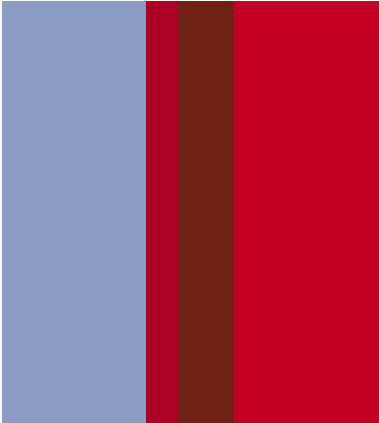




# Durable Water and Air Barrier Systems in Highly Insulated Walls.

DOE Building America Stake-Holders Meeting

Theresa A. Weston, PhD.

DuPont Building Innovations

March 17, 2011



*The miracles of science™*

## Overview

### **Need to develop details for water and air barrier continuity, including the details at penetrations such as windows and doors.**

- Significant amount of research has been conducted on traditional wall systems, leading to window installation and flashing recommendations in building codes and standards.
- We need to understand how these established recommendations relate to highly insulated walls.
- How do we ensure the durability of these installation methods and details? What are the appropriate test protocols?

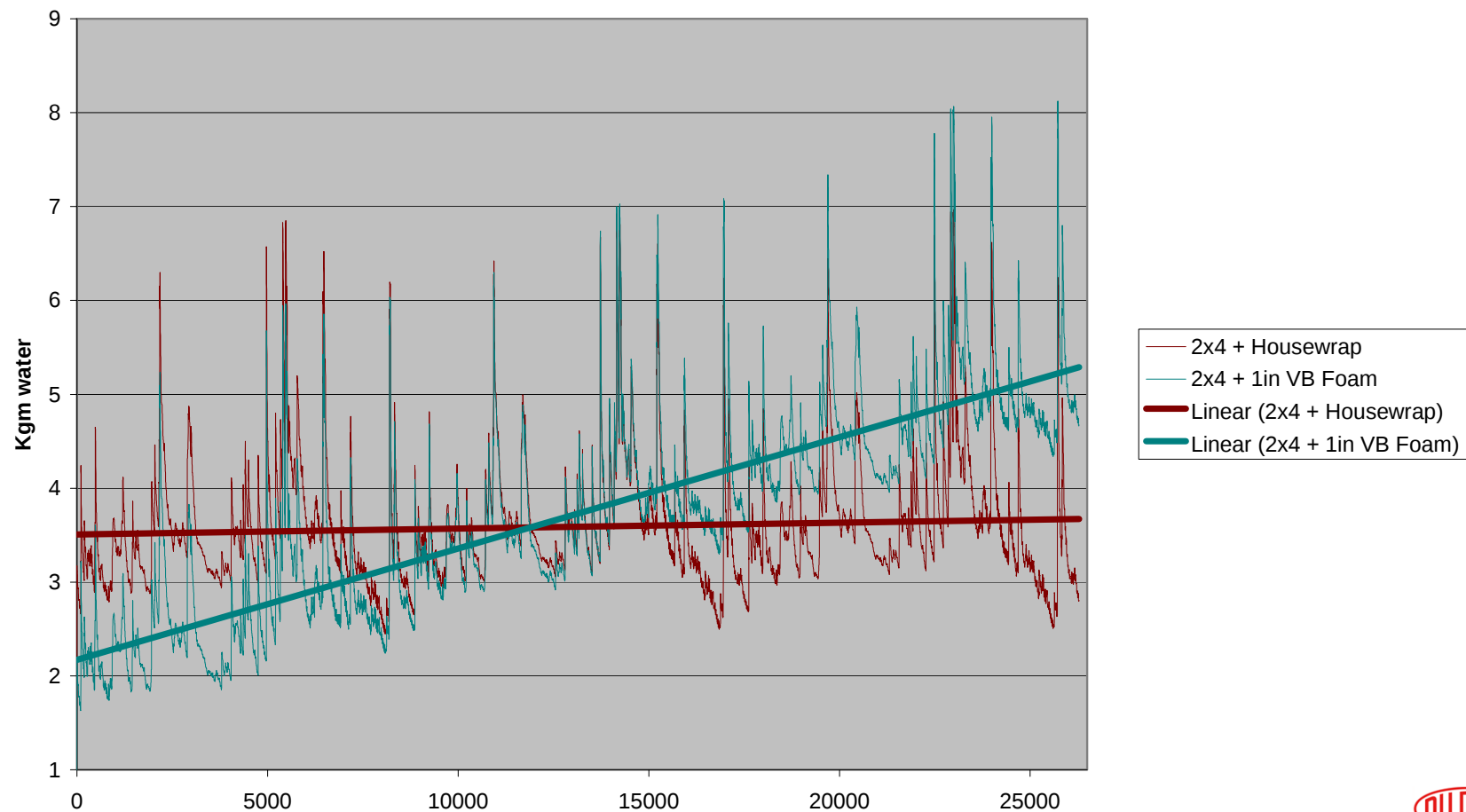
## Construction methods for meeting code requirements without sacrificing building durability



# Wall Drying – 99% Perfect Wall

## 3 year simulations: Total Wall Moisture Content vs. Time Pittsburgh (Zone 5)

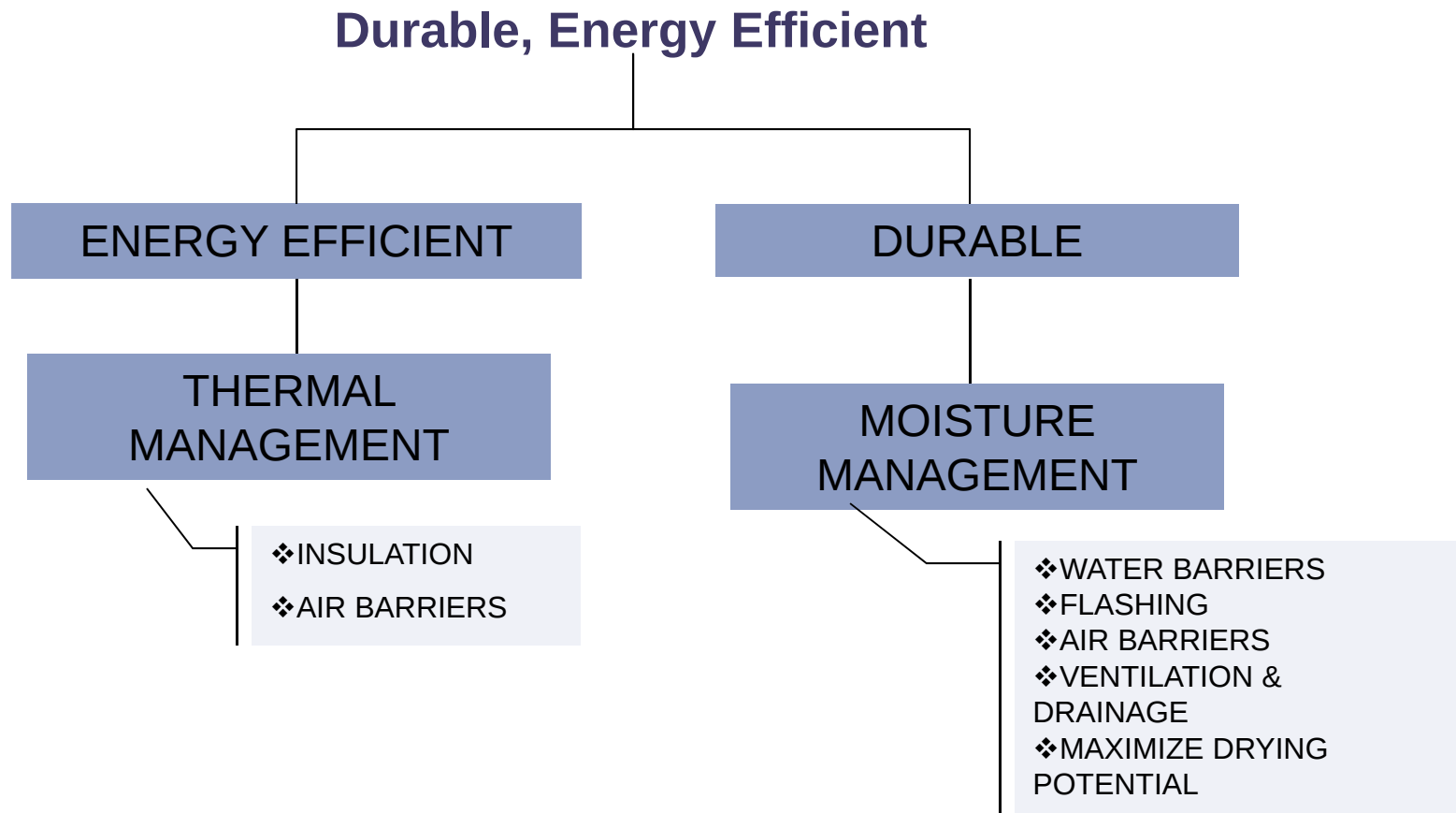
Wall Total Moisture Content  
1% Defect - 3 year simulations



3/9/2011

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*A building component /system cannot be energy or resource efficient unless it is durable.*

# Managing Bulk Water

## •Redundancy – Cladding + Second Line of Defense

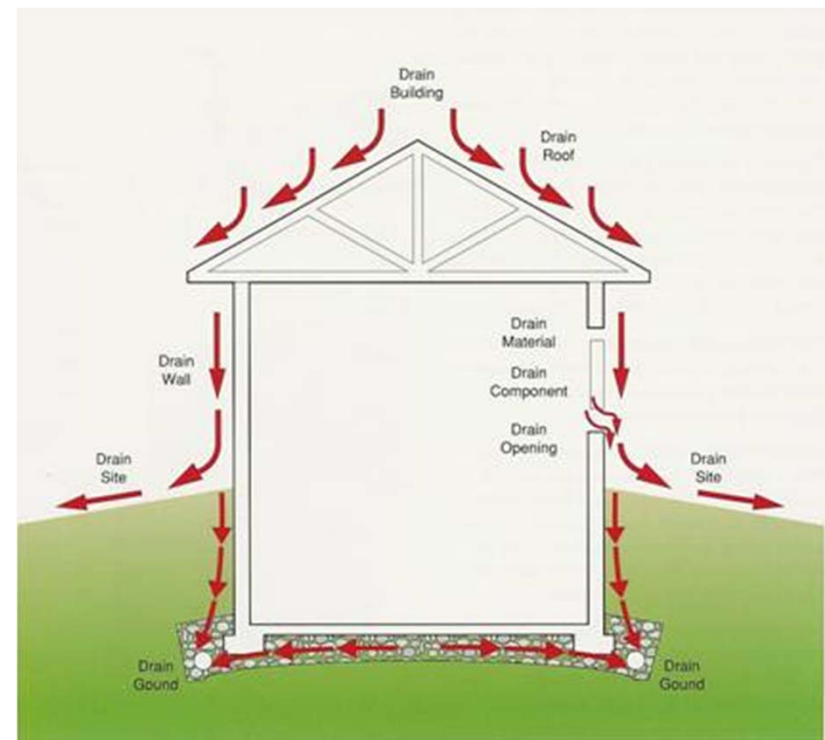
- Water-resistive barriers
- Flashing

## •Material Choice

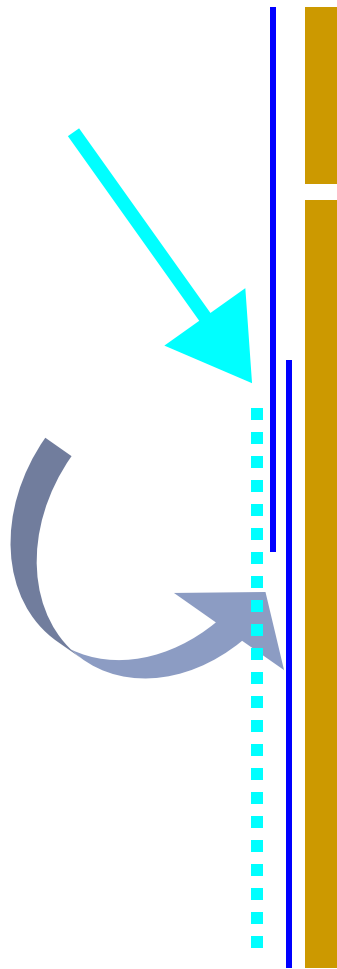
- Performance – Water & Resistance
- Allow Drying
- Durability

## •Installation -- Continuity

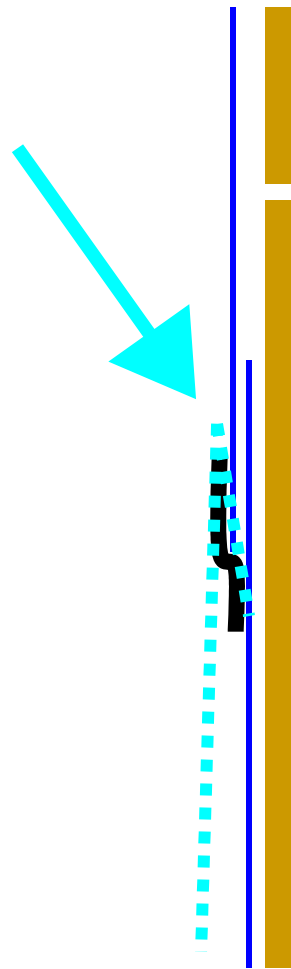
- Shingling correctly
- Beware of hidden water traps



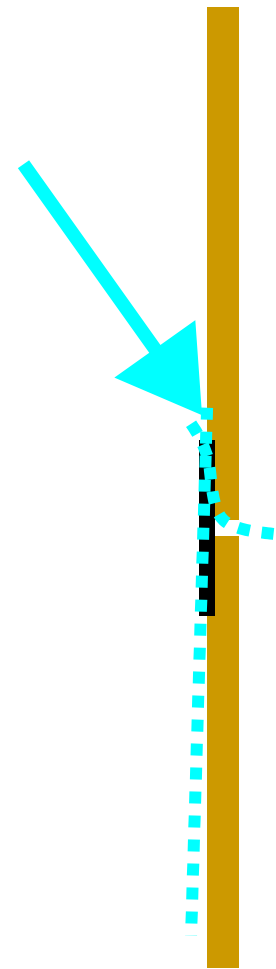
*Illustration from the EEBA Water Management Guide, 2002*



**Traditional  
shingling**



**Shingling with  
taped seams**



**Taped  
sheathing  
joints**



## Code Requirements – International Residential Code 2009

**R703.1.1 Water resistance.** The exterior wall envelope shall be designed and constructed in a manner that prevents the accumulation of water within the wall assembly by providing a water-resistant barrier behind the exterior veneer as required by Section R703.2 and a means of draining to the exterior water that enters the assembly. Protection against condensation in the exterior wall assembly shall be provided in accordance with Section R601.3 of this code.



## Code Requirements – International Residential Code 2009

**R703.2 Water-resistive barrier.** One layer of No. 15 asphalt felt, free from holes and breaks, complying with ASTM D 226 for Type 1 felt or other approved water-resistive barrier shall be applied over studs or sheathing of all exterior walls. Such felt or material shall be applied horizontally, with the upper layer lapped over the lower layer not less than 2 inches (51 mm). Where joints occur, felt shall be lapped not less than 6 inches (152 mm). The felt or other approved material shall be continuous to the top of walls and terminated at penetrations and building appendages in a manner to meet the requirements of the exterior wall envelope as described in Section R703.1.



## Code Requirements – International Residential Code 2009

**R612.1 General.** This section prescribes performance and construction requirements for exterior window and door installed in wall. Windows and doors shall be installed and flashed in accordance with the fenestration manufacturer's written installation instructions. **Window and door openings shall be flashed in accordance with Section R703.8. Written installation instructions shall be provided by the fenestration manufacturer for each window or door.**



## Code Requirements – International Residential Code 2009

**R703.8 Flashing.** *Approved* corrosion-resistant flashing shall be applied shingle-fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. The flashing shall extend to the surface of the exterior wall finish. *Approved* corrosion-resistant flashings shall be installed at all of the following locations:

1. Exterior window and door openings. Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to the water-resistive barrier for subsequent drainage.



## Code Requirements – International Residential Code 2012

**R703.8 Flashing.** *Approved* corrosion-resistant flashing shall be applied shingle fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. The flashing shall extend to the surface of the exterior wall finish. *Approved* corrosion-resistant flashings shall be installed at all of the following locations:

1. Exterior window and door openings. Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to the water-resistive barrier for subsequent drainage. Flashing at exterior window and door openings shall be installed in accordance with one or more of the following:

1.1. The fenestration manufacturer's installation and flashing instructions, or for applications not addressed in the fenestration manufacturer's instructions, in accordance with the flashing manufacturer's instructions. Where flashing instructions or details are not provided, pan flashing shall be installed at the sill of exterior window and door openings. Pan flashing shall be sealed or sloped in such a manner as to direct water to the surface of the exterior wall finish or to the water-resistive barrier for subsequent drainage. Openings using pan flashing shall also incorporate flashing or protection at the head and sides.

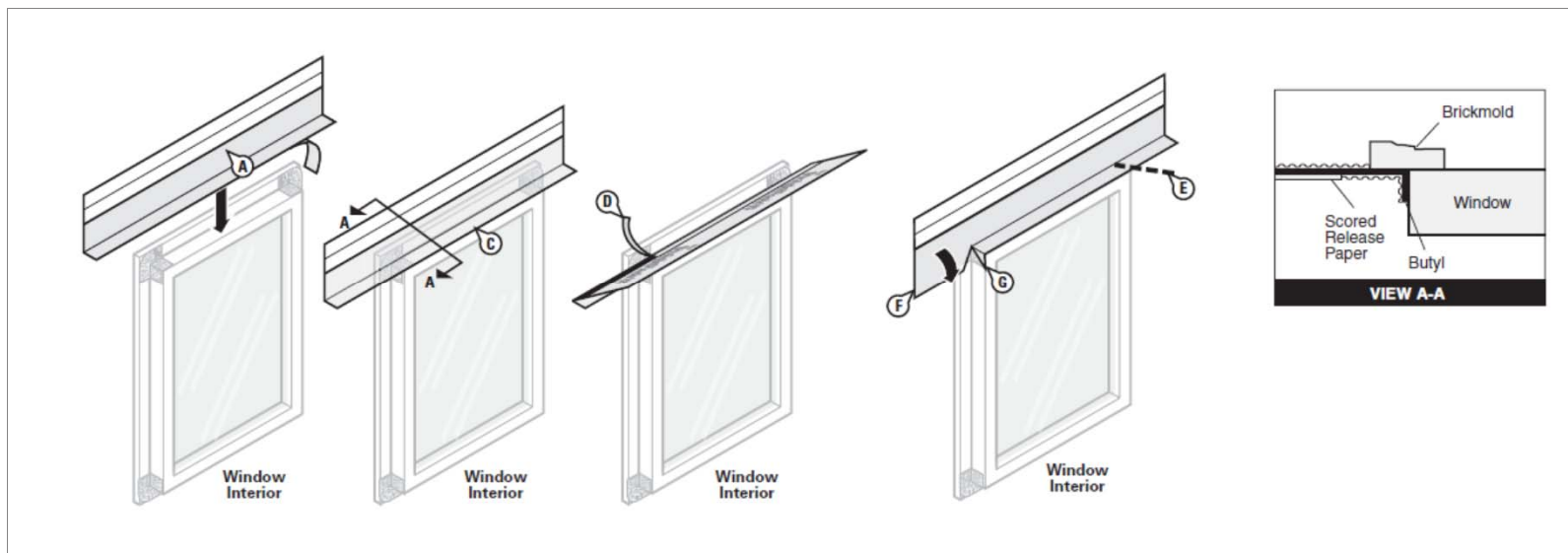
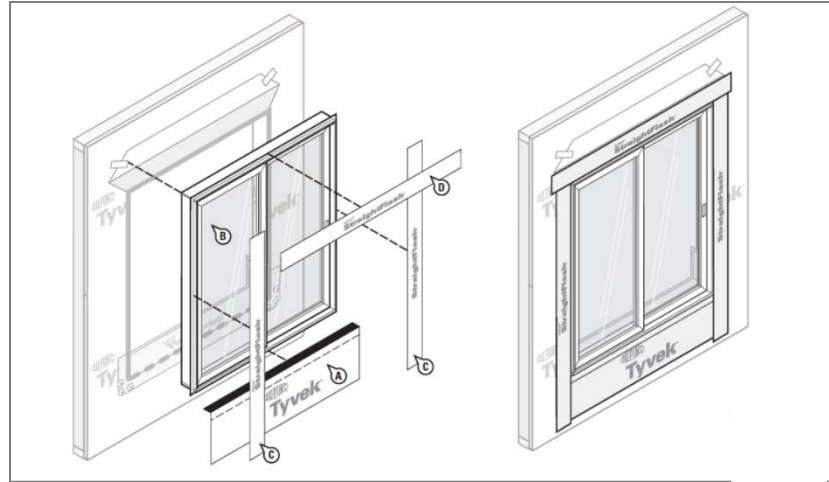
1.2. In accordance with the flashing design or method of a registered design professional.

1.3. In accordance with other approved methods.



# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?



# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?

**Shape of Window**

# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?

**Shape of Window**

**Position of WRB in wall section:** Behind exterior insulation? At exterior surface of exterior insulation?



*Picture for "Remote Wall System Manual" – Cold Climate Housing Research Center*

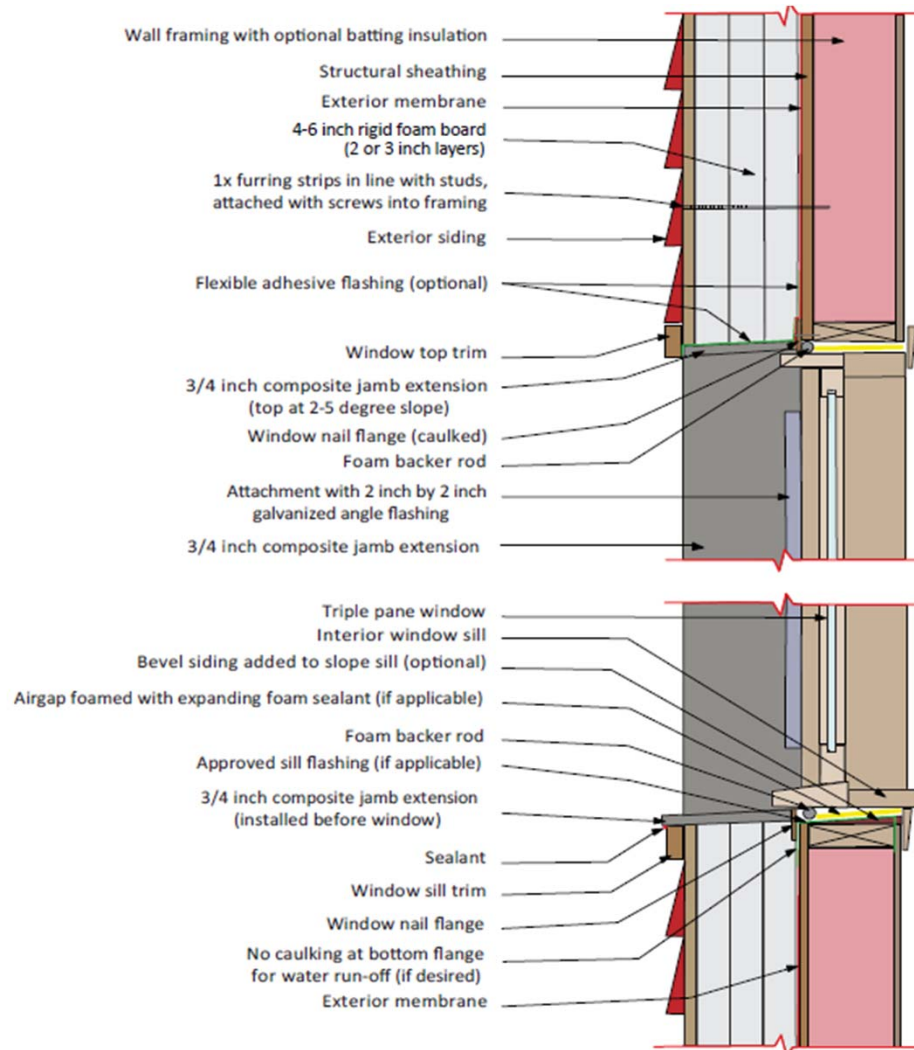
# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?

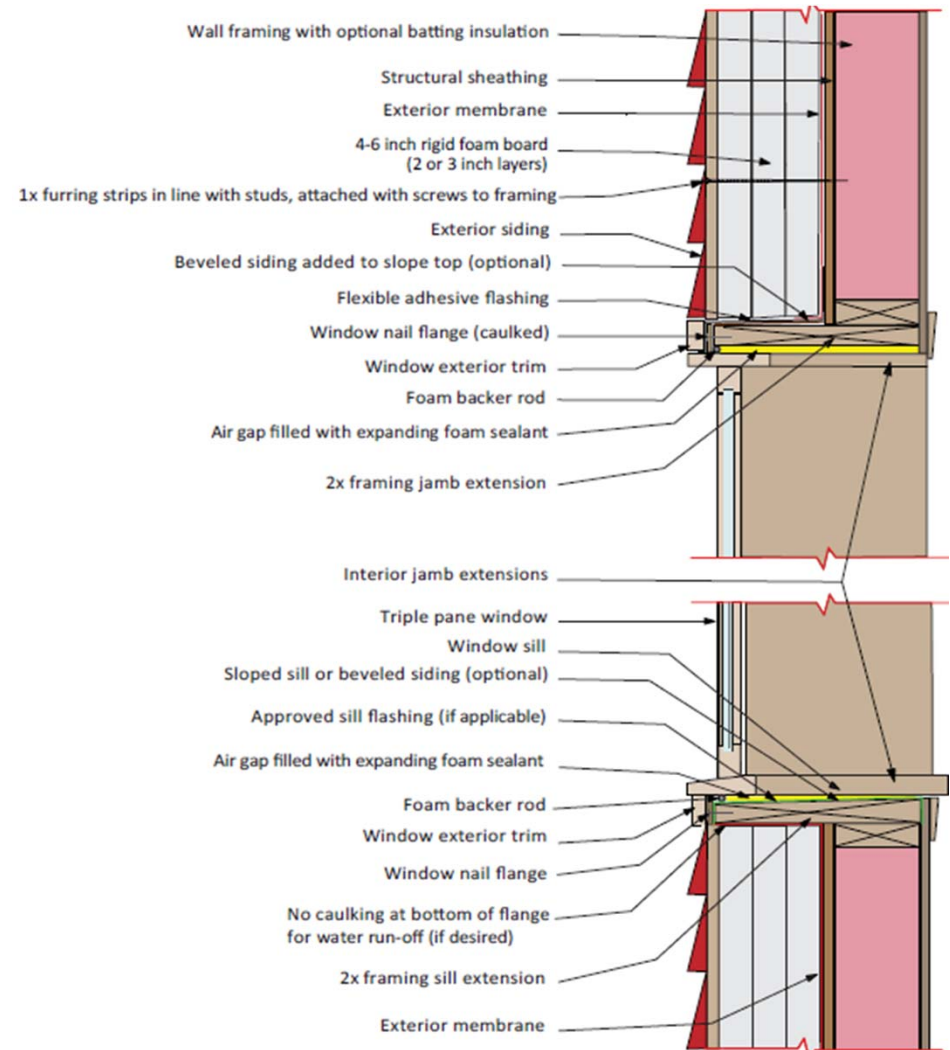
**Shape of Window**

**Position of WRB in wall section:** Behind exterior insulation? At exterior surface of exterior insulation?

## Interior Mounted Window



## Exterior Mounted Window



Figures for "Remote Wall System Manual" – Cold Climate Housing Research Center

# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?

**Shape of Window**

**Position of WRB in wall section:** Behind exterior insulation? At exterior surface of exterior insulation?

**Position of Window:** Recessed? Bumped out?



# Window Installation Variants

**Type of Window:** Flanged, Non-Flanged?

**Shape of Window**

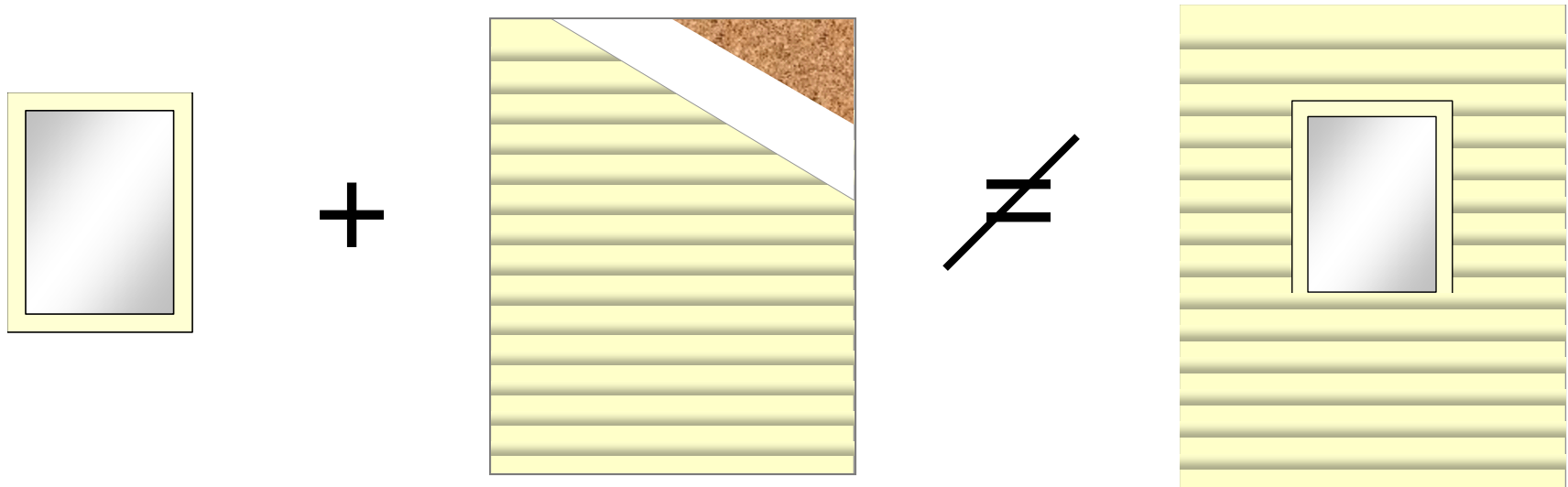
**Position of WRB in wall section:** Behind exterior insulation? At exterior surface of exterior insulation?

**Position of Window:** Recessed? Bumped out?

**Installation sequence:** Are the windows installed before or after the wrb?

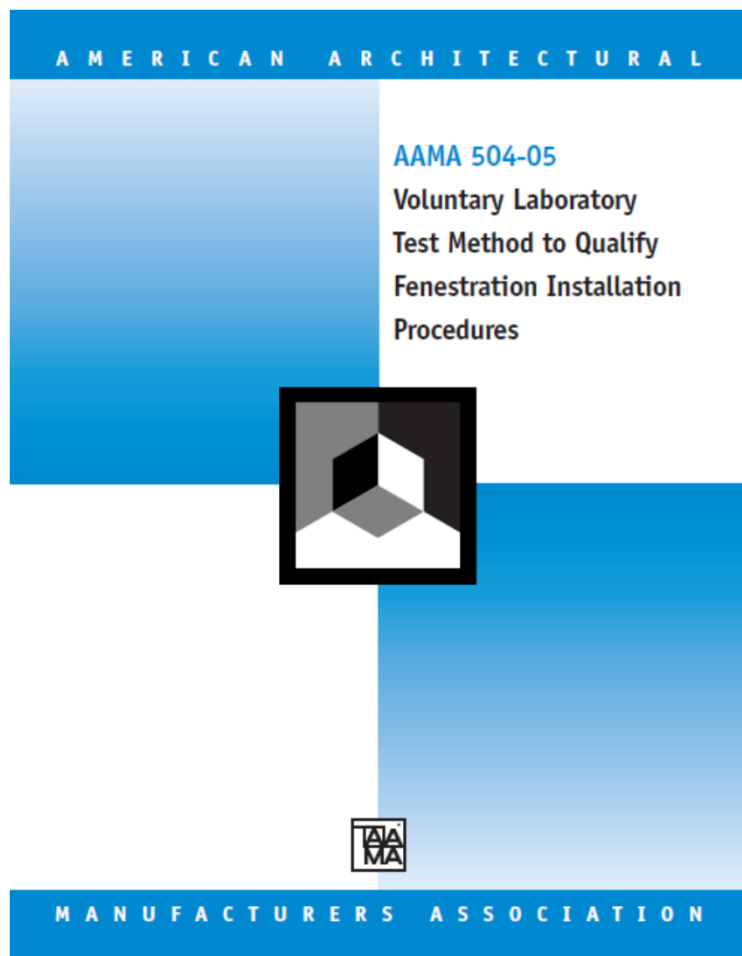


## Testing Installed Performance



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





Test Assembly: fenestration product, fasteners, sealant, flashing components and weather resistant barrier shall be included. Exterior cladding, interior perimeter cavity insulation and expanding foam shall not be applied to the test mockup for this evaluation.

The completed mockup shall be preloaded prior to testing using 10 positive cycles of 480 Pa (10 psf) followed by 10 negative cycles of 480 Pa (10 psf).

Test for air leakage in accordance with ASTM E 283 at a pressure differential of 75 Pa (1.57 psf).

Test for water penetration resistance in accordance with ASTM E 331 at a minimum test pressure of 150 Pa (3.0 psf) for 60 minutes.

The entire mockup shall be subjected to 14 twelve hour durability cycles in accordance with ASTM E 2264 Method A, Level 1:

•*Exterior Temperature Exposure*

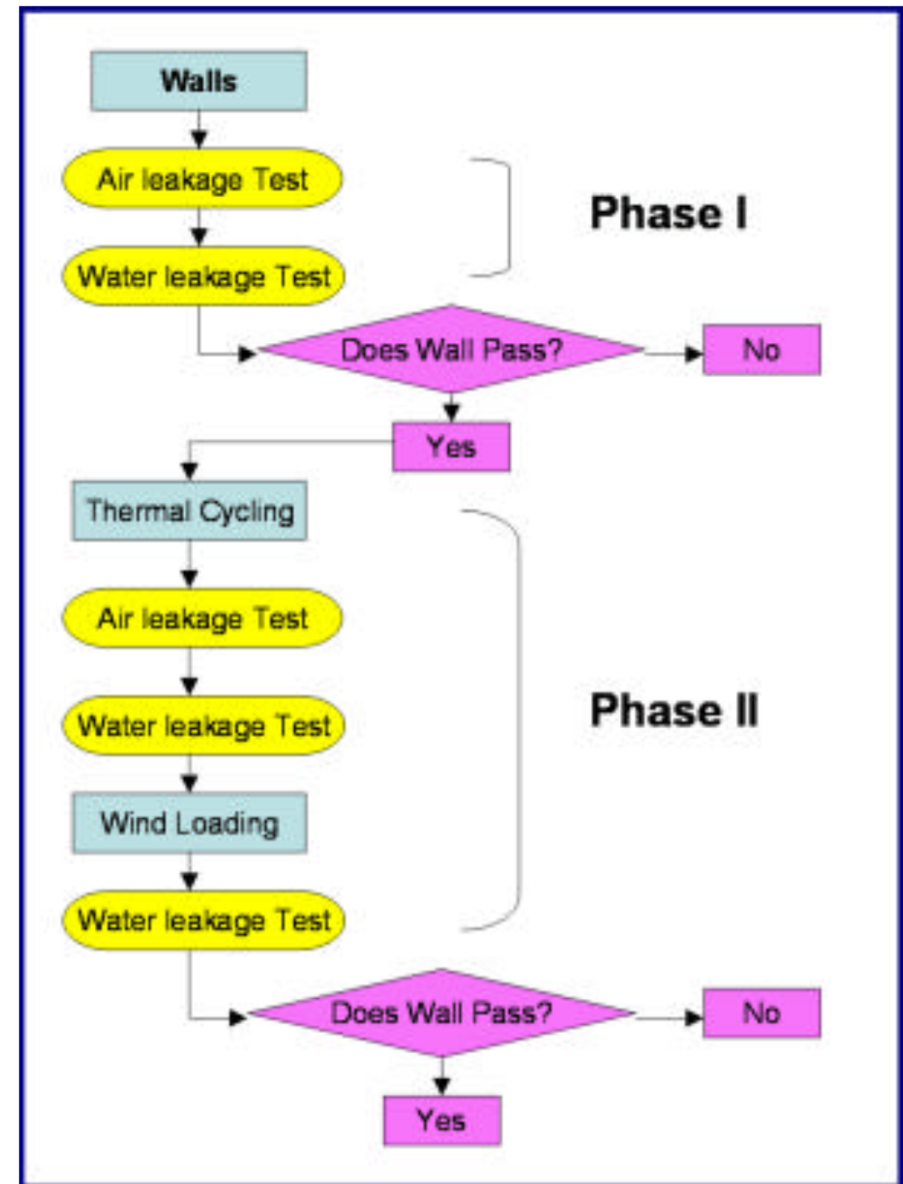
- Level 1 49°C (120 °F)**
- Level 2 3°C (150 °F)
- Level 3 82°C (180 6°F)

*Exterior Low Ambient Air Temperature: -30°C (-22°F)*

Following cycling, the mockup shall again be tested for air leakage and water penetration resistance

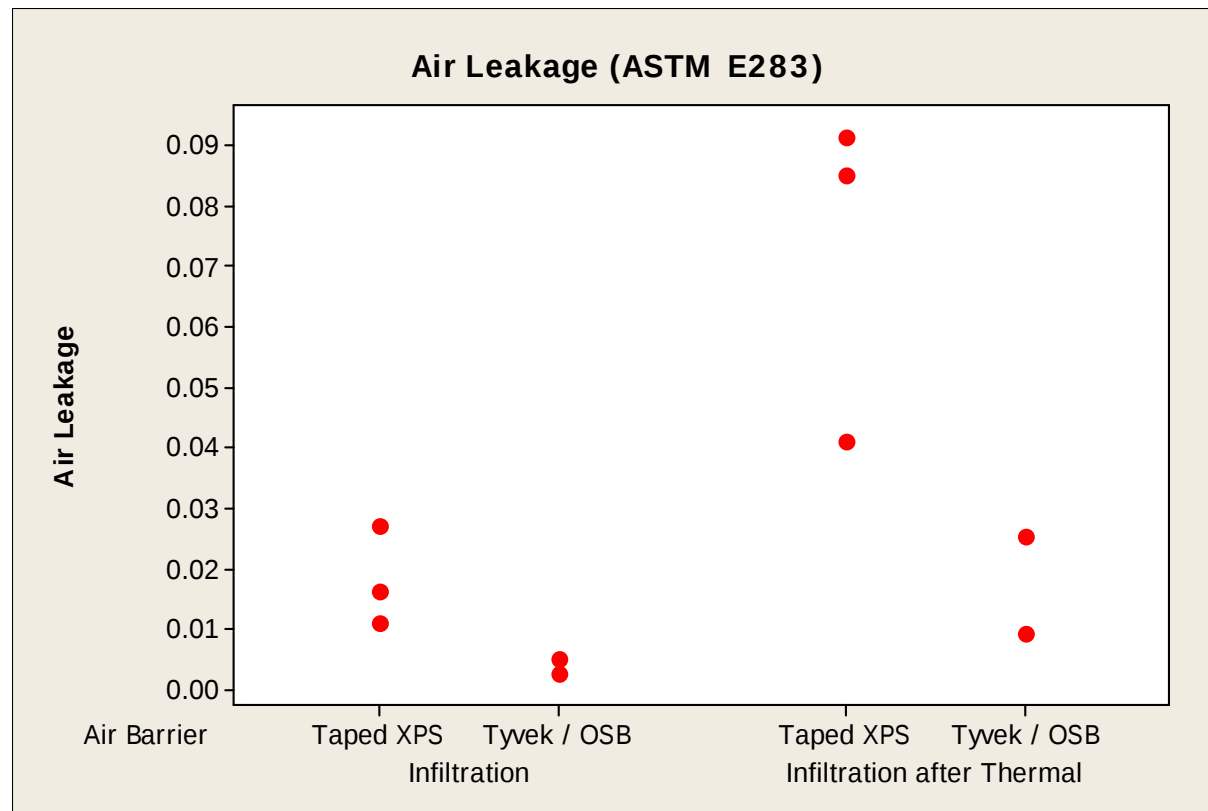
The entire mockup shall be tested for structural loads in accordance with ASTM E 330 at a minimum test pressure of 1440 Pa (30 psf) positive and negative.

## Installed Window –Wall Testing Protocol



“Taped rigid insulation is not allowed as an air barrier in Wisconsin. When some types of insulation boards get colder by 70°F, 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.



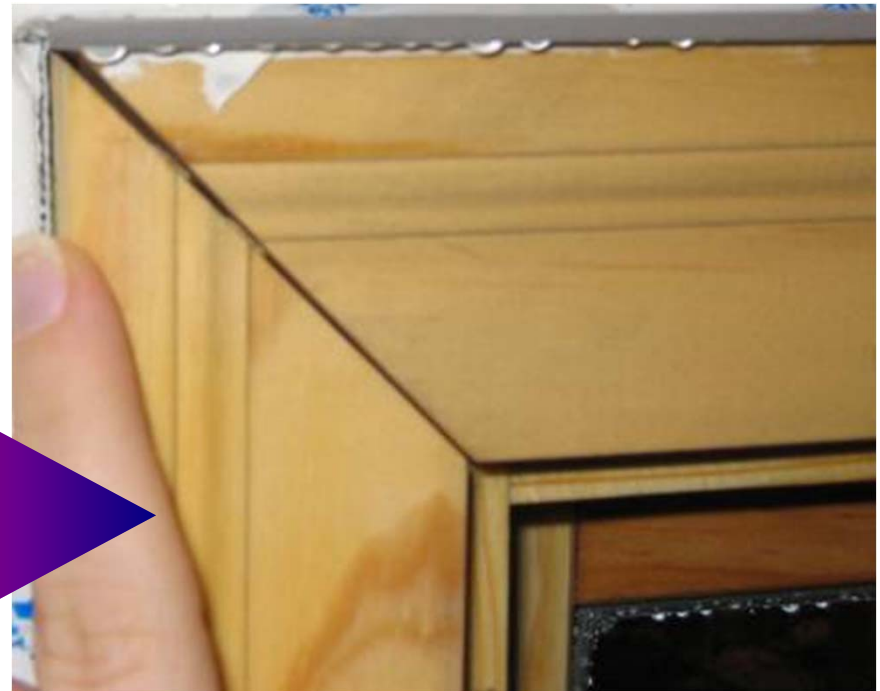


After exposure (160°F)

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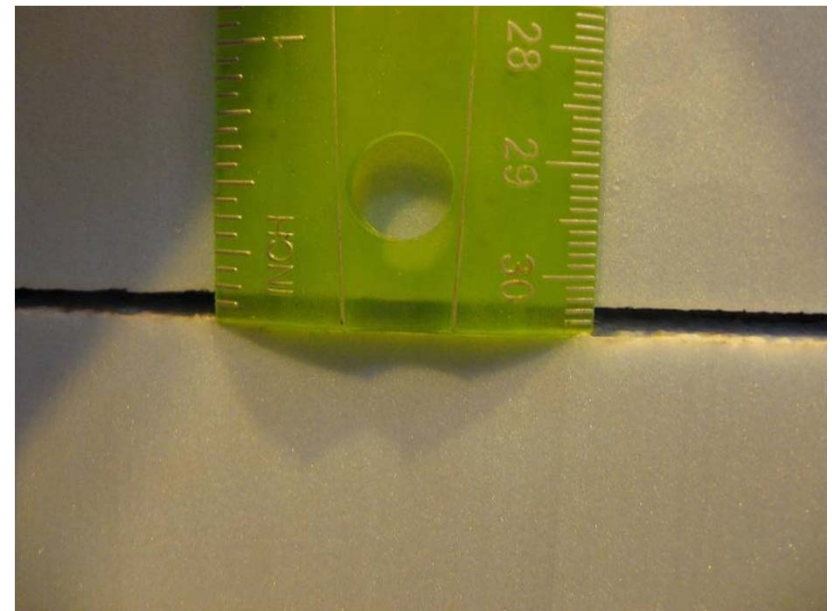
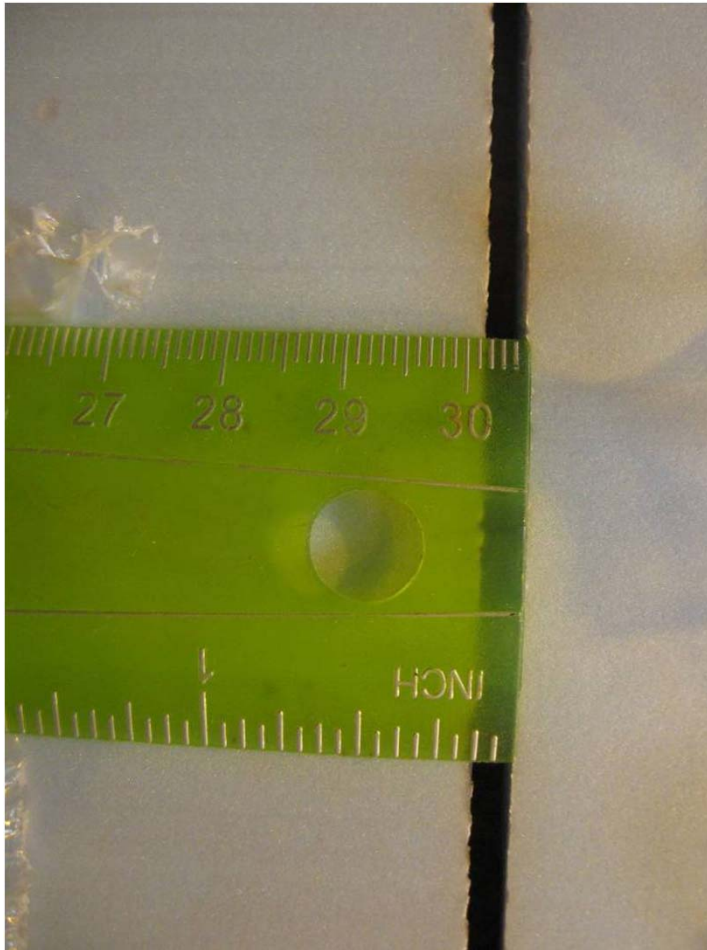
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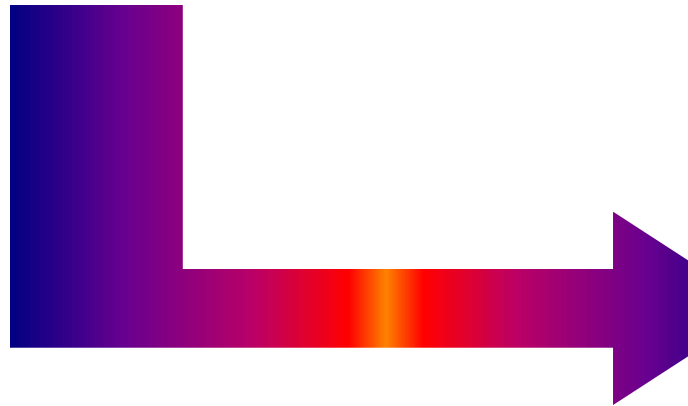


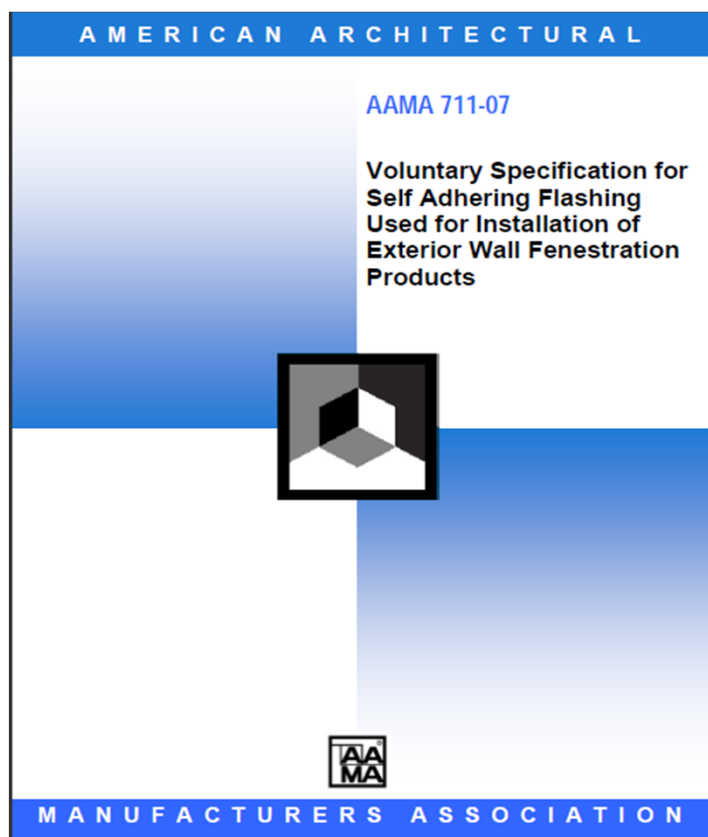


# Full Wall Assembly Testing

Gaps developed due to thermal cycling between 20 °F and 140 °F

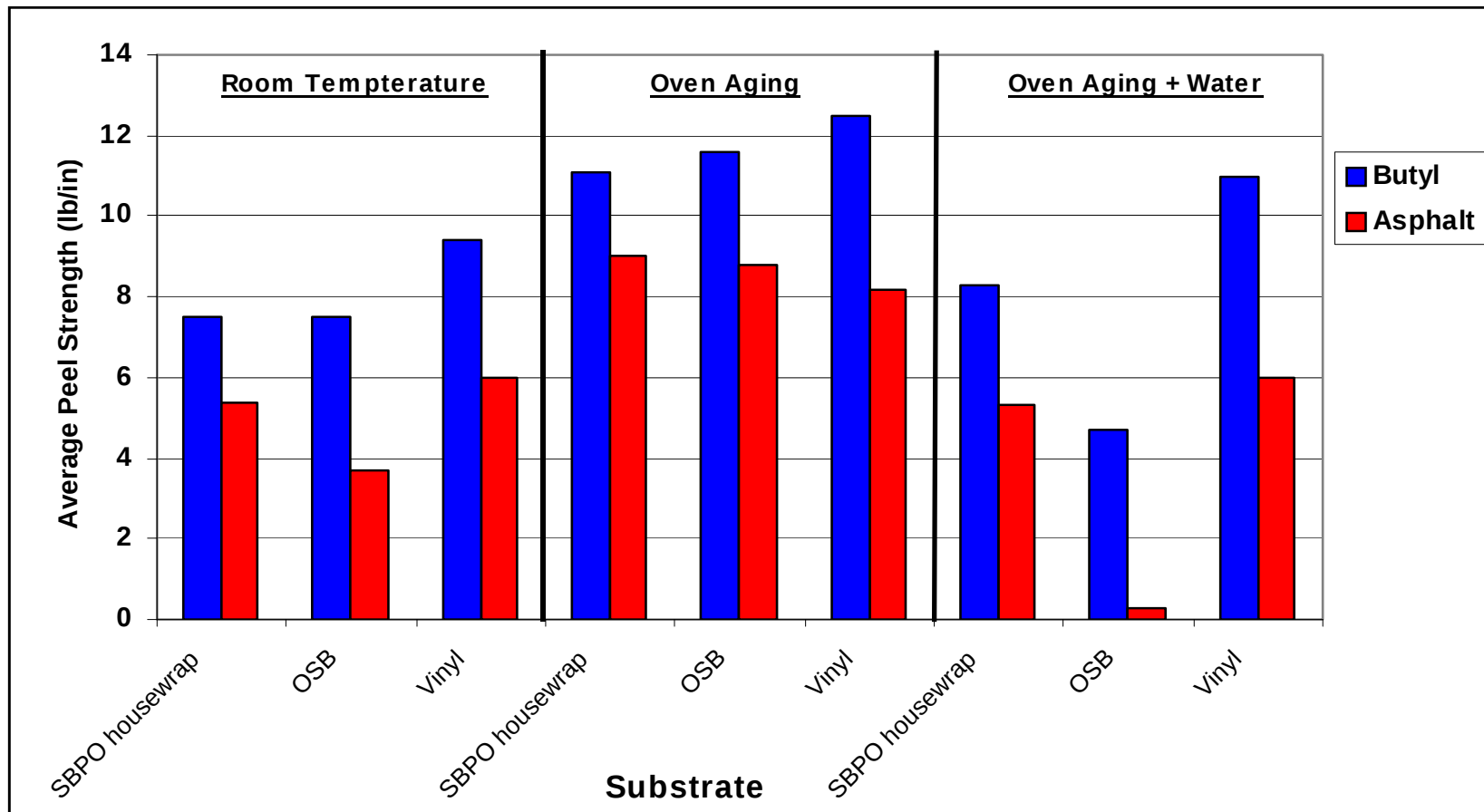






| Property                                             | Test Method                                    | Minimum Requirement                            |
|------------------------------------------------------|------------------------------------------------|------------------------------------------------|
| <b>Section 5.1</b>                                   |                                                |                                                |
| Tensile Strength-<br>Rubber and Thermoplastics       | ASTM D 412, Method A, Die C                    | 985 kPa (143 psi) minimum                      |
| Tensile Strength-<br>Polymer Modified Bitumens       | ASTM D 1970, Section 7.3                       | 985 kPa (143 psi) minimum                      |
| Tensile Strength-<br>Woven/Nonwoven Textile Fabrics  | ASTM D 5034                                    | 0.5 N/mm (2.9 lbs/in) minimum                  |
| <b>Section 5.2</b>                                   |                                                |                                                |
| Water Penetration Around Nails:                      |                                                |                                                |
| -After 24 hours @ 23°C ± 1°C (73°F ± 2°F) & 50% RH   | ASTM D 1970, Section 7.9, modified per 5.2.1.  | Must Pass 31 mm (1.2 in) of water              |
| -After thermal cycling (10 cycles)                   |                                                | Must Pass                                      |
| Water Penetration Around Nails (alt):                |                                                |                                                |
| -After 24 hours @ 23°C ± 1°C (73°F ± 2°F) & 50% RH   | ASTM E 331/E 547, or modified test per Annex 1 | Must Pass                                      |
| -After thermal cycling (10 cycles)                   |                                                | Must Pass                                      |
| <b>Section 5.3</b>                                   |                                                |                                                |
| 90° Peel Adhesion (initial)                          |                                                |                                                |
| After 24 hours @ 23°C ± 1°C (73°F ± 2°F) & 50% RH    | ASTM D 3330, Method F                          | 0.26 N/mm (1.5 lbs/in) minimum                 |
| All Suitable Substrates                              |                                                |                                                |
| <b>Section 5.4</b>                                   |                                                |                                                |
| Accelerated UV Aging (14 days)                       | ASTM G 154, UVA cycle 1 ASTM D 3330, Method F  | 0.26 N/mm (1.5 lbs/in) minimum                 |
| 90° Peel Adhesion                                    |                                                |                                                |
| Appearance                                           | Visual                                         | <i>NOTE 1: change from original appearance</i> |
| <b>Section 5.5</b>                                   |                                                |                                                |
| Elevated Temperature Exposure                        | ASTM D 3330, Method F                          | 0.26 N/mm (1.5 lbs/in) minimum                 |
| Level 1 - 50°C (122°F) 7 days                        |                                                |                                                |
| Level 2 - 65°C (149°F) 7 days                        |                                                |                                                |
| Level 3 - 80°C (176°F) 7 days                        |                                                |                                                |
| Appearance                                           | Visual                                         | <i>NOTE 2: change from original appearance</i> |
| <b>Section 5.6</b>                                   |                                                |                                                |
| Thermal Cycling (10 cycles)                          | AAMA (TBD), Section 5.5                        | 0.26 N/mm (1.5 lbs/in) minimum                 |
| 90° Peel Adhesion (See Section 5.6 for temperatures) | ASTM D 3330, Method F, Section 16              |                                                |
| Appearance                                           | Visual                                         | <i>NOTE 3: change from original appearance</i> |
| <b>Section 5.7</b>                                   |                                                |                                                |
| Cold Temperature Pliability                          | ASTM C 765                                     | Must Pass -18°C (0°F)                          |
| <b>Section 5.8</b>                                   |                                                |                                                |
| Adhesion after water immersion                       | AAMA 800, Section 2.4.1.3.1/2.4.1.4.3 Test B   | 0.26 N/mm (1.5 lbs/in) minimum                 |
| <b>Section 5.9</b>                                   |                                                |                                                |
| Resistance to Peel                                   | Annex 2                                        | Report Only                                    |

# Adhesion Testing



## Summary

**Energy Efficient Construction introduce increased challenges into durable construction.**

**There is a need for installation detail development which encompass the variation in field applications and practices.**

**These details should be tested as systems using a test protocol that challenges installation with structural and thermal cycling.**