Background
What Separation Roles?

- **Water control layer**
  - A.k.a. “drainage plane,” “water resistive barrier,” “weather resistive barrier,” WRB
  - Housewraps, tar paper… more modern options

- **Air control layer**
  - A.k.a. “air barrier”
  - Drywall, sheathing, spray foam… and continuity

- **Vapor control layer**
  - A.k.a. “vapor barrier”—poly, Kraft paper, latex paint

- **Thermal control layer**
  - Insulation (fluffy in stud bays, continuous on outside)
Water Control- Hydrostatic Pressure

Water Control and Drainage Gaps

- Water control layer
- Key is control of hydrostatic pressure
- All about “the gap”
- See “Mind the Gap” and “Hockey Pucks and Hydrostatic Pressure”
Hydrostatic Pressure

- Diagram showing the concept of hydrostatic pressure

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- Image of a hand holding a puck on a wooden surface
Wind Speed vs. Pressures

- \( \frac{1}{2} \)" of “perched” water \( \approx \) 35 mph wind force
Why Rainscreen/Air Gap

- “Sandwiched” water (surface tension) hangs up
- Staying wet or wet/dry cycling
  - Paint blow off
  - Damage over time

Drainage from Lap Sidings

- Added water between siding & housewrap
- Lap sidings “self draining”
- Window head flashings!
Cladding Ventilation

- Airflow behind cladding dries out both cladding & backup wall
- Brick veneer example
- Why vinyl siding and metal panel cladding work in cold climates

Water Control Layers and Spaces
Strapped Cavities/“Rainscreen Wall”

Shingle Wall Rainscreen/Air Gap

- Mesh style
  (Home Slicker, Keene Building Products)
Water Control Layer Options

Housewrap (Residential)
Housewrap (Commercial)

Billowing Housewrap

- Is it really an air barrier (network airflow)?
- Potential damage from cyclic loading
Vapor-Impermeable Adhered Membrane

- Cold climate + no exterior insulation = danger

Vapor-Permeable Adhered Membrane
Self-Adhered Membranes

- Self-sealing
- Air leakage improvement; no blow-off/billowing
- No ‘hidden path’ water leakage/bypass
- Reverse laps not as critical

Taped Sheathings (WRB Surface)

- Fast dry-in
- Airtightness
- Reliance on adhesive vs. laps? Surface prep
- Rigid foam insulation too
Taped Joints (Foam Sheathing)

- Membrane-type flashing tape at joints
- Horizontals more important than verticals

Fluid-Applied WRBs

- “Housewrap in a can” (GBA Column)
- Continuous water control
- Airtightness
- Can be applied with air gun (paint sub)
- Issues: surface prep, application temperature, substrate condition, etc.
Reverse Lap Termination

- “Termination mastic” at reverse lap condition
Windows Flashings

EIFS & Windows - Oops
Sill Pan Flashings

- Self-adhered flashing
- Formable flashing
- Manufactured flashing

Backdams and Sloped Sills

- Adhesive-backed sill flashing
- Interior air seal
- Backdamp
- A strip of wood nailed at the back of the rough opening; Housewrap forms a dam to prevent water from draining into the inter
- Beveled wood siding

A piece of wood bevel siding nailed over the sill to create positive drainage toward the exterior is even better. Note that the rough opening needs to be enlarged to account for this and tapered shims in the opposite direction of the slope may be required.
Formable Sub-sill Flashing

Subsill
Foam Sheathing Window Flashing

Window Failure Examples
Window Failure Examples

Window Failure Repair

- Stripped shingles and housewrap
- Windows pulled, re-flashed (fluid-applied window ‘wrap’), and reinstalled
- Fluid-applied WRB
- Added rainscreen mat under shingles
Wood Moves...

Wood Moisture Movement

Studs get much wider and thicker, but not much longer, when they pick up moisture.

Fibers get much thicker than longer when they pick up moisture.

Shrinkage vs. Moisture Content

![Diagram showing shrinkage vs. moisture content graph for a typical species.](image_url)
Room for Expansion

- Wood will move—let it expand
  - For every 4" width of dry Certi-label Western Cedar shingle material, the product will expand 1/8"
- Wood floors indoors similar

Stucco & Adhered Stone
Stucco on Wood Frame Walls

Stucco Failures (MN, PA)
Stucco-to-Paper Bond

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Adhered Stone Veneer
Air Flow

Airflow Control: Why

- Moisture control
  - air leakage condensation
- Comfort and Health
  - Drafts
  - Odors, particles, gases
- Energy
  - Heat transferred with air
- Sound
- Required by some codes

*If you can’t enclose air, you can’t condition it*
Driving Forces

- 1. Wind Pressures
- 2. Buoyancy (or stack effect)
- 3. HVAC
Wind Flow Patterns

Wind speed increases with height

2. Stack Effect: Cold Weather

- Hot air rises
- Tall Building in Winter = Heavy Balloon
Stack Effect: Cold Weather

- “Perfect” Building equally leaky everywhere
- Neutral Pressure Plane at mid-height

Stack Effect: Warm Weather

- “Perfect” Building equally leaky everywhere
- Neutral Pressure Plane at mid-height
Air Barriers

Air Barrier Systems

- Function: to stop airflow through enclosure
- ABS can be placed anywhere in the enclosure
- Must be strong enough to take wind gusts (code requirement)
- Many materials are air impermeable, but most systems are not airtight
Air Barrier Systems: Requirements

- Continuous
  - primary need, common failure
- Strong
  - designed for full wind load
- Durable
  - critical component - repair, replacement
- Stiff
  - control billowing, pumping
- Air Impermeable
  - (may be vapour permeable)
Poly can be (?) an air and vapour barrier
But
BEWARE when Air Conditioning
Definitely not in South

The Airtight Drywall Approach

Use drywall, framing members
- Seal with sealant, gaskets, etc.
- Is stiff, strong
- Often easier to ensure quality
- Widely applicable to all forms of commercial, residential
- Allows choice of vapor permeance
Air sealing around components: e.g., windows and walls other Openings and penetrations
Big holes

Problem: Filter

Solution: Seal
If you can see daylight it is not sealed

Spray Foam as an Air Barrier

- Spray foam doesn't air seal where it isn't there!
- Wood-to-wood connections
Spray Foam as an Air Barrier

Spray Foam as an Air Barrier
Cold Weather Condensation in Walls

Vapor Diffusion vs. Air Leakage

- Vapor Diffusion
  - more to less vapor
  - no air flow
  - flow through tiny pores

- Air Convection
  - more to less air pressure
  - flow through visible cracks and holes
  - vapor is just along for the ride
Wall w/o Insulated Sheathing

- Air leakage
- Cold = Condensation
- Vapor Diffusion

Frosting on Sheathing
Wall with Insulated Sheathing

- Air leakage
- Warm = no condensation
- Vapor Diffusion

Vapor Barriers and the Code

- **Class I**: 0.1 perm or less
  (polyethylene)
- **Class II**: 0.1 < perm ≤ 1.0 perm
  (Kraft facing, vapor retarder paint)
- **Class III**: 1.0 < perm ≤ 10 perm
  (Latex paint)
- Polyethylene = no inward drying
- More open vapor control allows greater drying—more “forgiveness” in wall
Vapor Barriers and the Code

<table>
<thead>
<tr>
<th>Zone</th>
<th>Class III vapor retarders permitted for:</th>
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<tr>
<td>Marine 4</td>
<td>Vented cladding over OSB&lt;br&gt;Vented cladding over plywood&lt;br&gt;Vented cladding over fiberboard&lt;br&gt;Vented cladding over gypsum&lt;br&gt;Insulated sheathing with R-value ≥ 2.5 over 2x4 wall&lt;br&gt;Insulated sheathing with R-value ≥ 3.75 over 2x6 wall</td>
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<td>5</td>
<td>Vented cladding over OSB&lt;br&gt;Vented cladding over plywood&lt;br&gt;Vented cladding over fiberboard&lt;br&gt;Vented cladding over gypsum&lt;br&gt;Insulated sheathing with R-value ≥ 5 over 2x4 wall&lt;br&gt;Insulated sheathing with R-value ≥ 7.5 over 2x6 wall</td>
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<td>6</td>
<td>Vented cladding over gypsum&lt;br&gt;Insulated sheathing with R-value ≥ 7.5 over 2x4 wall&lt;br&gt;Insulated sheathing with R-value ≥ 10 over 2x6 wall</td>
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<tr>
<td>7 and 8</td>
<td>Vented cladding over gypsum&lt;br&gt;Insulated sheathing with R-value ≥ 15 over 2x8 wall</td>
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Can just use latex paint (no vapor barrier) if you add enough insulation outside of the stud bay insulation. Safer -> controls diffusion and air leakage moisture.

Zone 5A = 30%/70% R-value ratio

Thermal Bridging at Framing
Thermal Bridging at Steel Framing

Steel is 400 times more conductive than wood

Steel studs are about 40 times thinner

A 2x6 steel stud wall 16" OC with R-19 Fiberglass Batt = effective R-9 wall assembly.
Thermal Bridging at Steel Framing

- Summertime/AC example
- Sun is hitting the wall (southeast orientation)

Exterior Rigid Foam
Exterior Rigid Foam (Taped Seams)

4” Polyisocyanurate Foam Retrofit
4" Polyisocyanurate Foam

Foam Sheathing Cladding

250 lbs/113 kg load (7.8 psf): <0.003" deflection
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

Image c/o Petersen Engineering
Foam Sheathing Cladding Attachment

- Substrate
- Deformed position of fastener
- Compressive "strut"
- Gravity load of cladding

Geometry

Force

Tension

Compression

Gravity

BSC Cladding Attachment Research

- System Mechanics

Shear and rotational resistance provided by fastener to wood connections

Rotational resistance provided by tension in fastener and compression of the insulation

Vertical movement resistance provided by friction between layers
Full System Laboratory Tests

- Looked at initial response full system capacity as well as long term sustained loading
- Used full scale samples to limit variations in fastener installation

Recommendations

- Based on the results of the testing it is currently recommended to use a maximum load per fastener of no more than 10lbs for up to 4” of insulation

<table>
<thead>
<tr>
<th>Cladding weight (psf)</th>
<th>16” oc Furring</th>
<th>24” oc Furring</th>
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<tr>
<td>5</td>
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The “Perfect Wall”

Design Info from the 1960’s (Canada)

1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation
The Perfect Wall

Cladding
Control layers
Structure

Wall
Slab
Roof
Diagram showing layers of a roof construction:
- Ballast
- Filter fabric
- Control layers
- Roof structure

Diagram showing layers of a cladding system:
- Cladding
- Control layers
- Structure
- Slab
- Control layers
- Stones
- Earth
The “Perfect” Wall: Higher Performance

The Commercial Steel Frame Wall
“Perfect Wall” Advantages

- Very robust enclosure—“500 year building”
  - Structural portion in “interior” conditions
- Institutional/long term buildings
- No risk of interstitial condensation
- Continuity of control layers
  - Continuous thermal insulation outside
  - Inspectable and simple air barrier “wrap”
  - Water control layer/WRB inspectable before insulation
- Any interior condition
- Any exterior condition

Questions?

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This presentation will be available at http://buildingscience.com/past-events
Document Resources

- Building Science Digest 014: Air Flow Control in Buildings

- Building Science Digest 163: Controlling Cold-Weather Condensation Using Insulation

- Building Science Insight 001: The Perfect Wall

- Building Science Insight 005: A Bridge Too Far
  http://www.buildingscience.com/documents/insights/bsi-005-a-bridge-too-far/

- Building Science Insight 029: Stucco Woes—The Perfect Storm

- Building Science Insight 038: Mind the Gap, Eh!

- Building Science Insight 048: Exterior Spray Foam

- Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure

- Building Science Insight 062: Thermal Bridges Redux