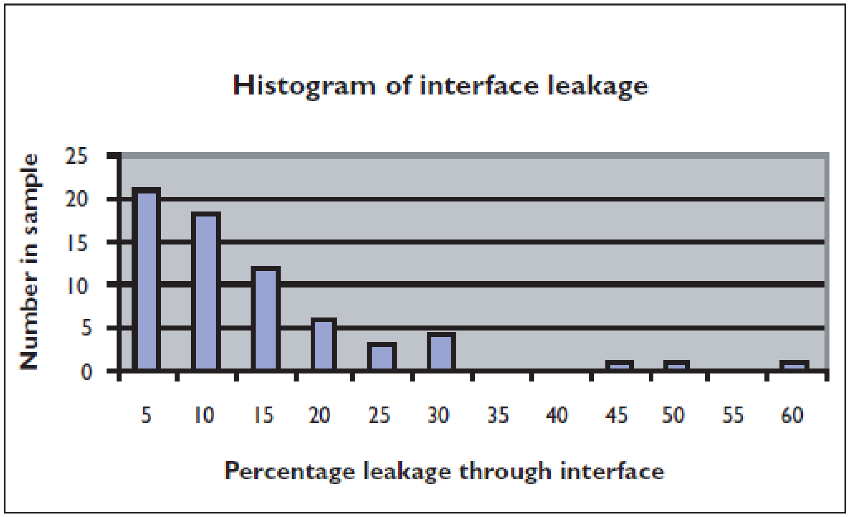
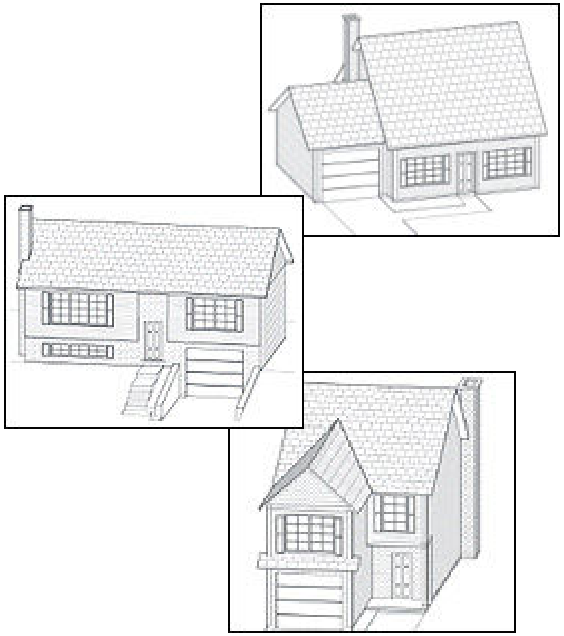
Garage / House Interface Air Leakage





1. "Based on the airtightness testing completed on an additional 42 homes with attached garages, it was found that, on average, interface leakage accounts for approximately 10 per cent to 13 per cent of the total house leakage area. At these levels of garage-to-house transfer, carbon monoxide (CO) concentrations remainwithin acceptable exposure limits recommended byHealth Canada.

2. If more than 25 per cent of the house air leakage occurs through the garage, our simulations show that garage based emissions could cause significant house indoor air quality problems.

3. Three remediation strategies were tested. All three strategies were found to reduce peak concentration of pollutants in both the garages and the houses where they were tested. Air sealing during construction is recommended to avoid pollutant entry. If a garage air infiltration problem is noticed in an existing house, airsealing should be the first line of defense."

Source: CMHC Research Highlight 04-108, April 2004

Summary, Air Leakage Impact

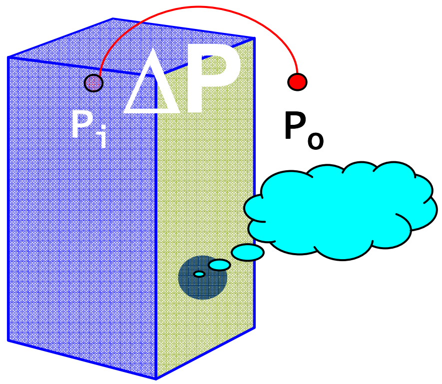
Energy Efficiency:
Direct & Indirect

Building Envelope Durability:
Moisture Damage

Comfort & Safety:
IAQ, Thermal Comfort

What is Air Leakage

Unplanned/**Un**predictable/**Un**intentional Airflow

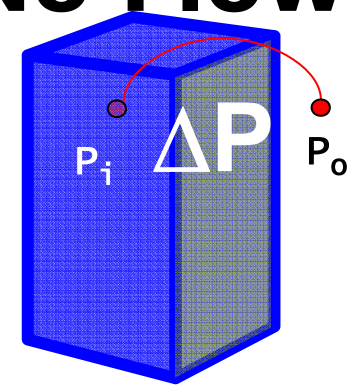


Air Leakage needs BOTH:

1. **A Driving Force** (Δ Pressure)
2. **A Pathway** (Unintended Opening)

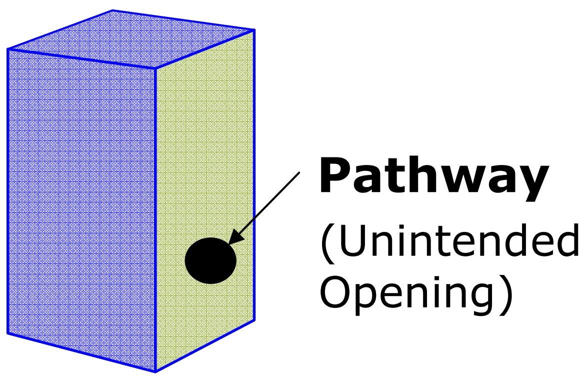
No pathway:

No Flow

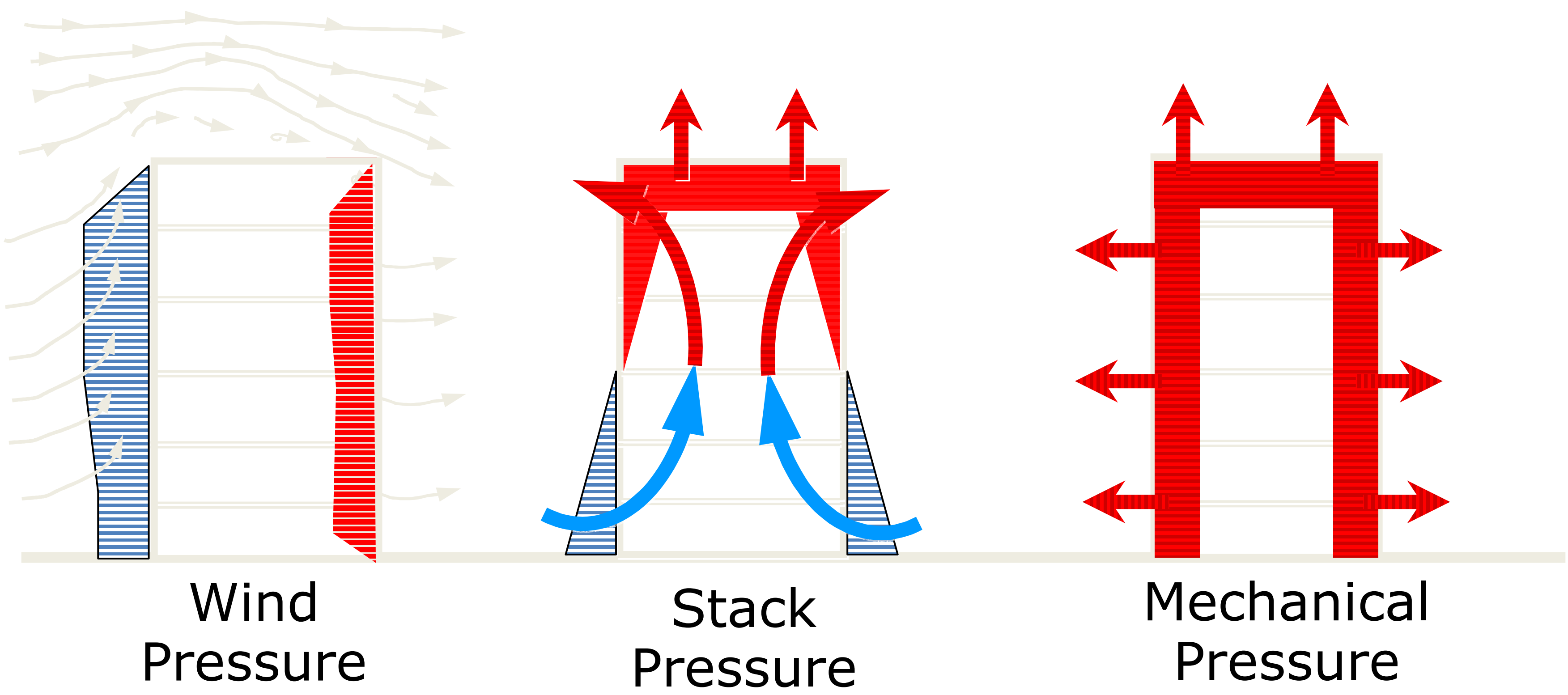


No Δ Air Pressure:

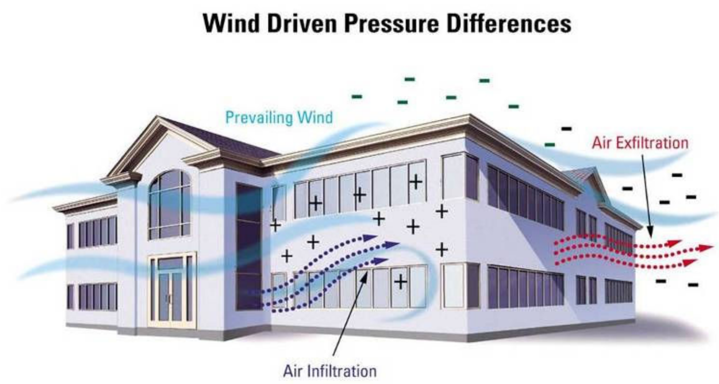
No Flow

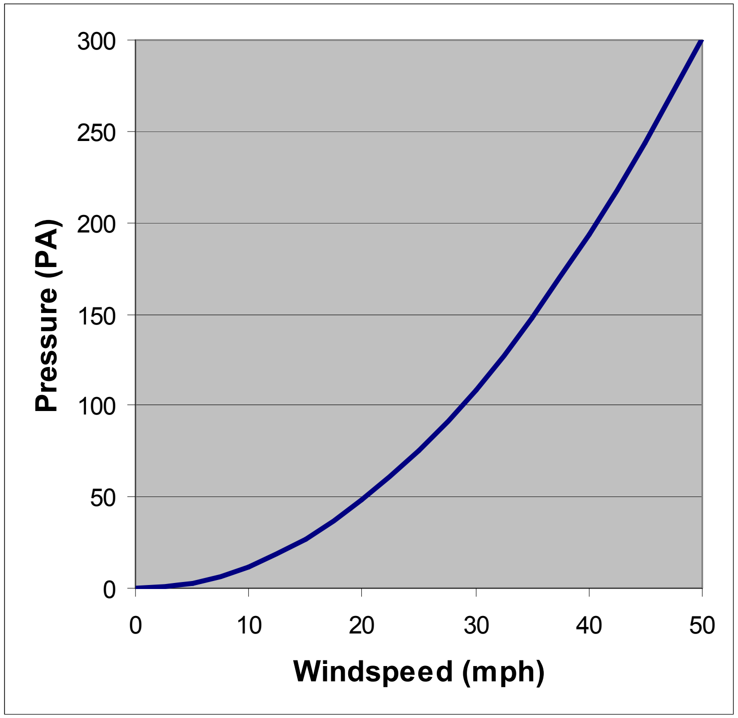


Sources of Air Pressure Difference (ΔP)

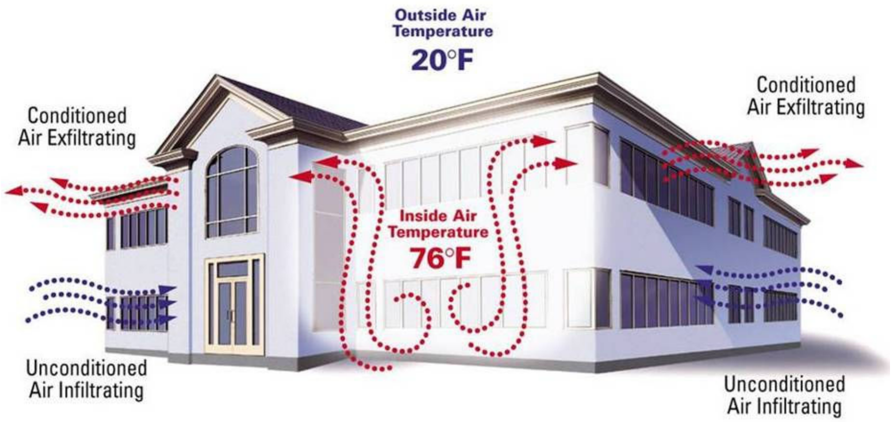


Wind Pressure





Stack Pressure



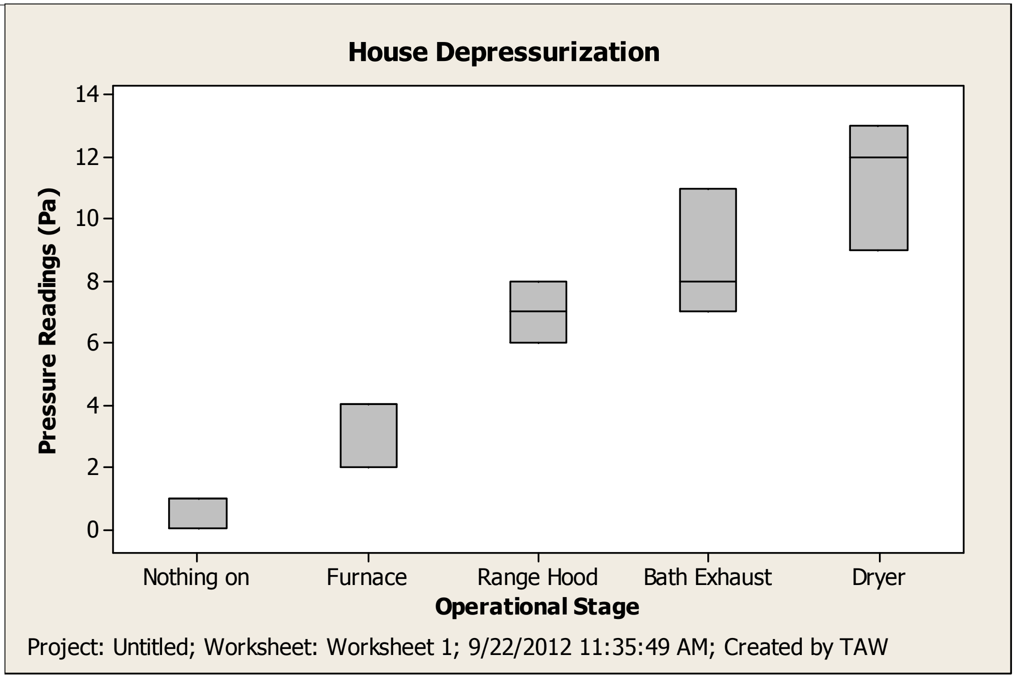
$$\Delta p_s = 0.00598(\rho_o - \rho_i)g(H_{\mathrm{NPL}} - H)$$

$$= 0.00598\rho_o\left(\frac{T_i - T_o}{T_i}\right)g(H_{\mathrm{NPL}} - H)$$

where

T_o = outdoor temperature, °R
T_i = indoor temperature, °R
ρ_o = outdoor air density, lb/ft^3
ρ_i = indoor air density, lb/ft^3
H_{NPL} = height of neutral pressure level above reference plane without any other driving forces, ft

Source: 2009 ASHRAE Handbook of Fundamentals.



Source: Weston, T. A. *et. al*. ,"Preliminary Investigation of Moisture in Walls of Manufactured Homes" presented at the Conference on Durability and Disaster Mitigation in Wood-Frame Housing, Madison, WI, October, 2001

What is Air Leakage

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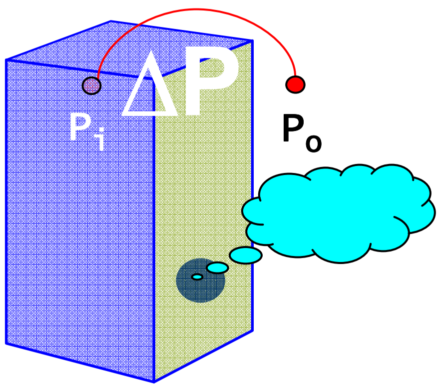

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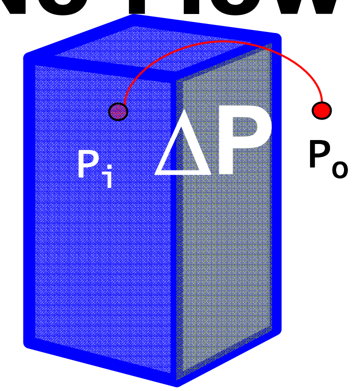
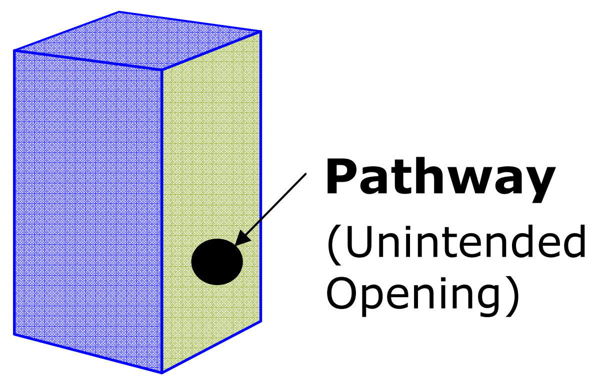


No Δ Air Pressure:

No Flow



Common Types of Air Barriers

Mechanically- Fastened Membranes

Fluid Applied Membranes

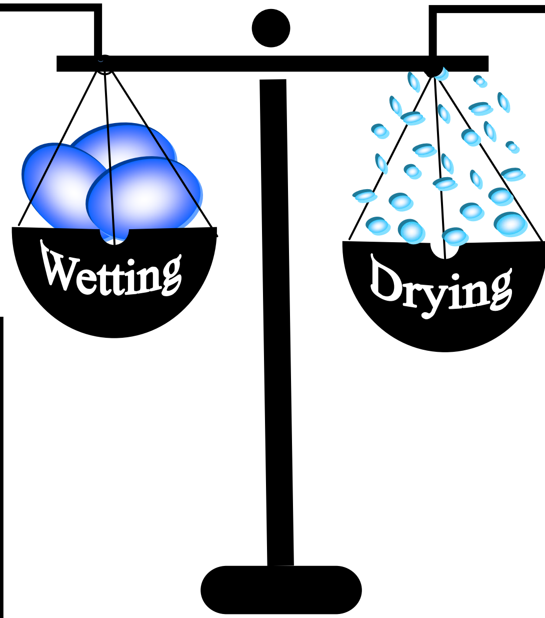
Self-Adhered Membranes

Spray Foam

Photo Source: ASHRAE Journal Nov. 2010"Exterior Spray Foam"
By Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE

Water Management

Minimize / **Maximize**



Wetting

1. **Bulk Water**
2. **Air transport**
3. *Diffusion*

Drying

1. *Drainage*
2. *Venting*
3. *Diffusion*

Good enclosure water management design and detailing will minimize the risk of wetting, but drying potential must ALWAYS be considered

ASHRAE Handbook, *Fundamentals*, S-I Edition, 2001. pp. 23.11 – 23.17, 24.2 – 24.16 *

"Liquid water and water vapor migrate by a variety of moisture transport mechanisms. The following are some of the most important mechanisms:

- *Liquid flow by gravity or air pressure differences*
- *Capillary suction of liquid water in porous building materials*
- *Movement of water vapor by air movement*
- *Water vapor diffusion by vapor pressure differences*

Although in the past many moisture control strategies focused on control of vapor diffusion through the installation of vapor (diffusion) retarders, the other mechanisms, when present, can move far greater amounts of moisture. Thus, liquid flow, capillary suction, and air movement should be controlled first"

Rating of Moisture Sources in Buildings

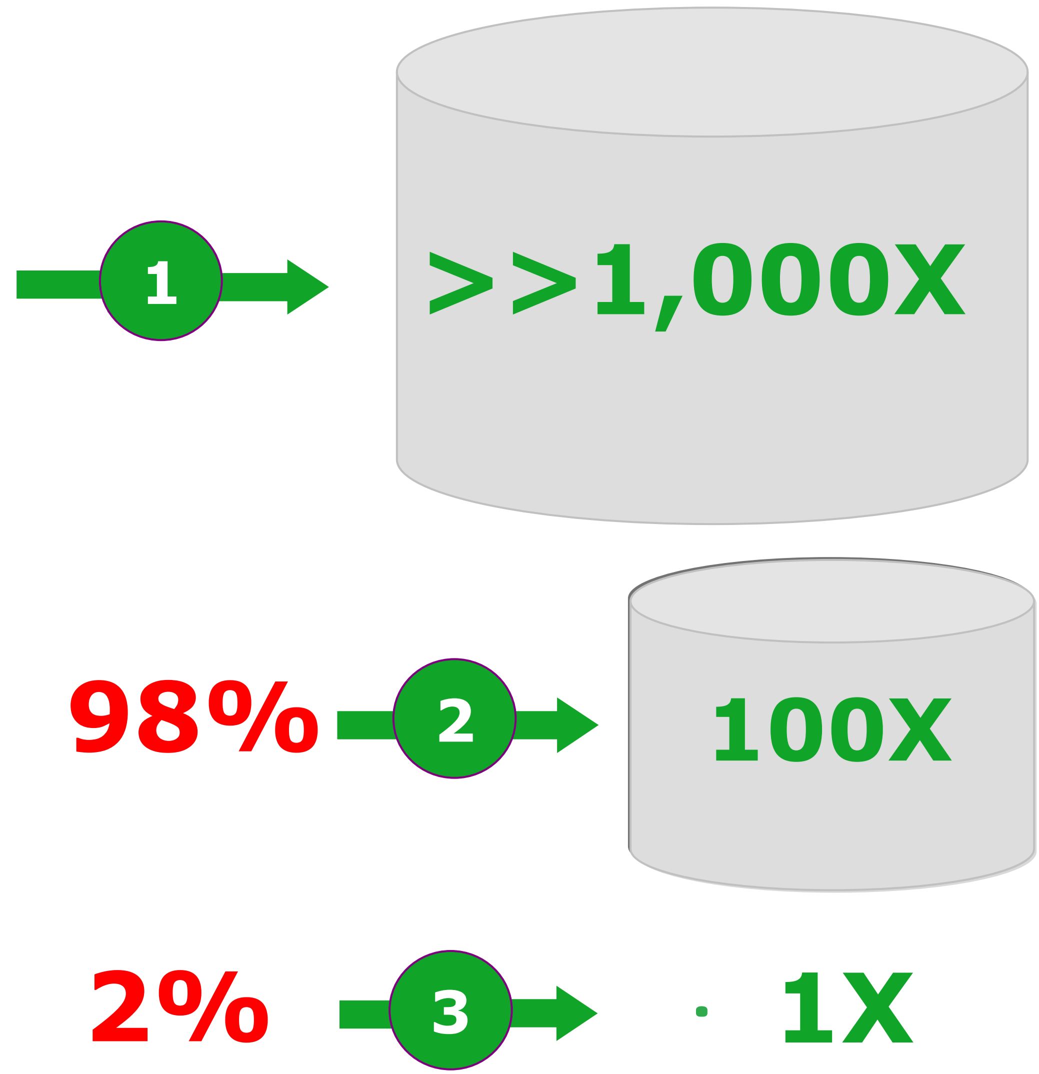
Bulk Water

Rain & Snow:
(above grade envelope)

Water Vapor

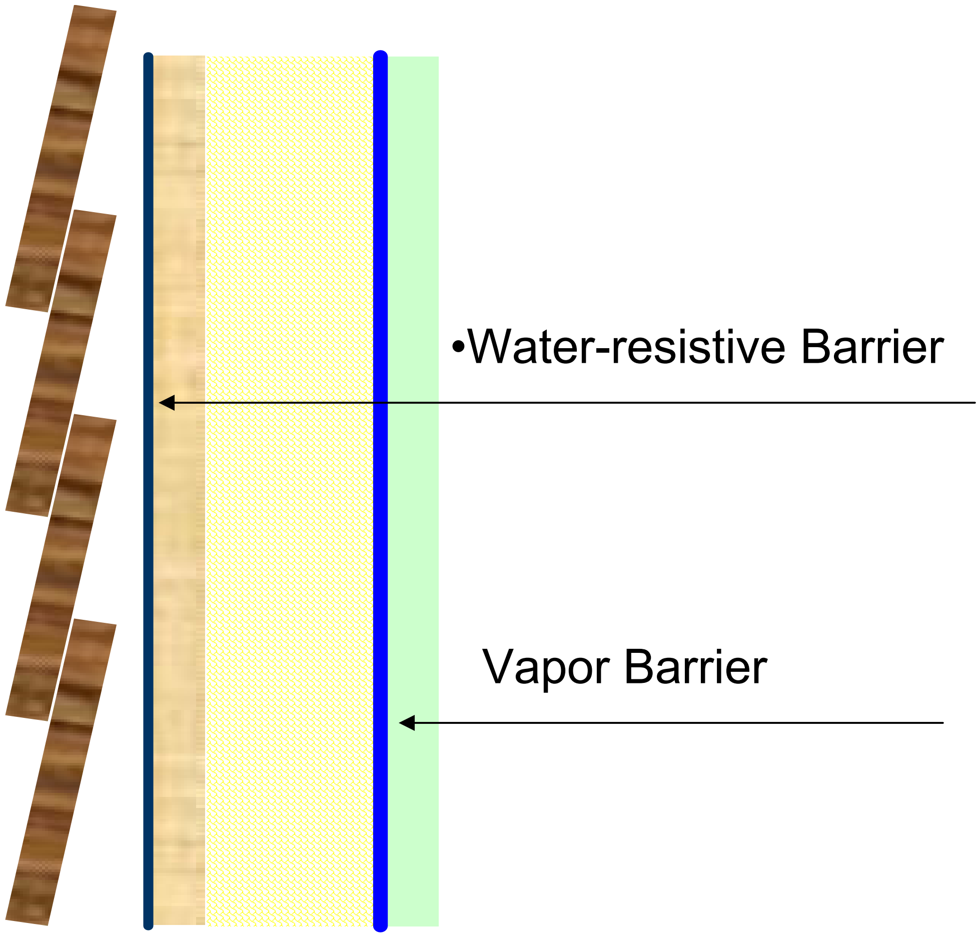
Transported by air currents

Diffusion

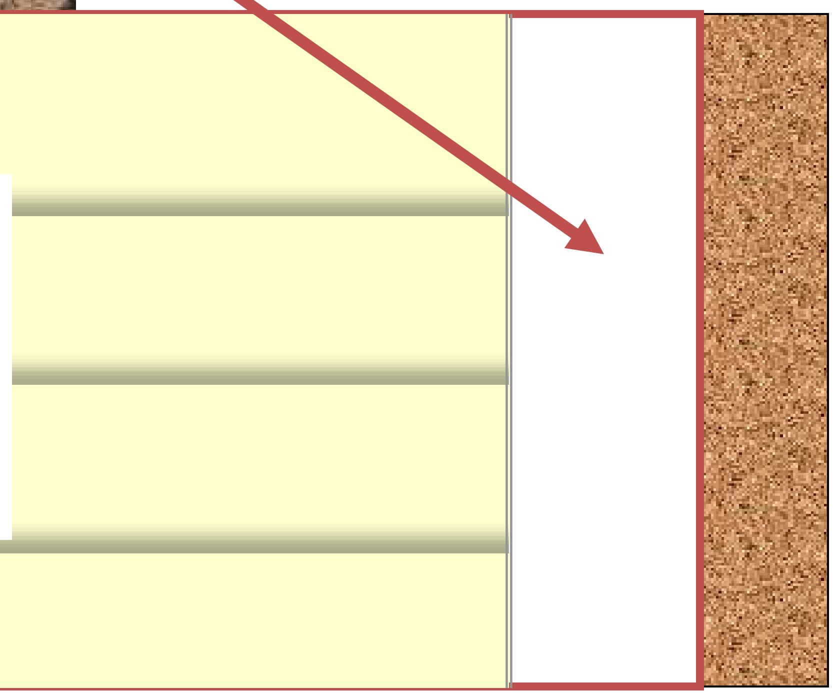


Air Barriers, Water-resistive Barriers and Vapor Barriers

Air barriers can be placed anywhere in the wall.



Water-Resistive Barriers



WATER-RESISTIVE BARRIER. **A material behind an exterior wall covering that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding** ***(IBC, IRC)***

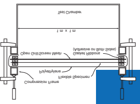
Water-Resistive Barriers

Building Papers / Felts

Building Wraps
- Perforated Wraps
- Non-Perforated Wraps
- Specialty Wraps
- Self-Adhesive Wraps

Fluid Applied

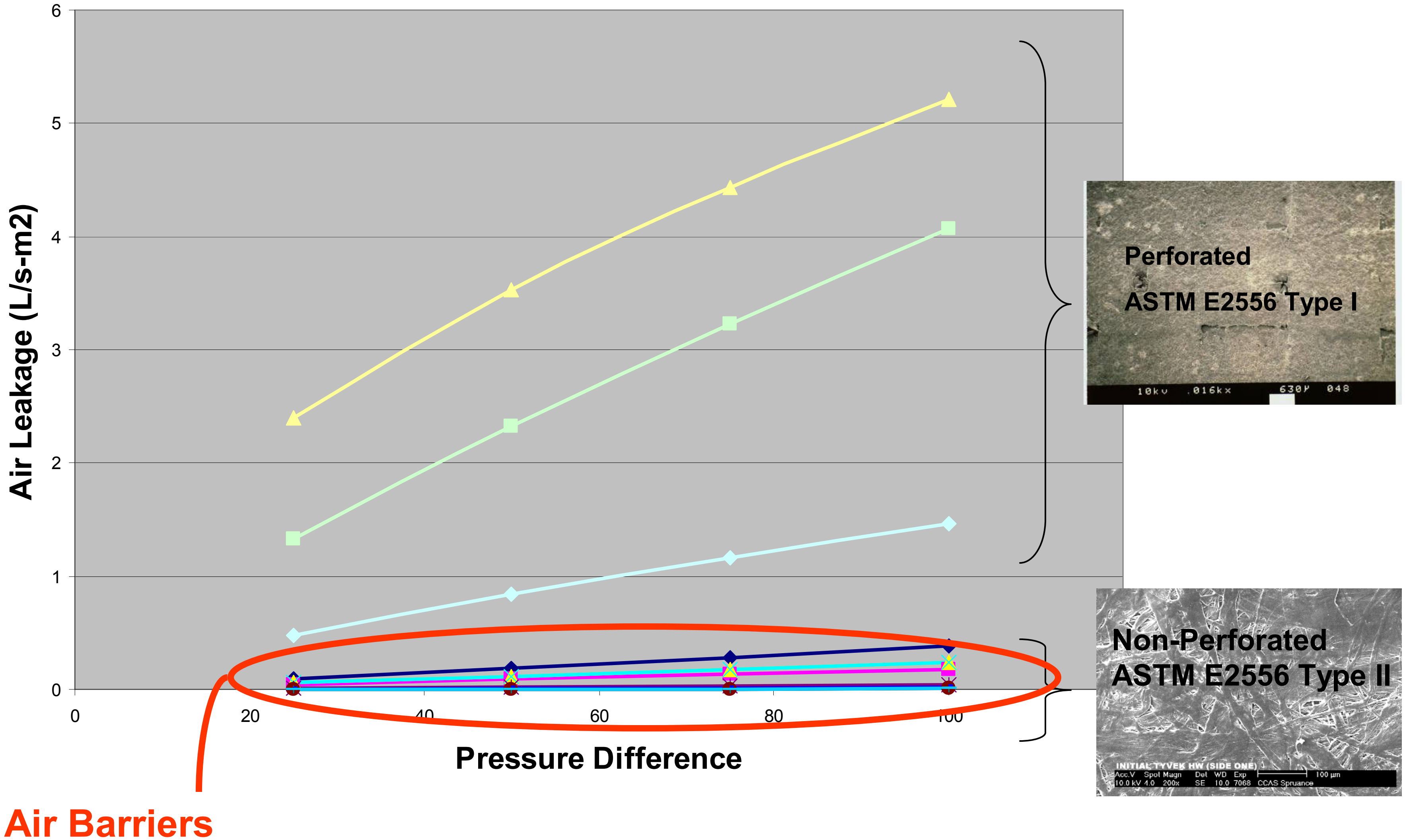
Sheathings
- Foam Sheathing
- WRB Laminated Wood-Based Sheathing
- Laminated Fibrous Sheathing



Air Barrier Materials – ASTM E2178

Diagram from CCMC Technical Guide for Air Barrier Materials Testing

Housewrap Material Air Leakage Properties



Code Evaluation Reports

ES REPORT™

ESR-2375

Issued September 1, 2008

This report is subject to re-examination in one year.

ICC Evaluation Service, Inc.
www.icc-es.org

Business/Regional Office ▪ 5360 Workman Mill Road, Whittier, California 90601 ▪ (562) 699-0543
Regional Office ▪ 900 Montclair Road, Suite A, Birmingham, Alabama 35213 ▪ (205) 599-9800
Regional Office ▪ 4051 West Flossmoor Road, Country Club Hills, Illinois 60478 ▪ (708) 799-2300

The sheet materials have an air leakage rate not exceeding 0.02 L/s-m^2 [0.004 cfm/ft^2 at 0.3 w.g. (1.57 psf)] when used as an air barrier material under IRC Section N1102.4.1 and IECC Section 402.4 or 502.4.

DIVISION: 07—THERMAL AND MOISTURE PROTECTION
Section: 07270—Air Barriers
Section: 07280—Water-resistive Barriers

REPORT HOLDER:

E.I. DUPONT DE NEMOURS & COMPANY, INC. (DuPONT™)
DuPONT BUILDING INNOVATIONS
WILMINGTON, DELAWARE 19880-0721
(800) 44-TYVEK
www.construction.tyvek.com
tyvekinfo@usa.dupont.com

EVALUATION SUBJECT:

DUPONT™ TYVEK® HOMEWRAP®–STYLE 1055B; DUPONT™ TYVEK® STUCCOWRAP®–STYLE 1062X; DUPONT™ TYVEK® DRAINWRAP™–STYLE 1063X; DUPONT™ TYVEK® COMMERCIALWRAP®–STYLE 1162B; AND DUPONT™ TYVEK® HEADERWRAP

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2006 *International Building Code*® (IBC)
- 2006 *International Residential Code*® (IRC)
- 2006 *International Energy Conservation Code*® (IECC)
- Other Codes (see Section 8.0)

Properties evaluated:

- Water resistance
- Surface-burning characteristics
- Air leakage
- Wall draining characteristics (DuPont™ Tyvek® StuccoWrap®–Style 1062X and DuPont™ Tyvek® DrainWrap™–Style 1063X only) for EIFS and one-coat stucco

2.0 USES

DuPont™ Tyvek® HomeWrap®–Style 1055B; DuPont™ Tyvek® StuccoWrap®–Style 1062X; DuPont™ Tyvek® DrainWrap™–Style 1063X; DuPont™ Tyvek® CommercialWrap®–Style 1162B; and DuPont™ Tyvek® HeaderWrap® are used as water-resistive barriers on the exterior side of exterior walls of buildings of any construction type under the IBC and construction permitted under the IRC, except as noted in Section 4.4. They are equivalent to Grade D paper with a 60-minute water-resistance rating as described in IBC Section 2510.6 and IRC Section R703.6.3. All products may be used as air

...

sheets with variations as described in Sections 3.2 through 3.6.

All products have a flame spread index of less than 25 and a smoke-developed index of less than 450, when tested in accordance with ASTM E 84.

The sheet materials have an air leakage rate not exceeding 0.02 L/s/m^2 (0.004 cfm/ft^2) when used as an air barrier material under IRC Section N1102.4.1 and IECC Section 402.4 or 502.4.

3.2 DuPont™ Tyvek® HomeWrap®–Style 1055B:

This product is a smooth sheet with a nominal basis weight of 1.8 ounces per square yard (61 grams per square meter) and is produced in rolls of varying sizes.

3.3 DuPont™ Tyvek® StuccoWrap®–Style 1062X:

The product has a surface texture that is intended to allow for drainage of water that may get behind the exterior wall finish material. This product has a nominal basis weight of 2.1 ounces per square yard (71 grams per square meter) and is produced in rolls of varying sizes.

3.4 DuPont™ Tyvek® DrainWrap™–Style 1063X:

The product has a surface texture that is intended to allow for drainage of water that may get behind the exterior wall finish material. This product has a nominal basis weight of 2.1 ounces per square yard (71 grams per square meter) and is produced in rolls of varying sizes.

3.5 DuPont™ Tyvek® CommercialWrap®–Style 1162B:

This product is a smooth sheet with a nominal basis weight of 2.7 ounces per square yard (92 grams per square meter) and is produced in rolls of varying sizes.

3.6 DuPont™ Tyvek® HeaderWrap®:

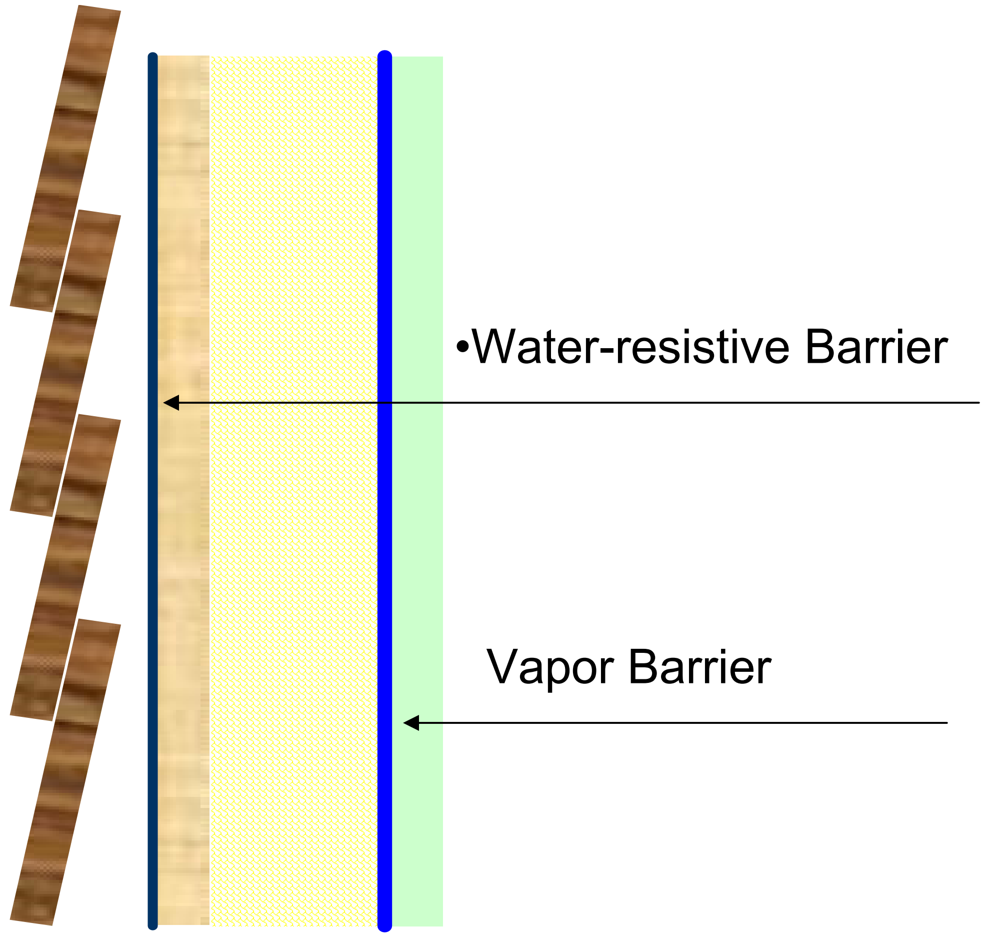
This product is the same as Tyvek® HomeWrap®, except that the rolls are narrower.

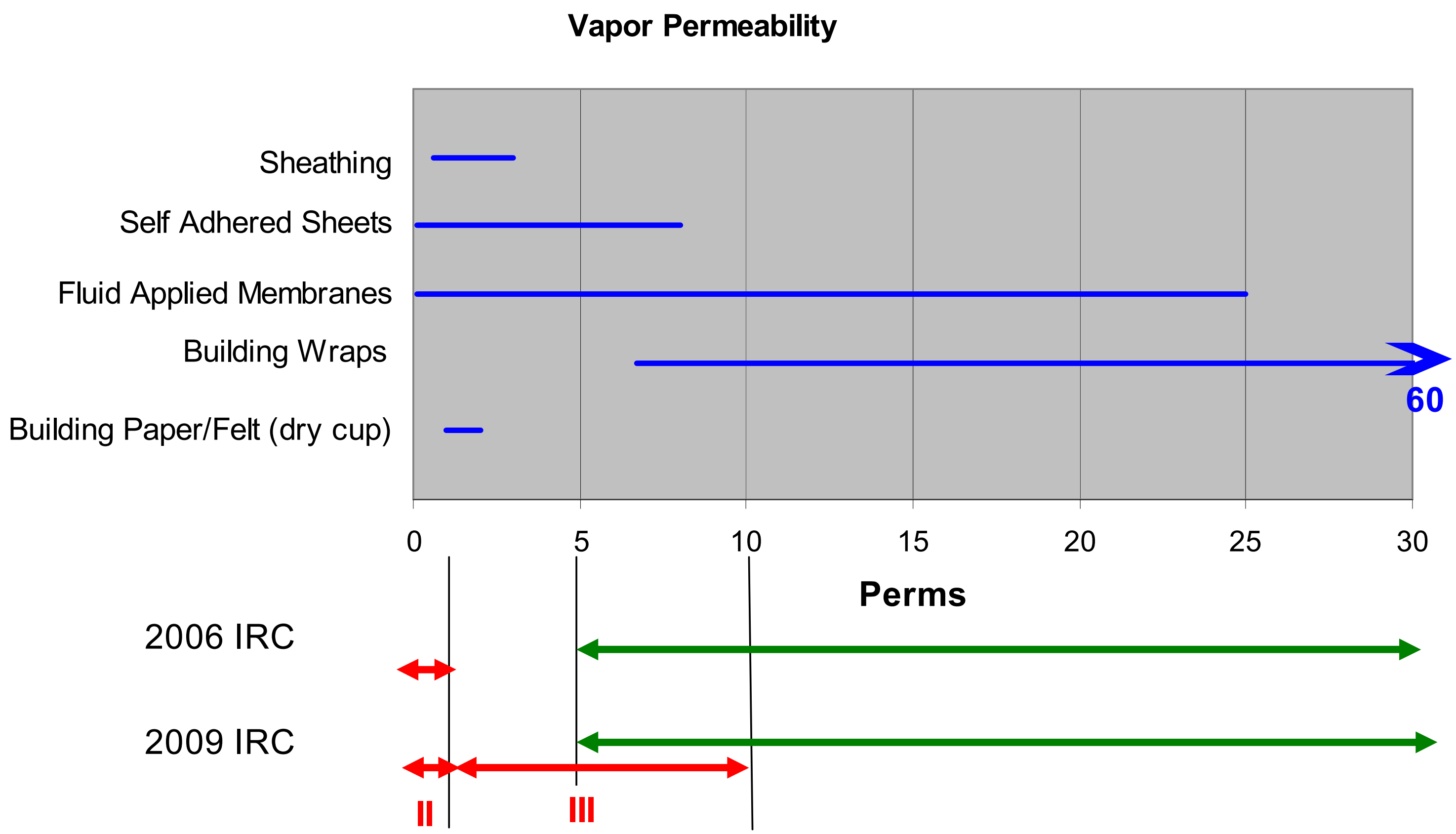
Products with ICC-ES Air Barrier Evaluation

COMPANY	PRODUCT NAME	TYPE
JX Nippon ANCI, Inc.	Exaire® Plus Housewrap, Exaire® Plus Commercial Housewrap and Exaire® Plus Low Perm Housewrap	Wrap
Fiberweb	Typar® HouseWrap, Surround™ Housewrap B, W and G Weather-Resistant Barriers; Typar® StormWrap Weather-Resistant Barriers; Typar® HouseWrap Weather-Resistant Barriers;Typar® MetroWrap Weather Resistant Barriers; and Typar® CertaWrap Weather-Resistant Barriers	Wrap
Huber Engineered Woods, LLC	ZIP System® Wall Sheathing	OSB Wood Structural Panel
Alpha ProTech Engineered Products, Inc.	REX Wrap Plus Protective House Wrap and Rex Wrap Homewrap Water-Resistive Barriers and Air Barriers	Wrap
E.I. du Pont de Nemours and Company	DuPont™ Tyvek® ThermaWrap™, DuPont™ Tyvek® HomeWrap®, DuPont™ Tyvek® StuccoWrap®, DuPont™ Tyvek® DrainWrap™, DuPont™ Tyvek® CommercialWrap®, DuPont™ Tyvek® CommercialWrap® D	Wrap
The Dow Chemical Company	Styrofoam™ Brand Insulation Boards and Dow Fan-Fold Products, FROTH-PAK™ Polyurethane Foam Insulation, WEATHERMATE Plus ™	Boards/ Foam Insulation/Wrap
Pactiv Building Products	GreenGuard® Ultra Wrap Building Wrap, GreenGuard® RainDrop Building Wrap, GreenGuard® MAX Building Wrap, GreenGuard® C500 Building Wrap and GreenGuard® C2000 Building Wrap	Wrap
Cosella-Dorken Products Inc	DELTA®-MAXX, DELTA®-MAXX PLUS, DELTA®-VENT S, DELTA®-VENT S PLUS,	

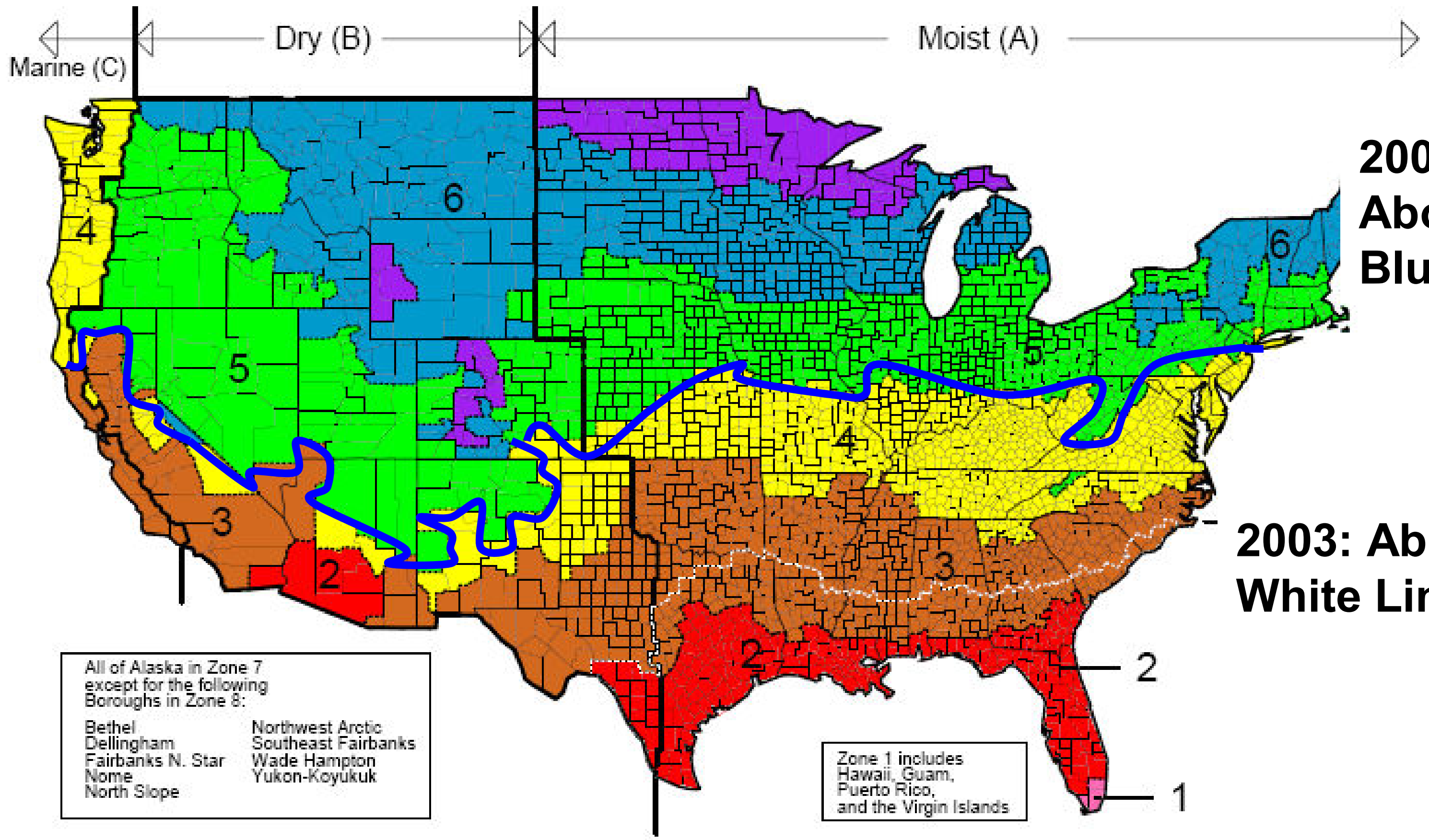
Air Barriers, Water-resistive Barriers and Vapor Barriers

Air barriers can be placed anywhere in the wall.




Vapor Permeability
Sheathing
Self Adhered Sheets
Fluid Applied Membranes
Building Wraps
Building Paper/Felt (dry cup)
60
0
5
10
15
20
25
30
Perms
2006 IRC
2009 IRC
II
III

Where are interior vapor retarders required?



2006: Above Blue Line

2003: Above White Line

March 24, 2003

2009

TABLE N1102.5.1
CLASS III VAPOR RETARDERS

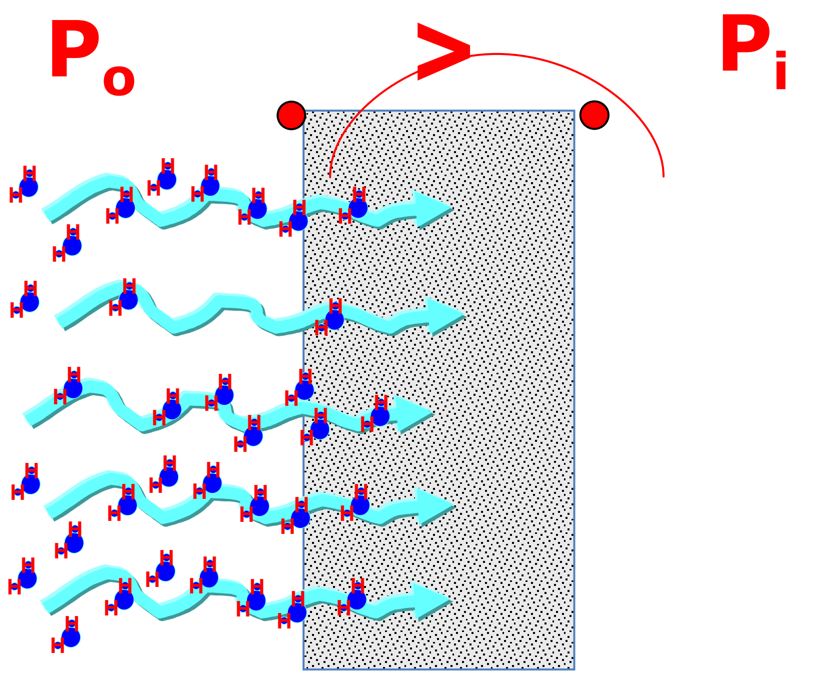
Zone	Class III vapor retarders permitted for:
Marine 4	Vented cladding over OSB Vented cladding over plywood Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ 2.5 over 2x4 wall Insulated sheathing with *R*-value ≥ 3.75 over 2x6 wall
5	Vented cladding over OSB Vented cladding over plywood Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ 5 over 2x4 wall Insulated sheathing with *R*-value ≥ 7.5 over 2x6 wall
6	Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ 7.5 over 2x4 wall Insulated sheathing with *R*-value ≥ 11.25 over 2x6 wall
7 and 8	Insulated sheathing with *R*-value ≥ 10 over 2x4 wall Insulated sheathing with *R*-value ≥ 15 over 2x6 wall

1405.3.3 Minimum clear air spaces and vented openings for vented cladding. For the purposes of this section vented cladding shall include the following minimum clear air spaces.

- 1. Vinyl lap or horizontal aluminum siding applied over a weather resistive barrier as specified in this Chapter.
- 2. Brick veneer with a clear airspace as specified in this code.
- 3. Other approved vented claddings.

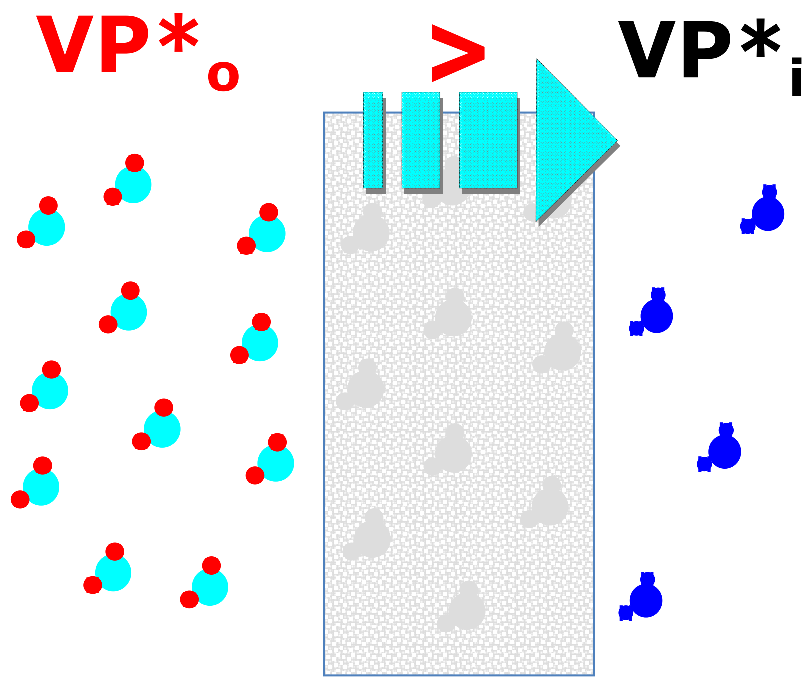
Air Transported Moisture **must not be confused** with Vapor Diffusion

Air Transported Moisture



98% of all water vapor migration

Water Vapor Diffusion



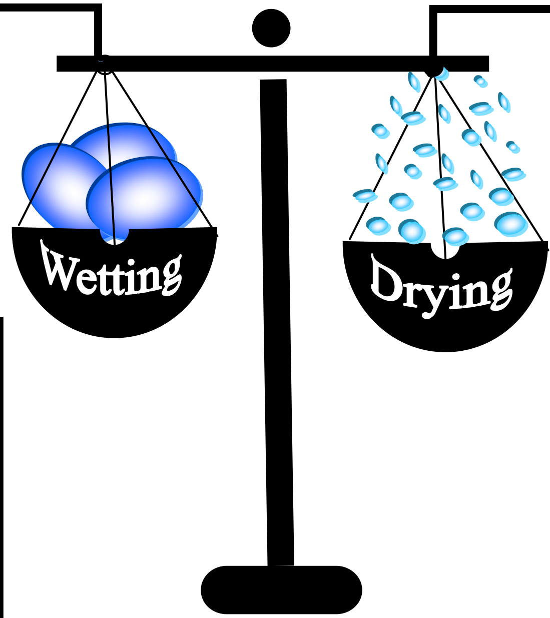
~ 2% of all water vapor migration

* Vapor pressure is proportional to Water Vapor Concentration

Water Management

Minimize

Maximize



Wetting

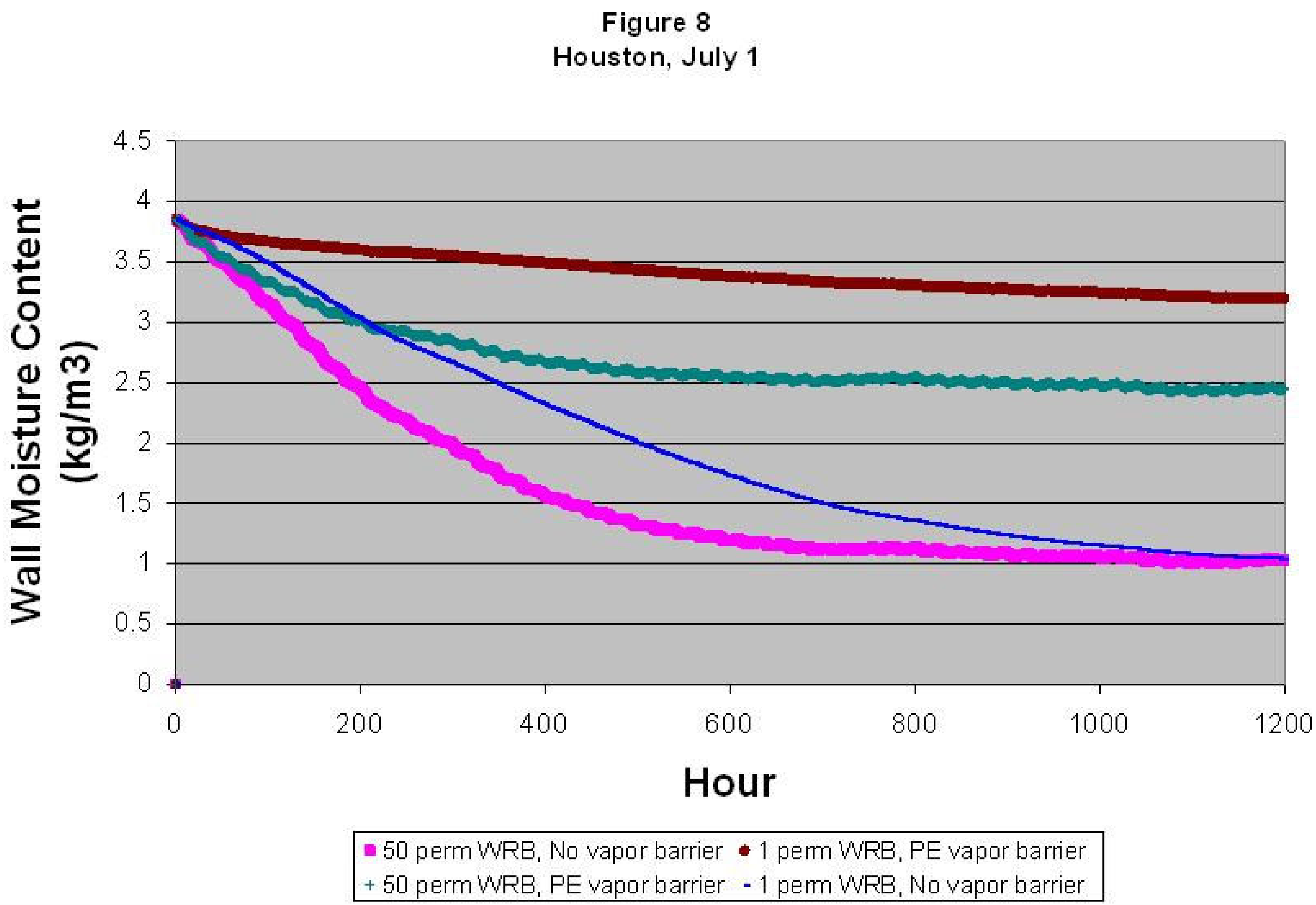
1. **Bulk Water**
2. **Air transport**
3. *Diffusion*

Drying

1. *Drainage*
2. *Venting*
3. *Diffusion*

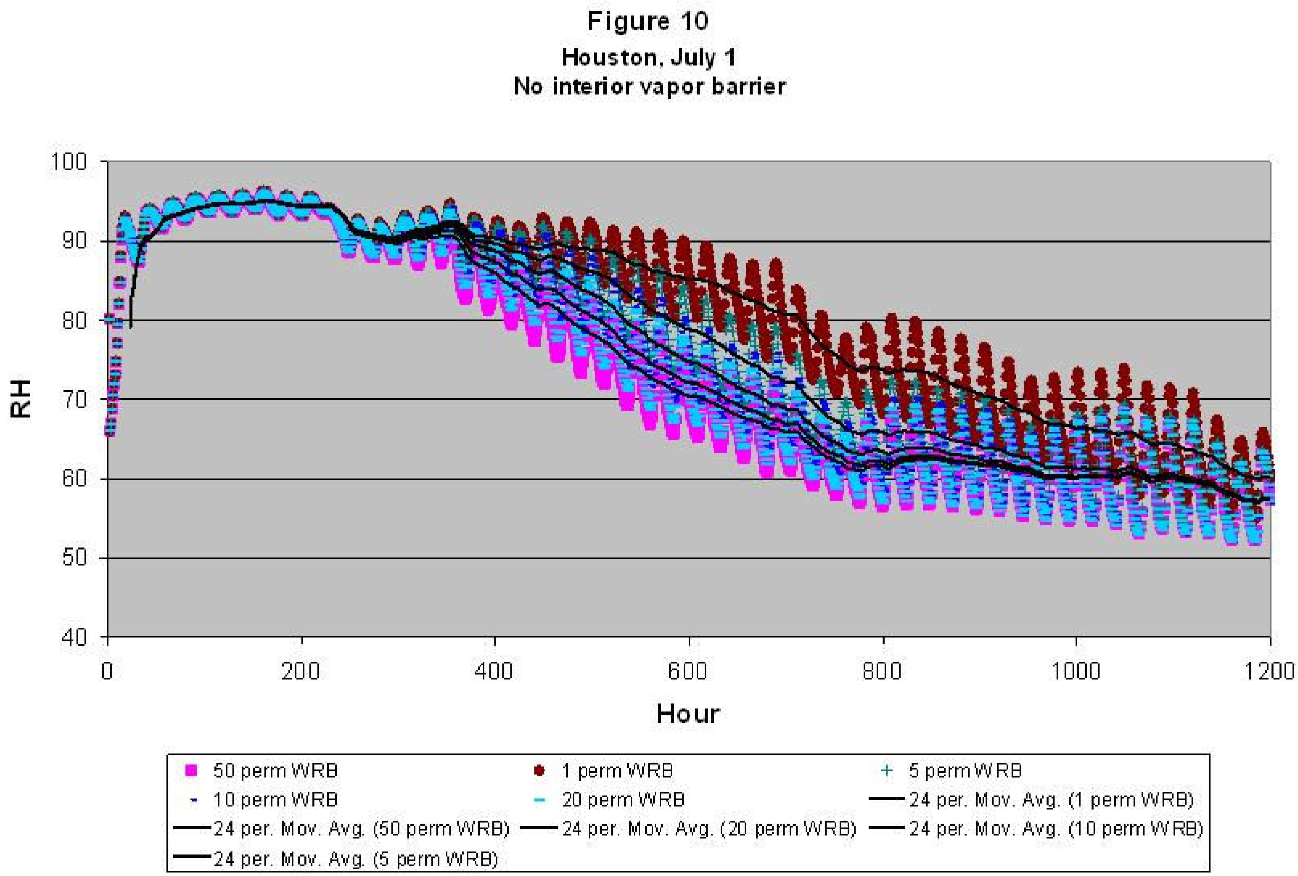
Good enclosure water management design and detailing will minimize the risk of wetting, but drying potential must ALWAYS be considered

Total Moisture Content of Wall System
Simulated 3 months starting July 1.



Data originally submitted to Texas Residential Constuction Council Task-Group on Mold and Moisture

Gypsum Board RH
Simulated 3 months starting July 1.



Data originally submitted to Texas Residential Constuction Council Task-Group on Mold and Moisture

Air Barrier Performance

Material Properties

- *Air Infiltration Resistance*
- *Vapor Permeability*
- *Durability*

Installation

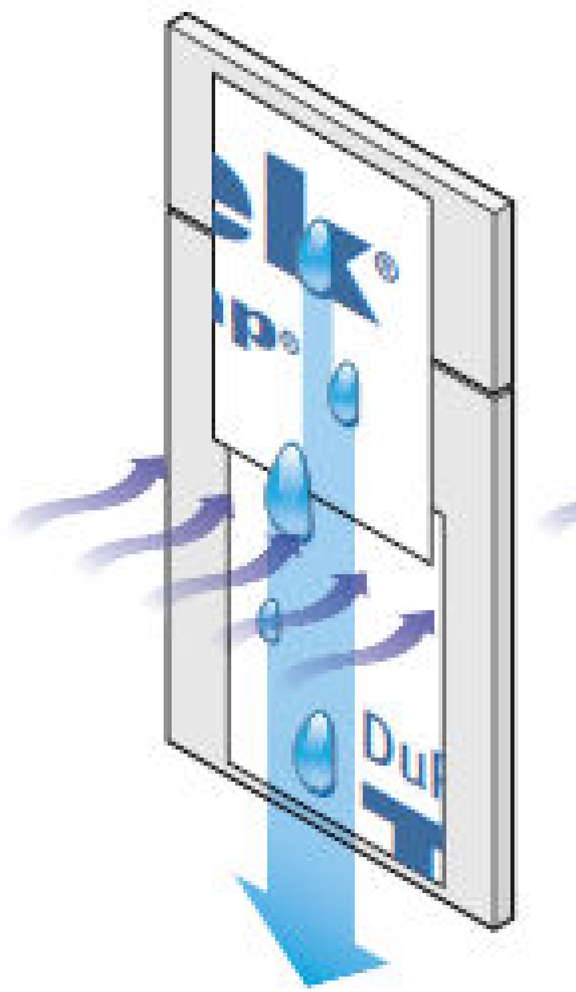
- *Continuity*
- *Structural Integrity*
- *Durability*

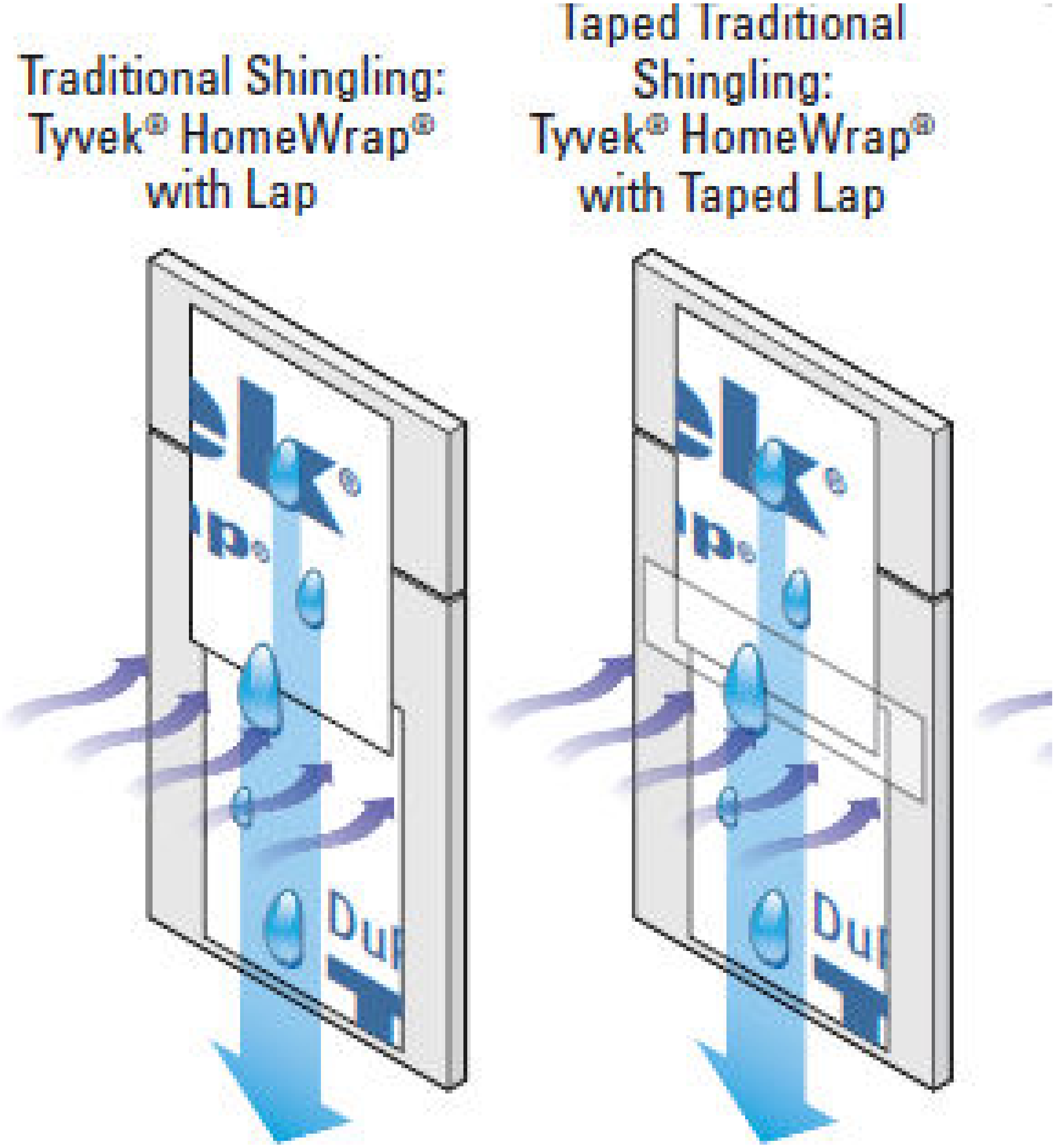
Continuity: Air Barrier System

The *building envelope* must be designed and constructed with a *continuous air barrier:*

- **Primary** Air Barrier Membranes
- **Installation & Continuity Accessories:** fasteners, adhesives & primers, tapes, flashing, transition membranes, caulks & sealants, etc…

Traditional Shingling: Tyvek® HomeWrap® with Lap

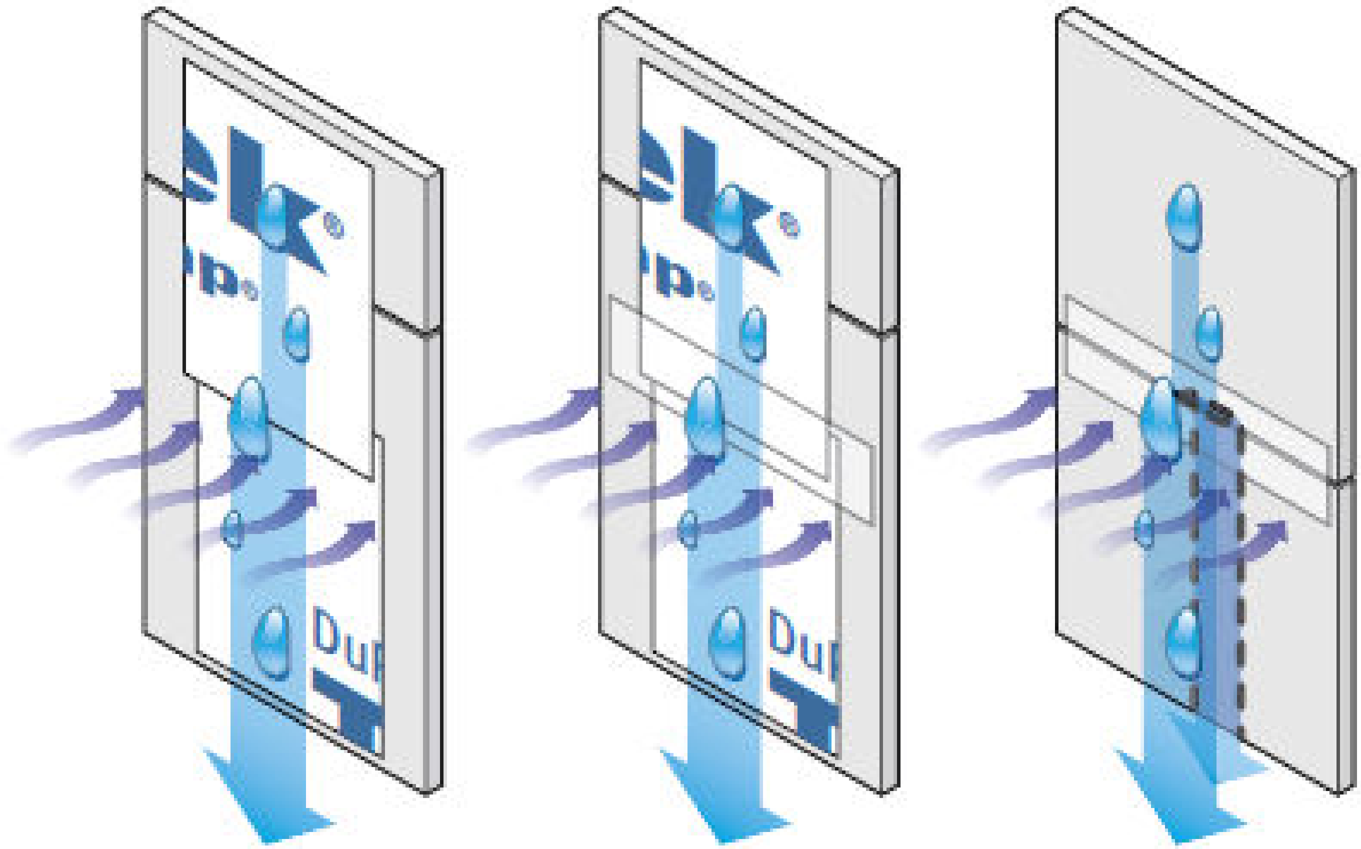



Traditional Shingling:
Tyvek® HomeWrap®
with Lap
Taped Traditional
Shingling:
Tyvek® HomeWrap®
with Taped Lap

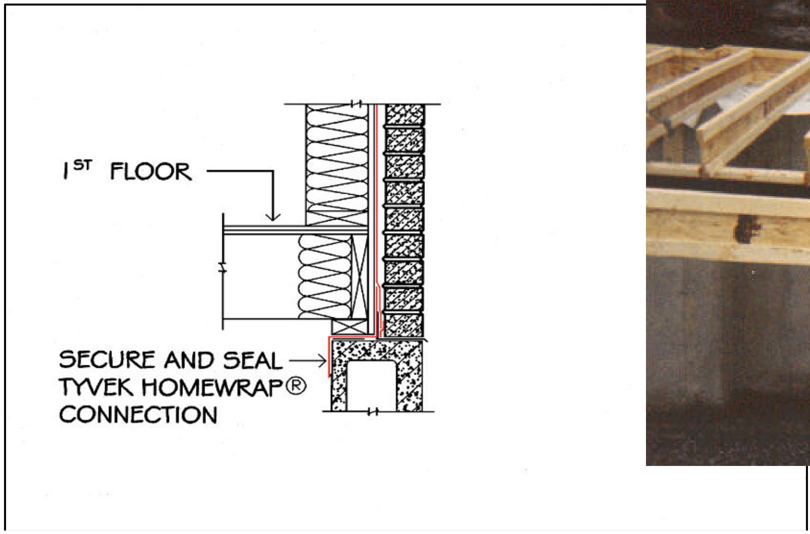
Traditional Shingling: Tyvek® HomeWrap® with Lap

Taped Traditional Shingling: Tyvek® HomeWrap® with Taped Lap

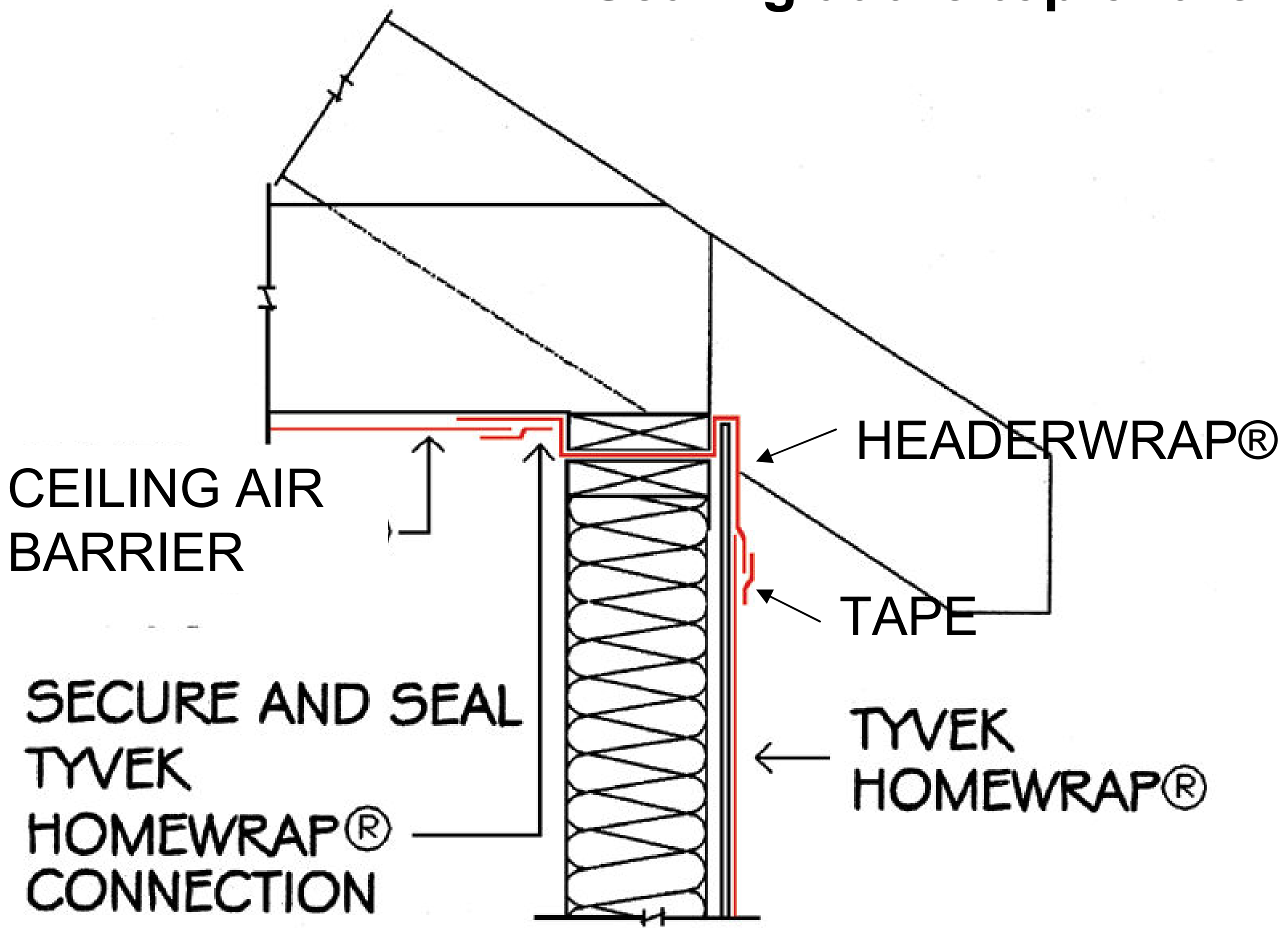
Taped Sheathing Joints: Taped XPS, EPS, or Polyiso



Sealing at Bottom of Wall

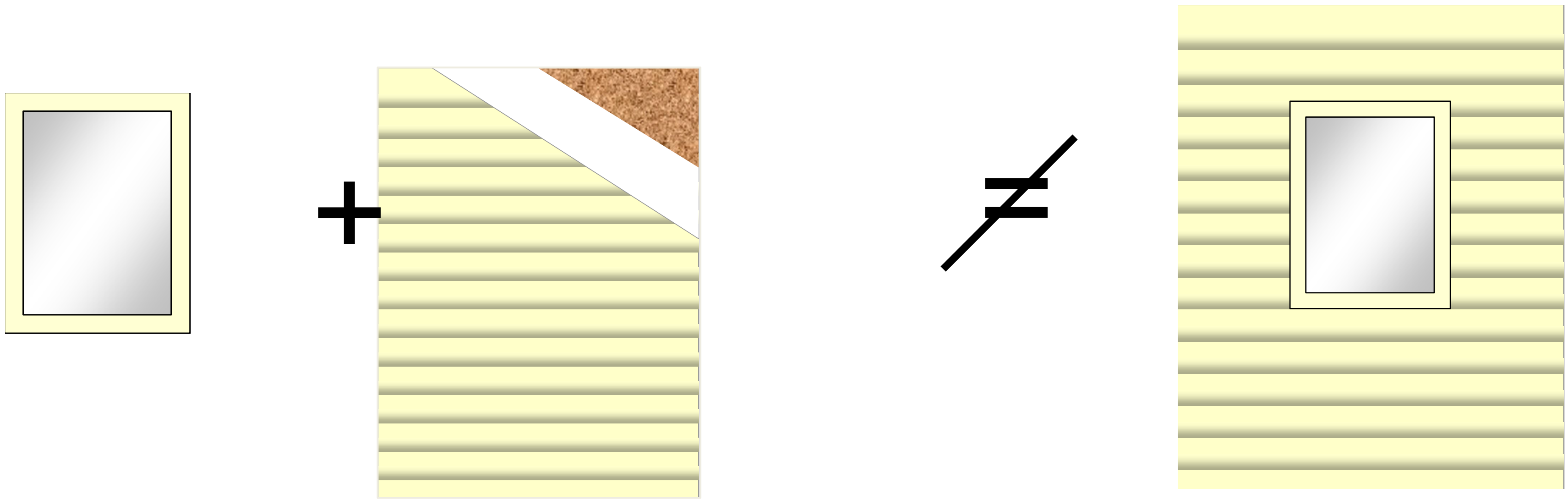


Sealing at the top of the Wall



Top of Wall Detail

Tested Systems



Window and Wall usually tested separately, should be tested as installed unit.

Structural Integrity

Air barriers must be able to withstand pressure loads *(from wind, stack effect and mechanical system)* **or be able to transfer the loads to other elements of the building enclosure without rupture or displacement.**

Assembly Testing: ASTM E 2357, ASTM E1677 or ASTM E 283

ASTM E1677 vs. ASTM E2357

	ASTM E1677-05	ASTM E2357-05
Number of Test Specimen and configuration	One Specimen: Opaque Wall (8 x 8-ft walls) (fasteners to simulate wood siding or brick ties required)	Test two of the three Specimens (8 x 8 -ft walls): 1 – Opaque Wall 2 – Wall with penetrations 3 – Wall-Foundation Interface
Conditions for Air Leakage Testing	**Five Test Pressures:** • 75Pa (1.56 psf, 25 mph) • two pressures below 75 Pa • two pressures above 75 Pa Air leakage results are reported at 75Pa ***(Positive & negative pressures)***	**Seven Test Pressures:** +/- 25Pa (0.56 psf, 15 mph) +/- 50Pa (1.04 psf, 20 mph) +/- 75Pa (1.56 psf, 25 mph) +/- 100Pa (2.09 psf, 30 mph) +/- 150Pa (3.24 psf, 35 mph) +/- 250Pa (5.23 psf, 45 mph) +/- 300Pa (6.24 psf, 50 mph) ***(Positive & negative pressures)***
Pressure Loading Schedule	Sustained loads up to +/- 500 Pa (10.4 psf, 65 mph) ***(Positive & negative pressures)***	1 - Sustained, +/- 600Pa (12.5 psf, 71 mph) 2 - Cyclic, +/- 800 Pa (16.7 psf, 82 mph) 3 - Gust, +/- 1200 (25 psf, 100 mph) ***(Positive & negative pressures)***

ASTM E1677: Two Air Barrier Classifications

Performance Properties	AB Classifications	
	Type I	Type II
Air leakage As tested by E283	< .06 cfm/ft² @ 75 Pa	
Structural Integrity As tested by E330	2 in. H_20 or 500 Pa (65 mph) for 1 hr in each direction	
Water Resistance As tested by E331	No penetration for 15 min of simulated wind driven rain @ 0.11 H_2O or 27 Pa (15 mph)	Not Required
Water Vapor Permeance As tested by E96A	Measured	

Durability

Air Barriers must withstands environmental exposures:

- UV* *(NOT to exceed manufacturer's recommendation for UV exposure)*
- Thermal exposure & thermal cycling
- Repeated exposure to water
- Abrasion
- Mechanical stresses

** Most air barrier membranes are not designed for continuous UV exposure*

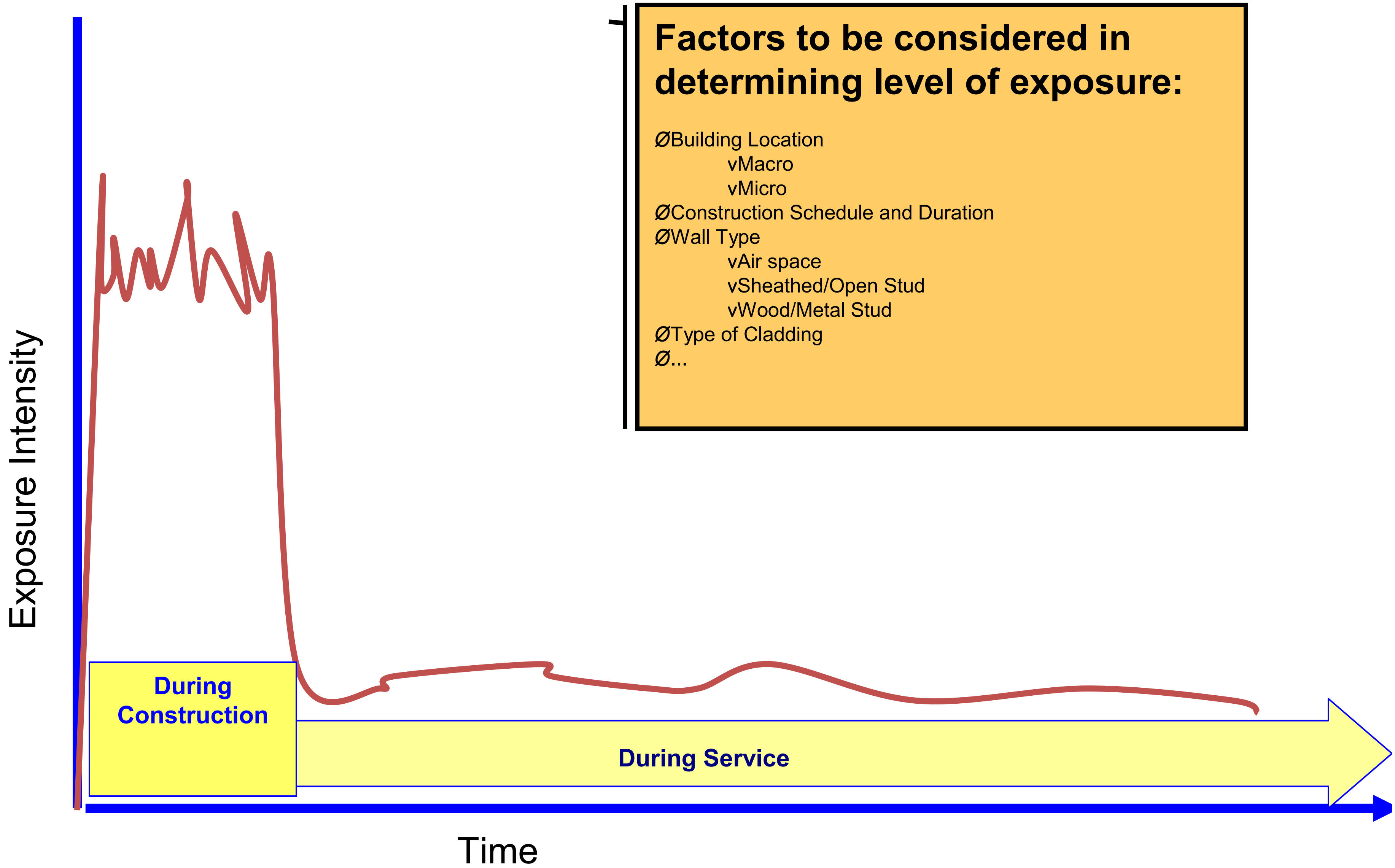
"Durability and cost were seen as the key factors in choosing green products by respondents to the BD&C White Paper Survey."

Green-product attributes

(rated by importance to user)

Ability to last the life of the building	4.38
Cost vs. equivalent conventional product	4.27
Availability of product to job site	4.16
Use of renewable resources	4.01

From Building Design & Construction White Paper on Sustainability, November 2003

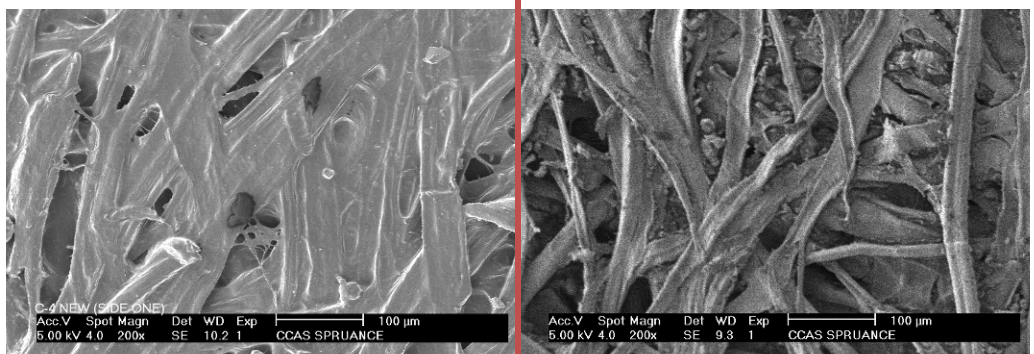


Factors to be considered in determining level of exposure:

- Building Location
  - Macro
  - Micro
- Construction Schedule and Duration
- Wall Type
  - Air space
  - Sheathed/Open Stud
  - Wood/Metal Stud
- Type of Cladding
- ...

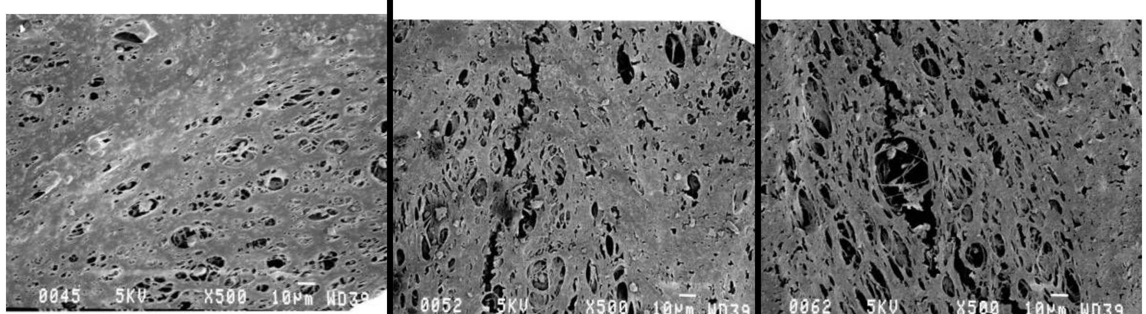
Material deterioration mechanism examples

Volatilization

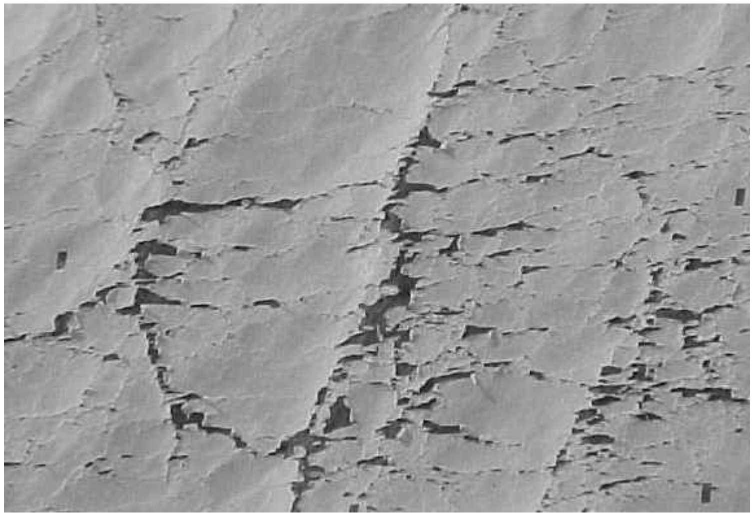


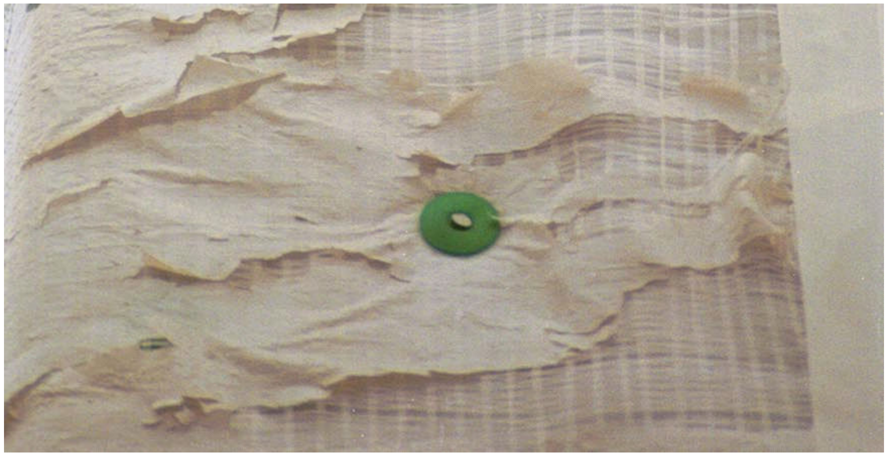
NEW ← → **AGED**

Polymer degradation (embrittlement & micro-cracking)



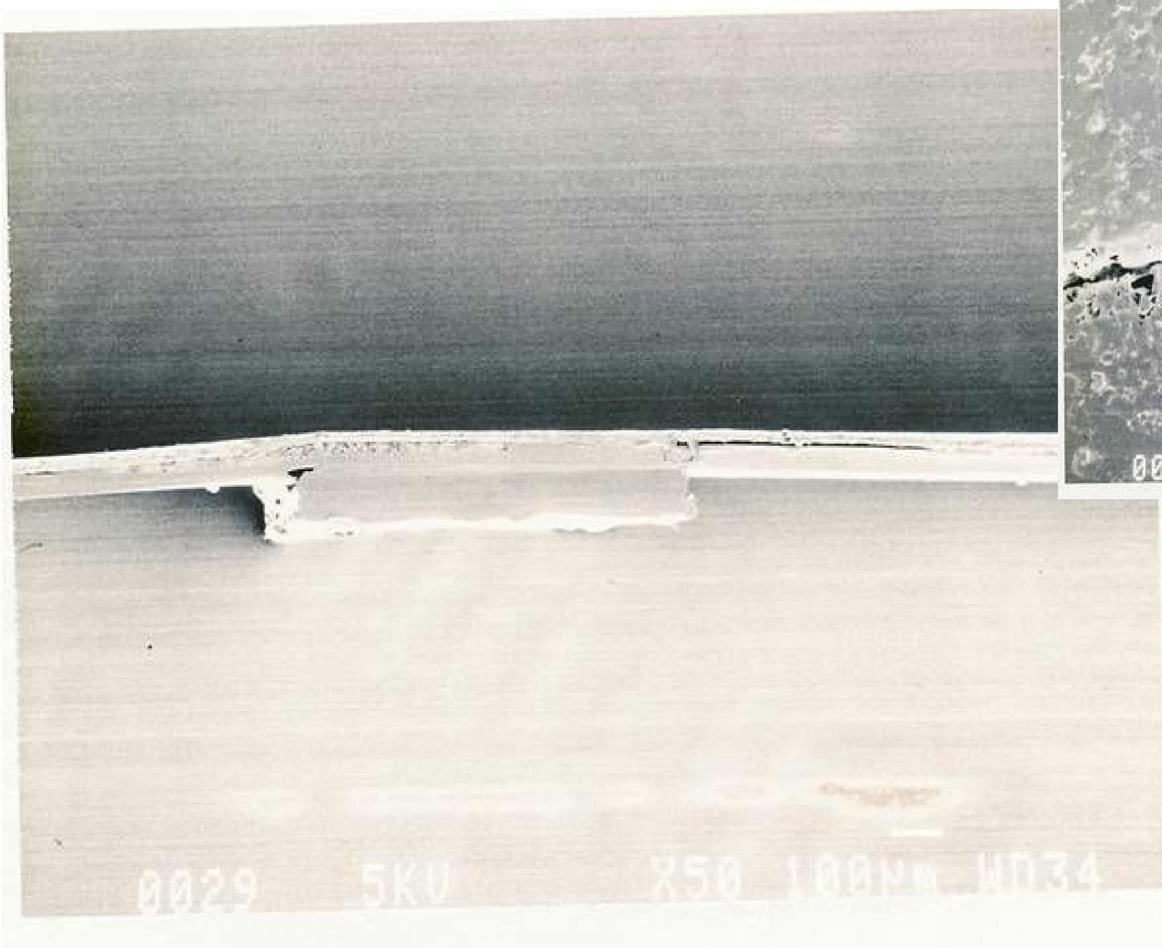
As received | **44 MJ** | **66 MJ**

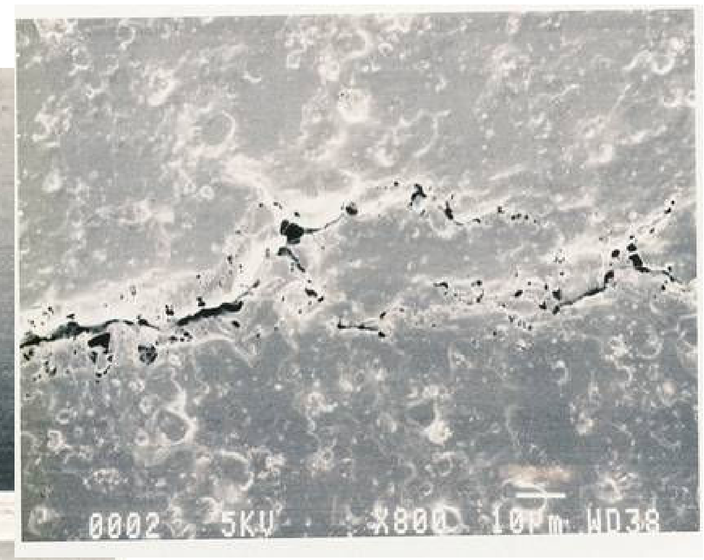




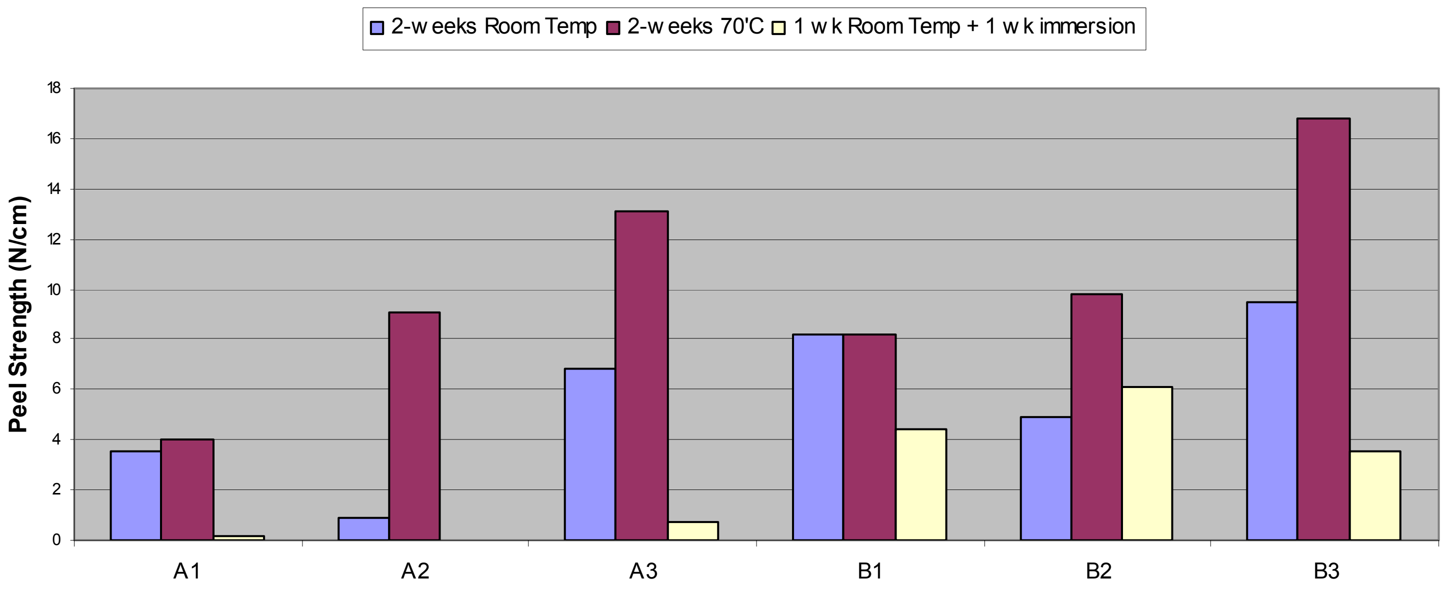
Delamanation – material mis-match

Laminate Stretched to 50% Break Elongation





Adhesion Loss - adhesive vs. cohesive failure



Material Compatibility

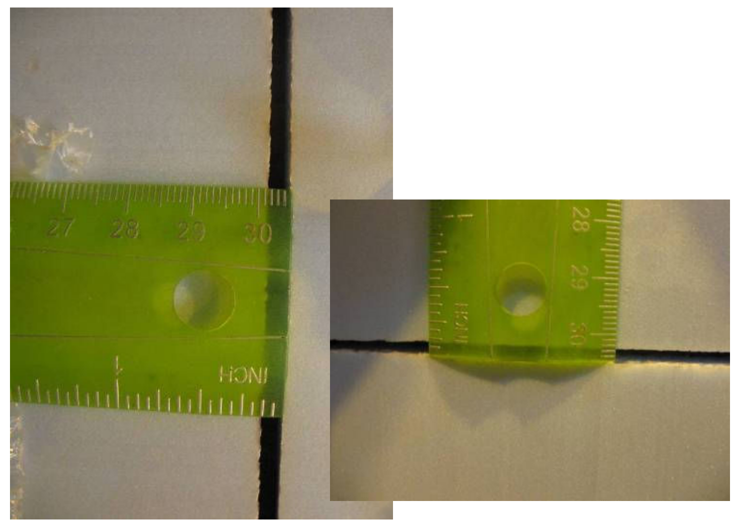
“*Certain asphalt-based peel-and-stick membranes used to seal sheathing membranes to vinyl doors and windows may react with the vinyl. The reaction results in the asphaltic membrane running and staining exterior surfaces. The asphaltic material is a first generation peel-and-stick product (4-in.-100-mm and 6-in.-150-mm rolls). In addition to staining the vinyl, it is likely the reaction also damages the window or door frame. Staining shows itself within one year of installation. It is not known if or when failure of the joint will occur.”*

-- *Incompatible Building Materials, A report documenting premature failure in residential construction resulting from material incompatibility*, Canada Mortgage and Housing Corporation, June 2003. prepared by J.F. Burrows Consulting



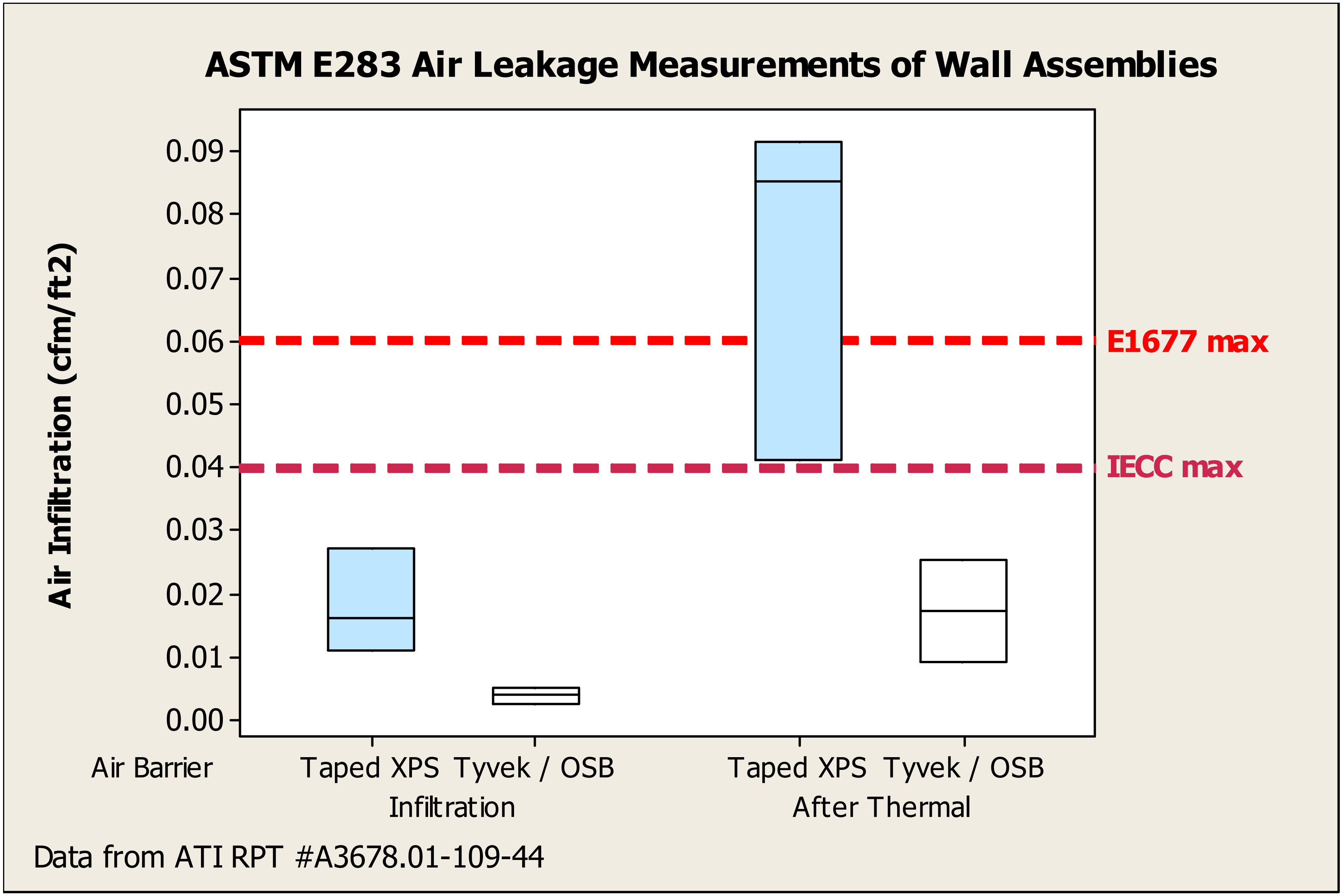
Material deformation and loss of adhesion

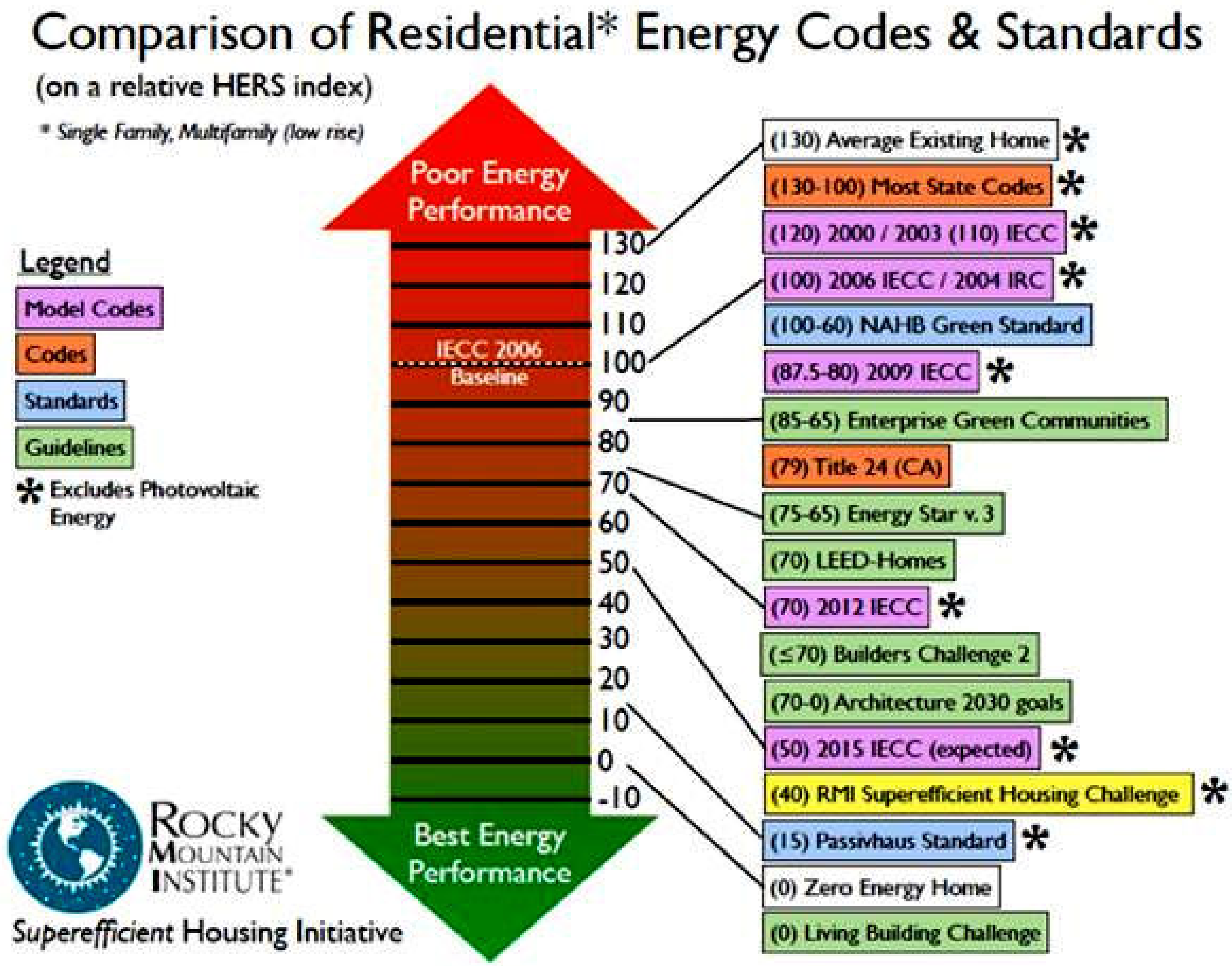
Joints open



“Taped rigid insulation is not allowed as an air barrier in Wisconsin. When some types of insulation boards get colder by 70oF, they can shrink ¼” on all sides. The tape cannot adequately perform under such circumstances.”

- Air Barrier Update, International Masonry Institute Technology Brief, January 2004.


ASTM E283 Air Leakage Measurements of Wall Assemblies
Air Infiltration (cfm/ft2)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
E1677 max
IECC max
Air Barrier
Taped XPS
Tyvek / OSB
Infiltration
Taped XPS
Tyvek / OSB
After Thermal
Data from ATI RPT #A3678.01-109-44


Comparison of Residential* Energy Codes & Standards
(on a relative HERS index)
* Single Family, Multifamily (low rise)
Legend
Model Codes
Codes
Standards
Guidelines
Excludes Photovoltaic Energy
Poor Energy Performance
130
120
110
IECC 2006 Baseline
100
90
80
70
60
50
40
30
20
10
0
-10
Best Energy Performance
(130) Average Existing Home
(130-100) Most State Codes
(120) 2000 / 2003 (110) IECC
(100) 2006 IECC / 2004 IRC
(100-60) NAHB Green Standard
(87.5-80) 2009 IECC
(85-65) Enterprise Green Communities
(79) Title 24 (CA)
(75-65) Energy Star v.3
(70) LEED-Homes
(70) 2012 IECC
(≤70) Builders Challenge 2
(70-0) Architecture 2030 goals
(50) 2015 IECC (expected)
(40) RMI Superefficient Housing Challenge
(15) Passivhaus Standard
(0) Zero Energy Home
(0) Living Building Challenge
Rocky Mountain Institute
Superefficient Housing Initiative

IECC Residential Building Envelope Air Leakage Requirements

Compliance options:

Checklist

or

Testing

< 7 ACH_{50}

2006	2009	2012
Qualitative requirement and location list	Qualitative requirement and location list **Compliance options:** Checklist or Testing < 7 ACH_{50}	

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	CRITERIA[a]
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
Rim joists	Rim joists shall be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the sub-floor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

IECC Residential Building Envelope Air Leakage Requirements

Compliance options:

Checklist

and

Testing

Z1,2: < 5ACH_{50}

Z3-8:: < 3ACH_{50}

Compliance options:

Checklist

or

Testing

< 7 ACH_{50}

Qualitative requirement and location list

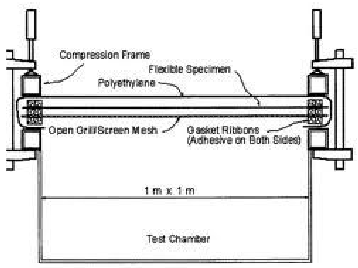
Qualitative requirement and location list

2006

2009

2012

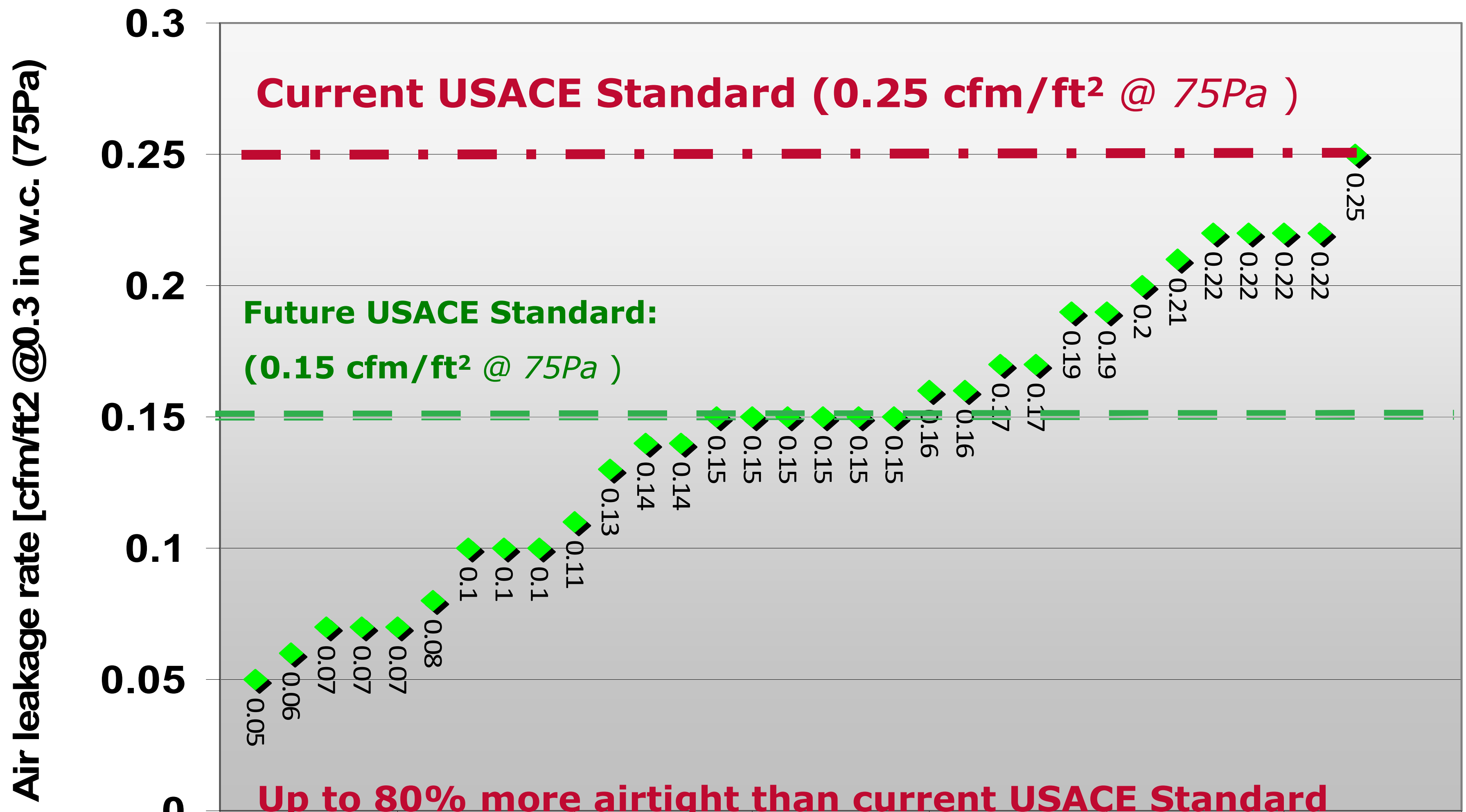
Air Barrier Test Methods and Usage

<table>
<tr><th></th><th>Product Testing</th><th>Assembly Testing</th><th>As-built Testing</th></tr>
<tr><td></td><td>

ASTM E2178</td><td>

ASTM E2357</td><td>
ASTM E779,</td></tr>
<tr><td>ABAA Certification</td><td>≤ .004 cfm/ft² at .3 in.H_2O
(≤ .02 L/(s•m²) @75 Pa
&</td><td>≤ .04 cfm/ft² at .3 in.H_2O
(≤ .2 L/(s•m²)@75 Pa)</td><td></td></tr>
<tr><td>IECC(2012) Residential</td><td></td><td></td><td>≤ 5 ACH_{50} (Climate Zones 1&2)
≤ 3 ACH_{50} (Climate Zones 3 - 8)</td></tr>
<tr><td>IECC (2012) Commercial</td><td>≤ .004 cfm/ft² at .3 in.H_2O
(≤ .02 L/(s•m²) @75 Pa)</td><td>≤ .04 cfm/ft² at .3 in.H_2O
(≤ .2 L/(s•m²)@75 Pa)</td><td>≤ .4 cfm/ft^2 at .3 in.H_2O</td></tr>
<tr><td>USACE Specification</td><td>≤ .004 cfm/ft² at .3 in.H_2O
(≤ .02 L/(s•m²) @75 Pa)</td><td>&</td><td>≤ .25 cfm/ft^2 at .3 in.H_2O
(modified by USACE protocol)</td></tr>
</table>

USACE Standard Experience



Source: Dr. Alexander Zhivov, USACE ERDC, Champaign, USA: AIVC Workshop, June 14, 2010, Brussels, Belgium

Implementing USACE Air tightness Requirements:
A General Contractor's Perspective

Follow the details – ***know what items are part of the continuous air barrier; attention to detail is critical in design and construction***

Materials compatibility – ***make sure the materials specified are compatible***

Manufacturers' installation instruction – ***engage manufacturers' representatives for training, site visits, inspections***

Verify & document – ***make sure that the details are being followed. Sealing the envelope is cheap during construction but more expensive afterwards (cost 10 to 1000X more afterwards).***

Source: Hensel Phelps Construction Co.

Ft. Sam Houston, San Antonio, TX

Pie Forensic Consultants

BRAC - FSH METC Student Dormitory 1

Description	Air Leakage (cfm/ft^2 @75Pa)	Percent above Max Allowable (0.25 cfm/ft^2 @75Pa) OR PASS
Pressurization	0.067	PASS
Depressurization	0.078	PASS
Average	0.073	PASS

BRAC - FSH METC Student Dormitory 2

Description	Air Leakage (cfm/ft^2 @75Pa)	Percent above Max Allowable (0.25 cfm/ft^2 @75Pa) OR PASS
Pressurization	0.073	PASS
Depressurization	0.067	PASS
Average	0.070	PASS

72% better **than the USACE max. allowable rate of *0.25 cfm/ft^2 @75Pa***

Fort Jackson, SC - Basic Training Complex

Commissioning Consultants, LLP

Basic Training Complex II- Building 1

Description	Air Leakage (cfm/ft^2 @75Pa)	Percent above Max Allowable (0.25 cfm/ft^2 @75Pa) OR PASS
Pressurization	0.11	PASS
Depressurization	0.10	PASS
Average	0.11	PASS

Basic Training Complex II- Building 2

Description	Air Leakage (cfm/ft^2 @75Pa)	Percent above Max Allowable (0.25 cfm/ft^2 @75Pa) OR PASS
Pressurization	0.09	PASS
Depressurization	0.07	PASS
Average	0.08	PASS

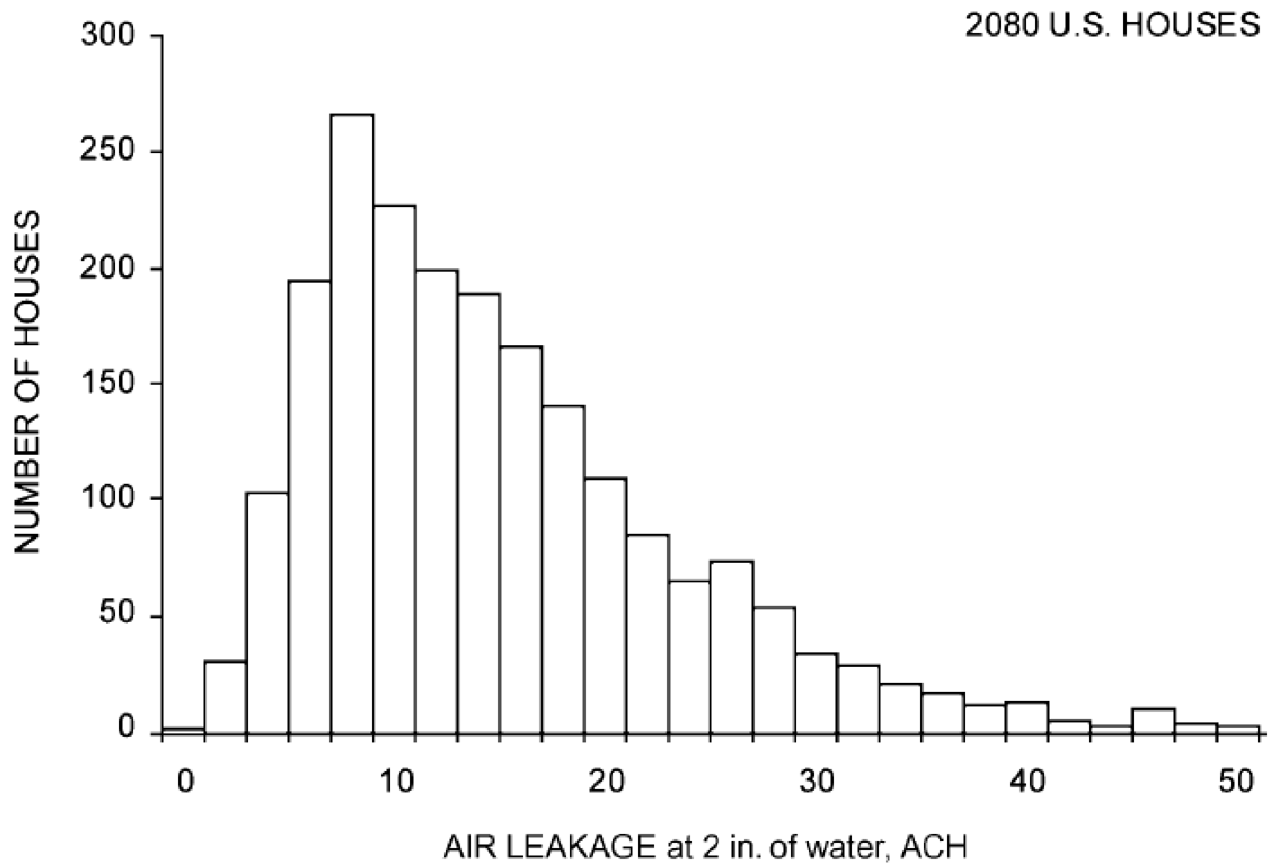
>60% better than the USACE max allowable rate of *0.25 cfm/ft^2 @75Pa*

Residential Air Leakage Sequential Testing: IBACOS Lab House

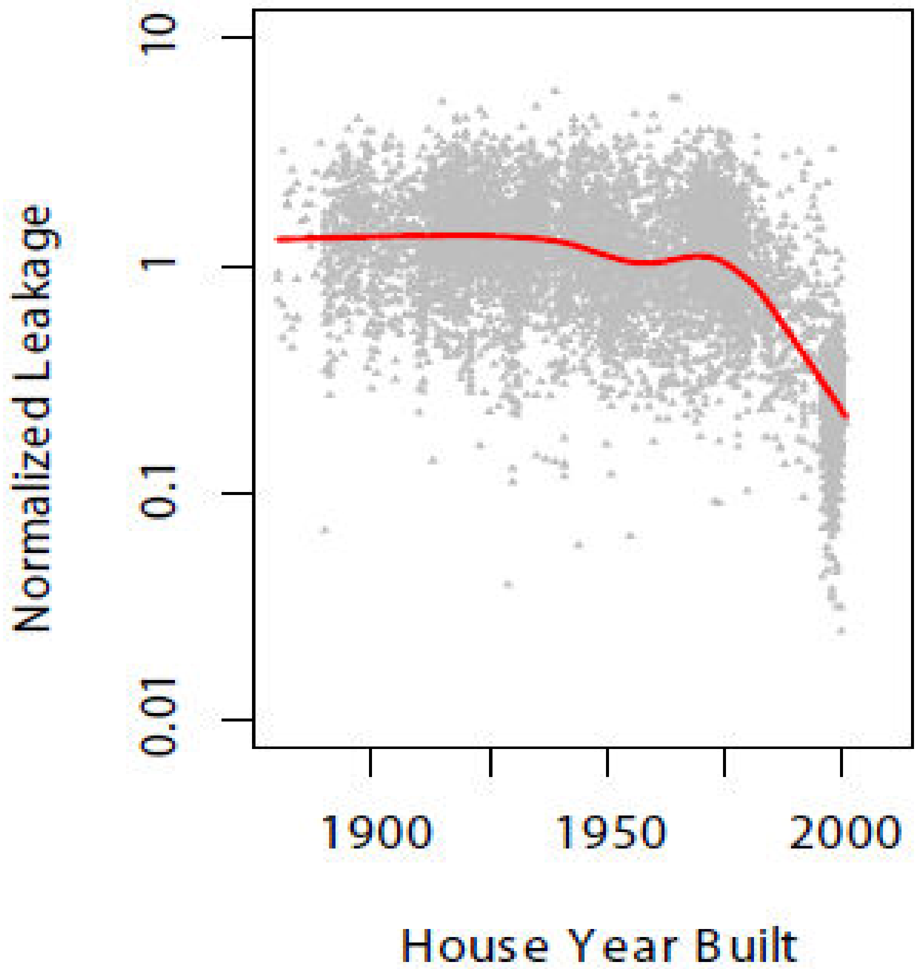
Stage	**Tested Air Leakage**	
Housewrap installed: Window and door openings andother penetrations integrated with air barrier and drainage plane	**3.0 ACH_{50}**	*"Housewrap as primary air barrier required great attention to detail…but it worked"*
After spray foam installed in attic, strategically sealing penetrations in 2nd floor ceiling plane	**0.88 ACH_{50}**	
After spray foam in the band joists	**0.77 ACH_{50}**	
After wall cavity insulation and drywall installed	**0.65 ACH_{50}**	
Complete	**0.54 ACH_{50}**	*"Ultimate target was Passivhaus level of airtightness, which is 0.6"*

*Source: Oberg, B, "**Energy Efficiency Lab Home: Case Study", EEBA Conference, September 2011.***

US Home Airtightness

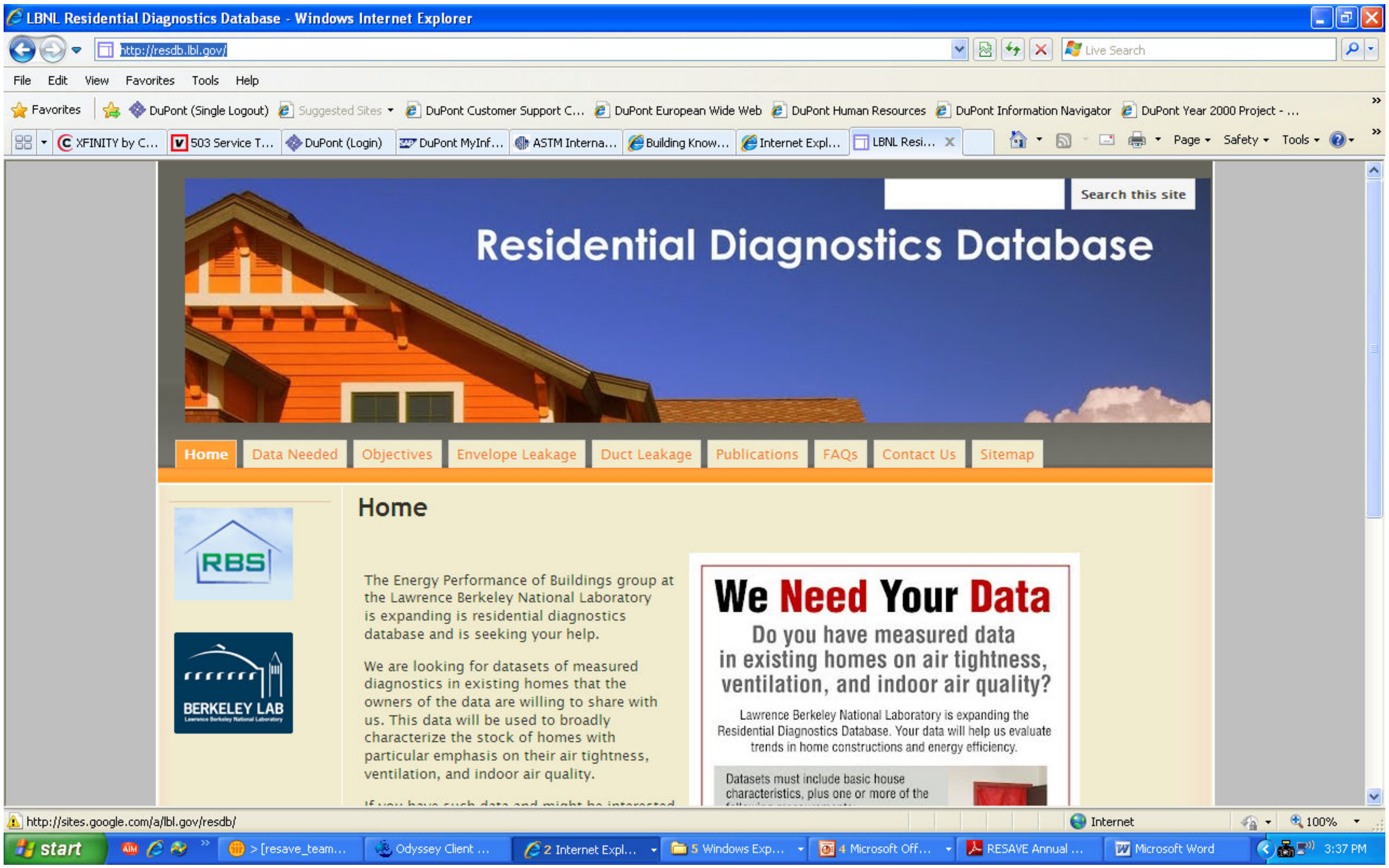


Source: 2009 ASHRAE Handbook of Fundamentals



Source: LBNL Report Number 53367: Chan, W. R, *et al*, *Analysis of U.S. Residential Air Leakage Database,* Indoor Environment Department, Lawrence Berkeley National Laboratory, July 2003

LBNL Data Base
http://resdb.lbl.gov/



Final Thoughts

Build tight, ventilate right

Build to last