Background
Environmental Separator

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 Layer

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
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
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 hydrostatic pressure with water flowing from a faucet and a cylinder with a cross-section labeled hydrostatic pressure]

2017-03 Rhode Island AIA Presentation 23
Wind Speed vs. Pressures

- ½” of “perched” water ≈ 35 mph wind force
Water Control Layers and Spaces

Strapped Cavities/“Rainscreen Wall”
Why Rainscreen/Air Gap

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

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
Drainage from Lap Sidings

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

Shingle Wall Rainscreen/Air Gap

- Mesh style
  (Home Slicker, Keene Building Products)
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
- Adhesive-backed sill flashing
- Interior air seal
- Beveled wood siding
- Sheathing
- Housewrap

A strip of wood nailed at the back of the rough opening forms a dam to prevent water from draining into the interior.

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
Housewrap Installation Sequence

[Diagram showing the sequence of housewrap installation]

Housewrap Installation Sequence

[Diagram showing the sequence of housewrap installation]
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
Stucco & Adhered Stone

Stucco on Wood Frame Walls

- Three-coat hard-coat stucco rendering
- Two layers of building paper (concealed barrier)
- Exterior
  - Engineered wood sheathing (OSB)
  - Flashing
- Interior
  - Cavity insulation
  - Interior gypsum
  - Timber frame
Stucco Failures (MN, PA)

Stucco-to-Paper Bond
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
Driving Forces

Wind Effect
Stack Effect
Combustion and Ventilation

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)
"Trace the line"

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
Typical Air Leakage Points

- At chimney / fireplace penetrations
- Around windows
- Through window joints
- At rim joists, sill plates, baseboards
- Behind bathtubs, enclosures, above suspended ceilings
- At drains and cracks
- Ceiling light fixtures
- Attic hatch
- Receptacle & switch boxes

Partition-Ceiling

Partition-Wall

Exterior wall
Taped joint
Interior wall
Air seals (caulking, adhesive, or gasket)
Drywall clip

Cavity insulation
Gypsum board
Tile
2x4 tub ledger
Thin profile sheathing

Bathtub
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

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**: $0.1 < \text{perm} \leq 1.0$ perm (Kraft facing, vapor retarder paint)
- **Class III**: $1.0 < \text{perm} \leq 10$ perm (Latex paint)
- Polyethylene = no inward drying
- More open vapor control allows greater drying—more “forgiveness” in wall

### TABLE N102.5.1
**CLASS III VAPOR RETARDERS**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Class III vapor retarders permitted for:</th>
</tr>
</thead>
</table>
| Marine 4 | Vented cladding over OSB  
|         | Vented cladding over plywood  
|         | Vented cladding over fiberboard  
|         | Vented cladding over gypsum  
|         | Insulated sheathing with $R$-value $\geq 2.5$ over $2\times4$ wall  
|         | Insulated sheathing with $R$-value $\geq 3.75$ over $2\times6$ wall  |
| 5       | Vented cladding over OSB  
|         | Vented cladding over plywood  
|         | Vented cladding over fiberboard  
|         | Vented cladding over gypsum  
|         | Insulated sheathing with $R$-value $\geq 5$ over $2\times4$ wall  
|         | Insulated sheathing with $R$-value $\geq 7.5$ over $2\times8$ wall  |
| 6       | Vented cladding over fiberboard  
| 7 and 8 | Insulated sheathing with $R$-value $\geq 10$ over $2\times4$ wall  
|         | Insulated sheathing with $R$-value $\geq 15$ over $2\times6$ wall  |

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

Steel is 400 times more conductive than wood

Steel studs are about 40 times thinner

R=4+

Cold

Hot

R<0.3

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 Continuous Insulation

Exterior Rigid Foam (Taped Seams)
4” Polyisocyanurate Foam Retrofit

Mineral Fiber, Nailbase Panel
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

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>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
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<td>3</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
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
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

Building the “Perfect Wall”
Self-adhered membrane, XPS insulation

Fluid-Applied Asphalt & Rock Wool

- Asphalt Drainage Plane Air Barrier
- Rock wool Insulation
Exterior Closed Cell Spray Foam

All Four Control Layers
Spray foam = air barrier & drainage plane & insulation & vapor control

Transitions, Continuity, Penetrations

Cladding Support (Z-Furring)

- Z-furring 16” o.c.,
- All this effort to cover up our thermal bridges with insulation… and then we punch steel through it…
Thermal Bridging at Cladding

- Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings (ASHRAE 1365-RP)

Thermally Broken Cladding Supports

- Cascadia Clip (pultruded fiberglass)
- Knight Wall (fasteners through foam)

Engineered Assemblies

T Clip
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