abaa 2025 building enclosure conference

Building Science Principles in Action

The Dews and Don’ts

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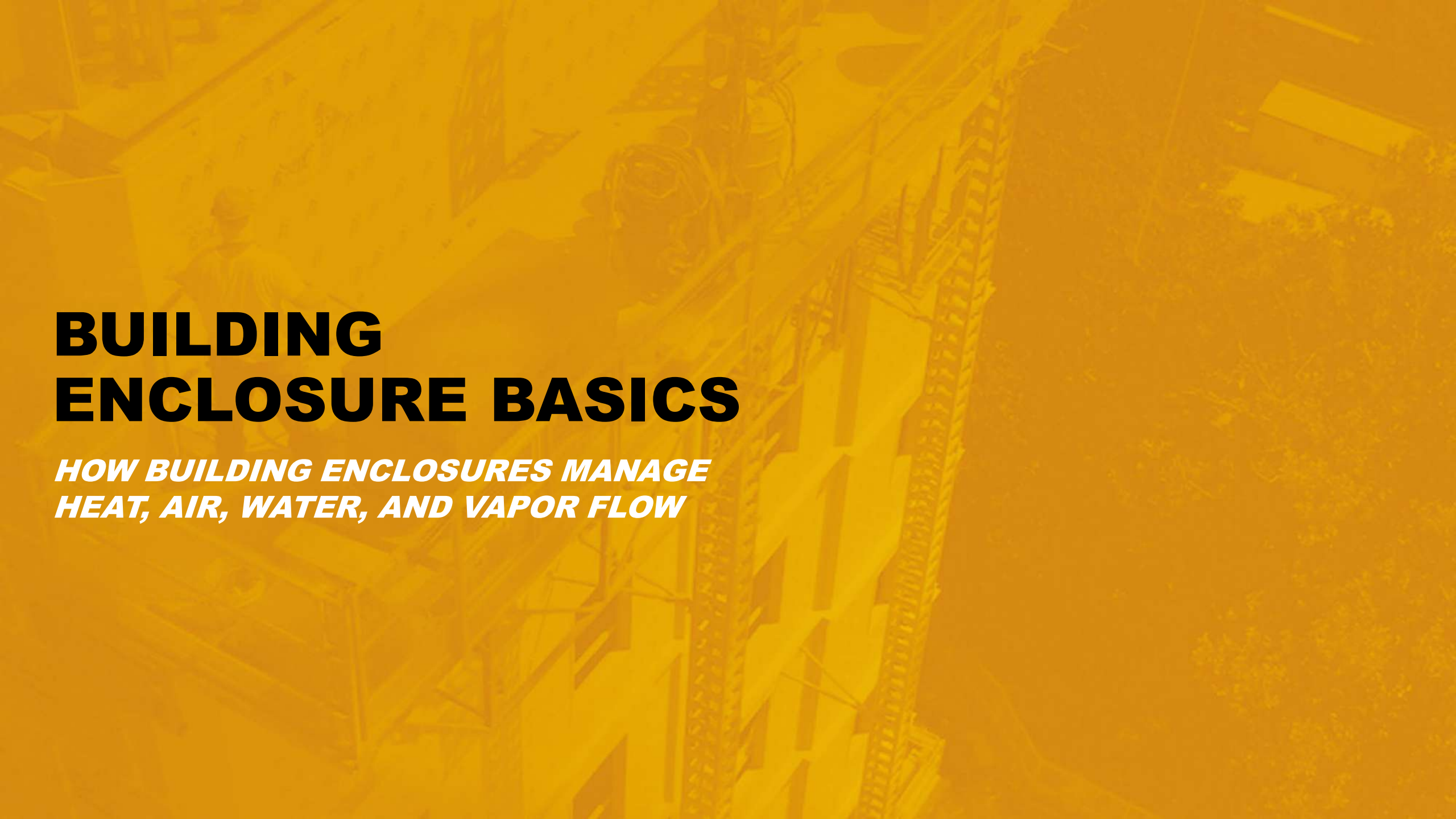
Building Science Principles in Action

Building science includes the study of how heat, air, and moisture interact with primary building systems, including the building enclosure. It is a critical component of design that that focuses on the interaction between the building enclosure, interior space conditions, and exterior climate conditions and can have significant impacts on building performance, durability, and occupant experience.

Informed by new design practice and investigation, this presentation will touch on the basics of applying building science concepts to building enclosure design. The presentation will also explore, through a series of project examples and industry practices, everyday building science questions and solutions that are often situationally dependent.

Learning Objectives

1. Identify key building science principles that apply to building enclosure design.
2. Understand how building enclosures manage heat, air, water, and vapor flow.
3. Discuss how codes and standards address building science issues.
4. Recognize the interdependency of building science concepts.
5. Recognize building science-related consequences and performance impacts of building enclosure design choices.



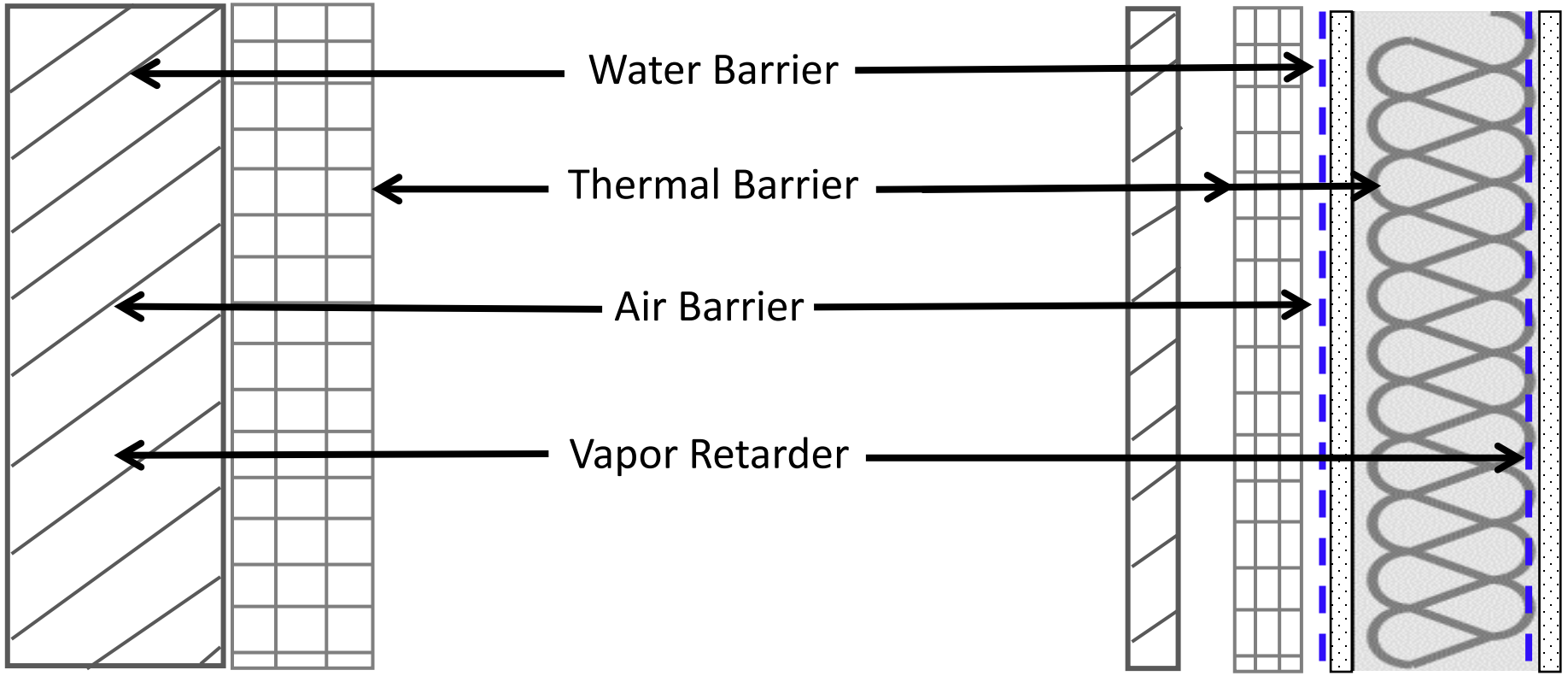
BUILDING ENCLOSURE BASICS

HOW BUILDING ENCLOSURES MANAGE HEAT, AIR, WATER, AND VAPOR FLOW

BUILDING ENCLOSURE BASICS

Barrier Wall
(Face-Sealed)

Rainscreen
(Drained Cavity Wall)

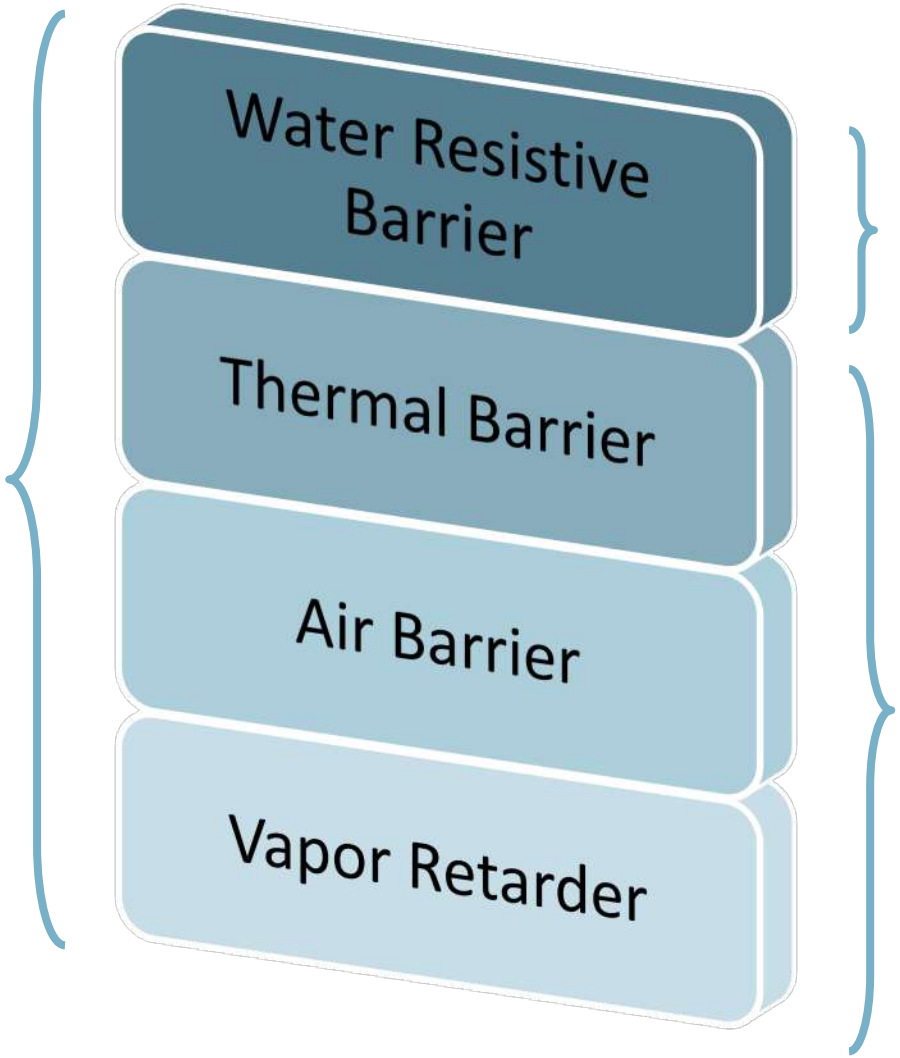


BUILDING ENCLOSURE BASICS

The Four Barriers

Evaluation Criteria:

Performance
Reliability
Durability
Suitability
Constructability
+
Continuity



Function:
Rainwater/
Groundwater
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Condensation
Control
&
Energy Consumption

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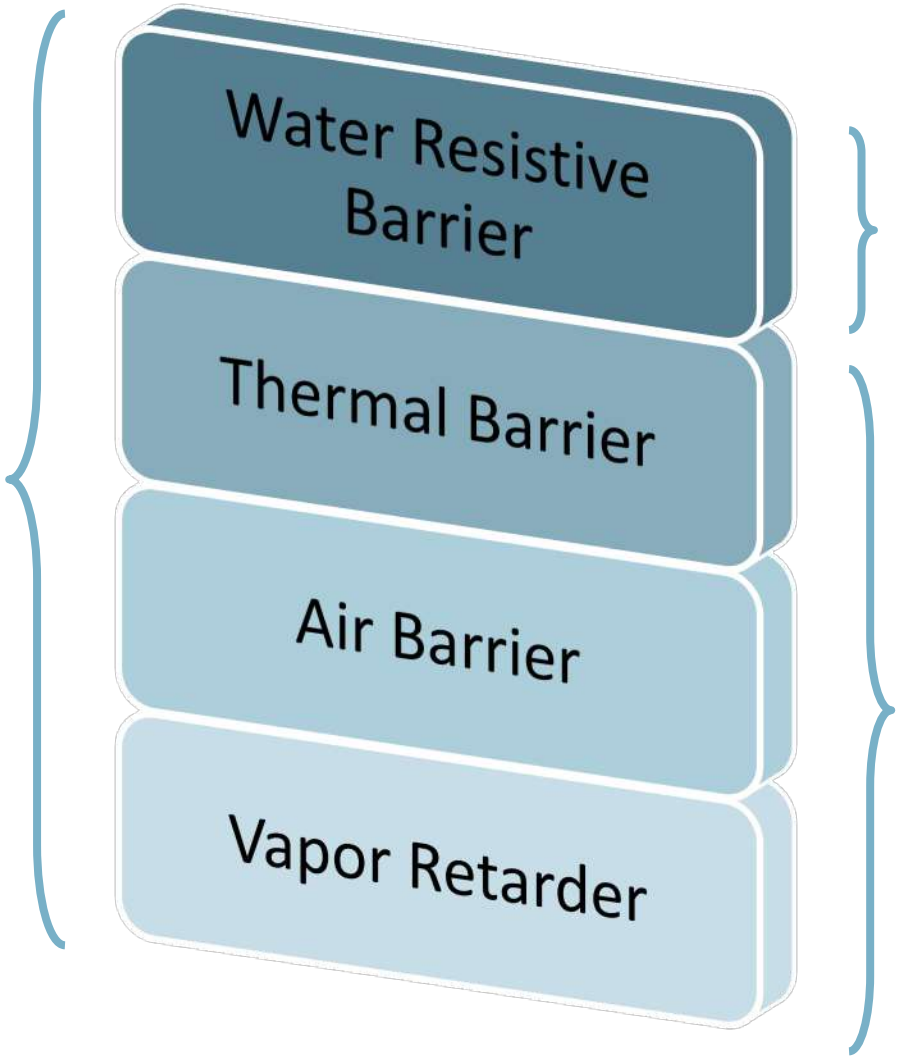

Function:
Rainwater/
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Building Science

BUILDING SCIENCE PRINCIPLES IN ACTION

TO VENT OR NOT TO VENT?

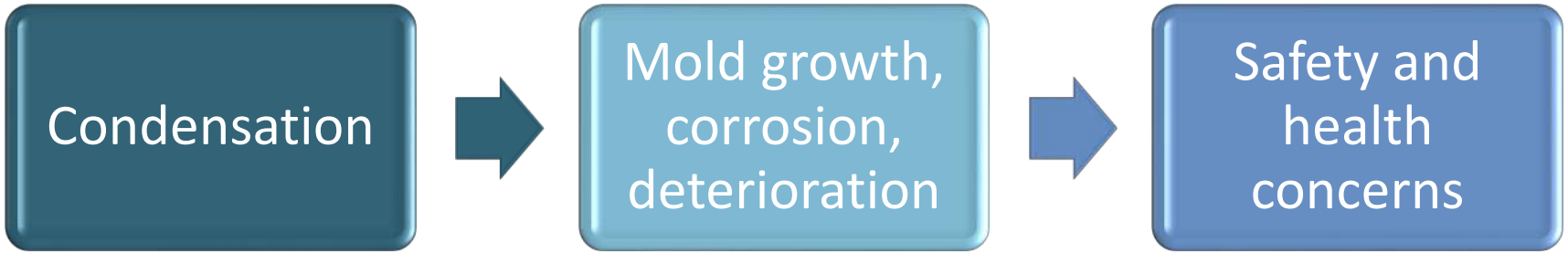
BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

Framed Roof Kickers

Soffits

BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

Why Do We Care?



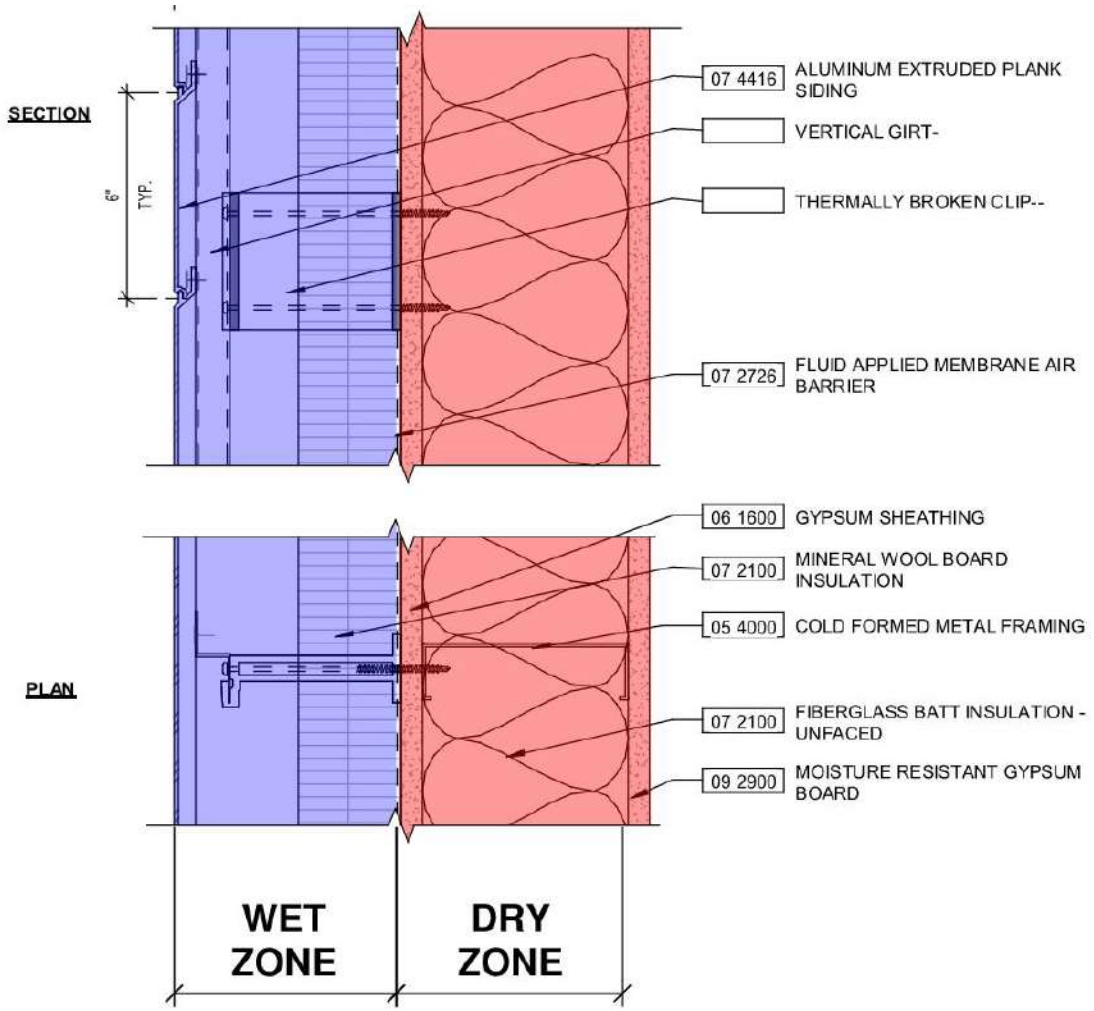
“Condensation is the process where water vapor in the air transforms into liquid water droplets when it comes into contact with a surface that is at or below the dew point temperature of the air”

“Dew point is the temperature at which water vapor has reached the saturation point (100% relative humidity).”

- American Society of Heating, Refrigerating and Air Conditioning Engineers

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wet Zone / Dry Zone



BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

What Conditions Increase the Risk of Condensation?

- Lack of ventilation
- Vapor flow from interior areas with higher vapor pressure
- Air leakage through enclosure assemblies

BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

Framed Roof Kickers

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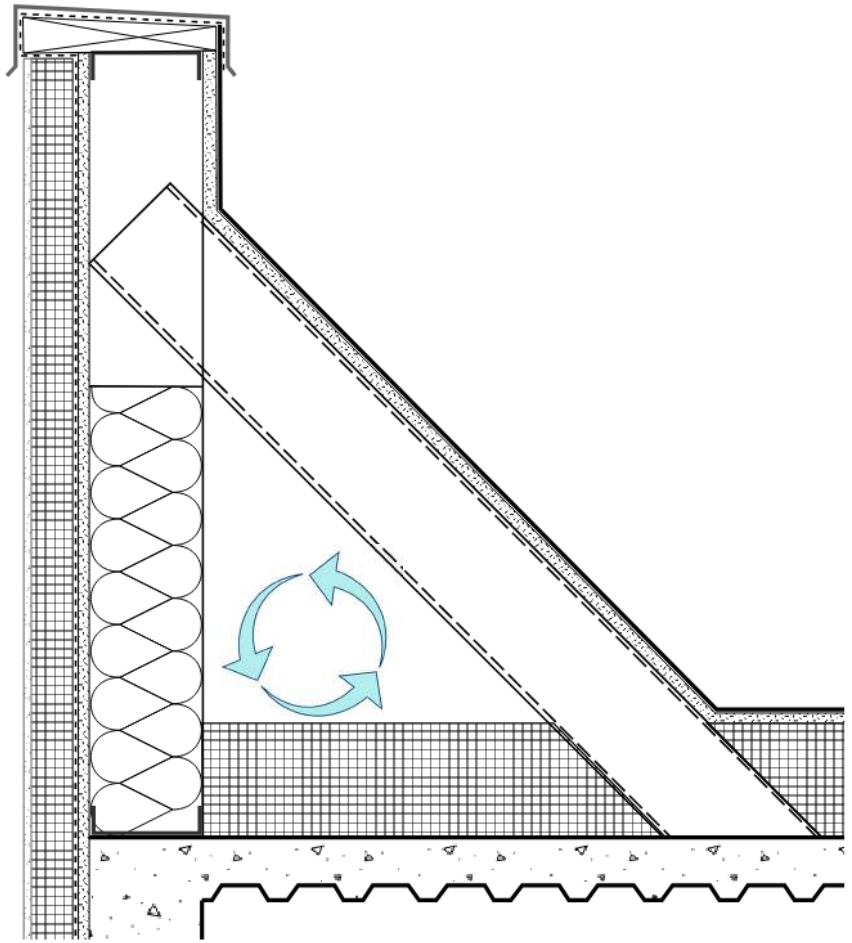

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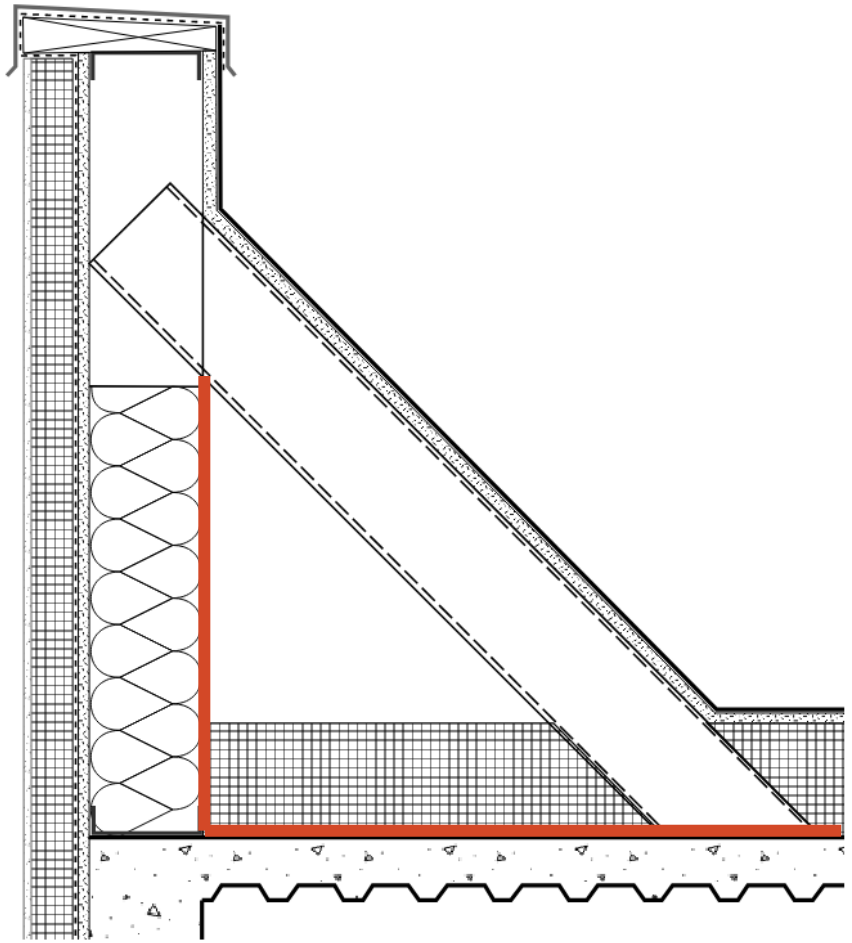

BUILDING SCIENCE PRINCIPLES IN ACTION:
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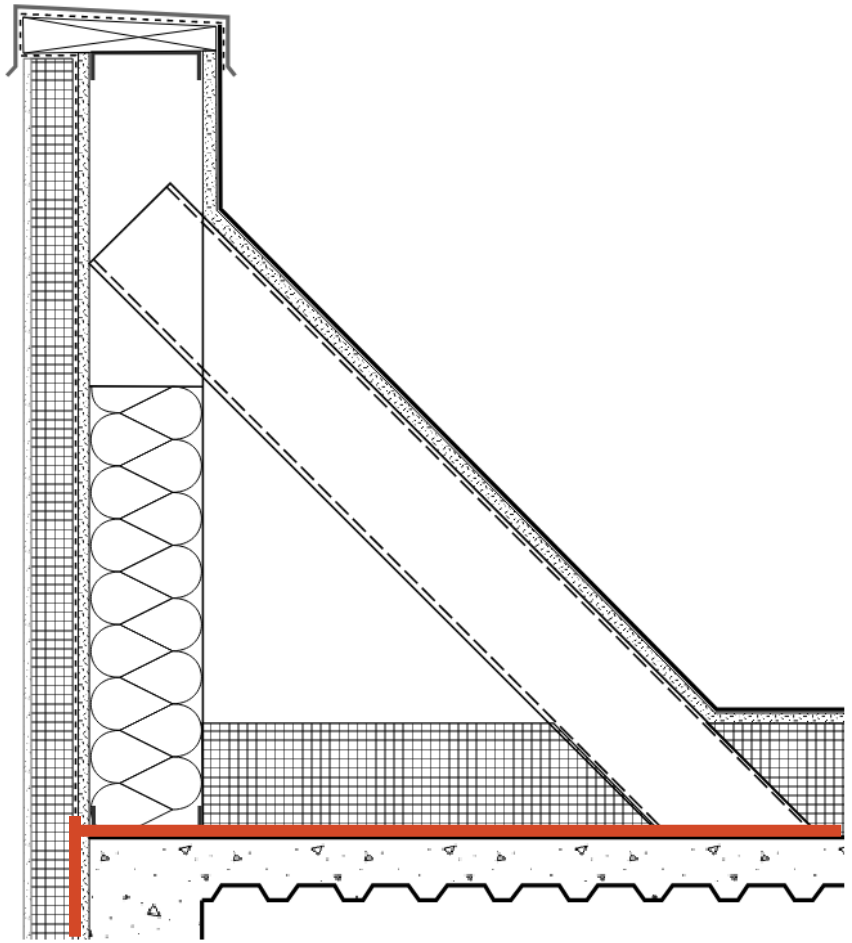

BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

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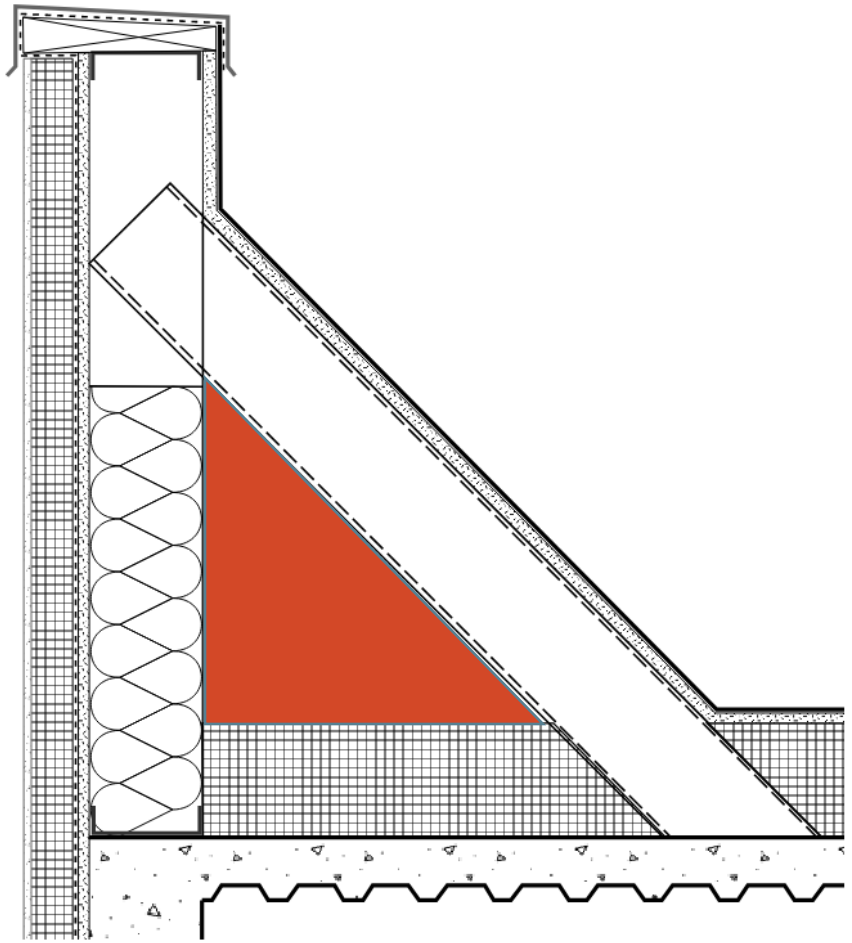


BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

Is All Of This Always Necessary?

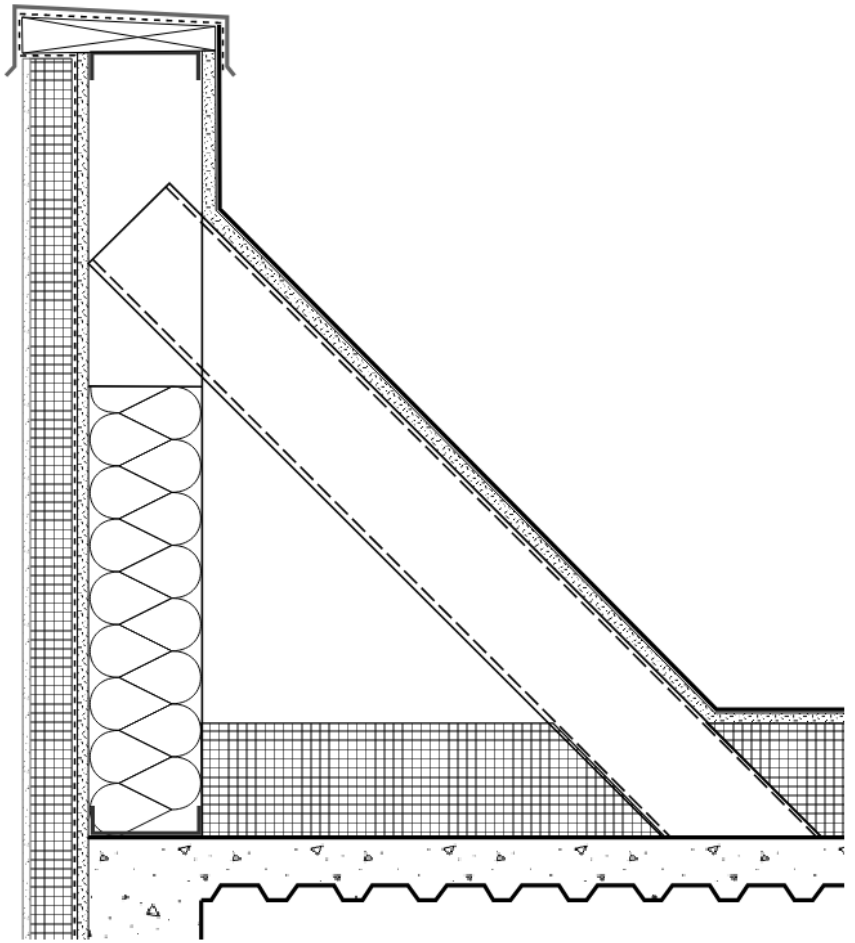
- Only in some places! Remember to consider climate

Denver:

Exterior temperature -1.4°F

Los Angeles:

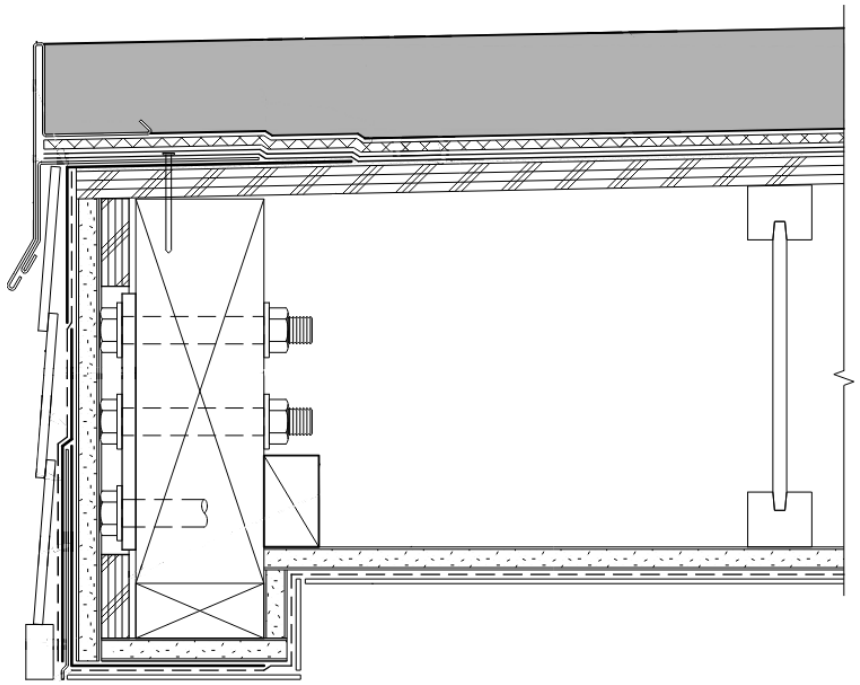
Exterior temperature 45°F



Interior temperature 68°F, 40% RH
Dew Point temperature 43 °F

BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

Soffits



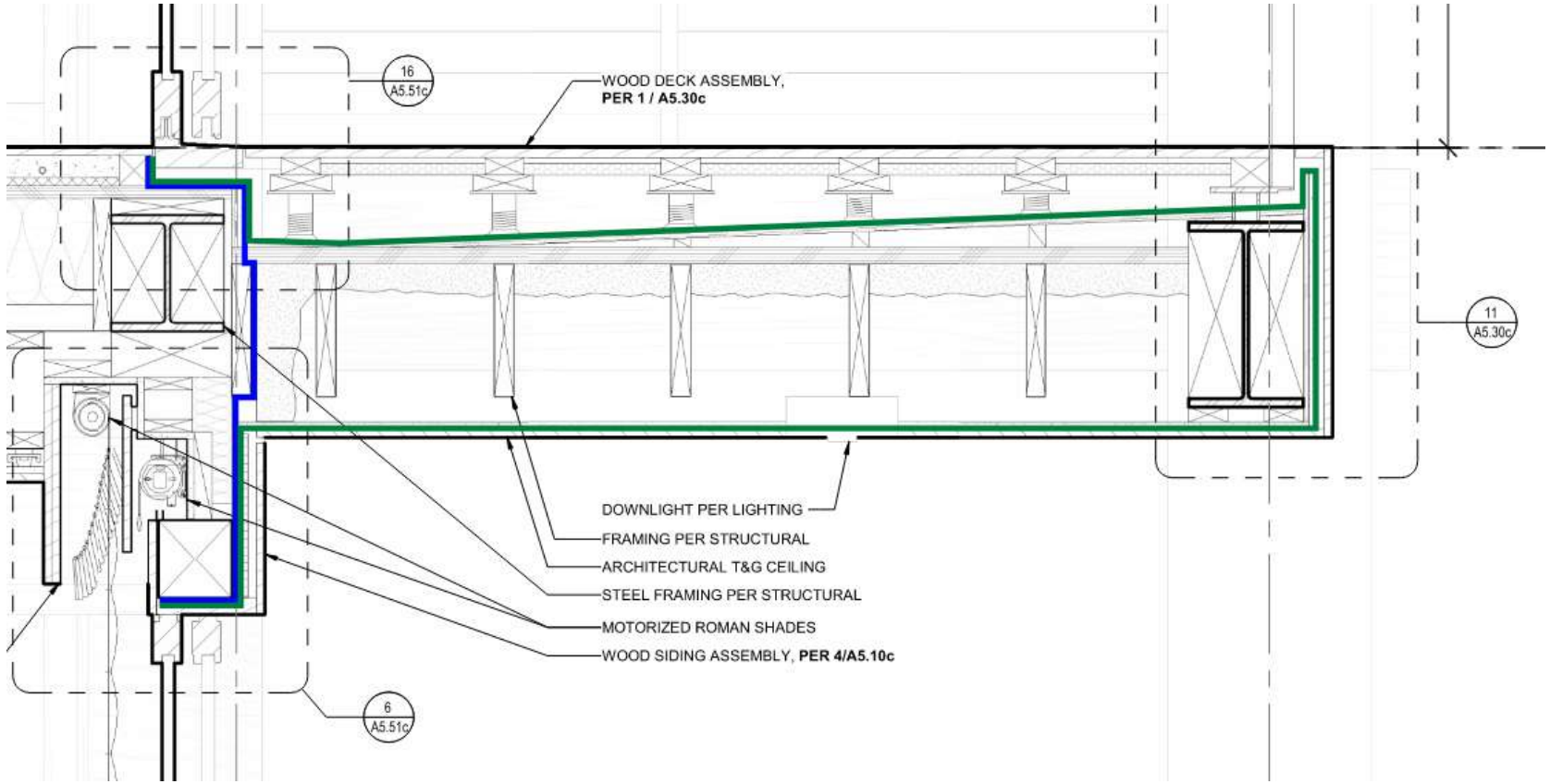
Should I Vent?

- IBC 2021, Chapter 23 requirements for wood-framed balconies

2304.12.2.5 Ventilation beneath balcony or elevated walking surfaces. Enclosed framing in exterior balconies and elevated walking surfaces that have *weather-exposed surfaces* shall be provided with openings that provide a net free cross-ventilation area not less than $^{1}/_{150}$ of the area of each separate space.

BUILDING SCIENCE PRINCIPLES IN ACTION:
ENCLOSED AIR SPACES

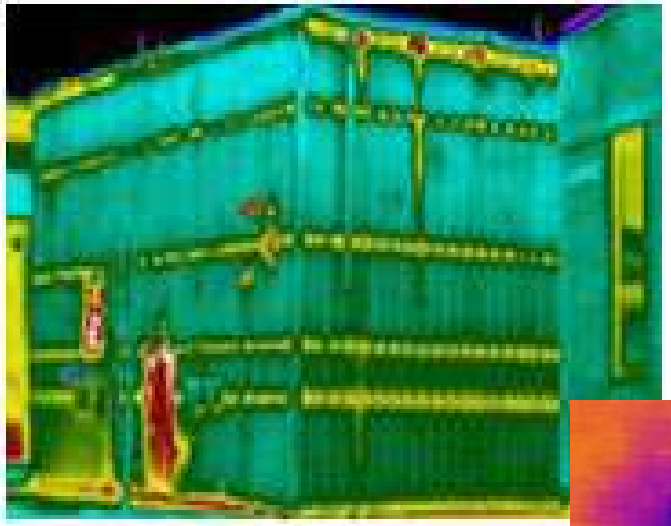
Soffits

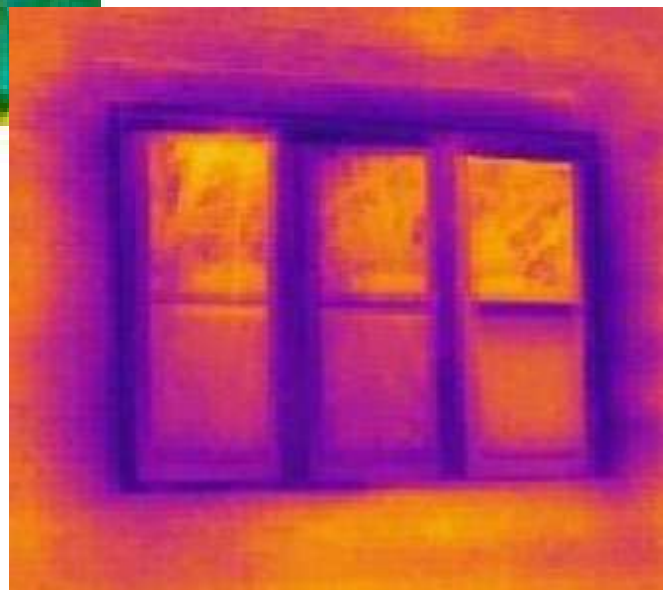


BUILDING SCIENCE PRINCIPLES IN ACTION

WHAT'S THE PATH OF LEAST RESISTANCE

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE





Thermal Bridge*

Any place in the building envelope where the otherwise uniform thermal resistance is changed due to:

- Full or partial **penetration** of the insulating layers by materials with a different thermal conductivity;
- **Change in thickness** of the insulating layers;
- **Variance** between **interior and exterior areas** of the envelope (e.g., at wall/floor/ceiling junctions, parapets, and building corners).

** As defined in Building Envelope Thermal Bridging Guide v. 1.4, 2020*

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

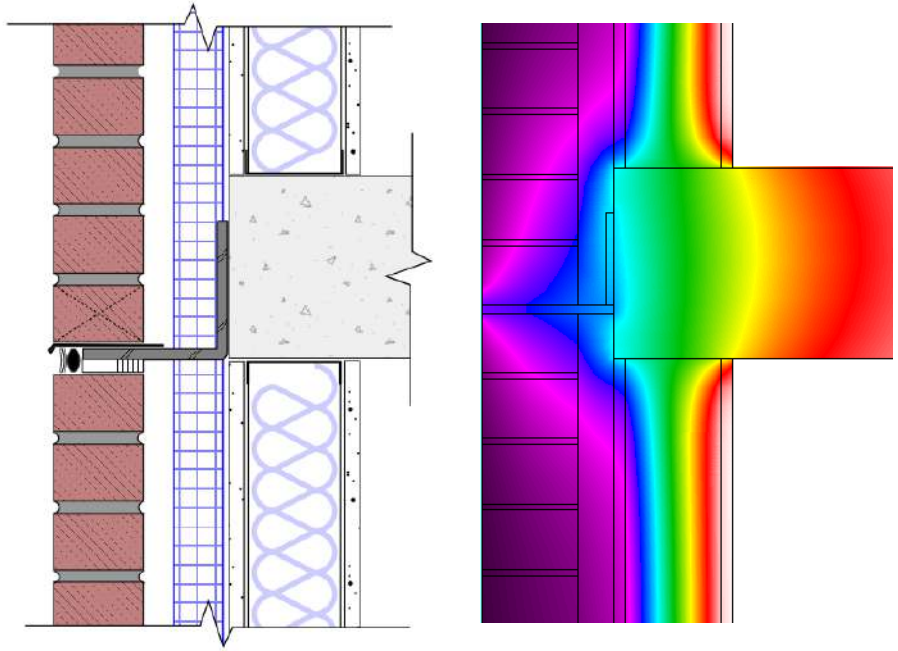
Why Do We Care?

- Effective R-Value Reduction
- Excess heat flow = wasted energy and expense
- Indoor thermal comfort (cold interior surfaces, drafts)
- Building durability (condensation, mold) and indoor air quality
- Building code advancement and energy performance certifications

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Examples of Thermal Bridges

Structural Steel Penetrations



- Brick relieving angle
- Steel supports at canopies/balconies and rooftop dunnage

Cladding Attachments

- Continuous hat channels or z-girts
- Repetitive discrete attachments (brick ties/stone anchors)

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Thermal Bridge Mitigation Strategies

Structural Steel Penetrations

- Thermal isolators/bearing pads/shims
- Discrete attachments/stand-offs

Cladding Attachments

- Thermally broken clips, ties, and anchors
- Non-metal structural composites
- Thoughtful configuration

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

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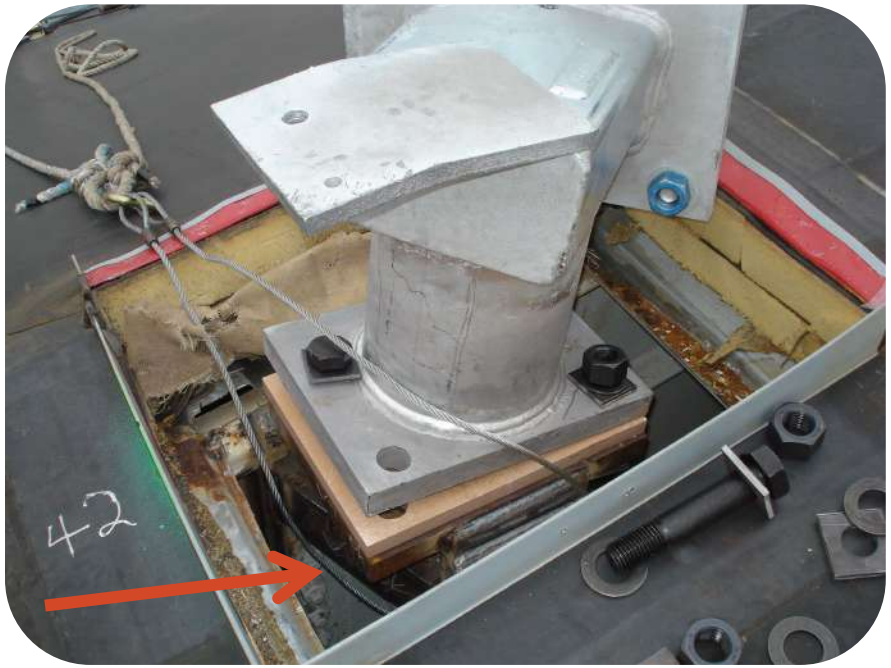


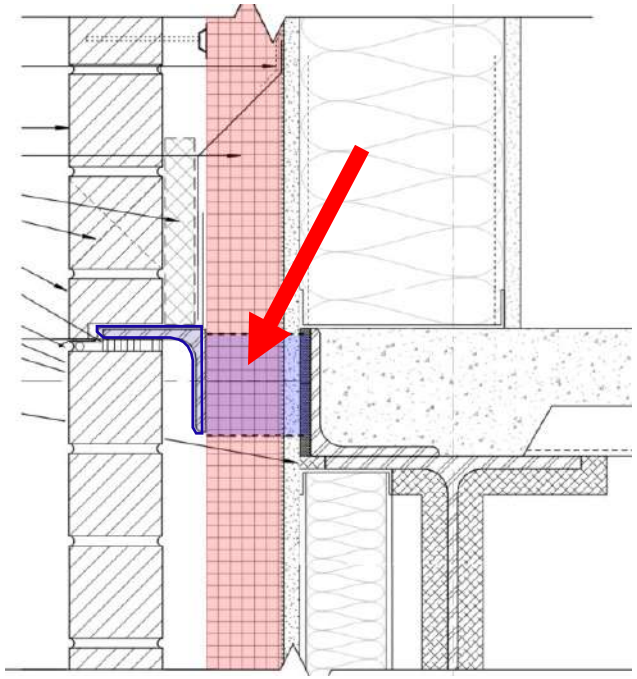
Thermal isolator pad at rooftop dunnage

Thermal isolator pad at steel canopy support

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Thermal Bridge Mitigation Strategies

Structural Steel Penetrations



Stand-off plate at relieving angle

Cladding Attachments

- Thermally broken clips, ties, and anchors
- Non-metal structural composites
- Thoughtful configuration

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

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Cladding Attachments

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- Non-metal structural composite attachments
- Thoughtful configuration of cladding attachments

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

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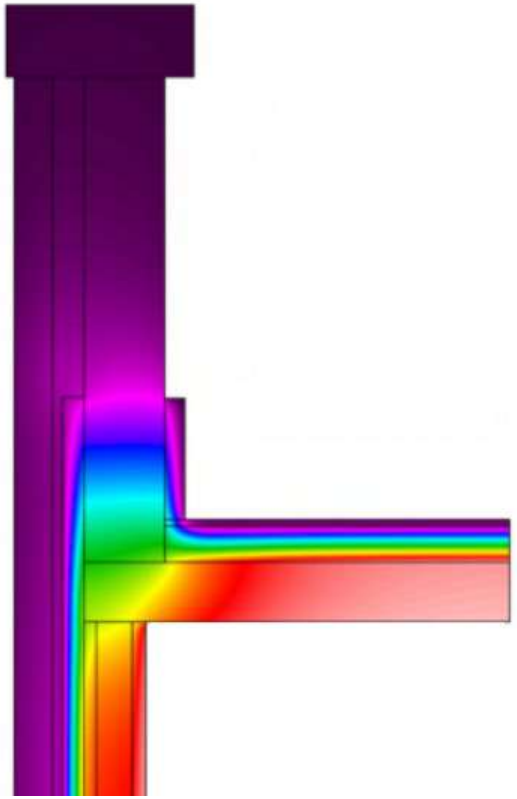
Cladding Attachments

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Examples of Thermal Bridges

Parapets



Balconies

Fenestration Frames

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Thermal Bridge Mitigation Strategies

Balconies & Parapets

- Structural thermal breaks
- Continuous insulation

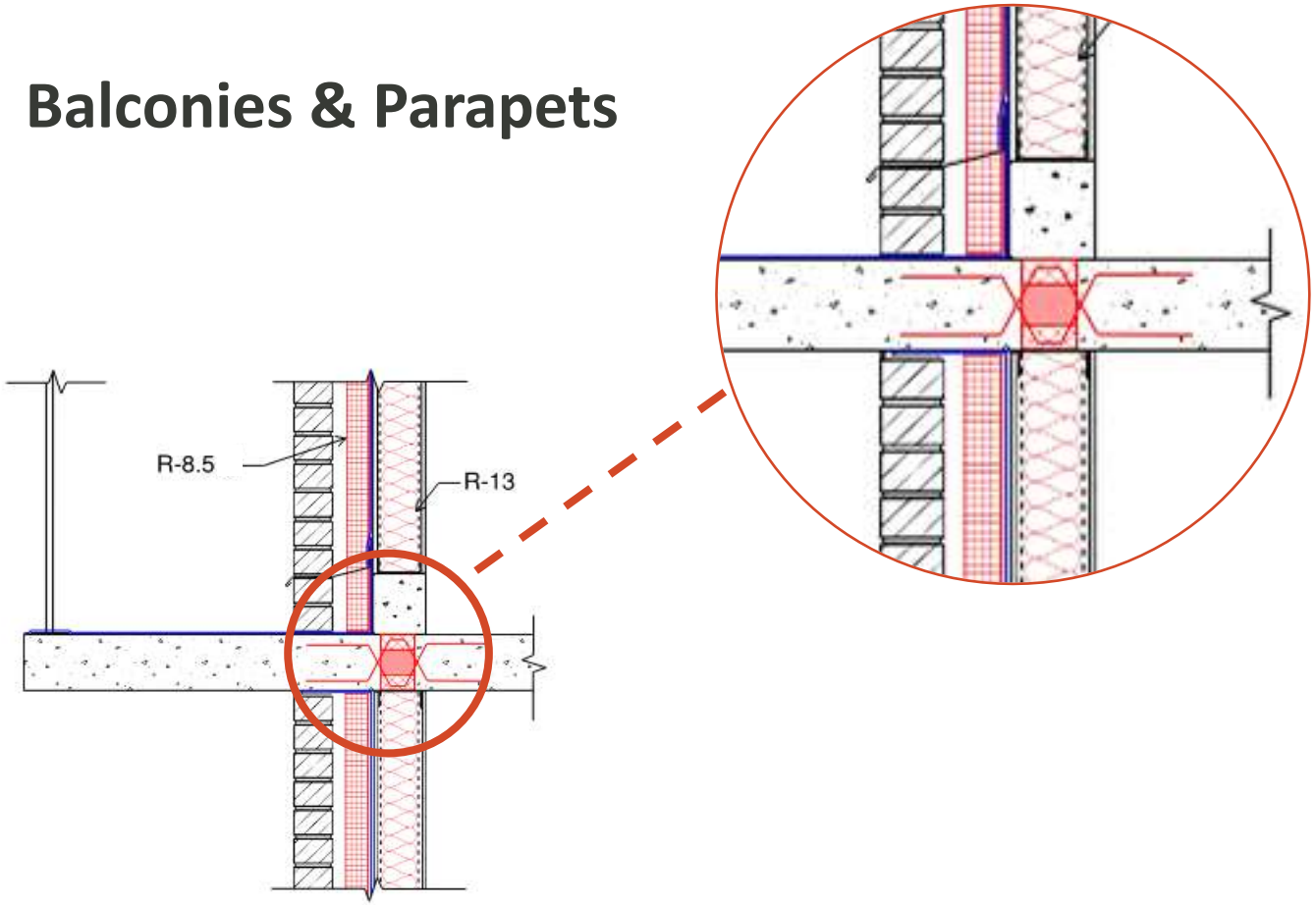
Window Frames

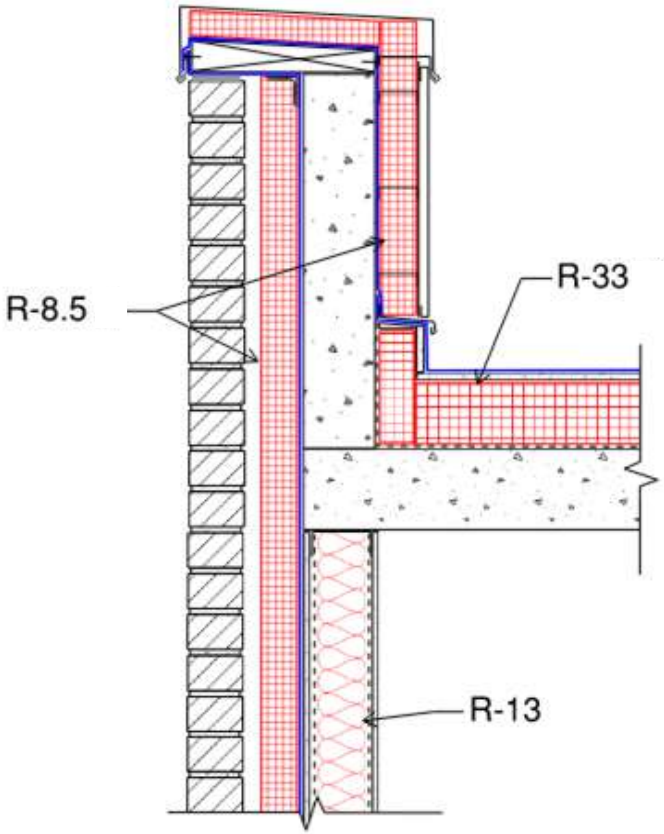
- Thermally broken or improved frames
- Alignment of exterior cavity insulation
- Continuous exterior cavity insulation

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Thermal Bridge Mitigation Strategies

Balconies & Parapets





BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

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CONTINUITY OF THERMAL ENVELOPE

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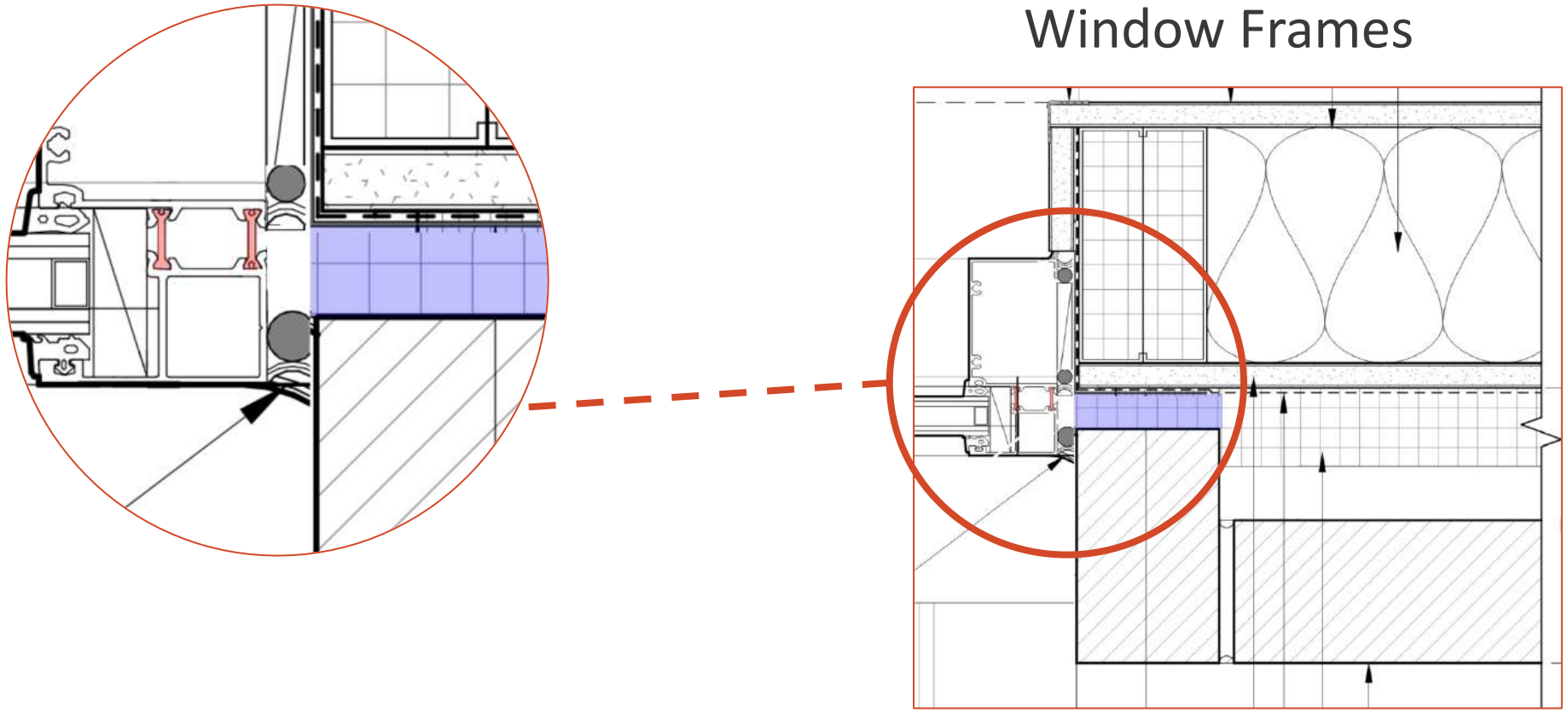

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Poll Question

True or False - The 2021 International Energy Conservation Code (IECC) requires designers to account for thermal bridges as part of complying with the prescriptive building enclosure requirements.

a. True

b. False

c. It depends on the type of thermal bridge

d. I'm not sure

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

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d. I'm not sure

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

Poll Question

- Exterior cavity insulation
- Stud wall framing
- Fenestration frames

2021 IECC

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope. (Ch. 2)

TABLE C402.1.4.2 EFFECTIVE *R*-VALUES FOR STEEL STUD WALL ASSEMBLIES (Ch. 4)

NOMINAL STUD DEPTH	SPACING OF FRAMING	CAVITY *R*-VALUE	CORRECTION FACTOR	EFFECTIVE *R*-VALUE[a][b]
(inches)	(inches)	(insulation)		
3½	16	13	0.45	5.85
		15	0.43	6.45

C402.4.3.4 Area-weighted *U*-factor. (Ch. 4)

An area-weighted average shall be permitted to satisfy the *U*-factor requirements for each fenestration product category listed in Table C402.4. Individual fenestration products from different fenestration product categories listed in Table C402.4 shall not be combined in calculating area-weighted average *U*-factor.

BUILDING SCIENCE PRINCIPLES IN ACTION:
CONTINUITY OF THERMAL ENVELOPE

What do the building codes say?

- 2021 International Energy Conservation Code
- 2022 Denver Energy Code

Specific thermal bridge requirements, more stringent, more defined

BUILDING SCIENCE PRINCIPLES IN ACTION

DOES THIS ASSEMBLY NEED A VAPOR RETARDER?

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

What is it?

HYGRO + **THERMAL**

Why do we care?

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Vapor Diffusion (Vapor Drive)

- The direction of vapor diffusion moves from higher vapor pressure to lower vapor pressure:
  - Exterior Conditions: 30°F, 70% RH
  - Interior Conditions: 70°F, 30% RH
  - P_{sat} for 30°F = 0.18 in. Hg
  - P_{vap} for 30°F = P_{sat} x RH = 0.18 in. Hg x 0.70
  - P_{vap} for 30°F = 0.13 in. Hg (0.06 psi)
  - P_{sat} for 70°F = 0.74 in. Hg
  - P_{vap} for 70°F = P_{sat} x RH = 0.74 in. Hg x 0.30
  - P_{vap} for 70°F = 0.22 in. Hg (0.11 psi)

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

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  - P_{sat} for 70°F = 0.74 in. Hg
  - P_{vap} for 70°F = P_{sat} x RH = 0.74 in. Hg x 0.30
  - P_{vap} for 70°F = 0.22 in. Hg (0.11 psi)

Vapor diffusion typically moves:

- From interior to exterior in cold weather
- From exterior to interior in warm weather (particularly if humid)

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

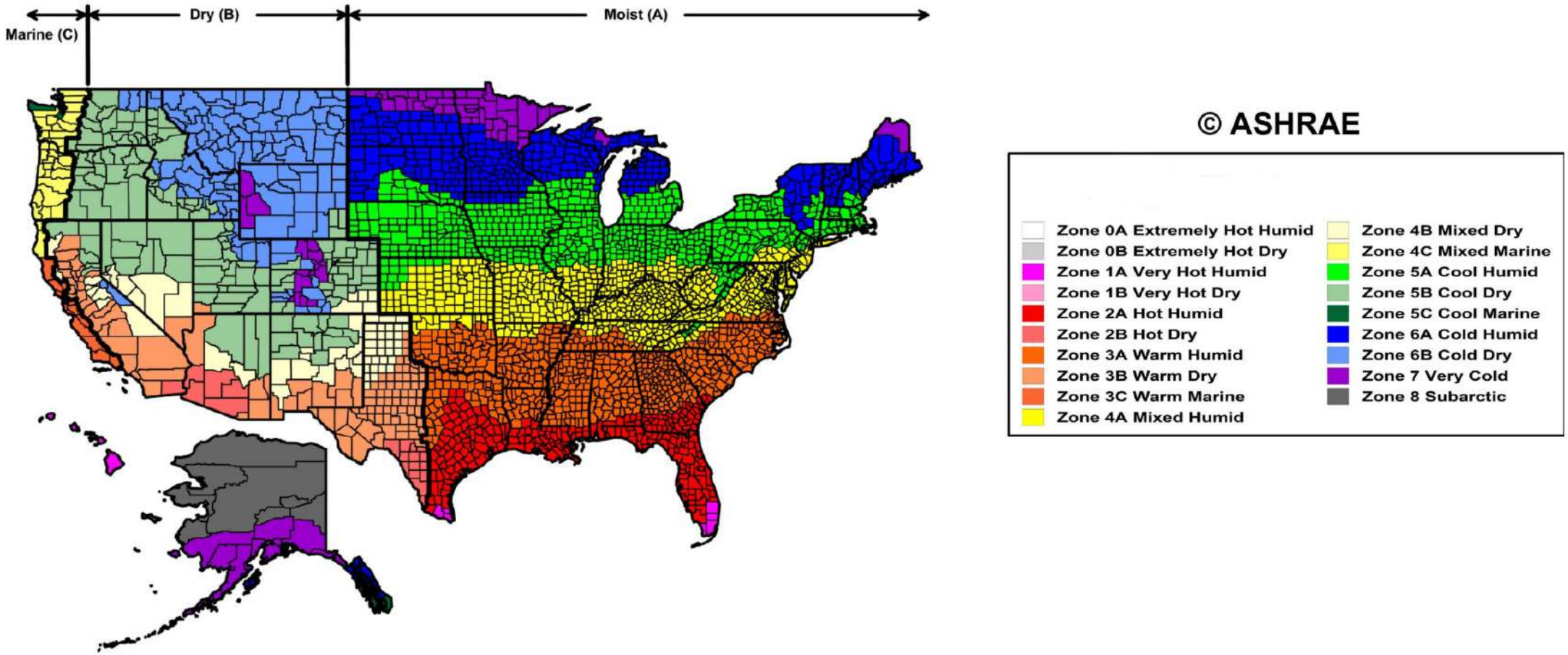

Figure Annex1-1 ASHRAE Standard 169-2013, Figure B-1: Climate zones for United States counties.

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Roof Vapor Retarder (Prescriptive)

1202.3 Unvented attic and unvented enclosed rafter assemblies. Unvented *attics* and unvented enclosed roof framing assemblies created by ceilings applied directly to the underside of the roof framing members/rafters and the structural roof sheathing at the top of the roof framing members shall be permitted where all of the following conditions are met:

2. No interior Class I vapor retarders are installed on the ceiling side (*attic* floor) of the unvented *attic* assembly or on the ceiling side of the unvented enclosed roof framing assembly.

4. In Climate Zones 5, 6, 7 and 8, any *air-impermeable insulation* shall be a Class II vapor retarder or shall have a Class II vapor retarder coating or covering in direct contact with the underside of the insulation.

   5.1. Item 5.1.1, 5.1.2, 5.1.3 or 5.1.4 shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.

5.1.2. Where air-permeable insulation is provided inside the building thermal envelope, it shall be installed in accordance with Item 5.1.1. In addition to the air-permeable insulation installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing in accordance with the *R*-values in Table 1202.3 for condensation control.

5.1.3. Where both air-impermeable and air-permeable insulation are provided, the *air-impermeable insulation* shall be applied in direct contact with the underside of the structural roof sheathing in accordance with Item 5.1.1 and shall be in accordance with the R-values in Table 1202.3 for condensation control. The *air-permeable insulation* shall be installed directly under the *air-impermeable insulation*.

IBC 2021, Section 1202.3

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE
Roof Vapor Retarder (Prescriptive)

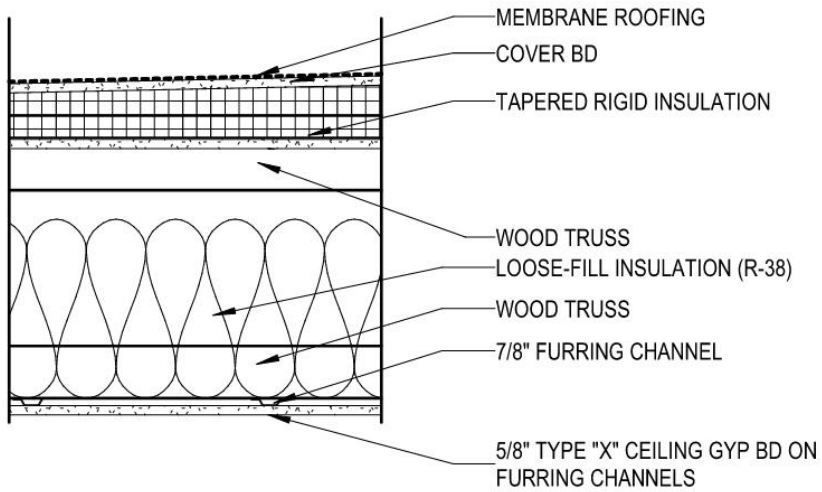

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TABLE 1202.3
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM *R*-VALUE OF AIR-IMPERMEABLE INSULATION[a]
2B and 3B tile roof only	0 (none required)
1, 2A, 2B, 3A, 3B, 3C	R-5
4C	R-10
4A, 4B	R-15
5	R-20
6	R-25
7	R-30
8	R-35

IBC 2021, Table 1202.3

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

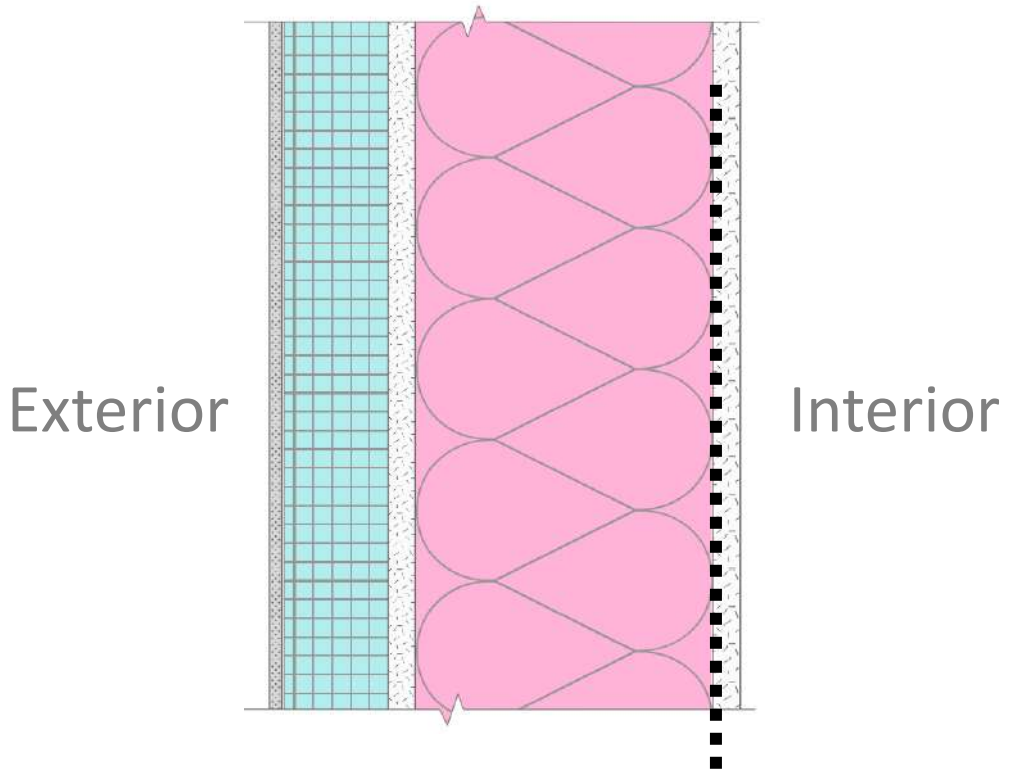
Vapor Barrier Placement per IBC 2021

TABLE 1404.3(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	I	II	III[a]
1, 2	Not permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not permitted	Permitted	Permitted
Marine 4, 5, 6, 7, 8	Permitted	Permitted	See Table 1404.3(3)

- Class I: 0.1 perm or less — Impermeable
- Class II: 0.1<perm≤1.0 perm — Semi-Impermeable
- Class III: 1.0<perm≤10 perm — Semi-permeable

§1404.3

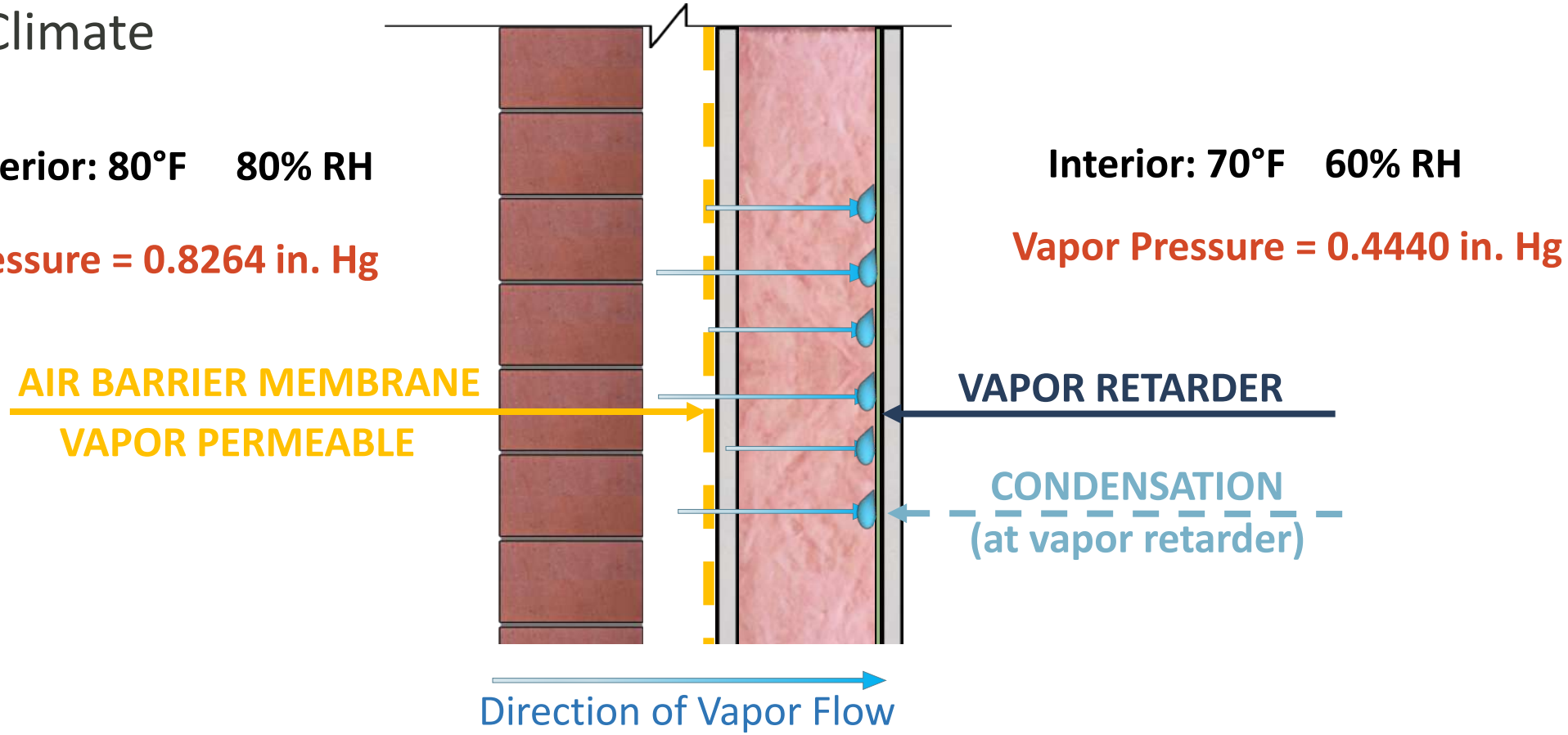


1404.3 Vapor retarders. Vapor retarder materials shall be classified in accordance with Table 1404.3(1). A vapor retarder shall be provided on the interior side of frame walls in accordance with Tables 1404.3(2) and 1404.3(3), ...

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wall Vapor Retarder (Prescriptive)

- Warm Climate



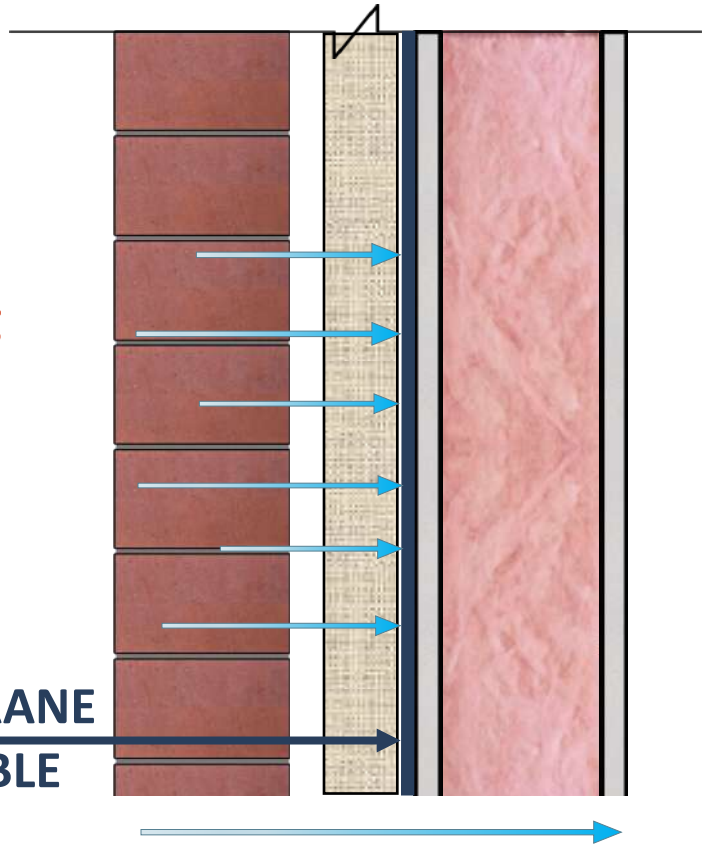
BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wall Vapor Retarder (Prescriptive)

- Warm Climate

Exterior: 80°F 80% RH

Vapor Pressure = 0.8264 in. Hg



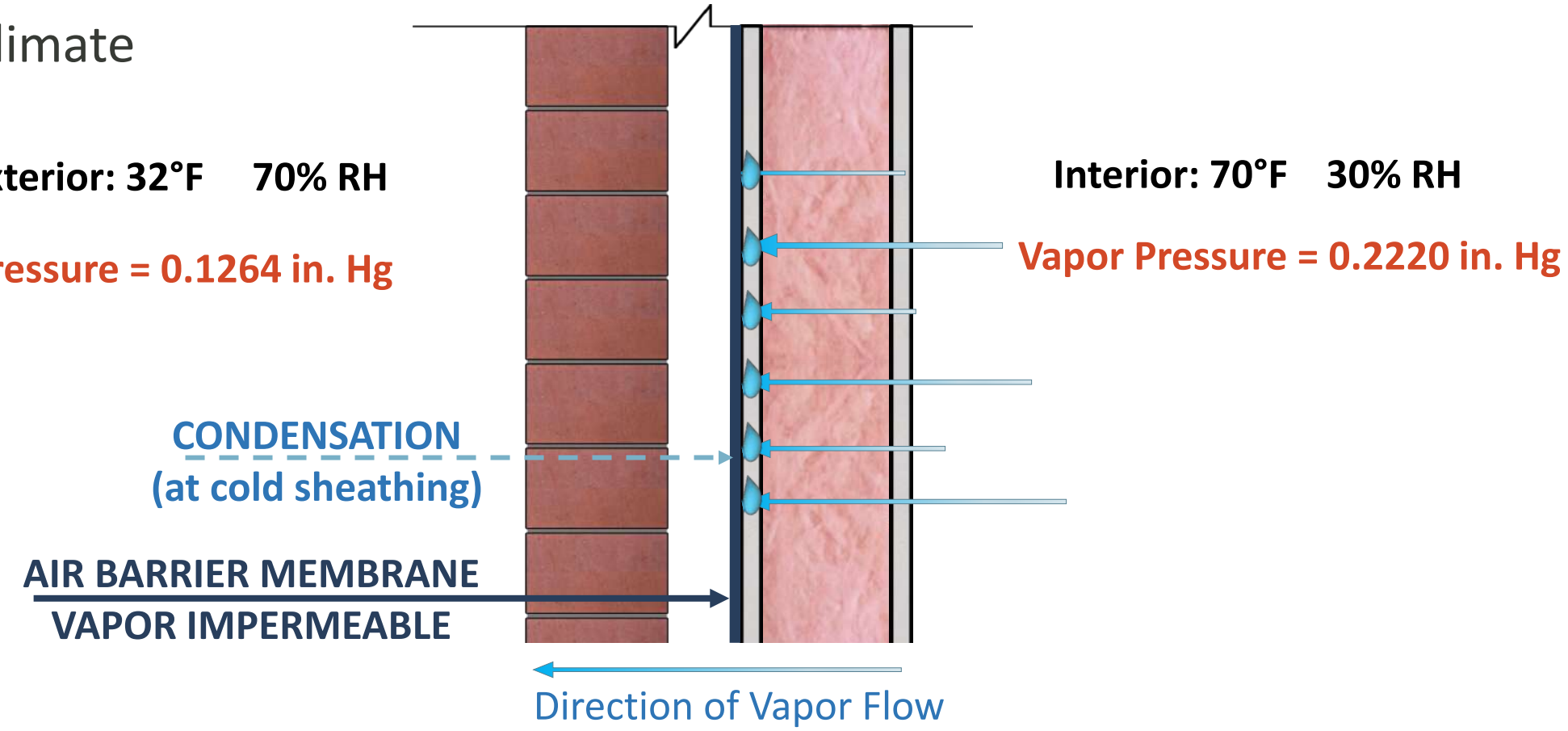
Interior: 70°F 60% RH

Vapor Pressure = 0.4440 in. Hg

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wall Vapor Retarder (Prescriptive)

- Cold Climate



BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wall Vapor Retarder (Prescriptive)

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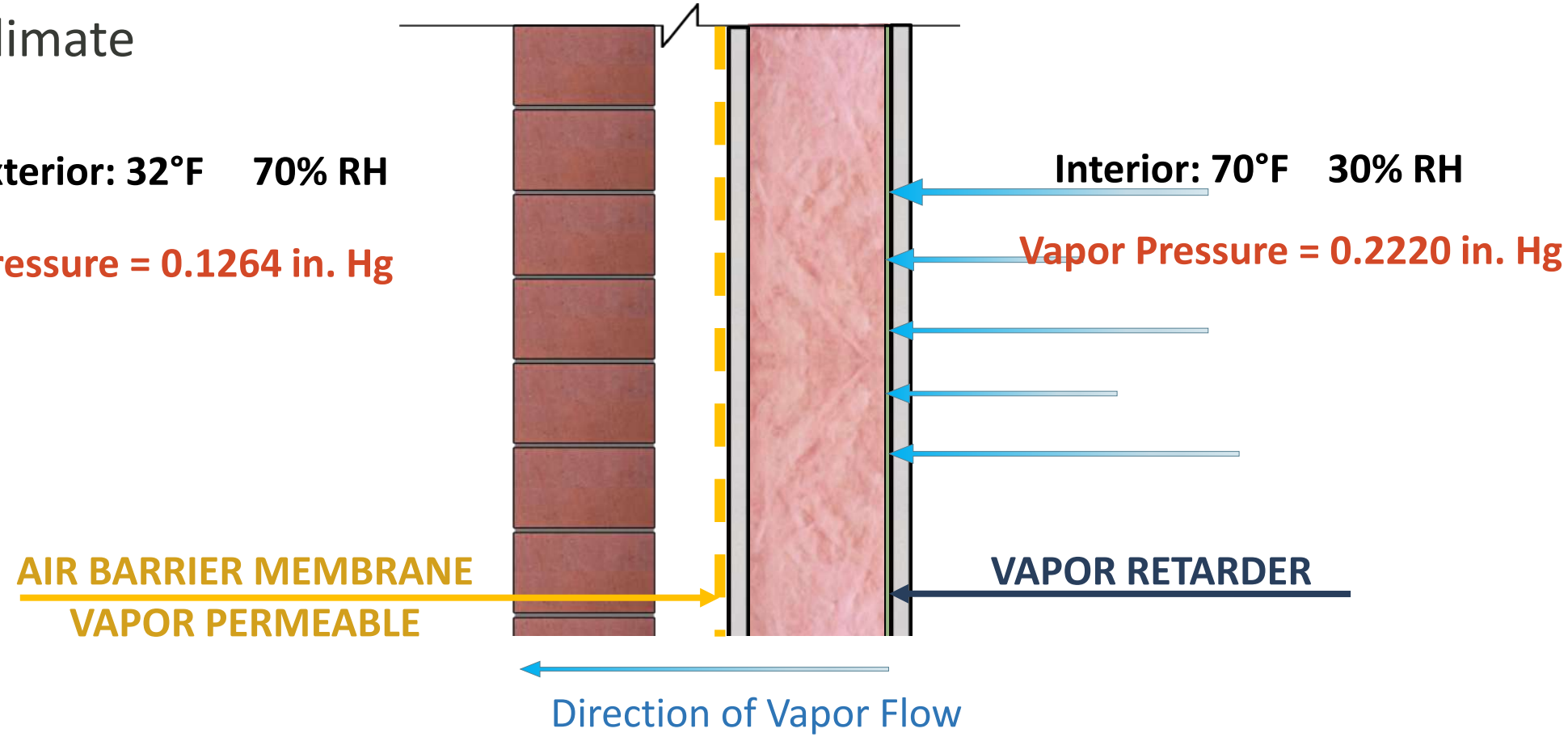
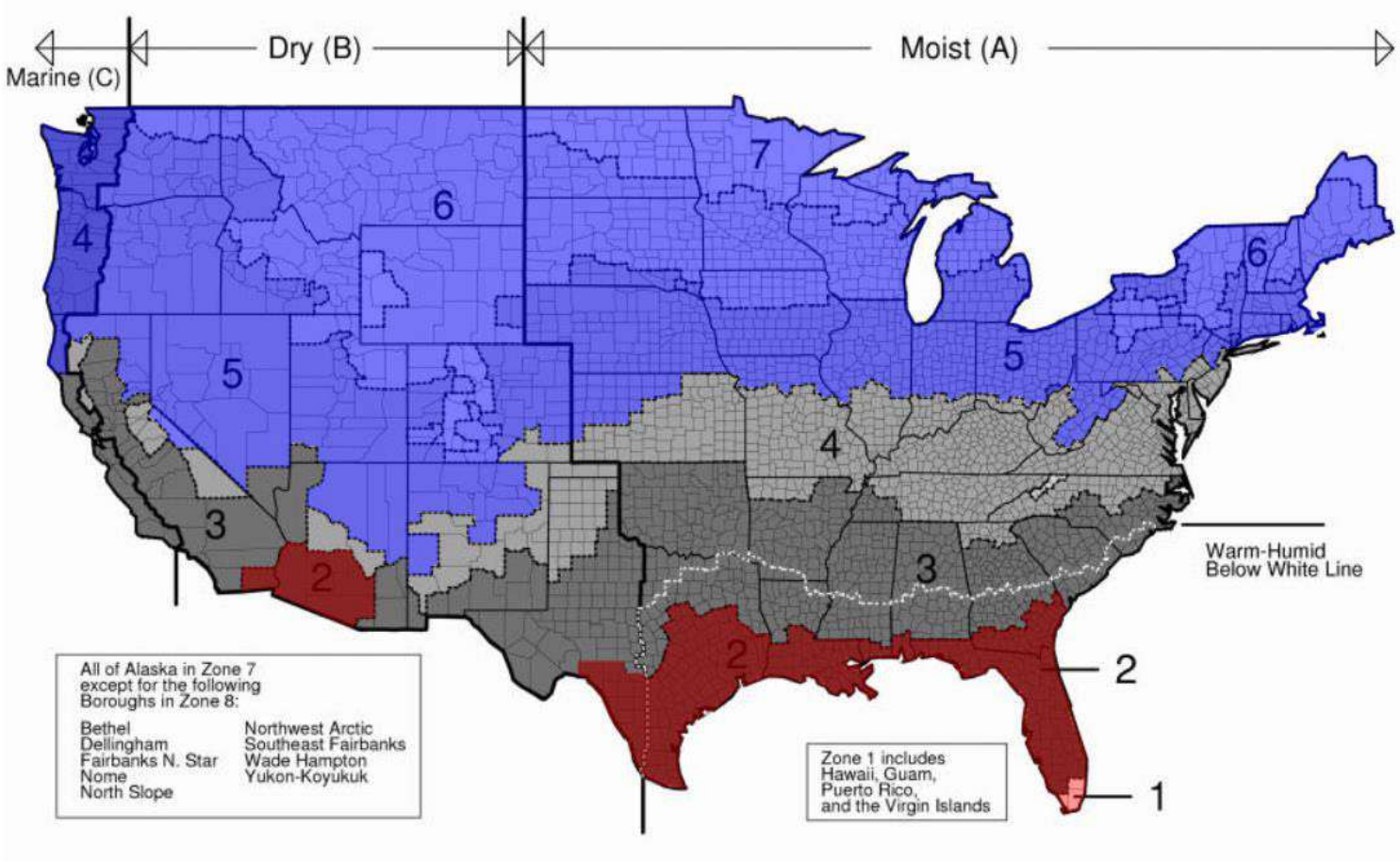


BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

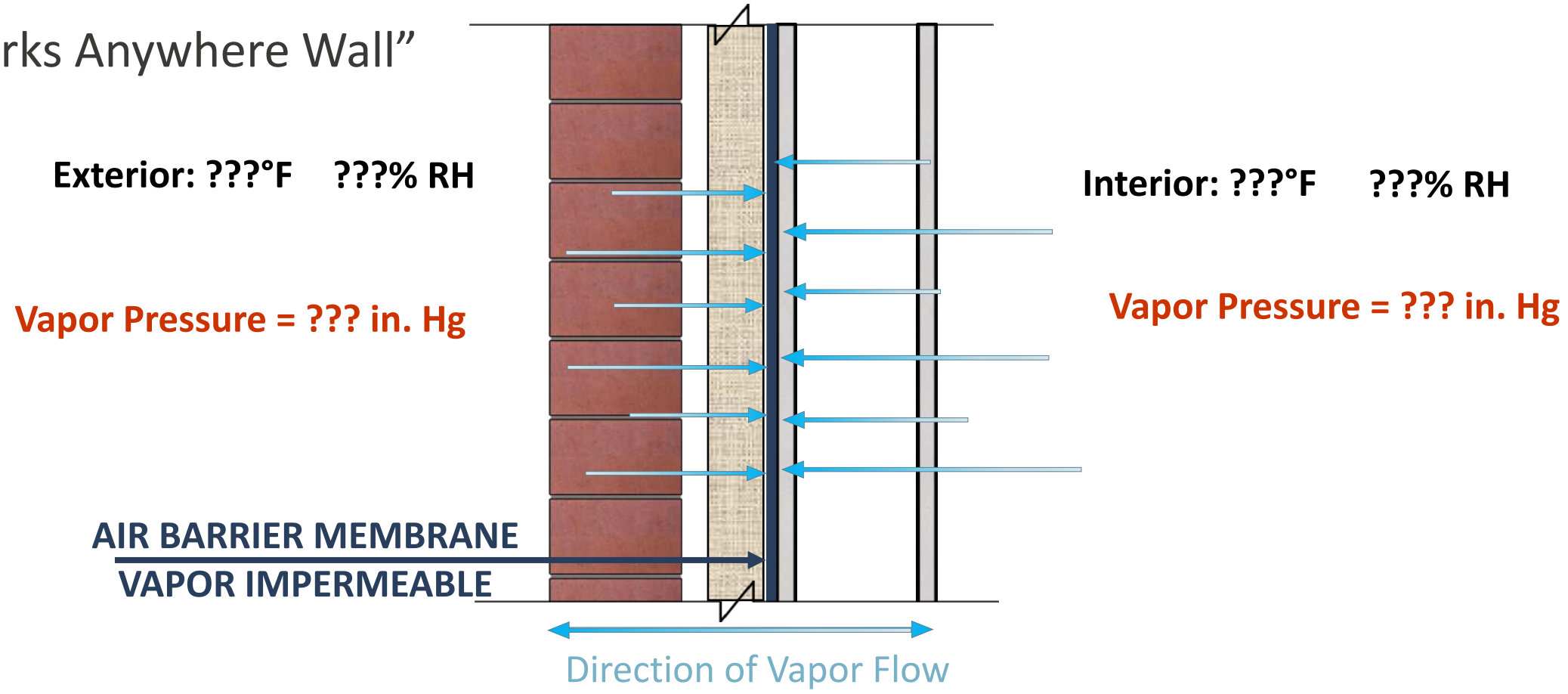
Wall Vapor Retarder (Prescriptive)



BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Wall Vapor Retarder

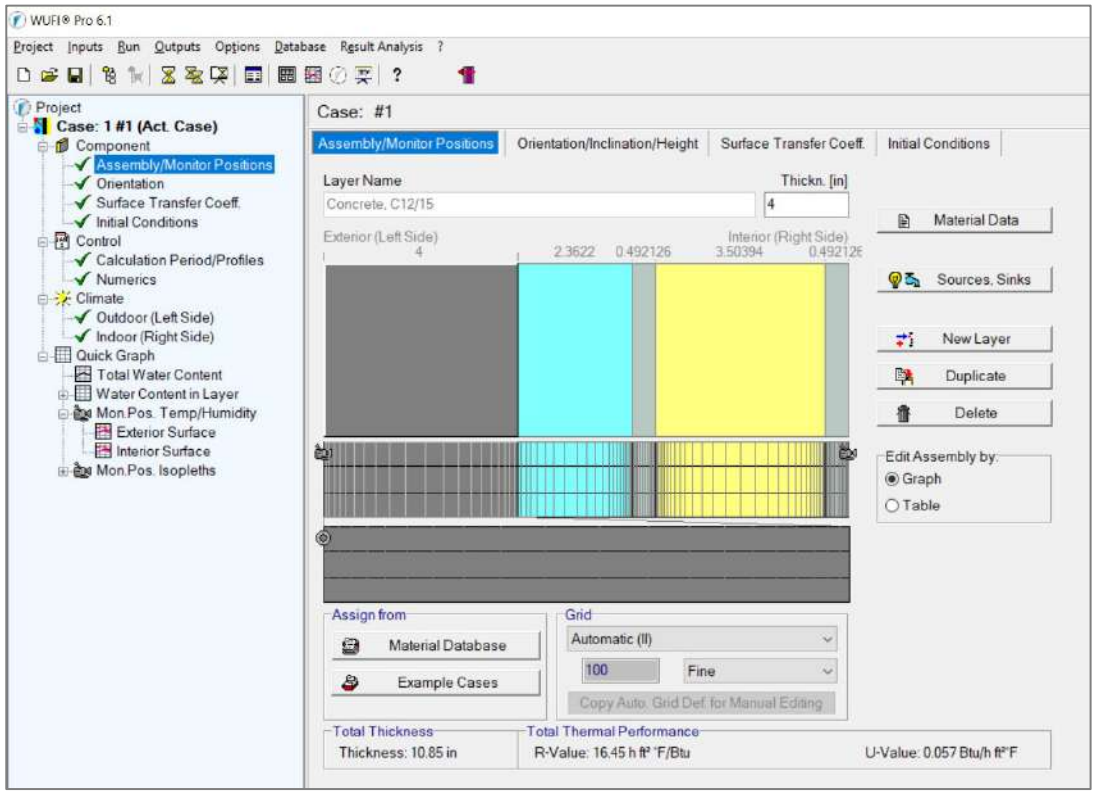
- "Works Anywhere Wall"



BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

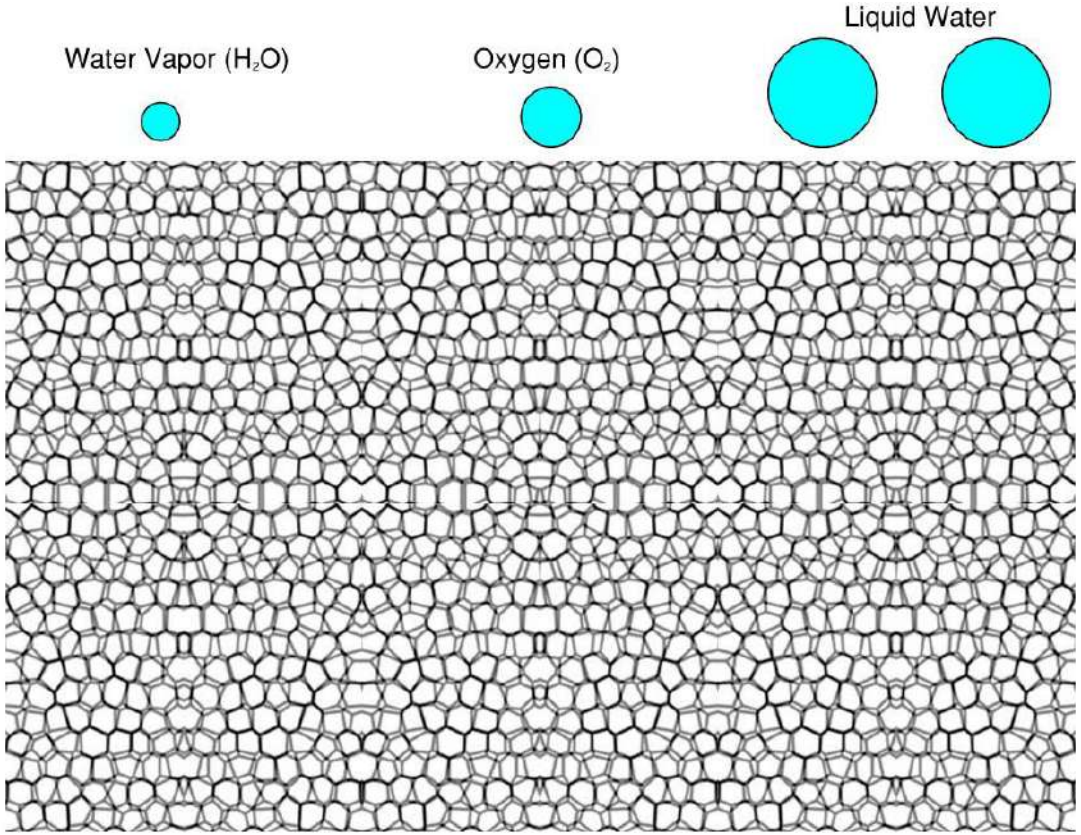
Hygrothermal Analysis

1404.3 Vapor retarders. Vapor retarder materials shall be classified in accordance with Table 1404.3(1). A vapor retarder shall be provided on the interior side of frame walls in accordance with Tables 1404.3(2) and 1404.3(3), or an approved design using accepted engineering practice for hygrothermal analysis. The appropriate climate zone shall be selected in accordance with Chapter 3 of the International Energy Conservation Code.



BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Additional Considerations for Hygrothermal Performance

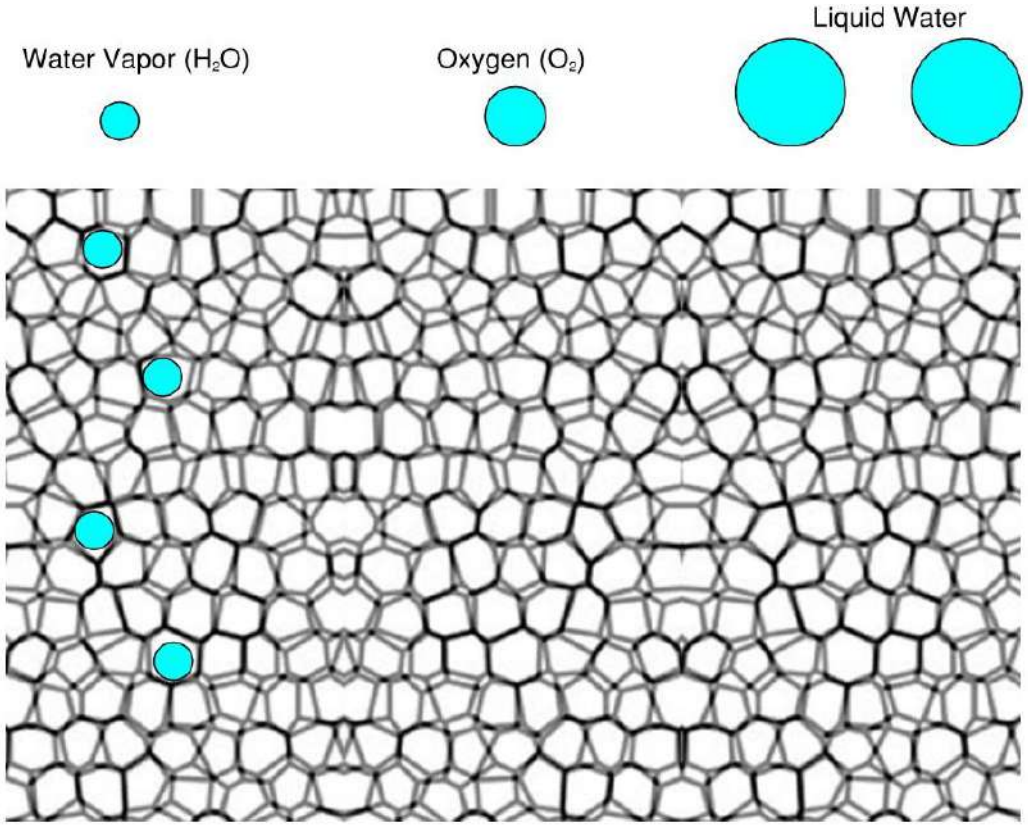


Vapor Impermeable Air & Water Barrier

- Permeability of each assembly layer
  - Closed cell insulations
  - Impermeable facers
  - Water-resistive barrier

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Additional Considerations for Hygrothermal Performance



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BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

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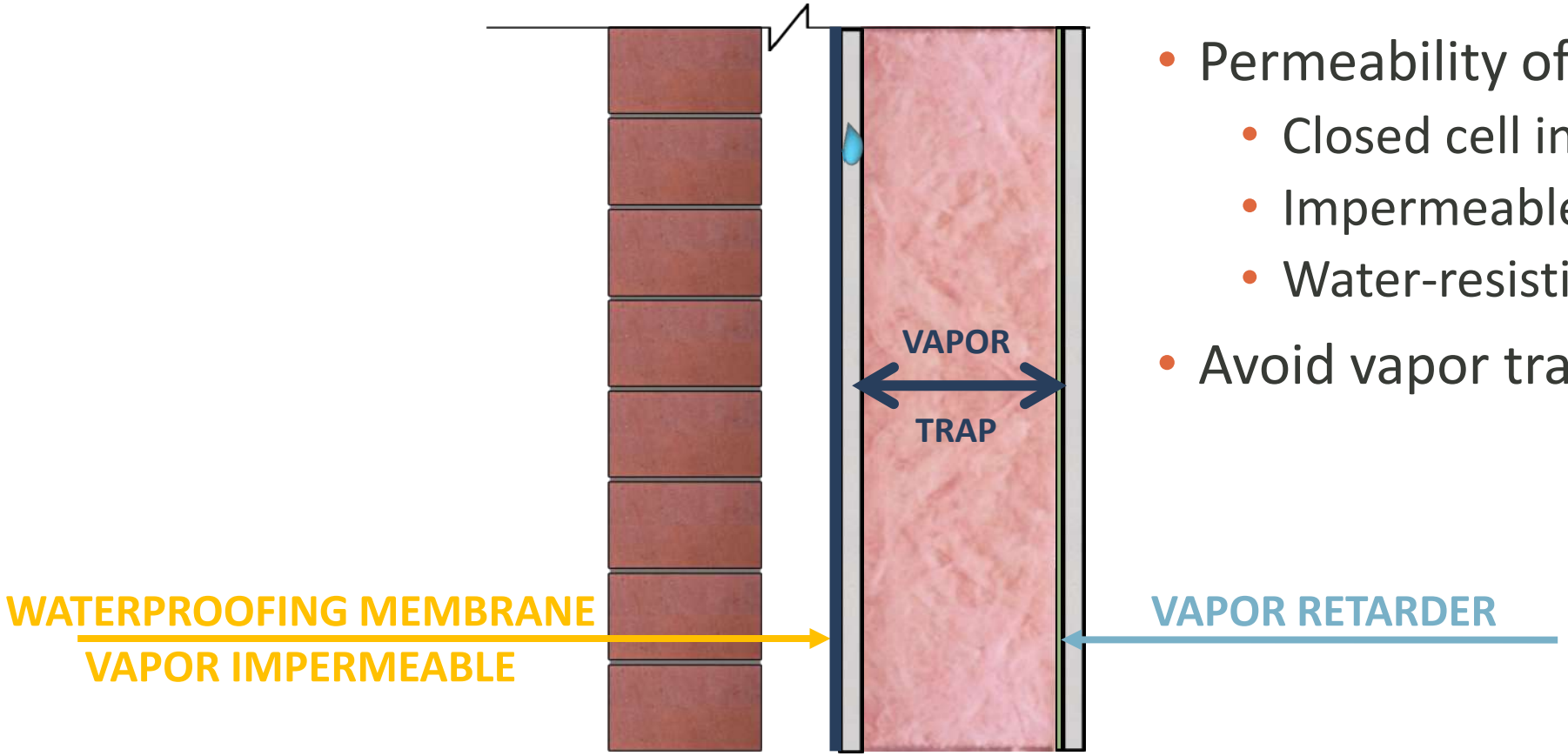


- Permeability of each assembly layer
  - Closed cell insulations
  - Impermeable facers
  - Water-resistive barrier
- Avoid vapor traps

BUILDING SCIENCE PRINCIPLES IN ACTION:
HYGROTHERMAL PERFORMANCE

Additional Considerations for Hygrothermal Performance

- Permeability of each assembly layer
  - Closed cell insulations
  - Impermeable facers
  - Water-resistive barrier
- Avoid vapor traps
- Unanticipated additions to the assembly

BUILDING SCIENCE PRINCIPLES IN ACTION

WHEN IS CONDENSATION AN ISSUE?

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Key Drivers

- Cold Surface Temperatures
- High RH

What to Focus On

- Wintertime conditions
- Spaces with high interior RH
- Other case-by-case conditions

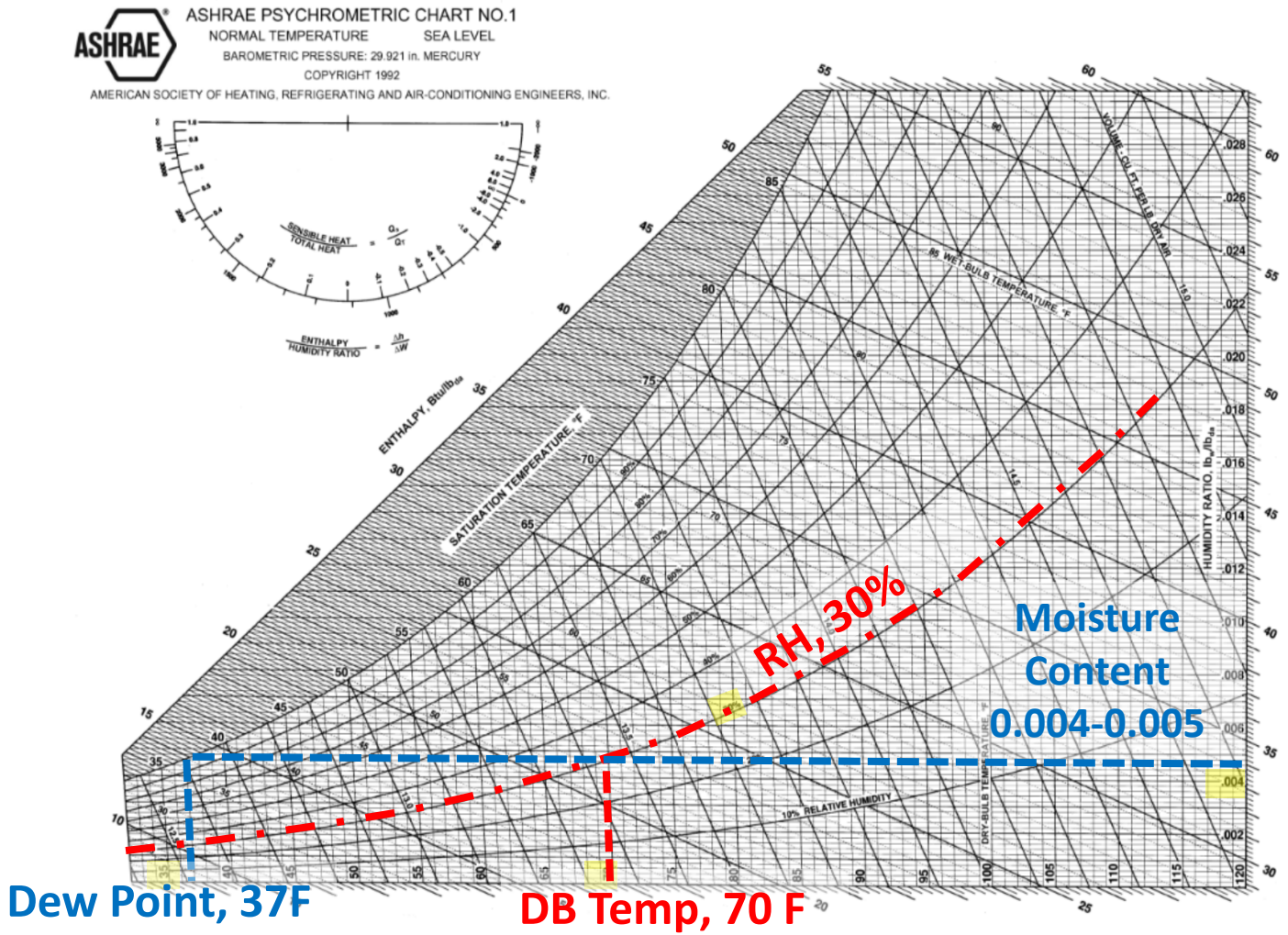


Image credit – ASHRAE Handbook of Fundamentals, 2017

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Surface Condensation

Ice on window frame

Condensation on window glass

Condensation on mechanical duct

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Why Do We Care?

Image credit – CMHC

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Why Do We Care?

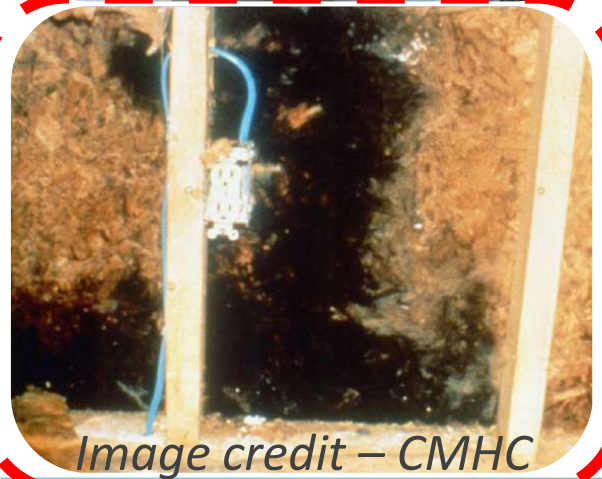
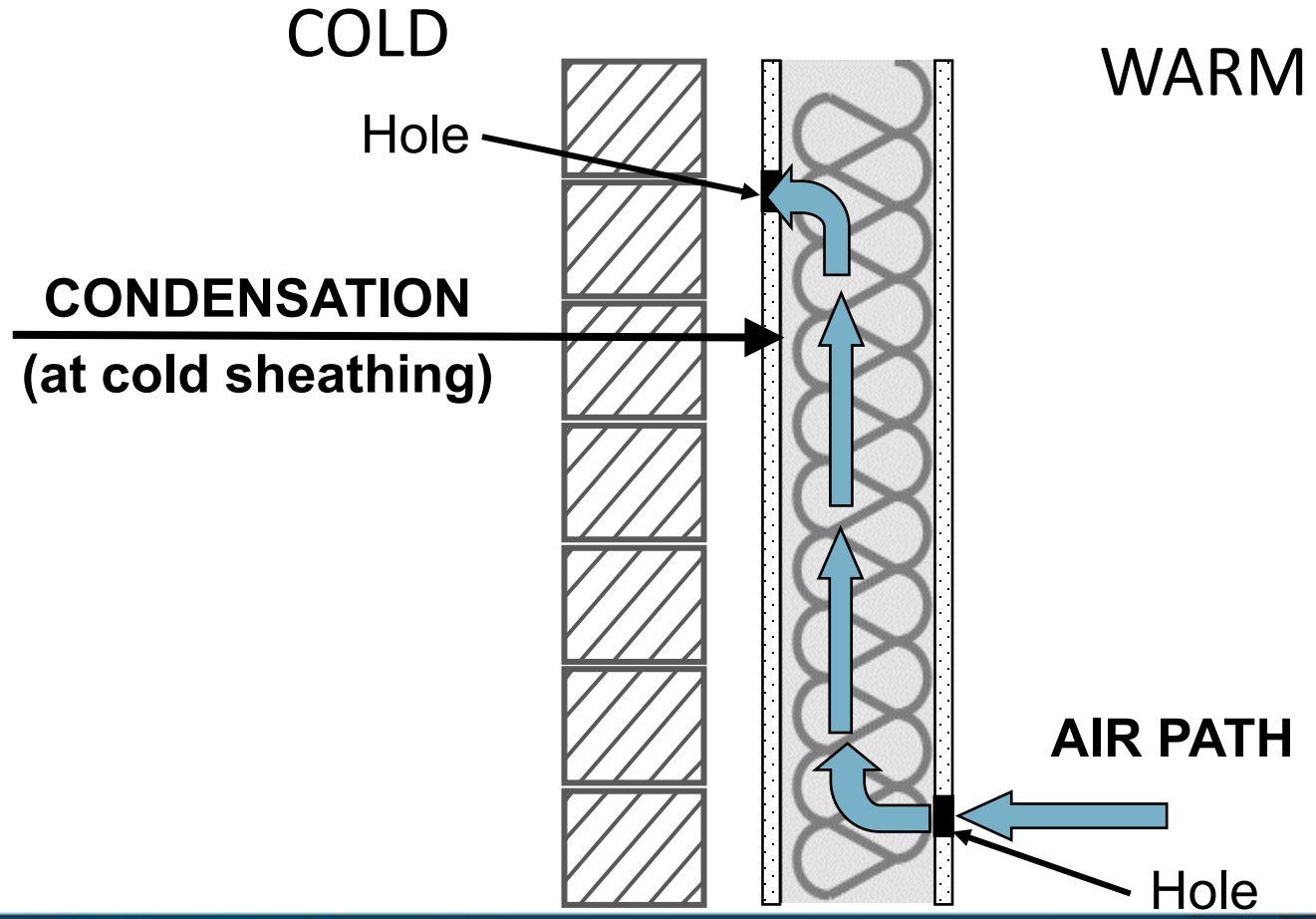
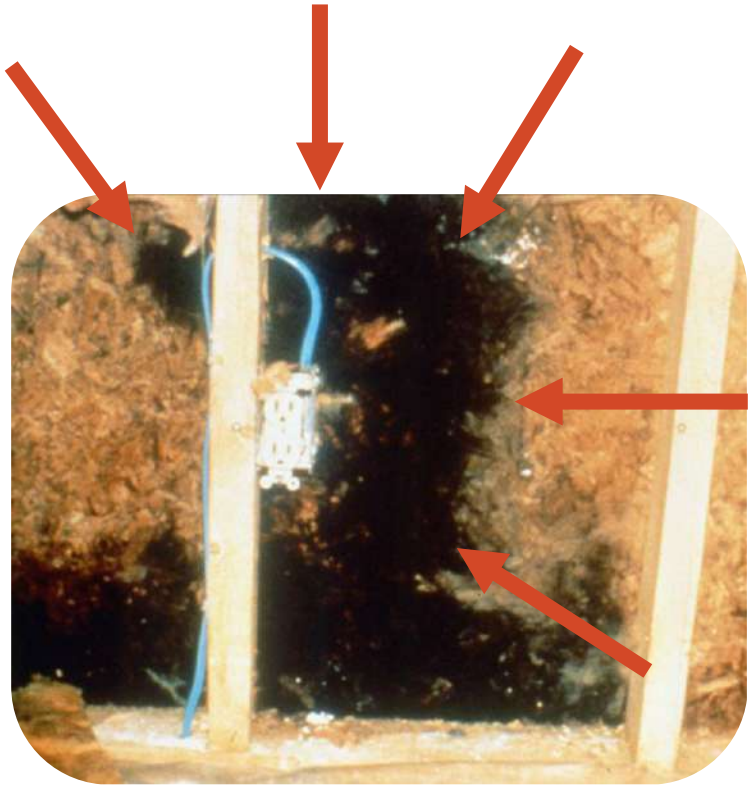


Image credit – CMHC

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Air Leakage





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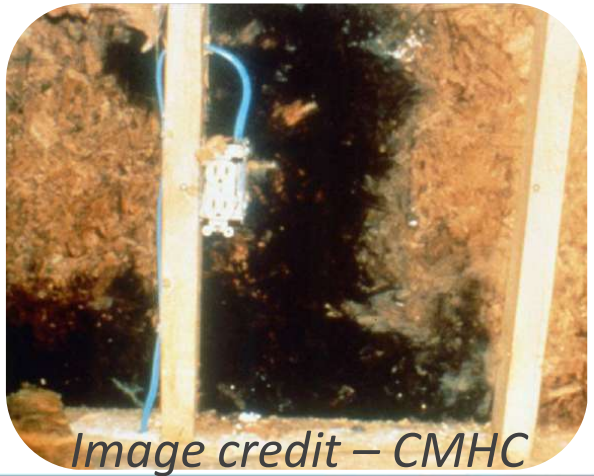
BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Why Do We Care?



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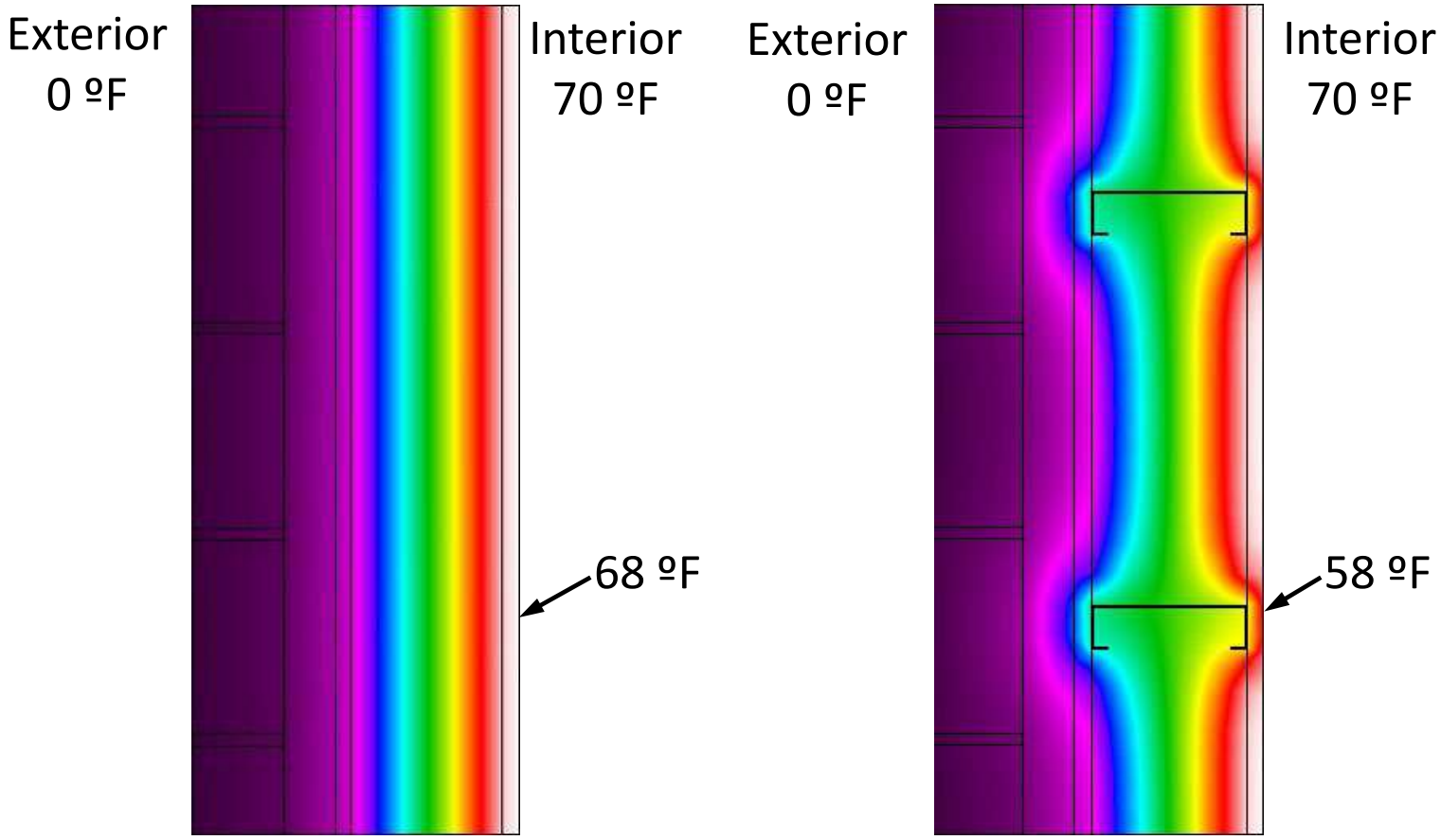
BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Why Do We Care?



Ghosting

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Surface Condensation Potential Analysis: *What Information do We Need?*

B

Exterior Design Conditions

(temp, wind speed)

THERM
WINDOWS & DAYLIGHTING
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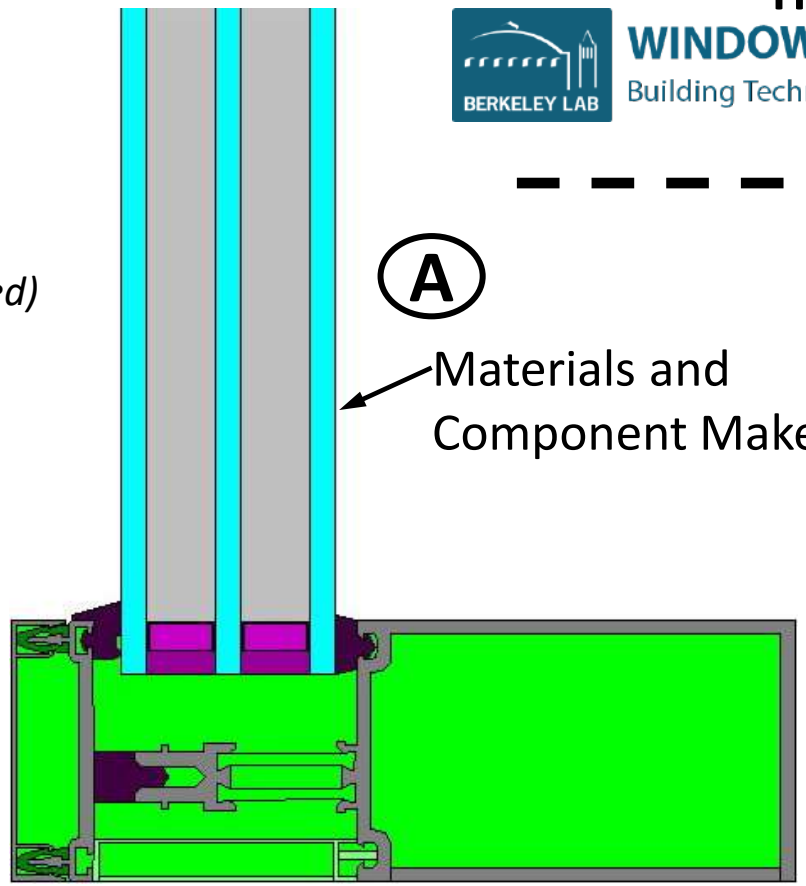
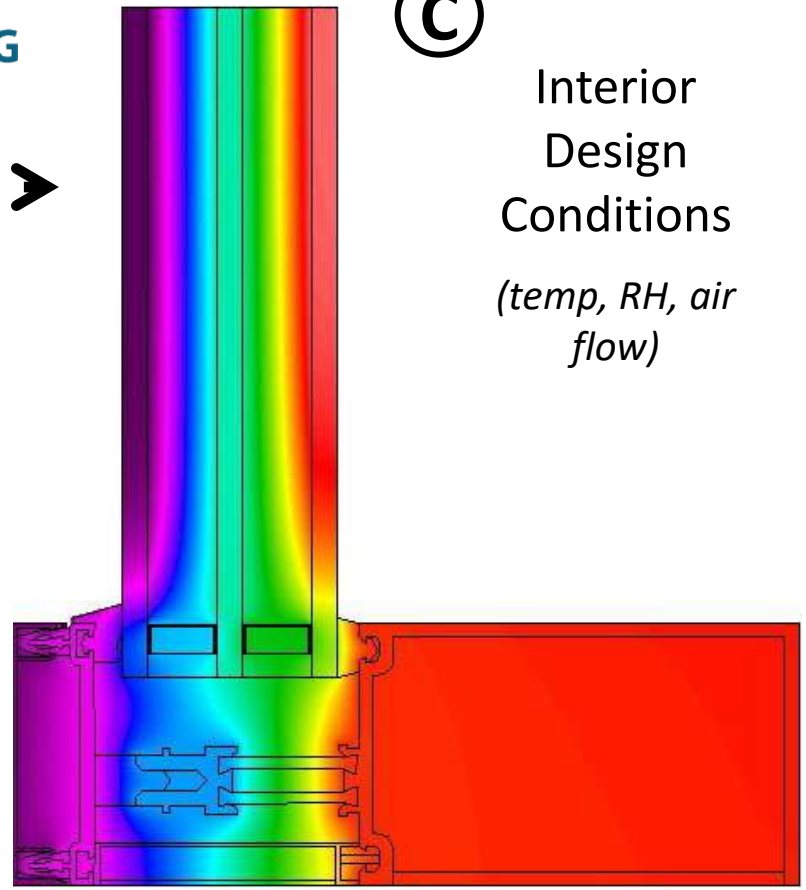
A

Materials and Component Make-up





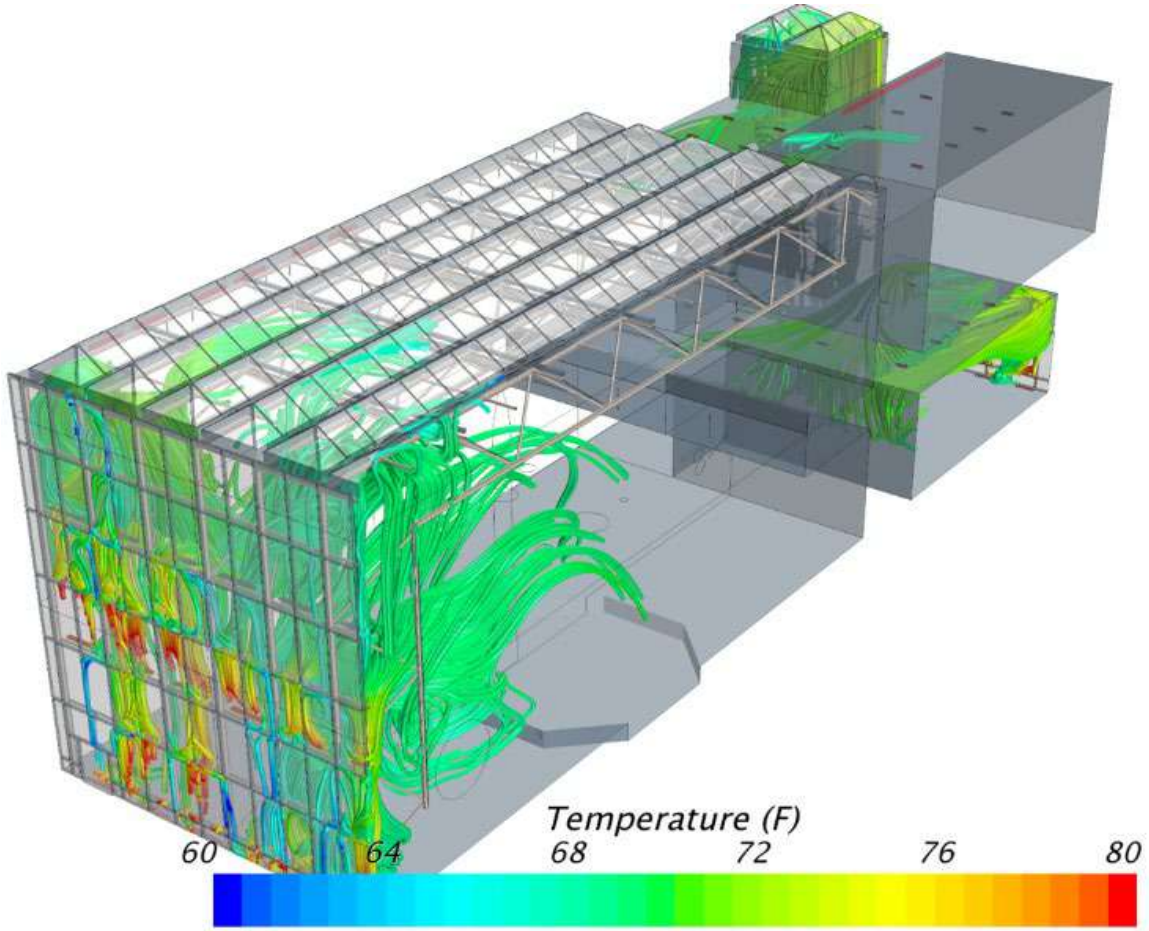
C

Interior Design Conditions

(temp, RH, air flow)

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Interdependency with Mechanical Design



BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Poll Question

Pick One - What conditions could result in interior surface condensation?

a. When it's cold outside

b. When it's cold inside

c. When a space is actively humidified

d. When the interior space ventilation is poor

e. All of the above

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

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BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

What Do We Do About It?

- Cold Surface Temperatures
- High RH

  - Detail systems with better thermal performance
  - Apply dedicated heat (warm air washing/heat trace)

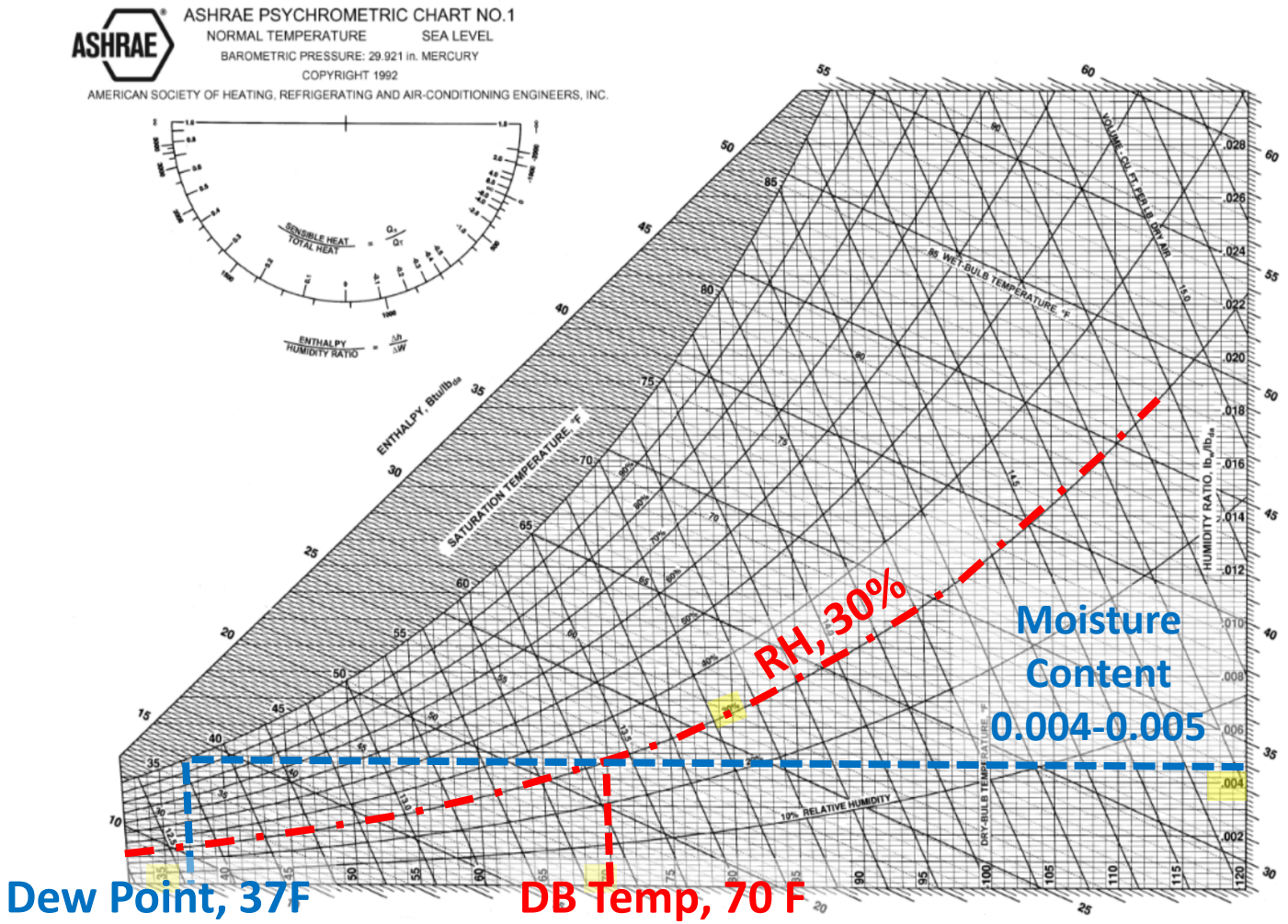
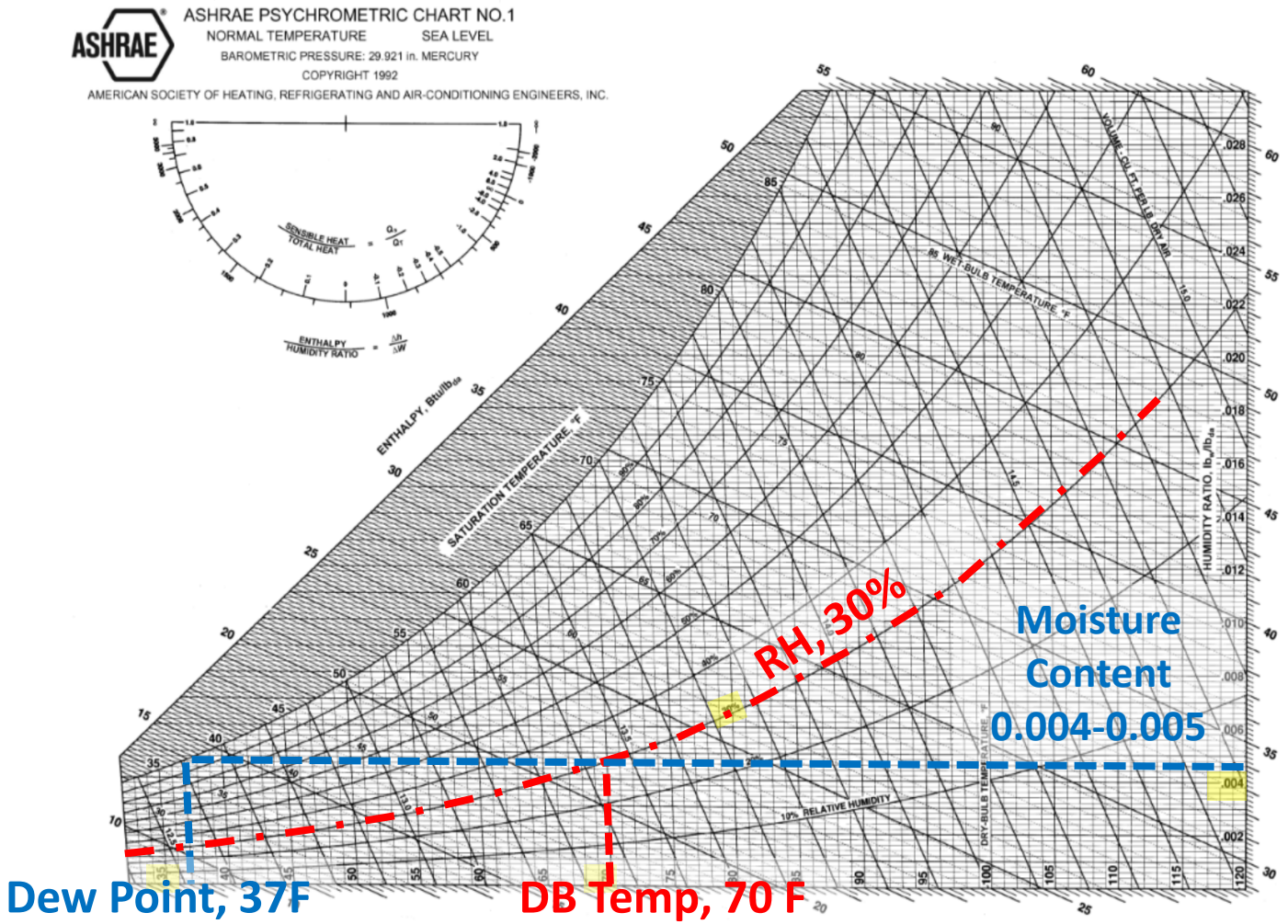


Image credit – ASHRAE Handbook of Fundamentals, 2017

BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

What Do We Do About It?

- Cold Surface Temperatures
- High RH
  - Provide ventilation
  - Avoid stagnant air
  - Provide dehumidification if required



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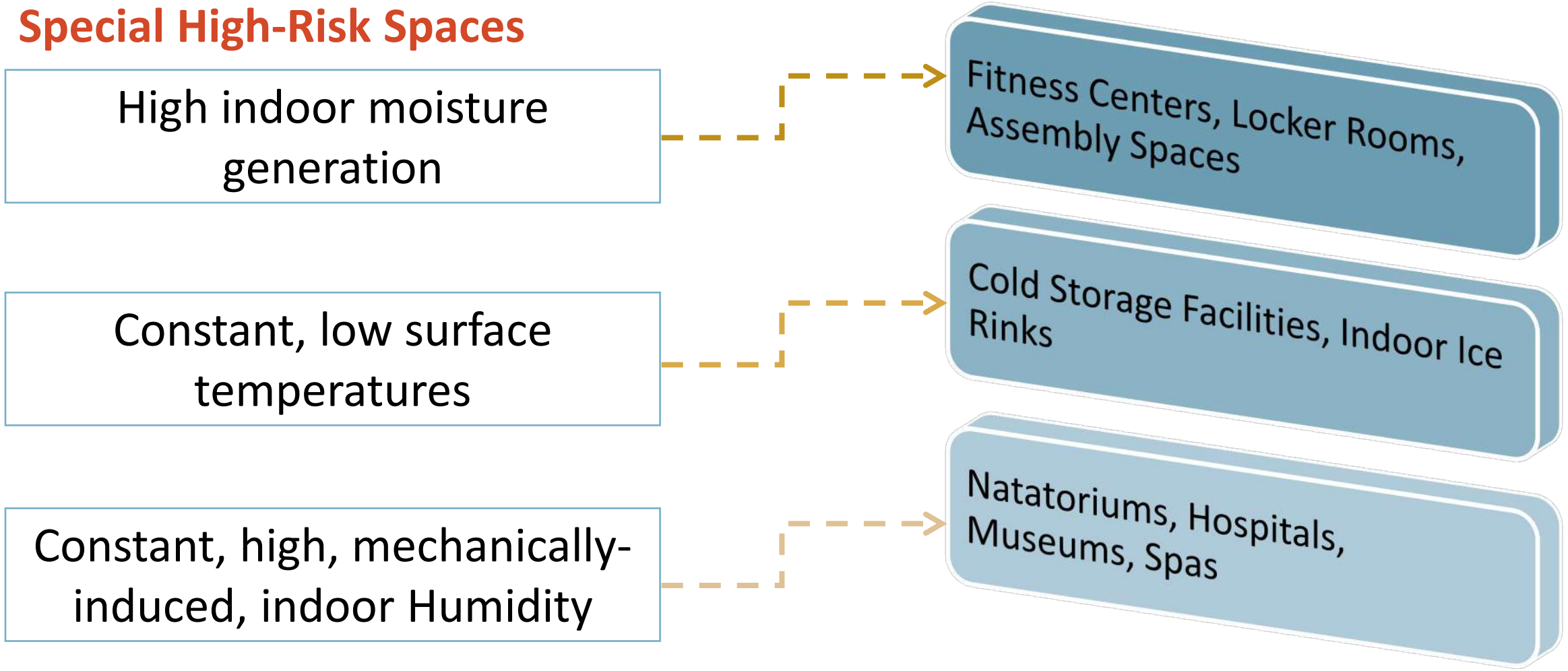
BUILDING SCIENCE PRINCIPLES IN ACTION:
INTERIOR SURFACE CONDENSATION

Special High-Risk Spaces



Takeaways

TAKEAWAYS

- The building enclosure is an **assembly of materials**, and some materials perform **multiple functions at once**
- Use of materials with multiple functions may result in **unintended** consequences
- Building science problems and solutions often deal with **more than one** of the four barriers, and **configuration is key**
- Building science solutions are **not one-size-fits-all**
- Changes to an established design can **inadvertently** create building science problems

QUESTIONS?

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conference