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Water, Vapor, Air: How Physics Can Help You Choose the Right Membrane

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Architectural Engineering

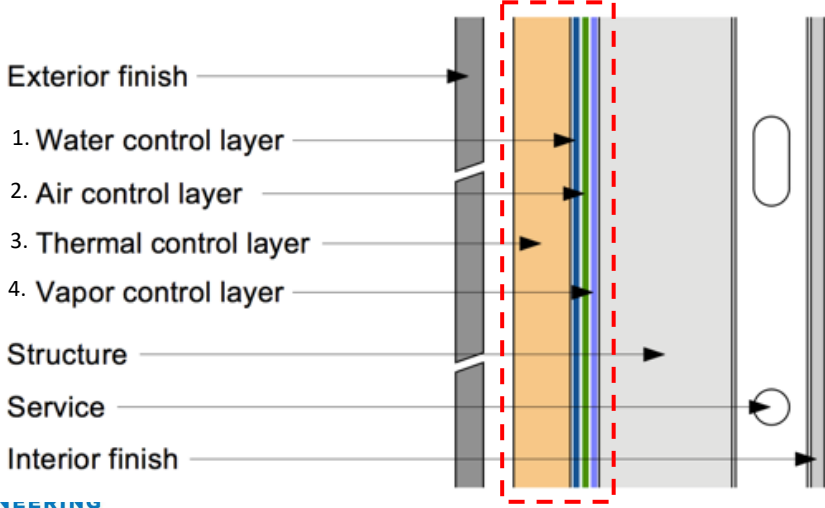
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The Ideal Enclosure

Clarity of **function**, ideal **arrangement** of materials

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Exterior finish

1. Water control layer

2. Air control layer

3. Thermal control layer

4. Vapor control layer

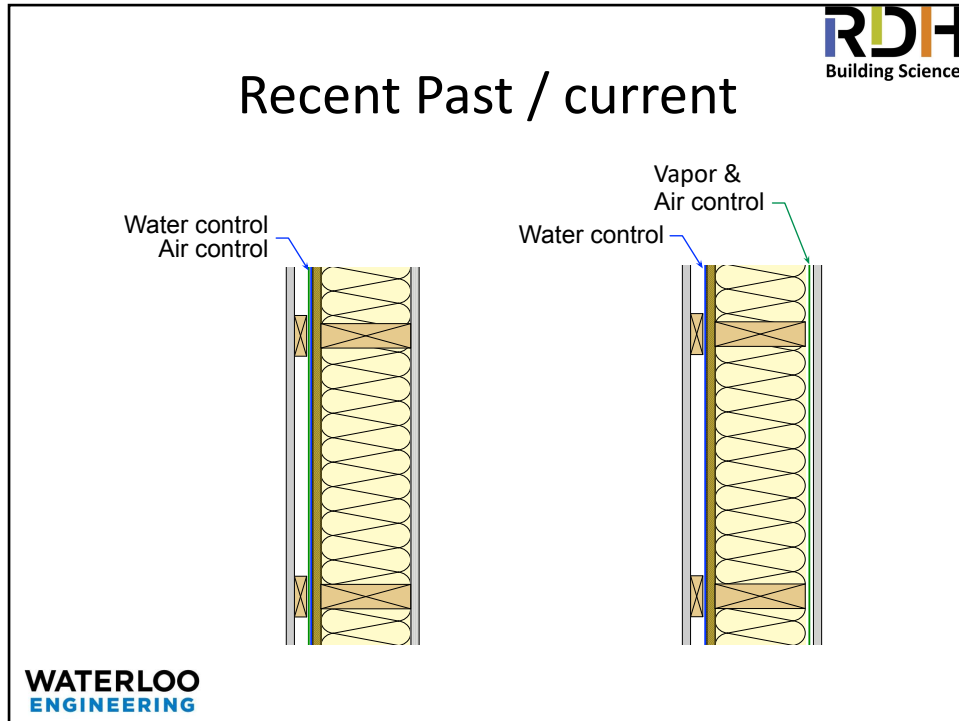
Structure

Service

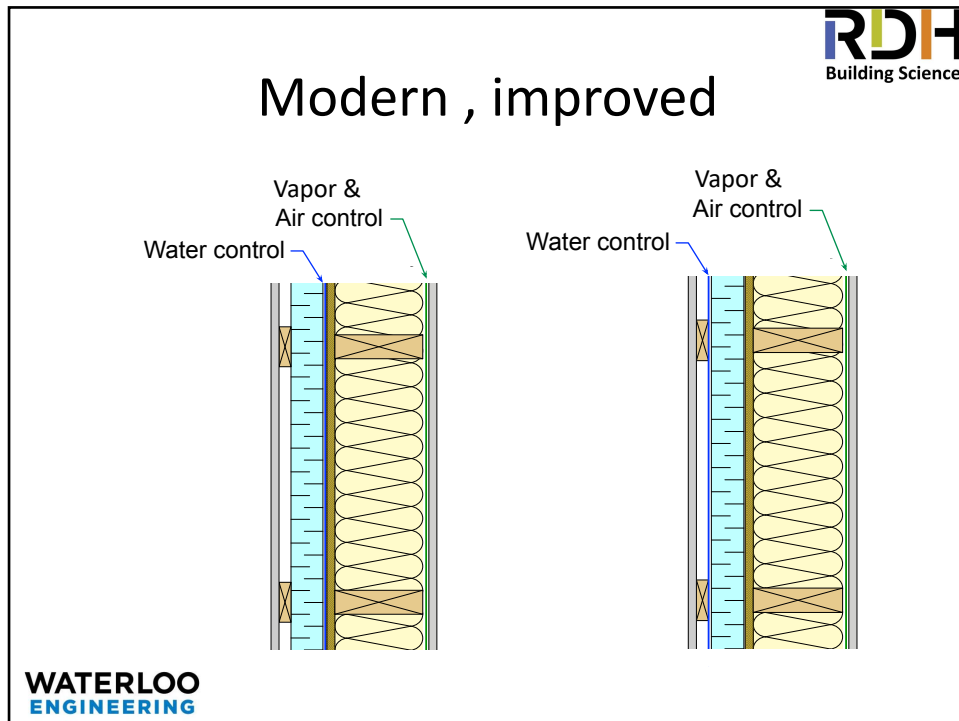
Interior finish

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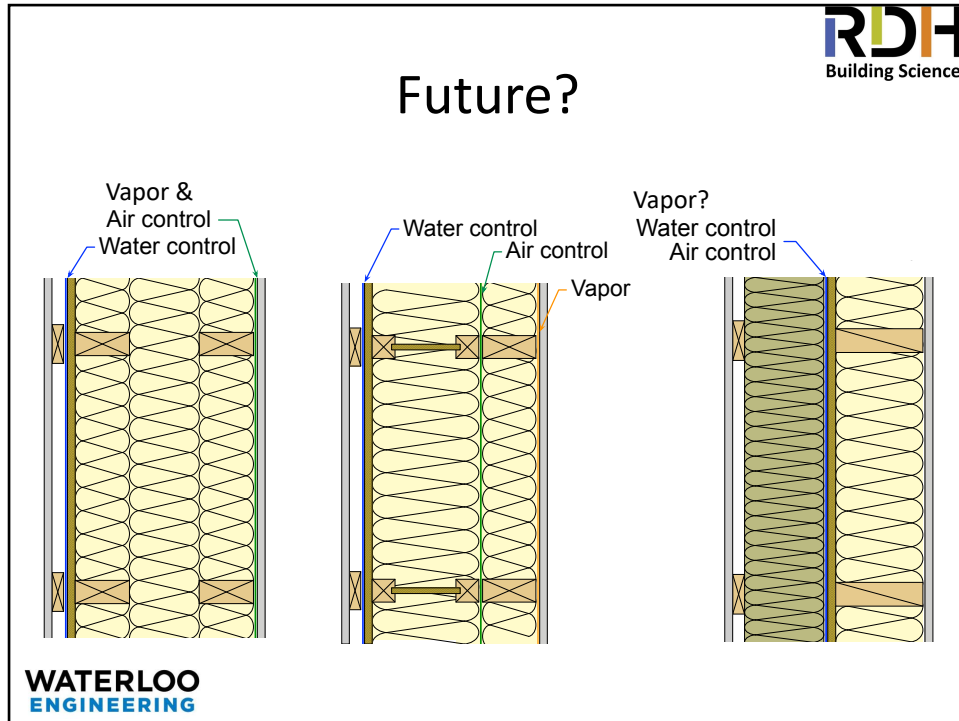
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All walls need control Layers

- 1. Rain Control
 - most important
- 2. Air Control
 - Energy, health, humidity
- 3. Thermal Control
 - Thermal bridging
- 4. Vapor control
 - Some holes can be tolerated

Confusion:
Can be *separate* layers / products or *combined* in same material / layer

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Continuity

- Many **materials** have good performance
- **But**, poor continuity limits performance
- **&** Poor continuity causes most problems too:
 - E.g. air leakage condensation
 - Rain leakage
 - Surface condensation
 - Cold windows
- Thus: *continuity + proper material*

Water Control Layer

- Continuous– lapped
 - Reverse laps: mechanical seal or good adhesive
- Water resistant
- Need not be vapor resistant or air resistant

Lapped “Drainage Plane”




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Only water control
together with drain gap
Not air
Not vapor
Not even
water”proof”

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Classic Drained System: Brick Veneer leaks



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The diagram illustrates the assembly layers: Building Paper, another layer of Building Paper, and a Flashing. A red arrow labeled 'DOWN' points from the top layer of Building Paper to the Flashing. A second red arrow labeled 'OUT' points away from the Flashing, indicating the path of water drainage.

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Water control Products

Control- Water (not at joints)

- Asphalt-impregnated felt
- Asphalt-coated paper
- Polymeric housewraps
- Faced (plastic,aluminum) SBS bitumen and butyl sheets
- Fluid-applied asphalts, urethanes, acrylics, silicones
- Thick layers of monolithic masonry
- 3-6" or more of high-quality reinforced concrete
- EPDM, TPO, fabric reinforced modified SBS, reinforced PVC, fabric reinforced asphalt
- Glass sheets
- Metal (aluminum, steel, zinc, copper) sheets
- Closed-cell plastic foams (spray or board)

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Combo Air-Water-Vapor Layers

- Often thin layers
- *Can be*
 1. Water control (vapor permeable, not airtight), **or**
 2. Air & water control (vapor permeable), **or**
 3. Air, water & vapor (vapor impermeable).
- Examples
 - Building paper, untaped housewrap, sealed and supported housewrap, fluid applied, peel and stick

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Air-water Barrier

- Tape for airtightness, lap for water tightness





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Air Control: Air Barrier 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)



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Example Air Control Products

Many products could be **part** of air barrier system

- Polymeric housewraps
- Wood panel boards (OSB, plywood)
- Faced (plastic, aluminum) SBS Bitumen and Butyl Sheets
- Fluid-applied asphalts, urethanes, acrylics, silicones, etc.
- Thick layers of monolithic masonry
- 3-6" or more of high-quality reinforced concrete
- EPDM, TPO, reinforced PVC, fabric reinforced SBS modified bitumen, fabric reinforced asphalt
- Glass sheet
- Metal (aluminum, steel, zinc, copper) sheets
- Closed-cell plastic foams (spray, e.g. ccSPF; or board XPS, PIC)
- Gypsum board

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Air Barriers Are Systems



Materials



Components



Accessories




**Whole Building
Airtightness**



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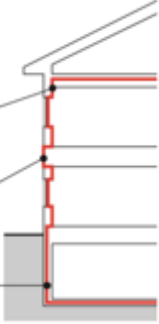
“Exterior” Air Barriers



- Many more penetrations and details with interior air barrier approach
- Exterior is preferred today

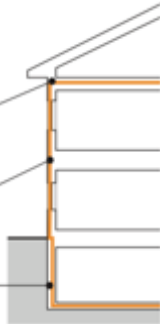
Interior Air Barrier Approach


- Interior connection to air barrier at ceiling/attic floor
- Complex transition at floor and interior walls
- Connection to below-grade air barrier components



Exterior Air Barrier Approach


- Transition from outside to inside at vented attic; Low-slope roof all exterior connection
- No interruption at floor and interior walls
- Connection to below-grade air barrier components






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Vapor Permeable membranes



- Vapor permeable air- and air-water barriers
 - Many products available
- Can be located anywhere in assembly
 - Tyvek was a huge innovation
 - Can locate outside moisture sensitive wood
- Fully-adhered vs loose membrane is biggest practical distinction



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Non-adhered, vapor permeable
=modest performance

**Supported flexible
membrane is better**



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Fully-adhered is better



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Fully-adhered air-water barrier

Vapor Permeable!



Self-adhered—no staple holes and tears that allow air and moisture to pass through walls

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Self-adhered membrane
(preformed sheet membrane)

Vapor Permeable

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Fluid-applied

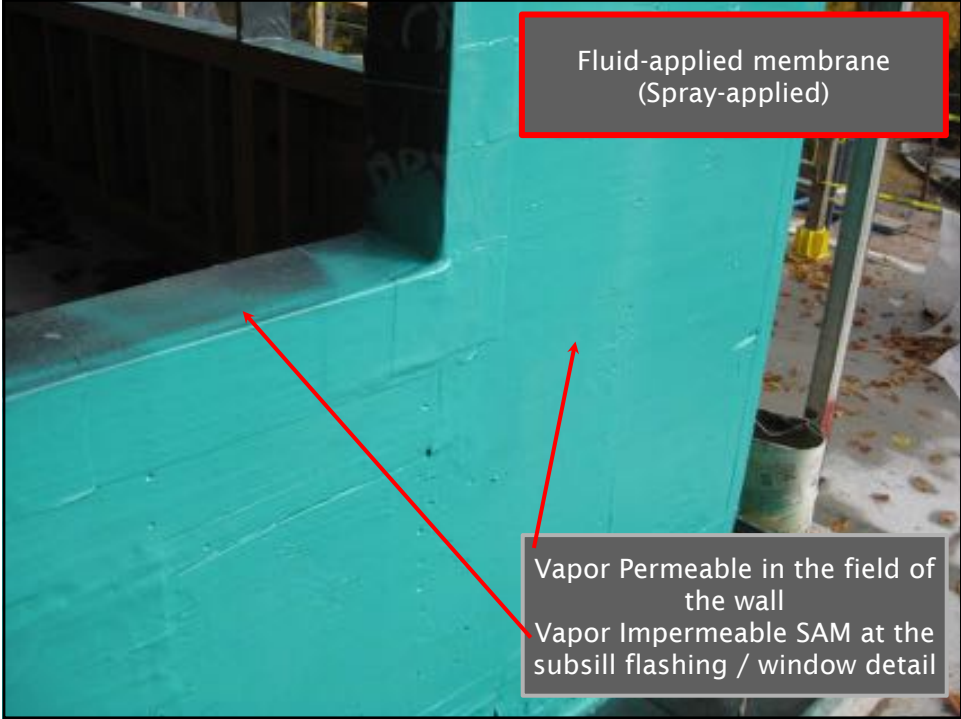
DuPont™ Tyvek® Fluid Applied WB

A DURABLE, VAPOR PERMEABLE FLUID APPLIED ~~WEATHER~~ BARRIER



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Fluid-applied membrane
(Spray-applied)

Vapor Permeable in the field of the wall
Vapor Impermeable SAM at the subsill flashing / window detail

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Air+water Taped Rigid Foam Sheathing



Moderately vapor permeable
Challenge is water sealing

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But some foams are vapor barriers



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Air Barriers vs Vapor Barriers

- ***Vapour Barriers Control Vapour Diffusion***
 - Why? 1. Moisture wetting and drying
- ***Air Barriers Control Air Leakage***
 - Why? At least **six** reasons.
 - Health (control contaminants)
 - Moisture (avoid condensation)
 - Heat (for comfort & energy considerations)
 - Smoke & odors
 - Sound

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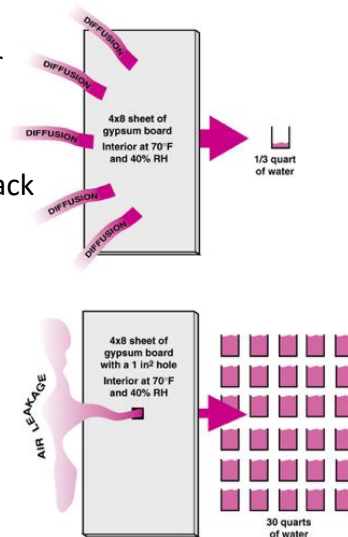
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Requirements

- Air Barriers
 - Continuous (no holes), strong, durable and preferably stiff I
 - Need in all assemblies and joints
- Vapor Barriers
 - Covers most of assembly, resists vapor diffusion through materials
 - May not be needed because of other wall layers having low permeance, climate, or design

Air leakage

- Confusion between air & vapor barrier arises because both control flow of water vapor
- Much more vapor can be carried on back of air flow than diffusion
- Condensation only happens if air flows towards cold surface

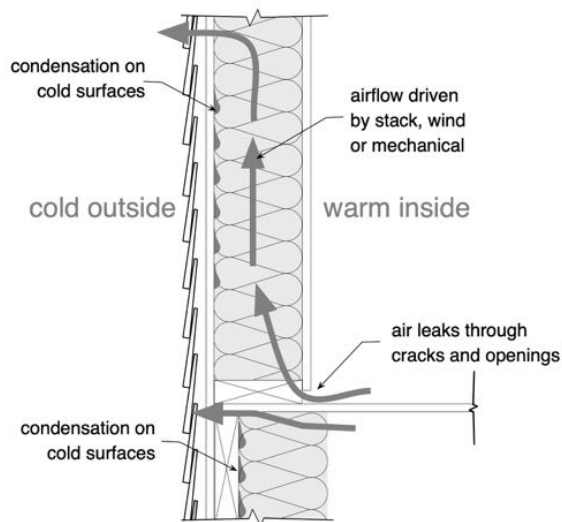


Water Vapor Transport

- Diffusion
 - Flow of water vapor from high concentration to low concentration
- Air leakage
 - Flow of water vapor along with the flow of air
 - Air moves from high to low pressure

Air leakage Condensation

- **Air leakage is much more critical than diffusion**
- **We limit air flow for reasons other than condensation!**



Air leaks concentrate



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Air Leakage or Vapor Diffusion?



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Where does condensation occur? Diffusion or Air Leakage (Convection)

OUTSIDE

INSIDE

21°C (70°F)

-15°C (0°F)

Exterior sheathing

"Dew point"

Location of condensation and frost

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OUTSIDE

Roof Sheathing

Condensation and Frost Accumulating on Underside of Roof Sheathing

VENTILATED ATTIC

Attic Insulation

-15°C (0°F)

Dew point

INSIDE BUILDING

21°C (70°F)

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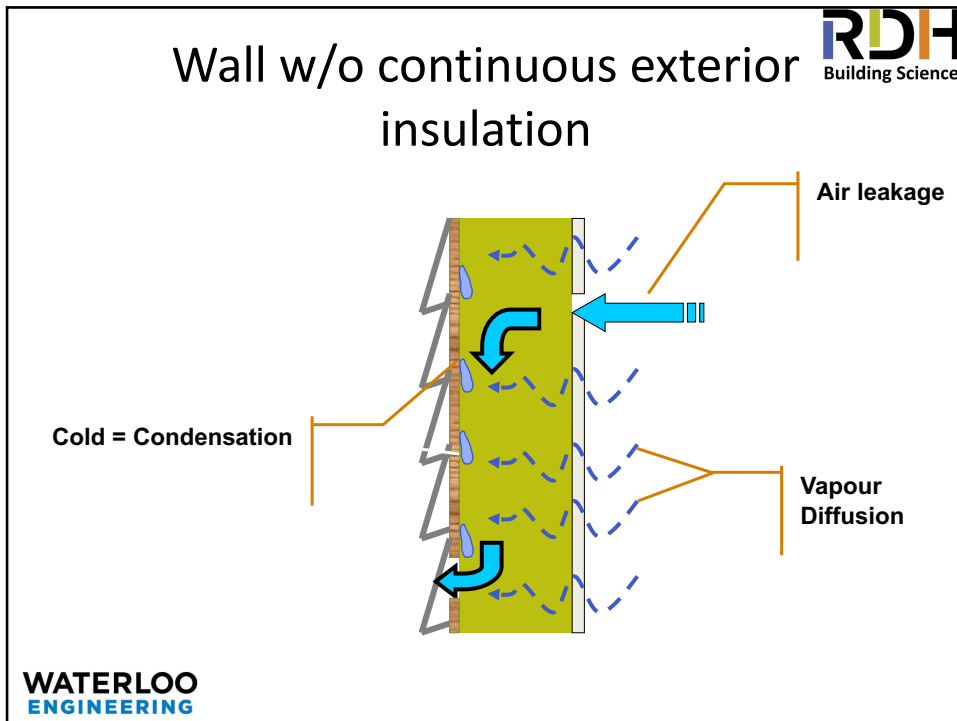
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"Condensation occurs on the first solid upstream facing surface downstream of the dewpoint being exceeded"

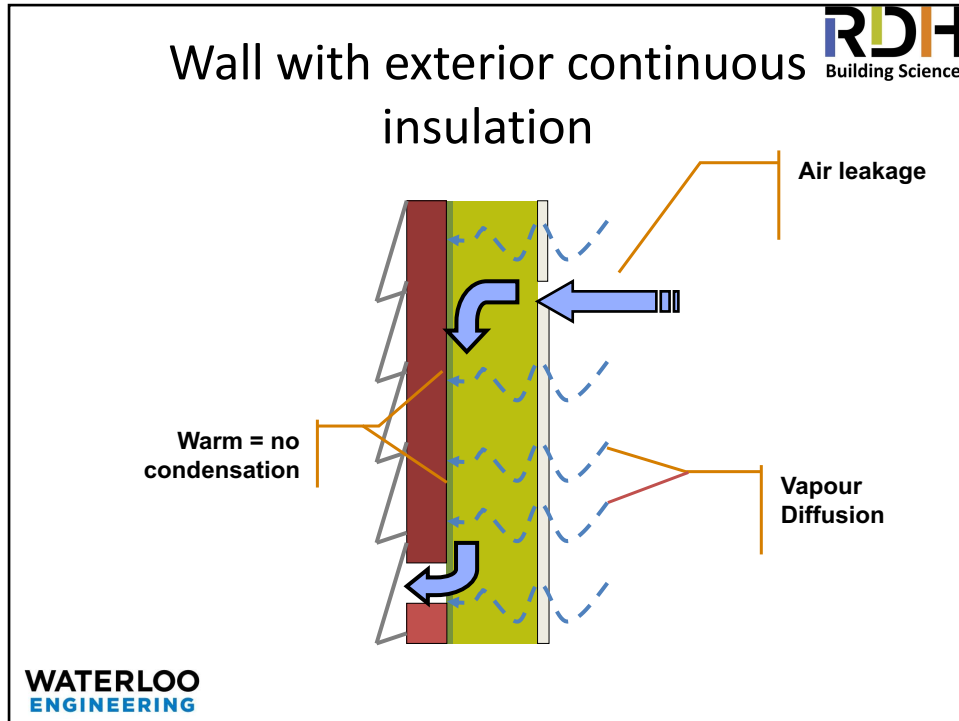
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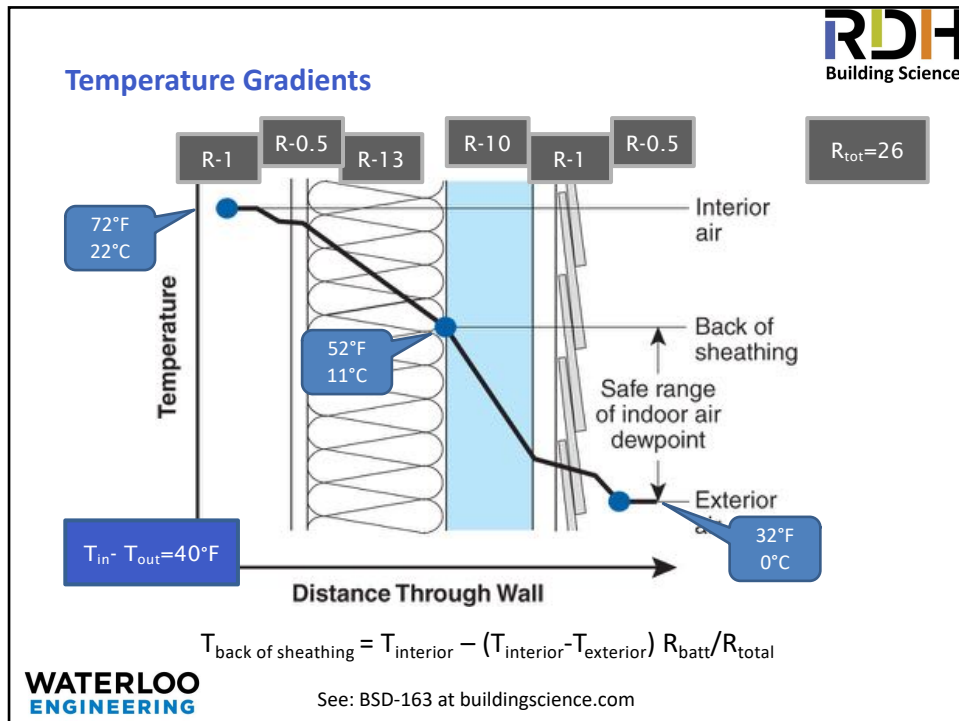
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Vapor Control

- Categories of vapor control
 - Permeable: over 10 US perms
 - Semi-permeable: 1-10
 - Semi-impermeable 0.1-1
 - Impermeable <0.1
- Less than 1 perm is often defined as a “vapor barrier”
- Designating only one material a vapor barrier does not mean others in wall are not!




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Vapor Control Layer Location

- Put in location where it is warm enough to avoid condensation
 - Inside in cold weather, outside in warm
- Or, if condensation can occur, adjoining materials must be water tolerant
 - E.g. precast, exposed masonry




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Vapor Control Layers

- Layer defined by Material & Thickness

Material	Inches to reach 1 perm
polyethylene	0.6 mil
Metal (facer)	>0 (assuming no pinholes)
wood	0.5 – 5.0 (depends on MC, species)
XPS	1-1.2
EPS	1.5 to 3
Polyiso	1.5-2.5 (unfaced)
ccSPF	1.5-2+
ocSPF	48
Concrete	3-10 (depends on density, porosity)
gypsum	16



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Vapor Control Materials

Specialty paints/coatings, such as epoxy

All metal sheets, extrusions, films, castings

Glass

Asphalt butyl coatings, thick enough (e.g., over 1 mm is enough)

Polyethylene, saran, polycarbonate, polypropylene as films, not woven or perforated

Closed cell polyurethane foam (over 2")

EXPS (over 1-2")


EPS (density matters, usually over 2" or so)

Concrete (good quality, over 2-3", lower quality porous, 6-10")

Dense stone (few pores, over 2-4" thickness or so)

Closely spaced perforations usually mostly eliminate vapor resistance

Wood, depending on density, species and thickness (over 4" for

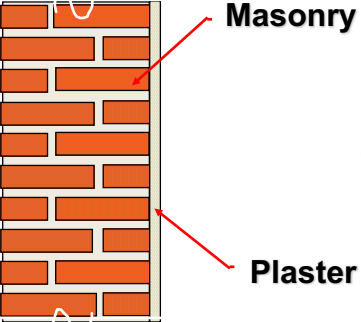


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Old Assemblies

- Vapour resistance integrated with insulation
 - Like foam today?
- Massive moisture storage



No vapour barrier, of course

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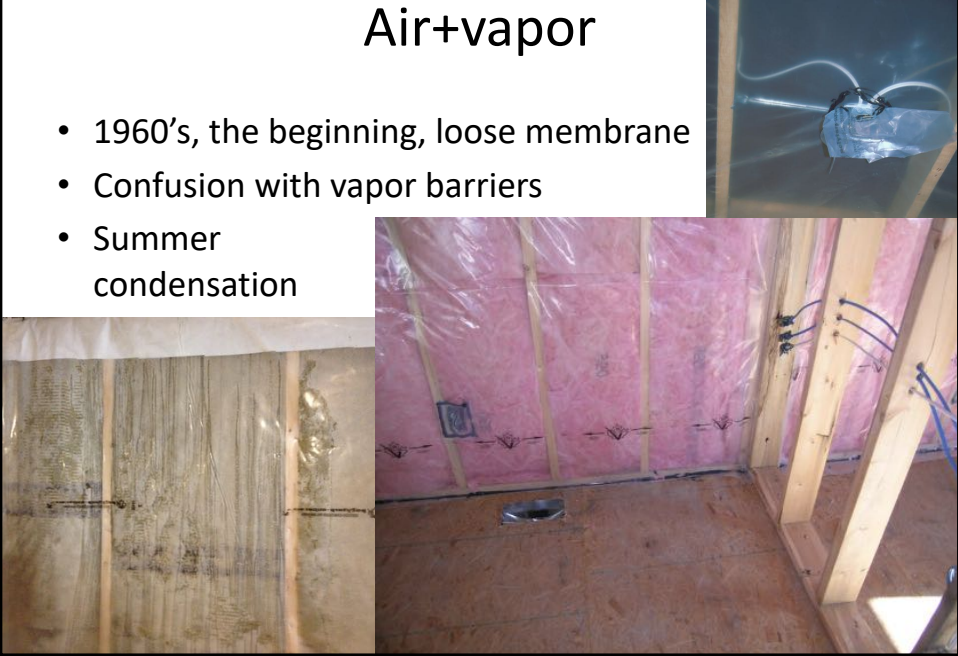
The diagram shows a cross-section of a brick wall. The top part is labeled 'Masonry' and the bottom part is labeled 'Plaster'. The text 'No vapour barrier, of course' is centered to the right of the diagram. The 'WATERLOO ENGINEERING' logo is at the bottom left.

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Air+vapor

- 1960's, the beginning, loose membrane
- Confusion with vapor barriers
- Summer condensation



The slide contains three photographs. The top right photo shows a blue membrane being torn or loose. The bottom left photo shows a close-up of a yellowish membrane with condensation. The bottom right photo shows a room with pink insulation and a blue membrane, with condensation visible on the walls.

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Controlling Interstitial Condensation (Sun-Driven Moisture)

Exterior Conditions	Brick Cavity Conditions	Interior Conditions
Temperature: 25°C (77°F)	Temperature: 40°C (104°F)	Temperature: 21°C (70°F)
Relative Humidity: 80%	Relative Humidity: 100%	Relative Humidity: 60%
Vapour Pressure: 2.5 kPa	Vapour Pressure: 7.4 kPa	Vapour Pressure: 1.8 kPa

1. Cladding (brick, stucco, or adhered stone) is saturated with rainwater.

2. Solar radiation strikes wall and heats cladding.

3. Vapour is driven inward and outward by a vapour pressure gradient between the brick and the interior (5.6 kPa) and the brick and the exterior (4.9 kPa).

The amount of vapour transmission to the interior is dependent on the vapour permeance of the materials (i.e., sheathing membrane, insulation, vapour control layer).

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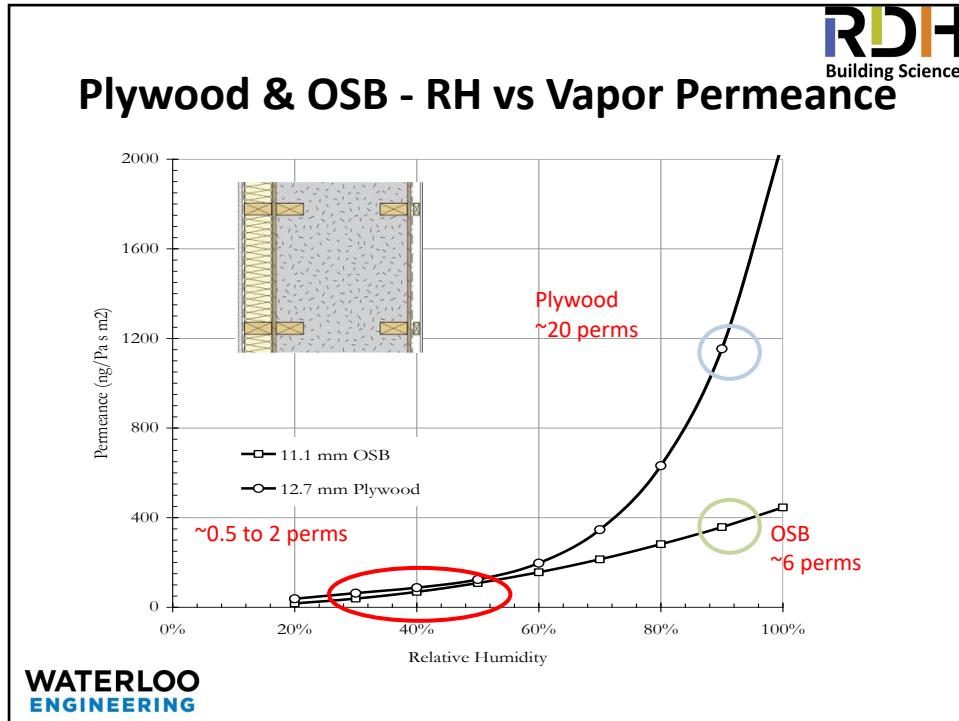
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Summer Condensation:

1. Air-conditioning
2. Interior vapor barrier
3. Permeable exterior layer
4. Humid exterior OR wet cladding

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Consider Vapor Diffusion through Layers

- Must consider the whole assembly, not only the properties of the Air (/Water /Vapor) Barriers
- Sheathing, exterior finishes can have significant resistance
- Don't be tricked by labels... low perm layers are vapor barriers

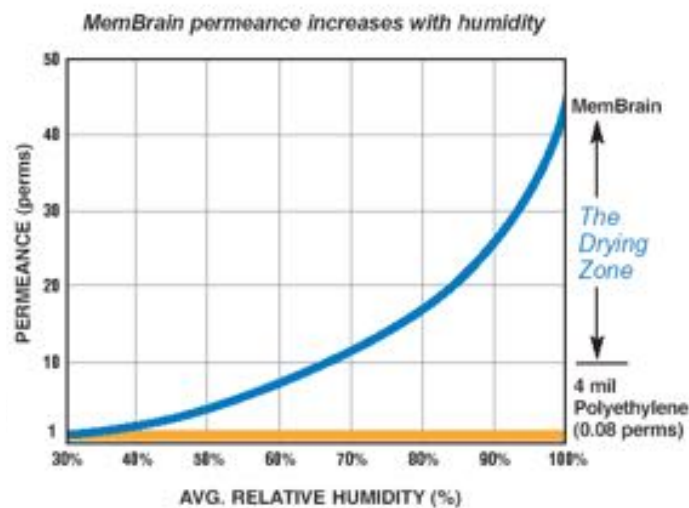
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Summary

- Identify control layers in design is critical
- Design/build continuity of air + water layers!
- Understand what you expect and what products provide for
 - Air
 - Water
 - Vapor
- Condensation can be controlled with insulation

Smart Vapor Barrier Permeance



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During the heating season when average relative humidities in insulated cavities are typically low, MemBrain works as a vapor retarder.

During the cooling season when average relative humidities in insulated cavities are typically high, MemBrain changes its permeance to increase the systems drying potential.

Molecular-scale pores close under dry conditions, blocking vapor transmission

Molecular-scale pores open under moist conditions, allowing vapor to pass

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Source: Certainteed

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