PACE
BUILDING ENVELOPE REPRESENTATIVES

Helping You Connect the Dots:

- Exterior Envelope Design (BOD) Packages
- Dew Point & Hygrothermal Analysis
- Fenestration Wind Loading Analysis
- Exterior Envelope Reviews for:
  - Air & Water Barrier Continuity & Compatibility
  - Energy Code Compliance
  - NFPA 285 Compliance
- Specification Assistance
- Detail Assistance

PACE

BUILDING ENVELOPE REPRESENTATIVES

BUILDING ENCLOSURE – IBC & IECC 2018 TO 2021 + LOCAL ISMS

COURSE #PACEBE2018TO2021

INTRODUCTION

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This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Provider #40107994

COURSE DESCRIPTION

Image Credit: Whole Building Design Guide

The Building Envelope is the system or assembly of components that provides environmental separation between the conditioned space and the exterior environment. This course will provide attendees with a general overview of building envelope science, impacts, functions, and evolution. The definition and key concepts for the four primary control layers (e.g., water, air, thermal & vapor) will be explained. Changes from IECC 2018 to 2021 will be reviewed in detail, including applicable local amendments and stretch codes. Assembly solutions & best practices for achieving high performance and resilient wall systems will also be reviewed.

LEARNING OBJECTIVES

After attending this session attendees should be able to:

- Identify and understand primary building envelope systems and functions
- Understand how building envelope systems have changed
- Understand changes in code requirements for building envelopes from 2018 to 2021 I-Codes
- Identify applicable local amendments and stretch codes
- Implement current best practices for high performance & resilient building envelopes in their current projects

DEFINITION(s)

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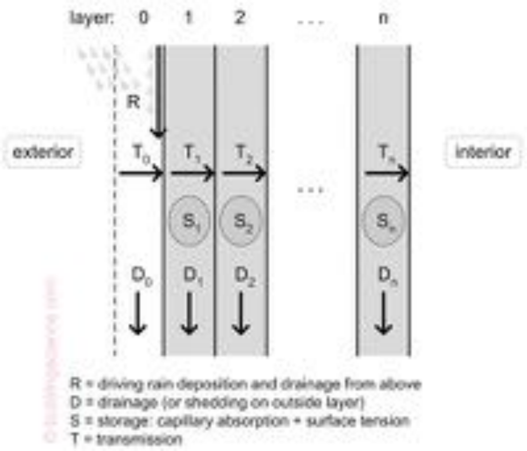

Image Credit: Building Science Corporation

Exterior Wall: A wall, bearing or nonbearing, that is used as an enclosing wall for a building, other than a *fire wall*, and that has a slope of 60 degrees or greater with the horizontal plane.

Exterior Wall Covering: A material or assembly of materials applied on the exterior side of *exterior walls* for the purpose of providing a weather-resisting barrier, insulation or for aesthetics, including but not limited to, *veneers,* siding, exterior insulation and finish systems, architectural *trim* and embellishments such as *cornices*, soffits, facias, gutters and leaders.

Exterior Wall Envelope: A system or assembly of *exterior wall* components, including *exterior wall* covering materials, that provides protection of the building structural members, including framing and sheathing materials, and conditioned interior space, from the detrimental effects of the exterior environment.

Building Thermal Envelope: The basement walls, exterior walls, floors, ceilings, roofs and any other building element assemblies that enclose conditions space or provide a boundary between conditioned space and exempt or unconditioned space.

PRIMARY SYSTEMS

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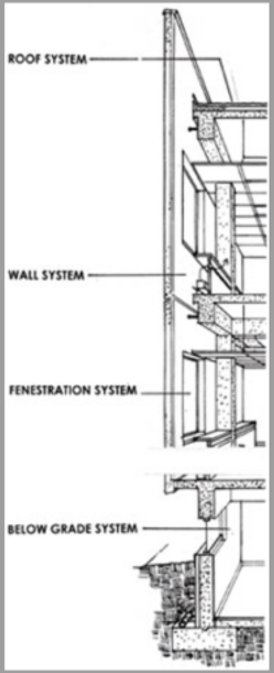

Image Credit: Whole Building Design Guide

- Roof Systems
- Above Grade Opaque Wall Systems
- Fenestration Systems
- Below Grade Wall Systems
- Base Floor Systems

PRIMARY FUNCTIONS

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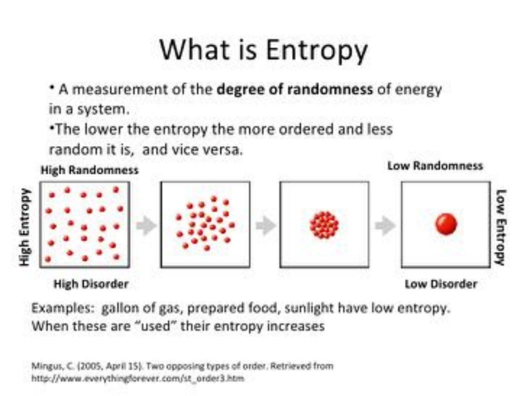
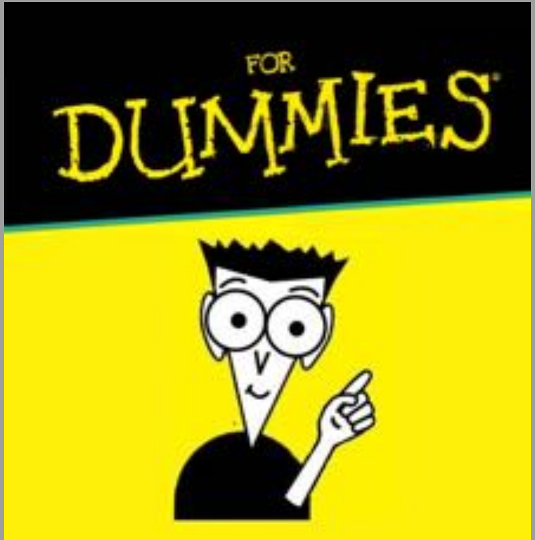
Image Credit: Whole Building Design Guide

- Resist Forces
- Provide Safety
- **Liquid Water Control**
- **Air Control**
- **Thermal Control**
- **Water Vapor Control**
- Daylight Control
- Beauty
- Noise Control
- …



The Second Law of Thermodynamics

The second law of thermodynamics is an expression of the universal principle of dissipation of kinetic and potential energy observable in nature. The second law is an observation of the fact that over time, differences in temperature, pressure, and chemical potential tend to even out in a physical system that is isolated from the outside world.



The Second Law Simplified:

- Heat seeks cold
- Warm air rises
- Cold air sinks
- Water vapor moves from high to low pressure
- Air moves from high to low pressure
- Gravity acts down

THE SCIENCE

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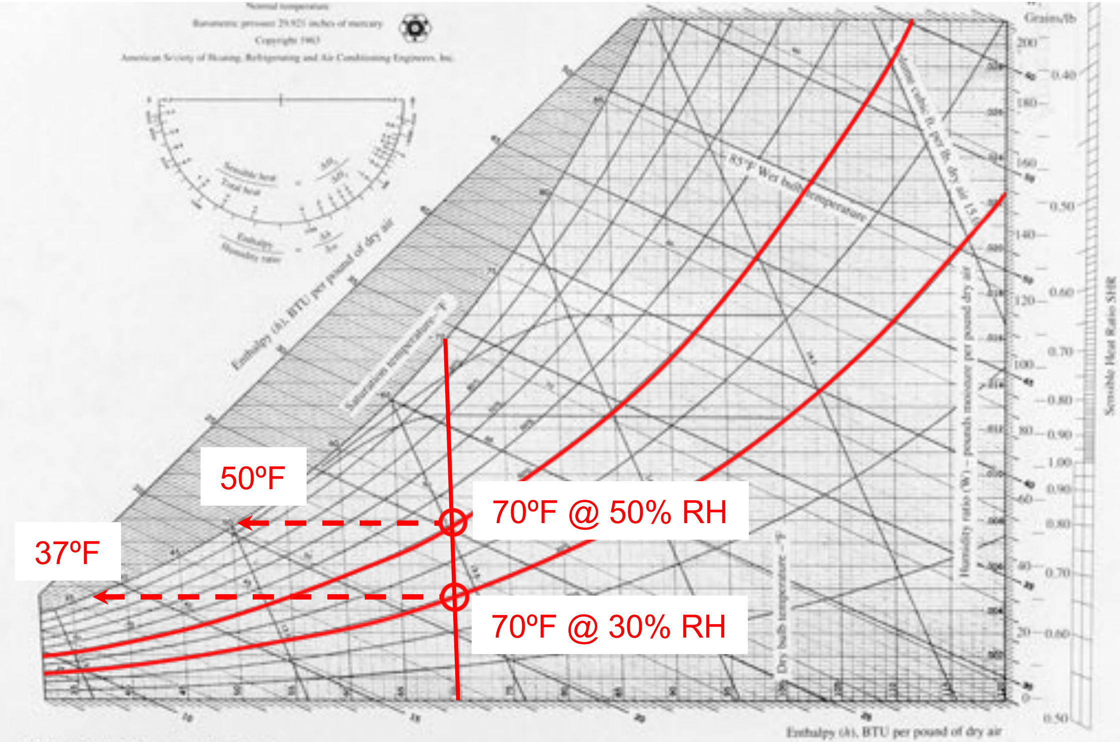
The Psychrometric Chart



APPENDIX II.1 Psychrometric Chart.
Based on ASHRAE Psychrometric Chart No. 1. Reprinted with permission from ASHRAE Inc.
Sensible heat ratio (SHR), humidity ratio scale in grains/lb, and two cooling and dehumidifying curves were added by author.

WHY IMPROVE THE BUILDING ENVELOPE?

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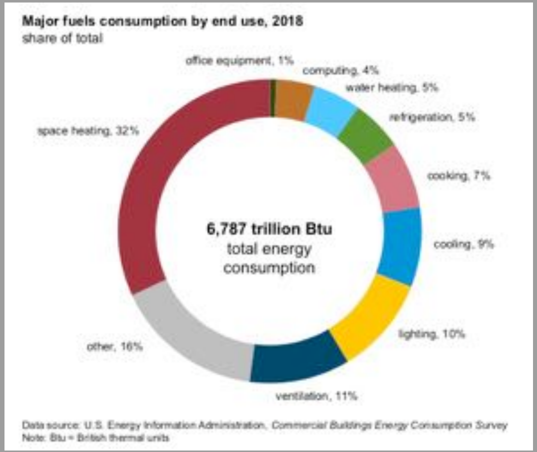

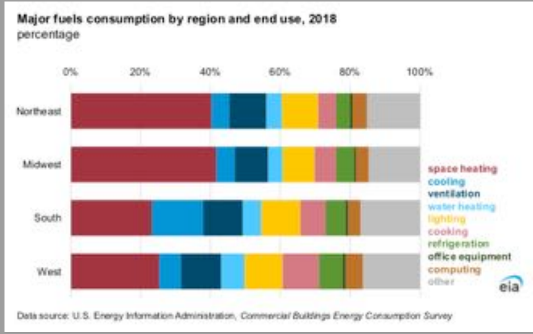

Image Credits: US Energy Information Administration

The Envelope's Impact

- Buildings account for ≈28% of our total energy use and ≈27% of our total carbon emissions
- Commercial buildings account for ≈50% of the energy use of all buildings
- The building envelope influences ≈51% of the energy end use of commercial buildings
- The building envelope of commercial buildings influences ≈7% of our total energy use!!
- Peak heating demand and renewable energy production are not coincident

WHY IMPROVE THE BUILDING ENVELOPE?

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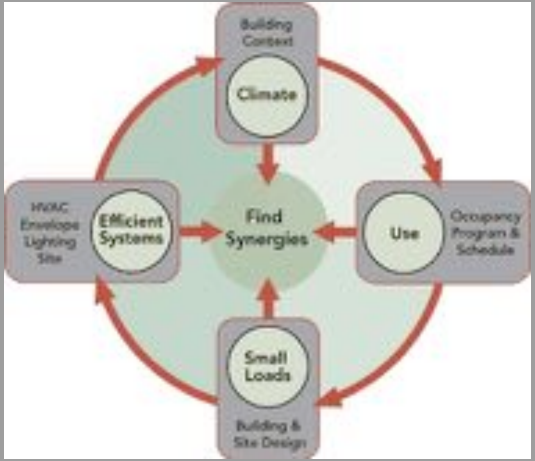

- It works 24/7/365
- It is one of the longest service life components of a building
- It is a passive system
  - Contributes to passive sustainability and resilience
- Improved performance will reduce peak loads
- Improved performance can potentially allow for the reduction or elimination of active systems

WHAT'S CHANGED?

- System Complexity
- Material Properties
- Indoor Design Conditions

WHAT'S CHANGED?

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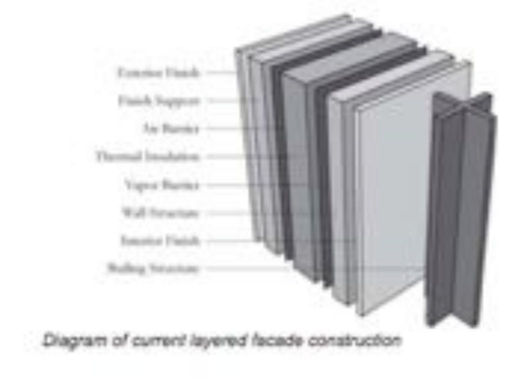

Diagram of current layered facade construction

Image Credit: Payette Research

<u>System Complexity</u>

- Increased thermal resistance
- Change in permeability of inner & outer layers
- Sensitivity of materials used
- Moisture storage & redistribution capacity of materials
- Increase number of layers *(3D airflow networks)*

WHAT’S CHANGED?

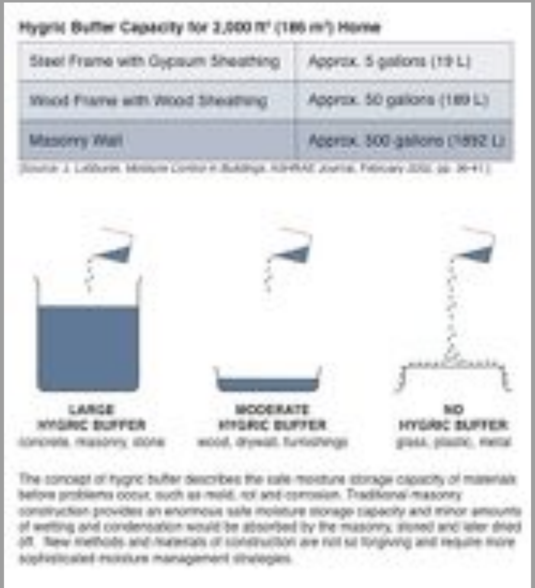

Image Credit: Whole Building Design Guide

Material Properties

- Framing *(wood & rocks to steel)*
- Sheathing *(wood to OSB or Gypsum)*
- Cladding *(wood & rocks to composites)*
- Interior Finish(s) *(nothing to vinyl wall covering)*

WHAT'S CHANGED?

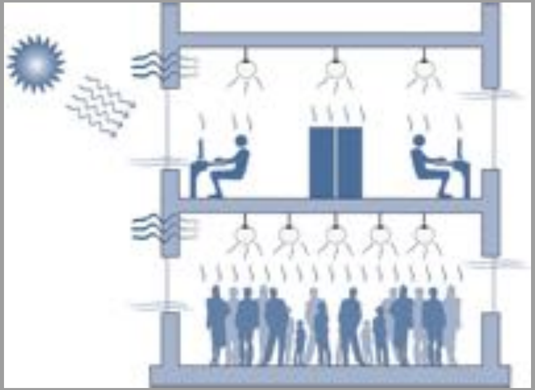

Image Credit: Whole Building Design Guide

Indoor Design Conditions

- Air Conditioning
- More stringent occupant comfort expectations
- Ventilation
- Materials Properties

WATER CONTROL LAYER

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Water Control Layer: A system that controls the passage of liquid water even after long or continuous exposure to moisture.

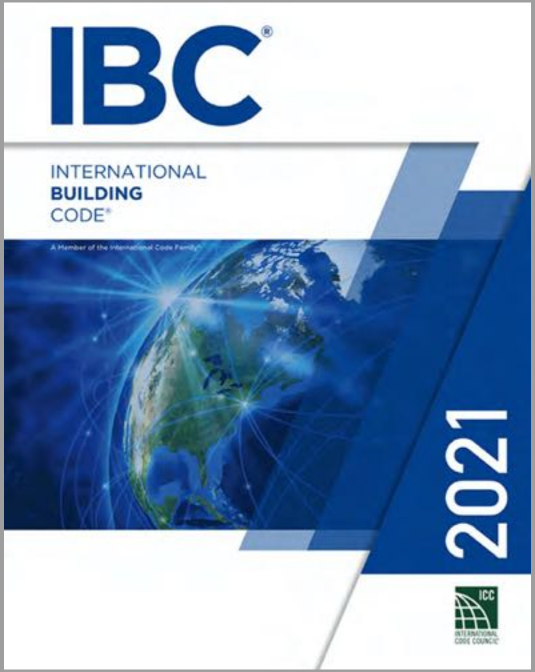
Water-Resistive Barrier: A material behind an *exterior wall covering* that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding into the *exterior wall* assembly.

WATER CONTROL LAYER

Common Water Control Layer Materials

- Self-adhered membranes
- Fluid-applied membranes
- Building wraps (e.g., Tyvek)
- Integral with sheathing
- Rigid Foam Insulations

WATER CONTROL LAYER

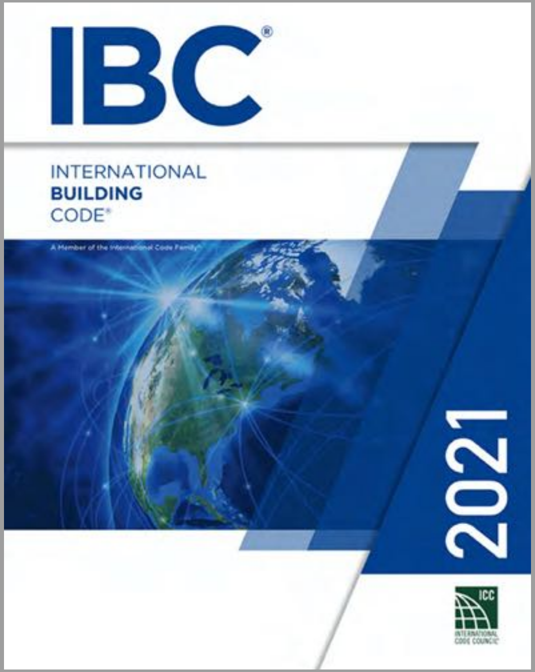


Chapter 14 – Exterior Walls

Section 1402.2 Weather Protection: Exterior walls shall provide the building with a weather-resistant *exterior wall envelope*. The exterior wall envelope shall include flashing, as described in Section 1405.4. The exterior wall envelope shall be designed and constructed in such a manner as to prevent the accumulation of water within the wall assembly by providing a *water-resistive barrier* behind the exterior veneer, as described in Section 1404.2, and a means for draining water that enters the assembly to the exterior.

1402.5 Water-Resistive Barriers: Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet in height above grade plane and contain a combustible *water-resistive barrier* shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.*

WATER CONTROL LAYER



1403.2 Water-resistive barrier: Not fewer than one layer of *water-resistive barrier* material shall be attached to the studs or sheathing, with flashing as described in Section 1404.4, in such a manner as to provide a continuous *water-resistive barrier* behind the exterior wall *veneer*.

- WRB materials shall comply with ASTM D226 (#15 felt), ASTM E2556 Type I or II (building wrap), ASTM E331 (performance test), or other approved materials (TBD)

1404.4 Flashing: Flashing shall be installed in such a manner so as to prevent moisture from entering the wall or to redirect it to the surface of the exterior wall finish or to a *water-resistive barrier*...

- Self-adhered flashing shall comply with AAMA 711
- Fluid applied flashing shall comply with AAMA 714

WATER CONTROL LAYER

Problem Statement:
"80% of all construction problems are related to water."*
Water intrusion accounts for more than 70% of construction litigation. Approximately 65% of this litigation is due to construction workmanship, 25% design deficiencies, and 10% material failures.

WATER CONTROL LAYER

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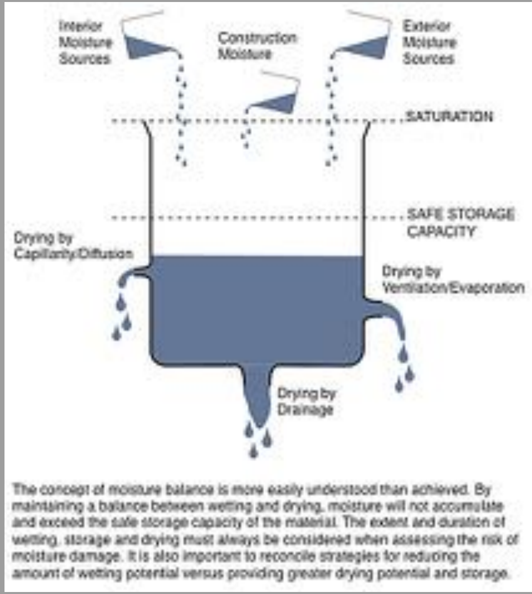
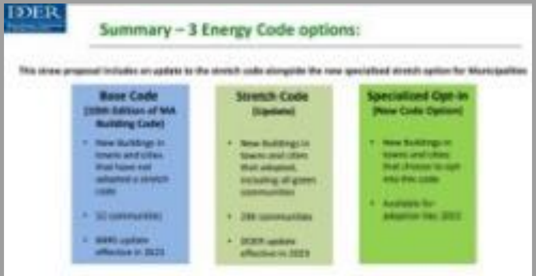


Image Credit: Whole Building Design Guide

Key Concepts:

- The quality of the water control material or system should be directly proportional to the consequence of the failure
- Specify water control systems, not materials
- Mind material compatibility
- Approximately 90% of water that hits the cladding of a ventilated rainscreen is drained at the cladding layer
- Reduce wetting commensurate with drying
- Don’t forget the end-dams

WATER CONTROL LAYER



Massachusetts Amendments - Base Code:

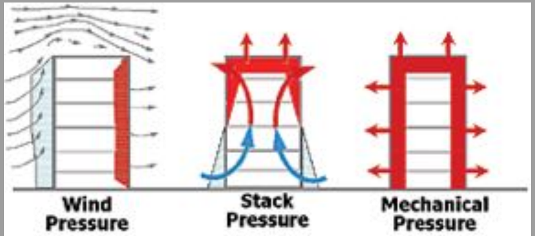
- None

Massachusetts Amendments – Stretch Code:

- None

AIR CONTROL LAYER

AIA Continuing Education



Air Control Layer: A system that is the primary boundary that separates indoor (conditioned) air and outdoor (unconditioned) air. In multi-unit/townhouse/apartment construction the air control layer also separates the conditioned air from any given unit and adjacent units. Air control layer systems also typically define the location of the pressure boundary of the building enclosure.

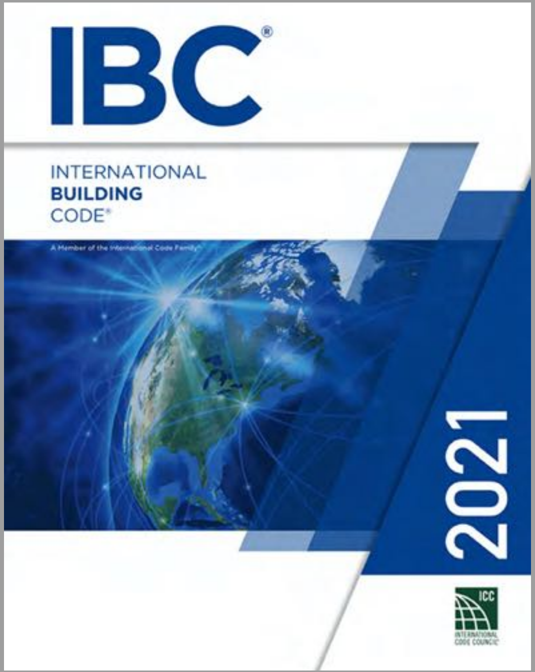
Air Barrier: One or more materials joined together in a continuous manner to restrict or prevent the passage of air through the *building thermal envelope* and its assemblies.

AIR CONTROL LAYER

Common Air Control Layer Materials

- Self-adhered membranes
- Fluid-applied membranes
- Spray foam
- Closed cell rigid foam insulation (e.g., XPS)
- ½” Gypsum board / gypsum sheathing
- Any material with an air permeability ≤0.004CFM/ft^2 @ 75Pa

AIR CONTROL LAYER

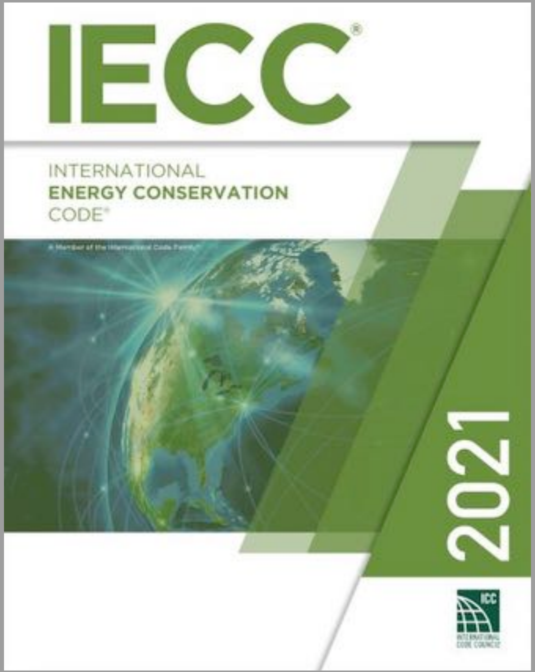


Chapter 13 – Energy Efficiency

Section 1301.1.1: Buildings shall be designed and constructed in accordance with the *International Energy Conservation Code*. (i.e., IECC 2021)

AIR CONTROL LAYER

AIA Continuing Education

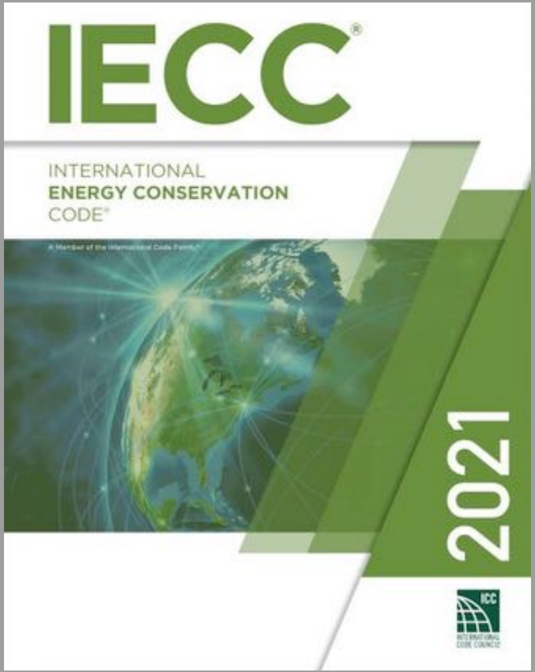


Section C402 - Building Envelope Requirements

C402.5 Air leakage – Thermal Envelope: The *building thermal envelope* shall comply with Sections C402.5.1 through C402.5.11.1. **OR** shall be tested in accordance with ASTM E 779 (or AHJ approved equivalent) at a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) and have a tested air leakage rate not greater than 0.40 cfm/ft2 (0.02 L/s • m2).

C402.5.1 Air barriers: A continuous air barrier shall be provided throughout the *building thermal envelope*. The continuous air barriers shall be located on the inside or outside of the building thermal envelope, located within the assemblies composing the building thermal envelope, or any combination thereof. The air barrier shall comply with Sections C402.5.1.1 and C402.5.1.2.

AIR CONTROL LAYER

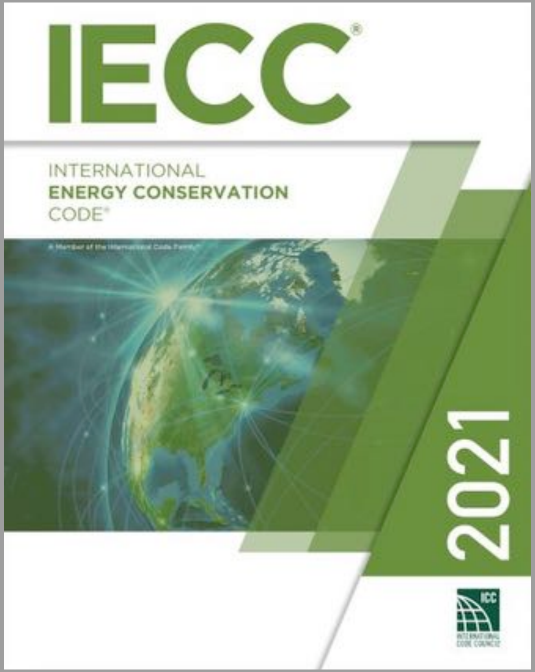


C402.5.1.1 Air Barrier Construction:

- The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
- Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
- Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location.

AIR CONTROL LAYER

AIA Continuing Education



C402.5.1.2 Air Barrier Compliance:

- Group R and I occupancies shall meet provisions of Section C402.5.2 (0.30 cfm/ft2 @ 50 Pa)
- All other occupancies shall meet provisions of Section C402.5.3 (0.40cfm/ft2 @ 75 Pa)

C402.5.1.3 Materials: Materials with an air permeability no greater than 0.004 cfm/ft2 (0.02 L/s • m2) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178… Some materials are preapproved (e.g., GWB, OSB, fully grouted CMU, single-ply roof membrane, etc.)

C402.5.1.4 Assemblies: Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft2 (0.2 L/s • m2) under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283… Select assemblies are preapproved (e.g., sealed CMU walls & ½" thick stucco)

AIR CONTROL LAYER

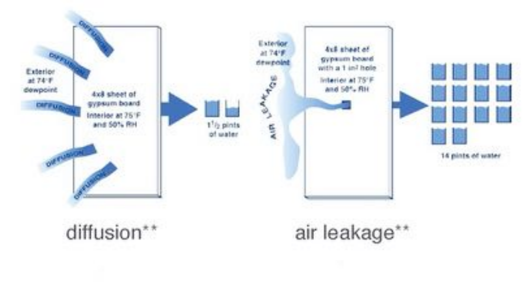


Image Credit: Building Science Corporation

Problem Statement:
Uncontrolled air movement can significantly reduce the performance of a building. It can account for:

- over 30% of the energy use of a building
- 10-100 times more vapor migration than due to vapor diffusion
- Reduced material life
- Microorganism growth

AIR CONTROL LAYER

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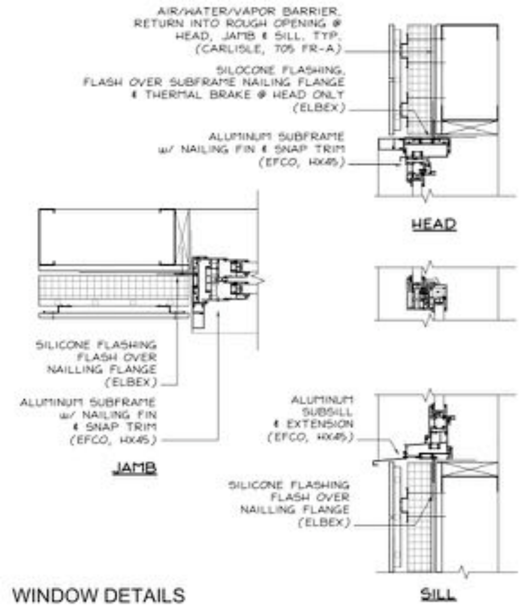

Key Concepts

- The air control layer can be located anywhere within the building thermal envelope
- The air control layer must be continuous and have the ability to resist positive and negative air pressures
- Specify an air barrier system, not just materials
- The devil is in the details. Continuity is critical.
- Air tightness helps with IAQ & moisture management

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Massachusetts Amendments - Base Code:

- None

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Massachusetts Amendments – Stretch Code:

- Adds new Section C402.5.1.1
  - Adds additional detailing and documentation requirements.
  - Requires identification of testing locations and field inspection plan.
- Renumbers sections for air barrier material, assembly and performance verification requirements
- Reduces maximum allowable air leakage to 0.35 cfm/ft2 @ 75 Pa.
- Requires air tightness verification testing

THERMAL CONTROL LAYER

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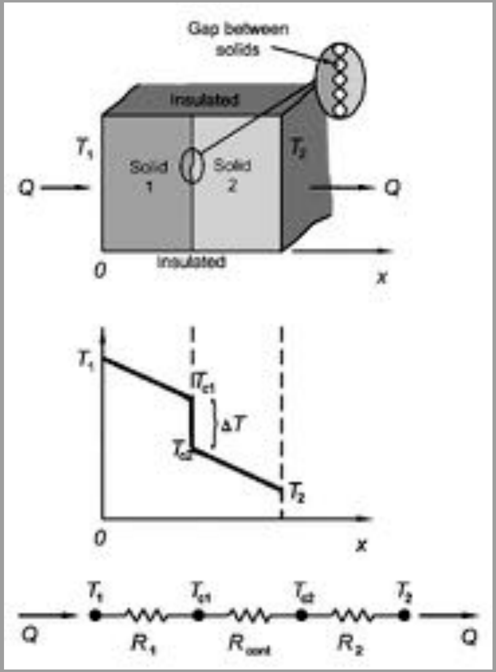

Thermal Control Layer: The component or components (i.e., insulation) that are designed and installed in an assembly to control the transfer of thermal energy (i.e., heat).

R-Value: Quantitative measure of a material resistance to heat flow for a unit temperature difference and a unit area. As R-value increases, conduction through a material decreases for the same temperature difference.

U-Value: A quantitative measure of heat flow or conductivity; the reciprocal of R-value. While building scientists will use R-values for measures of the resistance to heat flow for individual building materials, U-factor is usually used as a summary metric for heat transfer through building assemblies.

Continuous Insulation (CI): Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings.*

THERMAL CONTROL LAYER

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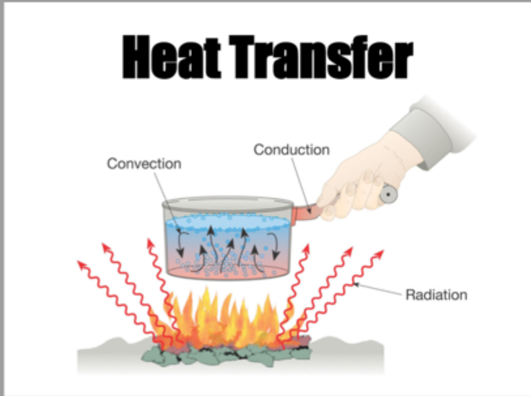

Methods of Heat Transfer

Conductive Heat Flow: The flow of heat through direct molecular contact, either through a single material or through multiple materials.

Convective Heat Flow: The flow of heat by molecules (either liquid or gas) via a change in their heat content.

Radiation: The transfer of heat by electromagnetic waves through a gas (or vacuum), and requires a line of sight between the source and the contact surface.

THERMAL CONTROL LAYER

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Common Insulation Materials

- Fiberglass Batt
- Rigid Extruded Polystyrene (XPS) Foam
- Rigid Polyisocyanurate Foam
- Mineral Fiber Board & Batt
- Spray Foam
- Blown Cellulose
- Structural Insulated Sheathing

THERMAL CONTROL LAYER

$$R = \frac{F^{\circ} \times ft^{2} \times hr}{BTU}$$

imperial units

R-Value per Inch of Common Insulation Materials

Material	R-Value/Inch
Fiberglass Batt	≈R-3.6
Extruded Polystyrene (XPS)	≈R-5.0
Foil Faced Polyisocyanurate	≈R-6.5
Mineral Fiber	≈R-4.2
Spray Foam (closed cell)	≈R-6.4
Spray Foam (open cell)	≈R-4.1
Blown Cellulose (dense pack)	≈R-3.8

R-Value at 75°F mean temp. per ASTM C 518

THERMAL CONTROL LAYER

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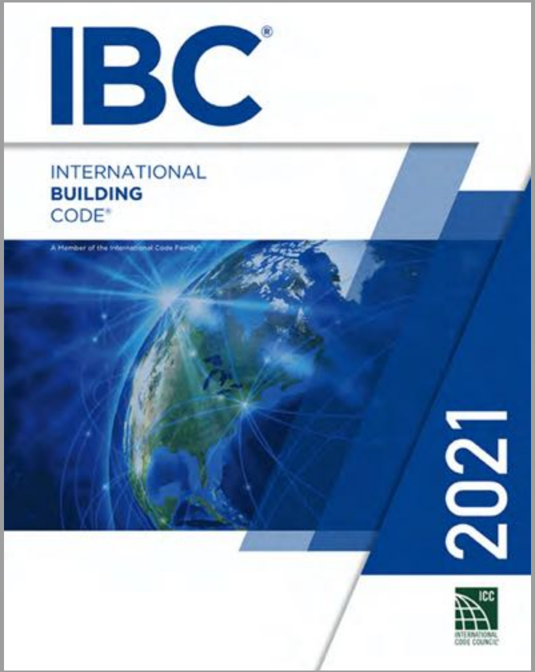

Chapter 13 – Energy Efficiency

Section 1301.1.1: Buildings shall be designed and constructed in accordance with the *International Energy Conservation Code*. (i.e., IECC2021)

THERMAL CONTROL LAYER

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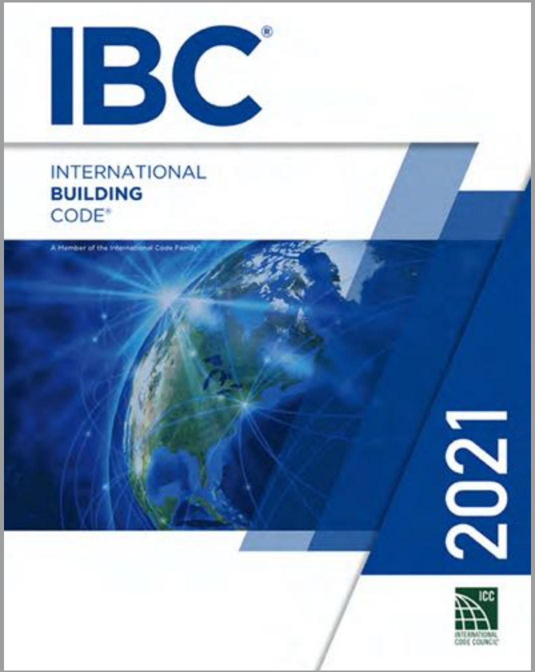

Chapter 26 – Plastic

Section 2603 Foam Plastic Insulation
2603.4 Thermal barrier: Except as provided for in Sections 2603.4.1 and 2603.9, foam plastic shall be separated from the interior of a building by an approved thermal barrier of 1/2-inch (12.7 mm) *gypsum wallboard* or a material that is tested in accordance with and meets the acceptance criteria of both the Temperature Transmission Fire Test and the Integrity Fire Test of NFPA 275.

2603.5 Exterior walls of buildings of any height: Exterior walls of buildings of Type I, II, III or IV construction of any height shall comply with Sections 2603.5.1 through 2603.5.7… Exterior walls of buildings of Type V construction shall comply with Sections 2603.2, 2603.3 and 2603.4.

THERMAL CONTROL LAYER

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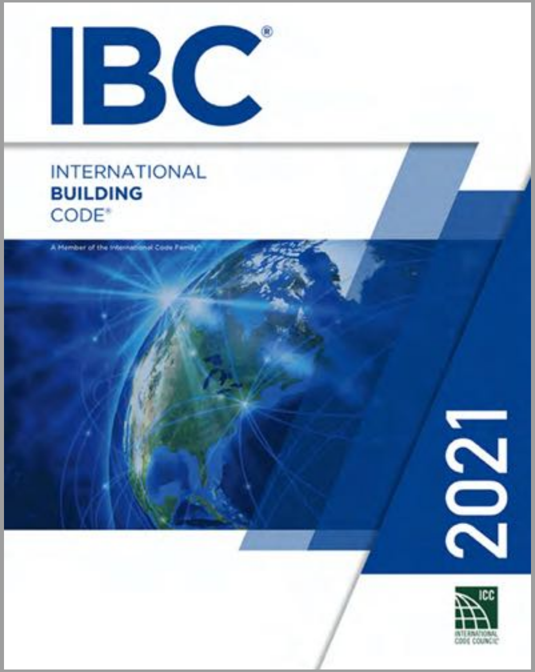

2603.5.4 Flame spread and smoke-developed indexes: Foam plastic insulation, exterior coatings and facings shall be tested separately in the thickness intended for use, but not to exceed 4 inches (102 mm), and shall each have a flame spread index of 25 or less and a smoke-developed index of 450 or less as determined in accordance with ASTM E 84 or UL 723.

2603.5.5 Vertical and lateral fire propagation: The exterior wall assembly shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.

Exceptions for one-story buildings &/or protected insulation.

2603.5.7 Ignition: Exterior walls shall not exhibit sustained flaming where tested in accordance with NFPA 268. Where a material is intended to be installed in more than one thickness, tests of the minimum and maximum thickness intended for use shall be performed.

Exceptions for select cladding materials.

What is NFPA 285?

IBC 2021 NFPA 285 Requirements

- A means to evaluate flame propagation of an exterior wall assembly exposed to a “typical” fire scenario
- An assembly test, not a component test
- Two-story test wall assembly
- 30 minute test duration (window burner after 5 mins.)
- Evaluates exterior, core and internal vertical &/or lateral flame propagation
- A pass/fail for flame &/or heat propagation

THERMAL CONTROL LAYER

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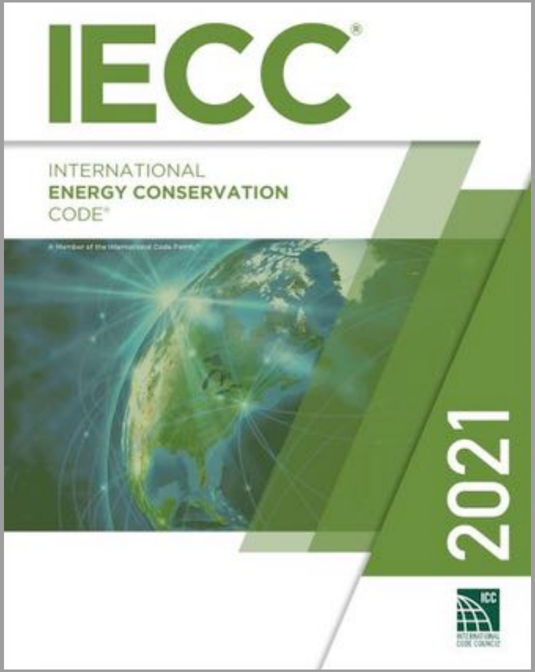

Chapter 4 – Commercial Energy Efficiency

C401.2 Application. Commercial buildings shall comply with Section C401.2.1 or C401.2.2:

C401.2.1 International Energy Conservation Code

1. Prescriptive Compliance. … compliance with Sections C402 through C406 and C408.
2. Total Building Performance. …compliance with Section C407.

C401.2.2 ASHRAE 90.1. …comply with requirements of ASHRAE 90.1

C401.3 Thermal Envelope Certificate. A permanent thermal envelope certificate shall be competed by an *approved* party.

THERMAL CONTROL LAYER

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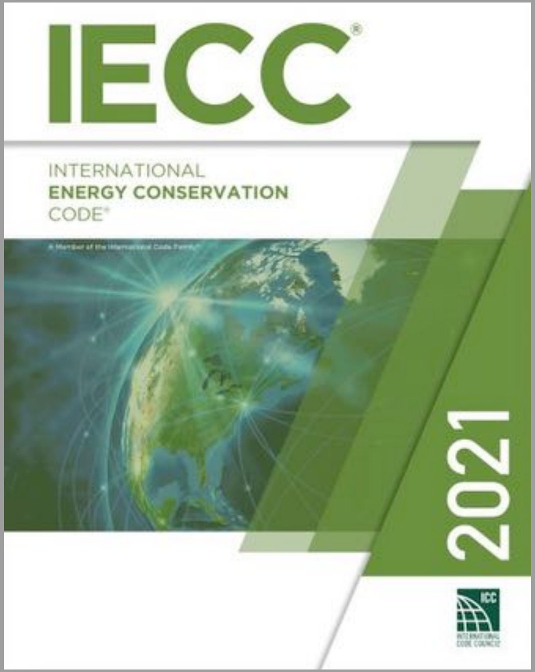
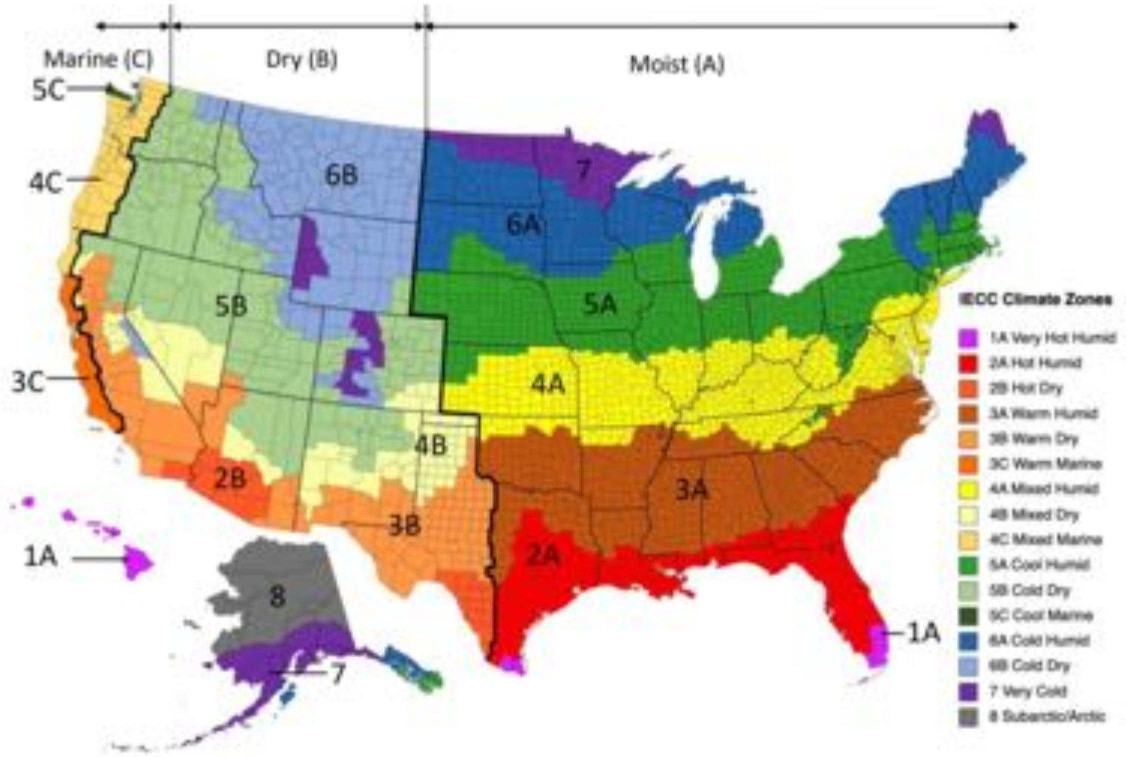


Section C402 Building Envelope Requirements

C402.1 General (Prescriptive): Building *thermal envelope assemblies* for buildings that are intended to comply with the code on a prescriptive basis, in accordance with the compliance path described in Item 1 (i.e., IECC 2021) of Section C401.2.1, shall comply with the following:

- The opaque portions of the building thermal envelope shall comply with the specific insulation requirements of Section C402.2 and the thermal requirements of either the *R*-value-based method of Section C402.1.3; the *U*-, *C*- and *F*-factor-based method of Section C402.1.4; or the component performance alternative of Section 402.1.5.
- Fenestration in building envelope assemblies shall comply with Section C402.4.

THERMAL CONTROL LAYER



THERMAL CONTROL LAYER

AIA Continuing Education

IECC 2021 - TABLE C402.1.3 OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, R-VALUE METHOD						
CLIMATE ZONE	**5 AND MARINE 4**		**6**		**7**	
	All Other	**Group R**	**All Other**	**Group R**	**All Other**	**Group R**
Roofs						
Insulation Entirely Above Roof Deck	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci
Attic and Other	**R-49**	**R-49**	**R-49**	**R-49**	**R-60**	**R-60**
Walls, Above Grade						
Mass	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci
Metal Framed	**R-13 + R-10ci**	**R-13 + R-10ci**	**R-13 + R-12.5ci**	**R-13 + R-12.5ci**	**R-13 + R-12.5ci**	**R-13 + R-15.6ci**
Wood Framed and Other	**R-13 + R-7.5ci or R-20 + R-3.8ci**	**R-13 + R-7.5ci or R-20 + R-3.8ci**	**R-13 + R-7.5ci or R-20 + R-3.8ci**	**R-13 + R-7.5ci or R-20 + R-3.8ci**	**R-13 + R-7.5ci or R-20 + R-3.8ci**	**R-13 + R-7.5ci or R-20 + R-3.8ci**
Walls, Below Grade						
Below-Grade Wall	**R-7.5ci**	**R-10ci**	**R-10ci**	**R-15ci**	**R-15ci**	**R-15ci**
Slab-On-Grade Floors						
Unheated Slabs	**R-15 for 24” below**	**R-20 for 24” below**	**R-20 for 24” below**	**R-20 for 48” below**	**R-20 for 48” below**	**R-20 for 48” below**
Heated Slabs	R-15 for 36” below + R-5 full slab	R-15 for 36” below + R-5 full slab	R-15 for 36” below + R-5 full slab	R-20 for 48” below + R-5 full slab	R-20 for 48” below + R-5 full slab	R-20 for 48” below + R-5 full slab

THERMAL CONTROL LAYER

AIA Continuing Education

IECC 2021 - TABLE C402.1.4 OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, U-FACTOR METHOD						
CLIMATE ZONE	**5 AND MARINE 4**		**6**		**7**	
	All Other	**Group R**	**All Other**	**Group R**	**All Other**	**Group R**
Roofs						
Insulation Entirely Above Roof Deck	U-0.032	U-0.032	U-0.032	U-0.032	U-0.032	U-0.032
Attic and Other	**U-0.021**	**U-0.021**	**U-0.021**	**U-0.021**	**U-0.017**	**U-0.017**
Walls, Above Grade						
Mass	U-0.090	U-0.080	U-0.080	U-0.071	U-0.071	U-0.071
Metal Framed	**U-0.055**	**U-0.055**	**U-0.049**	**U-0.049**	**U-0.049**	**U-0.042**
Wood Framed and Other	**U-0.051**	**U-0.051**	**U-0.051**	**U-0.051**	**U-0.051**	**U-0.051**
Walls, Below Grade						
Below-Grade Wall	**C-0.119**	**C-0.092**	**C-0.092**	**C-0.063**	**C-0.063**	**C-0.063**
Slab-On-Grade Floors						
Unheated Slabs	**F-0.52**	**F-0.51**	**F-0.51**	**F-0.434**	**F-0.51**	**F-0.434**
Heated Slabs	**F-0.62**	**F-0.62**	**F-0.62**	**F-0.602**	**F-0.602**	**F-0.602**

THERMAL CONTROL LAYER

AIA Continuing Education

TABLE C402.1.4.2
EFFECTIVE R-VALUES FOR STEEL STUD WALL ASSEMBLIES

NOMINAL STUD DEPTH (inches)	SPACING OF FRAMING (inches)	CAVITY R-VALUE (insulation)	CORRECTION FACTOR (F_c)	EFFECTIVE R-VALUE (ER) (Cavity R-Value × F_c)
$3^1/_2$	16	13	0.46	5.98
		15	0.43	6.45
$3^1/_2$	24	13	0.55	7.15
		15	0.52	7.80
6	16	19	0.37	7.03
		21	0.35	7.35
6	24	19	0.45	8.55
		21	0.43	9.03
8	16	25	0.31	7.75
	24	25	0.38	9.50

Section C402 Building Envelope Requirements

C402.1.4.2 Thermal resistance of cold-formed steel walls. *U*-factors of walls with cold-formed steel studs shall be permitted to be determined in accordance with Equation 4-1:

$U = 1 / [R_s + (ER)]$ **(Equation 4-1)**

R_s = The cumulative *R*-value of the wall components along the path of heat transfer, excluding the cavity insulation and steel studs.

ER = The effective R-value of the cavity insulation with steel studs as specified in Table C402.1.4.2.

THERMAL CONTROL LAYER

AIA Continuing Education

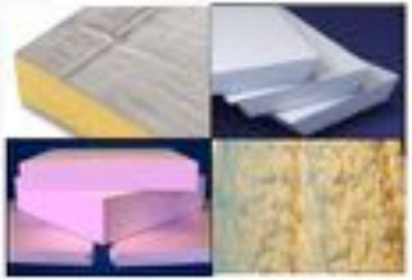
IECC 2021 - TABLE C402.1.4 OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, U-FACTOR METHOD						
CLIMATE ZONE	**5 AND MARINE 4**		**6**		**7**	
Vertical Fenestration						
U-Factor						
Fixed Fenestration	**0.36**		**0.34**		0.29	
Operable Fenestration	0.45		**0.42**		**0.36**	
Entrance Doors	**0.63**		**0.63**		**0.63**	
SHGC						
	Fixed	**Operable**	**Fixed**	**Operable**	**Fixed**	**Operable**
PF < 0.2	**0.38**	**0.33**	**0.38**	**0.34**	**0.40**	**0.36**
0.2 ≤ PF < 0.5	**0.46**	**0.40**	**0.46**	**0.41**	**0.48**	**0.43**
PF ≥ 0.5	**0.61**	**0.53**	**0.61**	**0.54**	**0.64**	**0.58**
Skylights						
U-Factor	0.50		0.50		0.50	
SHGC	0.40		0.40		NR	

THERMAL CONTROL LAYER

AIA Continuing Education

Rain Screen Cavity Insulation Comparison

FOAM



- Plastic-based (combustible).
- Rigid closed-cell boards.
- Air barrier with facer options.
- Resists water absorption.

FIBER

- Mineral-based (non-combustible).
- Semi-rigid open-cell.
- Permeable to air and moisture.
- Absorption potential.

Information presented at Carlisle 2015 Sustainable Roofing & Waterproofing Conference

THERMAL CONTROL LAYER

Rain Screen Cavity Insulation Comparison

FOAM

- 2" foil-faced polyiso (R-13.0)
- 4' x 8' (32ft²) = 12lbs.
- 0.38 lb./ft²
- 6 manufacturers, 30 plants

FIBER

- 3" dual-density mineral fiber (R-12.9)
- 4' x 6' (24ft²) = 66lbs.
- 2.75 lb./ft²
- 2 manufacturers, 2 plants

Information presented at Carlisle 2015 Sustainable Roofing & Waterproofing Conference

AIA Continuing Education

Rain Screen Cavity Insulation Comparison

	2" Foil-Faced Polyiso (R-13.0)			3" Dual Density Mineral Fiber (R-12.9)		
	Dry	Wet	Change	Dry	Wet	Change
R-Value @75°F Mean Temp	12.8	12.4	-4%	12.5	2.8	-78%
R-Value @40°F Mean Temp	13.3	13.0	-2%	13.8	4.9	-64%
Density [lb/ft³]	2.38	2.67	+12%	4.43	29.5	+566%

- Test method: ASTM C 518.
- Wet samples: 2h immersion in water at room temp, no drainage allowed. Samples placed in plastic bag during measurement.

Information presented at Carlisle 2015 Sustainable Roofing & Waterproofing Conference

THERMAL CONTROL LAYER

AIA Continuing Education

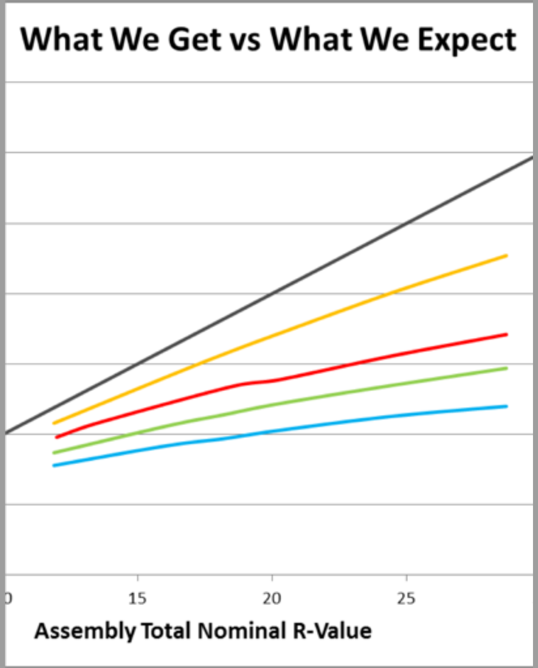


Image Credit: Knight Wall

Problem Statement:
The thermal performance requirements of our building enclosures has increased significantly in the last 20 years. Increased performance requirements have outpaced readily available and understood solutions. As a result, the actual thermal resistance of many opaque wall systems currently used does not achieve its intended thermal performance and sometimes does not even meet the minimum requirements of the energy code.

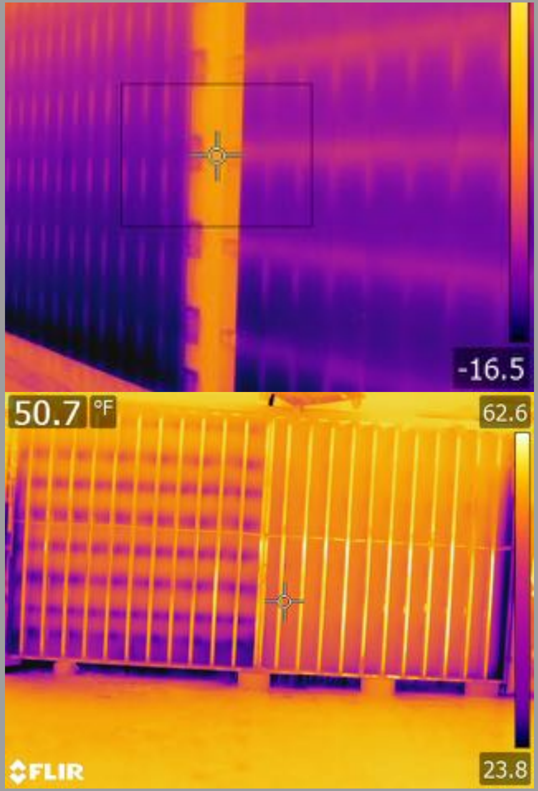


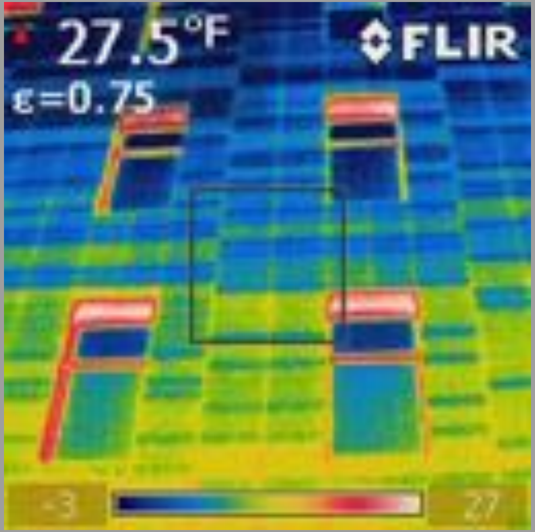
Image Credit: CCW/KWS/Dow Assembly Testing

Problem Statement: (con't)
Many commonly used opaque wall systems achieve only 40-80% of their nominally rated thermal performance which leads to:

- Increased Energy Use
- Decreased Occupant Comfort
- Decreased System Service Life

THERMAL CONTROL LAYER

AIA Continuing Education



Key Concepts:

- Many commonly used opaque wall systems achieve only 40-80% of their nominally rated thermal performance
- There are multiple code compliant insulation options
- Minimize thermal bridging before adding additional insulation
- Insulation selection for wet and dry areas
- Optimal effective assembly thermal performance of R-20 (U-0.050) to R-25 (U-0.040)

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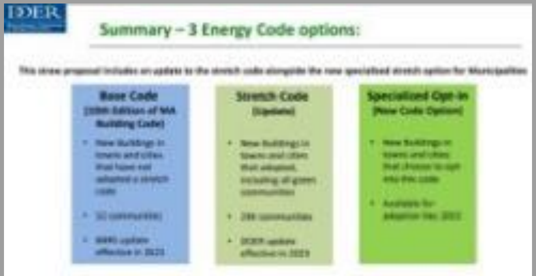


Massachusetts Amendments - Base Code:

- Adds sections for IECC Zero Energy Code and MA Stretch Energy Code
- Modifies C402.1.5 Component Performance Alternative
- Modifies Table C402.4 Fenestration U-Factor
  - Fixed Fenestration = U-0.30
  - Operable Fenestration = U-0.32

THERMAL CONTROL LAYER

Massachusetts Amendments - Stretch Code

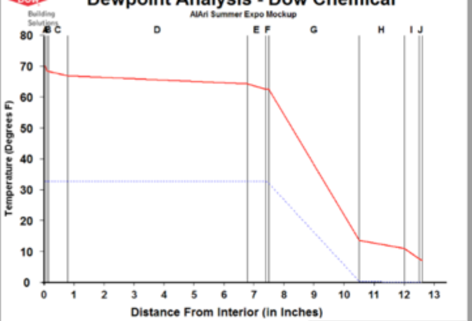
- Prescriptive compliance only allowed up to 20,000sf
- Adds Targeted Performance and Relative Performance compliance options
- Adds Certified Performance compliance options (Passive House & HERS)
- Deletes R-Value Table C402.1.3
- Replaces Component Performance Alternative section
- Adds Section C402.7 Derating and Thermal Bridges

VAPOR CONTROL LAYER

AIA Continuing Education

Dewpoint Analysis - Dow Chemical

AIAri Summer Expo Mockup



Legend
Actual Temperature
Dewpoint Temperature

Dewpoint Theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

Conditions:	Interior	Exterior
Temperature	70.0	7.0
Humidity	25.0	70.0

	Component Name	Thickness	R-Value	Rep
A	Interior Air Film	0.100	0.68	0.001
B	Latex Paint 2 Coat	0.050	0.01	0.500
C	Gypsum Wall Board	0.625	0.56	0.023
D	Wall Air Space NonRefl	6.000	1.05	0.028
E	Exterior Sheathing	0.625	0.67	0.083
F	Carlisle 705 FR-A	0.100	0.01	20.000
G	DOW THERMAX (ci)	3.000	19.00	500.000
H	Wall Air Space (KWS)	1.500	1.01	0.028
I	Oko Skin Cladding	0.500	1.30	0.050
J	Out Air Film Winter	0.100	0.17	0.001
K				
L				
	TOTAL	12.600	24.46	520.714

Interface	Temperature Actual	Temperature Dewpnt	Accum
-A	70.00	32.60	0.000
AB	68.25	32.60	0.000
BC	68.22	32.58	0.000
CD	66.78	32.58	0.000
DE	64.08	32.58	0.000
EF	62.35	32.58	0.000
FG	62.32	31.84	0.000
GH	13.39	0.08	0.000
HI	10.79	0.07	0.000
IJ	7.44	0.06	0.000
JK	7.00	0.06	0.000
KL			
L-			

NOTICE: This calculation is based on the theory of Water Vapor Migration presented in the ASHRAE 1993 Fundamentals Handbook. Actual performance may vary depending upon air infiltration, workmanship, and building materials. Since the information is provided without charge, The Dow Chemical Company assumes no obligation or liability for its use.

July 22 2015 9:21:12 AM

Vapor Control Layer: The component (or components) that is (or are) designed and installed in an assembly to control the movement of water by vapor diffusion.

Vapor Retarder Class: A measure of a material or assembly's ability to limit the amount of moisture that passes through that material or assembly. Vapor retarder class shall be defined using the desiccant method of ASTM E 96 as follows:

- Class I: 0.1 perm or less.
- Class II: 0.1 < perm ≤ 1.0 perm.
- Class III: 1.0 < perm ≤ 10 perm.

Vapor Permeable Membrane: The property of having a moisture vapor permeance rating of 10 perms or greater, when tested in accordance with the desiccant method using Procedure A of ASTM E 96.

VAPOR CONTROL LAYER

AIA Continuing Education

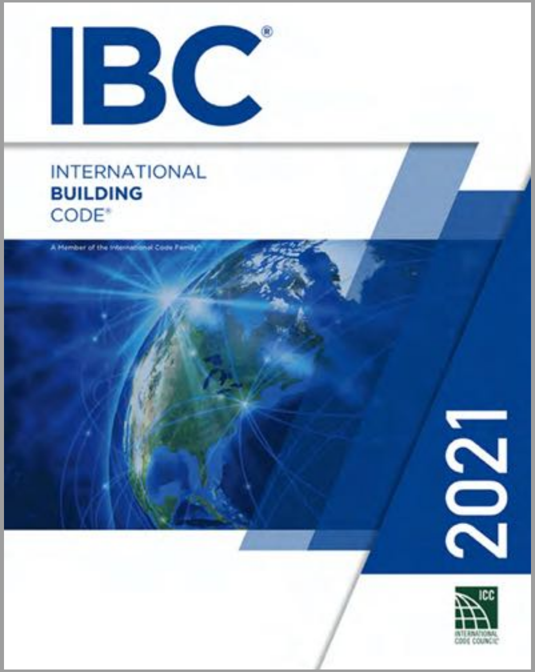
Image Credit: Matt Risinger

Common Vapor Control Layer Materials

- Self-adhered membranes
- Fluid-applied membranes
- Polyethylene sheeting
- Kraft paper facing
- Latex paint
- Any material with a vapor permeance of <10 perm

VAPOR CONTROL LAYER

AIA Continuing Education



Chapter 14 – Exterior Walls

Section 1402.2 Weather Protection: …Protection against condensation in the exterior wall assembly shall be provided in accordance with Section 1404.3.

1404.3 Vapor Retarders: …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 zone shall be selected in accordance with Chapter 3 of the *International Energy Conservation Code*.

Exceptions:

1. Basement walls.
2. Below-grade portion of any wall.
3. Construction where moisture or its freezing will not damage the materials.
4. Conditions where Class III vapor retarders are allowed per Section 1405.3.2.

VAPOR CONTROL LAYER

AIA Continuing Education

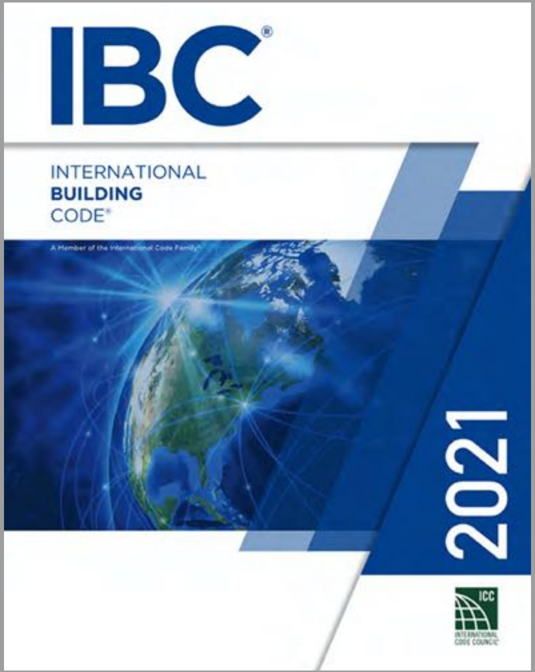


	TABLE 1404.3(2) VAPOR RETARDER OPTIONS		
CLIMATE ZONE	VAPOR RETARDER CLASS		
	I	II	III[a]
1, 2	Not Permitted	Not Permitted	Permitted
3	Not Permitted	Permitted	Permitted
4 (except marine)	Not Permitted	Permitted	See Table 1404.3(3)
Marine 4, 5, 6, 7, 8	Permitted	Permitted	See Table 1404.3(3)

a. See also Sections 1404.3.1 and Section 1404.3.2

VAPOR CONTROL LAYER

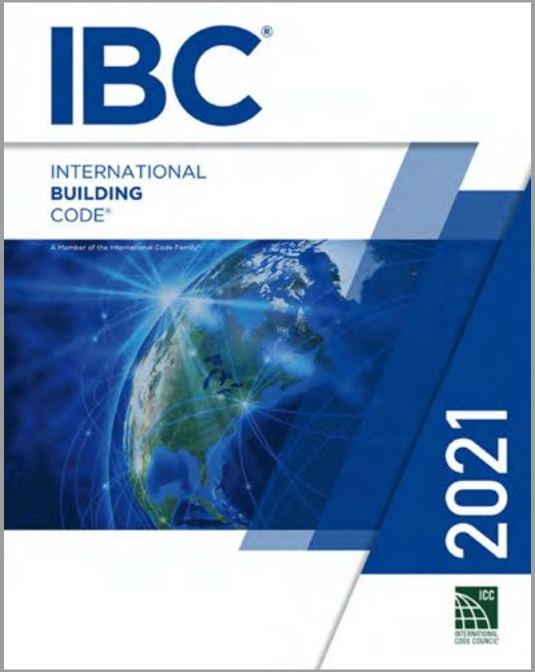


TABLE 1404.3(3) CLASS III VAPOR RETARDERS	
ZONE	**CLASS III VAPOR RETARDERS PERMITTED FOR:**
4	Vented cladding over wood structural panels Vented cladding over fiberboard Vented cladding over gypsum Continuous insulation with R-Value ≥ R-2.5 over 2x4 wall Continuous insulation with R-Value ≥ R-3.75 over 2x6 wall
5	Vented cladding over wood structural panels Vented cladding over fiberboard Vented cladding over gypsum Continuous insulation with R-Value ≥ R-5 over 2x4 wall Continuous insulation with R-Value ≥ R-7.5 over 2x6 wall
6	Vented cladding over fiberboard Vented cladding over gypsum Continuous insulation with R-Value ≥ R-7.5 over 2x4 wall Continuous insulation with R-Value ≥ R-11.25 over 2x6 wall
7	Continuous insulation with R-Value ≥ R-10 over 2x4 wall Continuous insulation with R-Value ≥ R-15 over 2x6 wall
8	Continuous insulation with R-Value ≥ R-12.5 over 2x4 wall Continuous insulation with R-Value ≥ R-20 over 2x6 wall

VAPOR CONTROL LAYER

AIA Continuing Education

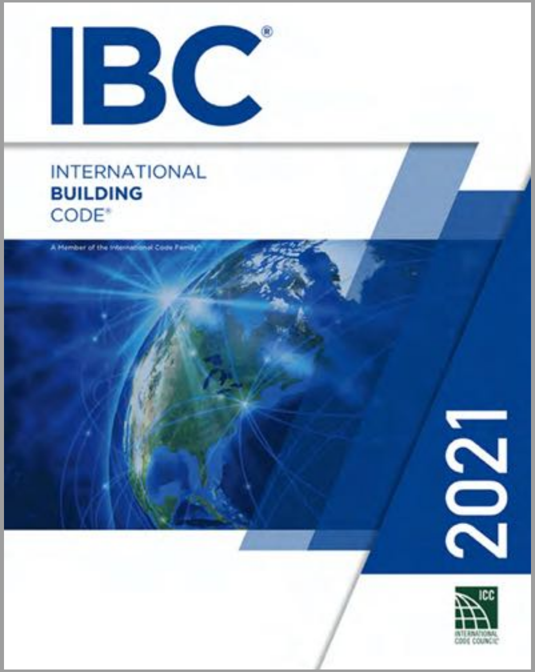


TABLE 1404.3(4) CONTINUOUS INSULATION WITH CLASS II VAPOR RETARDER [a]	
ZONE	**PERMITTED CONDITIONS:**
3	Continuous insulation with R-Value ≥ R-2
4, 5, 6	Continuous insulation with R-Value ≥ R-3 over 2x4 wall Continuous insulation with R-Value ≥ R-5 over 2x6 wall
7	Continuous insulation with R-Value ≥ R-5 over 2x4 wall Continuous insulation with R-Value ≥ R-7.5 over 2x6 wall
8	Continuous insulation with R-Value ≥ R-7.5 over 2x4 wall Continuous insulation with R-Value ≥ R-10 over 2x6 wall

a. In addition to the vapor retarder, spray foam with a maximum permeance of 1.5 perms at the installed thickness, applied to the interior cavity side of sheathing is deemed to comply with the continuous insulation requirement for moisture control purposes of this table where the spray foam R-Value plus any continuous insulation R-Value equals or exceeds the specified continuous insulation R-Value.

VAPOR CONTROL LAYER

AIA Continuing Education

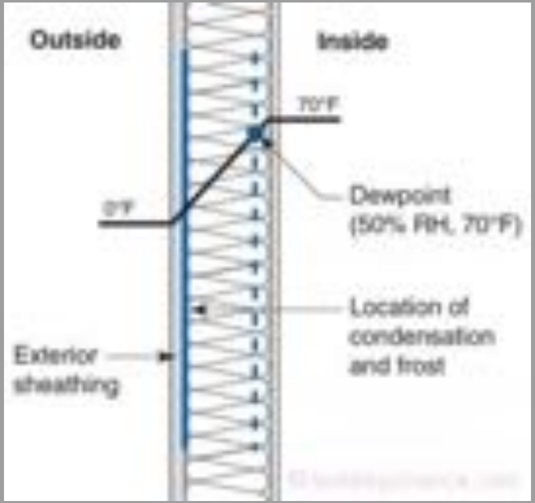


Image Credit: Building Science Corporation

Problem Statement:

- Vapor migration has been misunderstood for decades
- The proper location for vapor retarders can be climate zone and seasonally specific
- Improperly located vapor retarders can increase the potential for condensation
- Vapor retarders have the potential to trap construction moisture and limit drying potential

VAPOR CONTROL LAYER

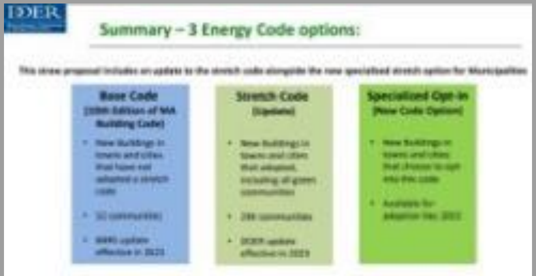
AIA Continuing Education

Key Concepts

- The vapor control layer should be located on the warm side of the thermal control layer
- The vapor control layer can be combined with other control layers if the location in the wall assembly allows
- Care should be taken to not design multiple vapor retarders into a wall assembly
- Mind construction moisture

VAPOR CONTROL LAYER

AIA Continuing Education



Massachusetts Amendments - Base Code:

- None

Massachusetts Amendments – Stretch Code:

- None

BEAUTY

AIA Continuing Education

Beauty: The quality of being pleasing, especially to look at, or someone or something that gives great pleasure, especially when looking at it.

The experience of "beauty" often involves an interpretation of some entity as being in balance and harmony with nature, which may lead to feelings of attraction and emotional well-being. Because this can be a subjective experience, it is often said that "beauty is in the eye of the beholder.”

SOLUTIONS

"If you build the wrong thing right, it's still wrong, right?" - *Joe Lstiburek, Building Science Corporation*

AIA Continuing Education

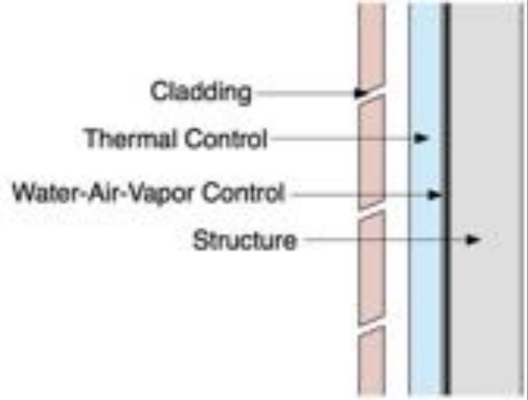
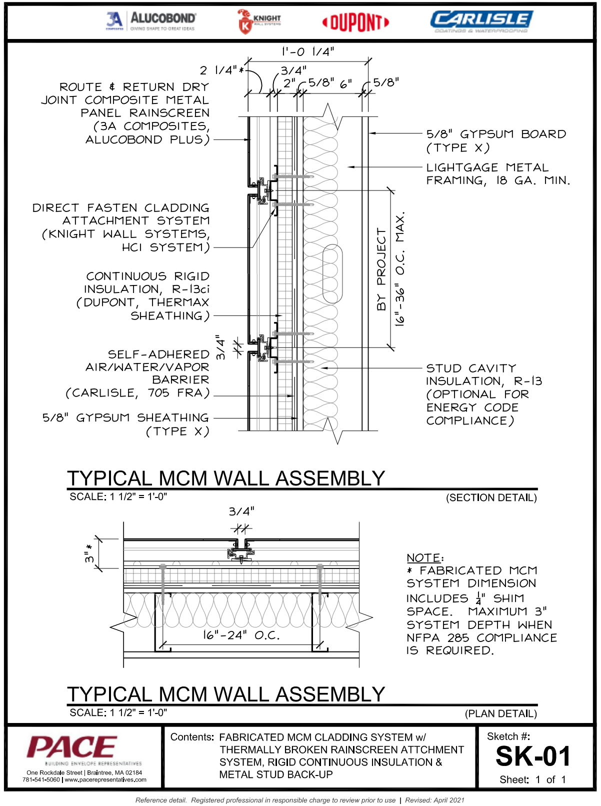


Image Credit: Building Science Corporation

The Perfect Wall

- The water, air & vapor control layer is combined and located outside of the structure to protect the structure and maintain continuity
- The water, air & vapor control layer is decoupled from the cladding and thermal control to allow the wall to work in any climate in any season
- The thermal control layer is moved outside of the structure to maintain continuity & minimize thermal bridging
- Cladding is back vented to promote draining and drying

SOLUTIONS



IECC 2018 – Metal Stud

R-13 + R-7.5ci | U-0.064

Proposed

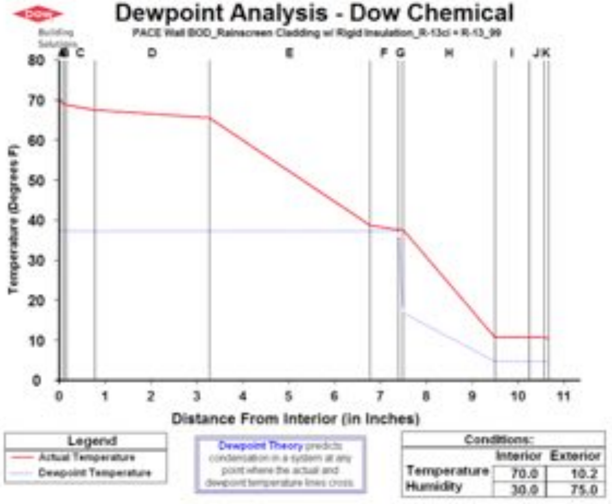
2" Thermax (R-13ci) w/ Knight Wall HCI (24" o.c.)
optional R-13 cavity insulation

<u>ASHRAE Appendix A</u>

R-13ci = U-0.063
R-13 + R-13ci = U-0.048

<u>MA Stretch Code - 9th Edition</u>

N/A

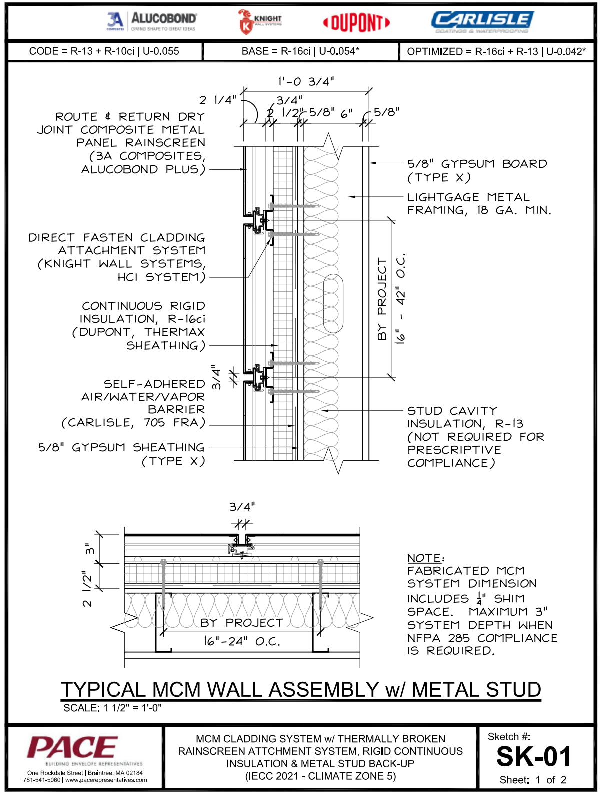


	Component Name	Thickness	R-Value	Rep
A	Interior Air Film	0.100	0.68	0.001
B	Latex Paint 2 Coat	0.050	0.01	0.500
C	Gypsum Board	0.625	0.56	0.023
D	Wall Air Space NonRefl	2.500	1.01	0.006
E	Stud Cavity Insulation	3.500	13.00	0.040
F	Gypsum Sheathing	0.625	0.56	0.027
G	CCW 705 FRA	0.100	0.01	100.000
H	DuPont Thermax Sheathing	2.000	13.00	30.000
I	Wall Air Space NonRefl	0.750	0.00	0.000
J	Rainscreen Cladding	0.313	0.00	0.000
K	Out Air Film Winter	0.100	0.17	0.001
L				
	TOTAL	10.863	29.00	130.598

Interface	Temperature Actual	Temperature Dewpnt	Accum
-A	70.00	37.17	0.000
AB	68.60	37.17	0.000
BC	68.58	37.09	0.000
CD	67.42	37.08	0.000
DE	65.34	37.08	0.000
EF	38.53	37.08	0.000
FG	37.38	37.07	0.000
GH	37.36	16.70	0.000
HI	10.55	4.52	0.000
IJ	10.55	4.52	0.000
JK	10.55	4.52	0.000
KL	10.20	4.52	0.000
L-			

SOLUTIONS

AIA Continuing Education



Reference detail. Registered professional in responsible charge to review prior to use | Revised: September 2023
* Assembly U-Factor based on ASHRAE Standard 90.1 Table A3.3 for insulation values noted

IECC 2021 – Metal Stud

R-13 + R-10ci | U-0.055

Proposed

2 1/2" Thermax (R-16ci) w/ Knight Wall HCI (24" o.c.) optional R-13 cavity insulation

ASHRAE Appendix A

R-16ci = U-0.053

R-13 + R-13ci = U-0.048

R-13 + R-16ci = U-0.041

MA Stretch Code – 10th Edition

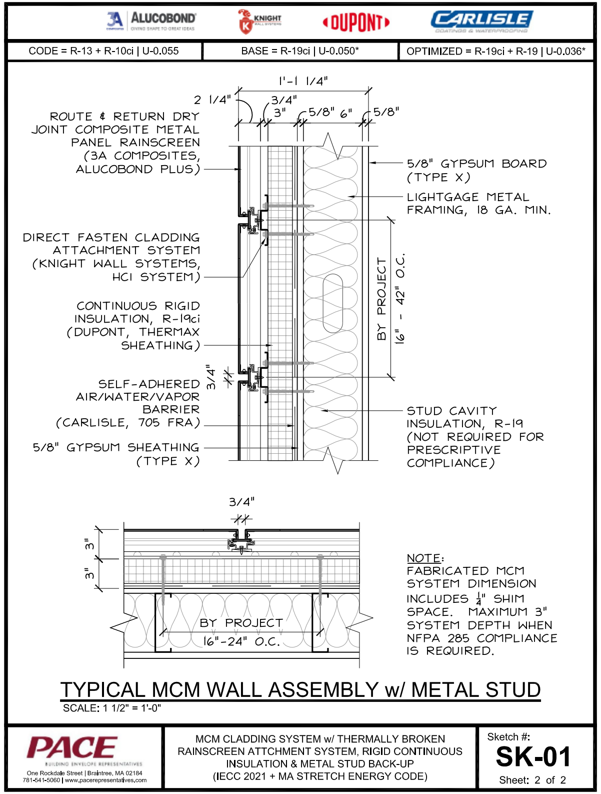
R-16ci = U-0.102 *(prescriptive)*

R-16ci = U-0.057 *(modelled)*

R-13 + R-16ci = U-0.042 *(modelled)*

R-19ci = U-0.050 *(modelled)*

R-19 + R-19ci = U-0.036 *(modelled)*



Reference detail. Registered professional in responsible charge to review prior to use | Revised: September 2023
* Assembly U-Factor thermal derating based on manufacturer's 3D thermal modeling for cladding attachment system and 24" o.c. girt spacing and 16" o.c. fastener spacing

SOLUTIONS

Show Your Work - Prescriptive

R_o = >R-15

Derating Factor = 0.55 – (0.007 * R-16) = 0.44

$R_{derated}$ = R-16 * 0.44 = R-7.04

ASHRAE 90.1 - Appendix A – Table A3.3

R-7ci = U-0.102

Show Your Work - Modelled

3.1 Scenario 1: Knight Wall HCI System with Steel Stud Backup Wall

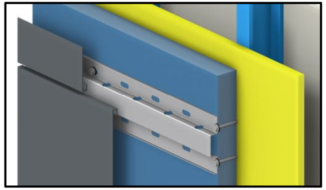


Figure 3: *HCI System w/ Steel Stud Backup Wall*

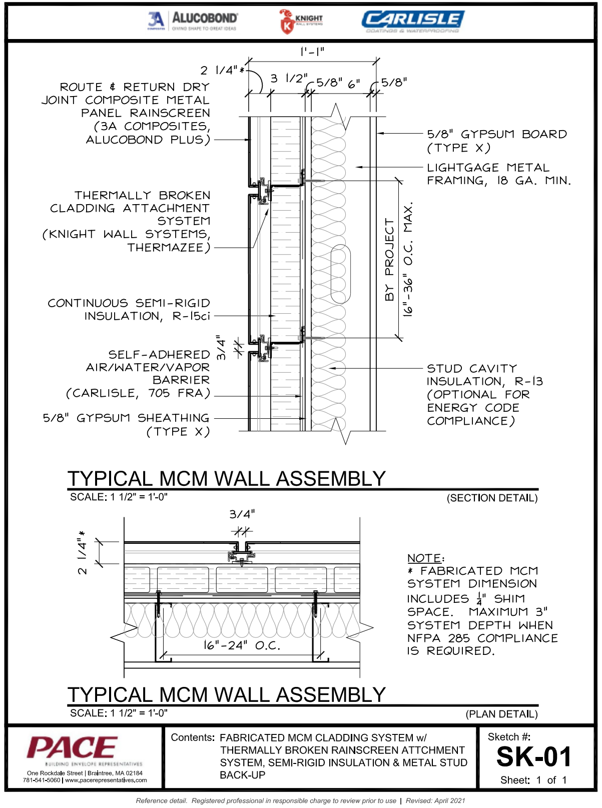
The Knight Wall HCI System with a steel stud backup wall is shown in Figure 3. Clear field U- and R-Values for this scenario are provided below in Table 1. The scenario was analyzed for two vertical spacings of the horizontal girt and for three thicknesses of polyiso insulation.

Table 1: *Thermal Transmittance and Resistance values for Exterior Insulated Steel Stud Wall Assembly with HCI System*

Girt Vertical Spacing	Exterior Polyiso Insulation Thickness	Exterior Insulation Nominal R-Value hr°Fft^2/BTU (m^{2}K/W)	Assembly R_{1D} Value hr°Fft^2/BTU (m^{2}K/W)	Assembly U-Value BTU/hr°Fft^2 (W/m^{2}K)	Assembly Effective R-Value hr°Fft^2/BTU (m^{2}K/W)	% Effective
24"	1.55"	R-10.1 (1.78)	R-13.3 (2.34)	0.081 (0.46)	**R-12.4** (2.18)	94%
	2"	R-13.0 (2.29)	R-16.2 (2.85)	0.067 (0.38)	**R-14.9** (2.62)	92%
	3"	R-19.0 (3.35)	R-22.2 (3.91)	0.050 (0.29)	**R-19.9** (3.51)	90%
30"	1.55"	R-10.1 (1.78)	R-13.3 (2.34)	0.079 (0.45)	**R-12.6** (2.22)	95%
	2"	R-13.0 (2.29)	R-16.2 (2.85)	0.066 (0.37)	**R-15.1** (2.67)	94%
	3"	R-19.0 (3.35)	R-22.2 (3.91)	0.048 (0.27)	**R-20.7** (3.65)	93%

SOLUTIONS

AIA Continuing Education



IECC 2018 – Metal Stud

R-13 + R-7.5ci | U-0.064

Proposed

3 1/2” mineral wool (R-15.1ci) w/ Knight Wall ThermaZee (24” o.c.) optional R-13 cavity insulation

ASHRAE Appendix A

N/A

MA Stretch Code – 9th Edition

N/A

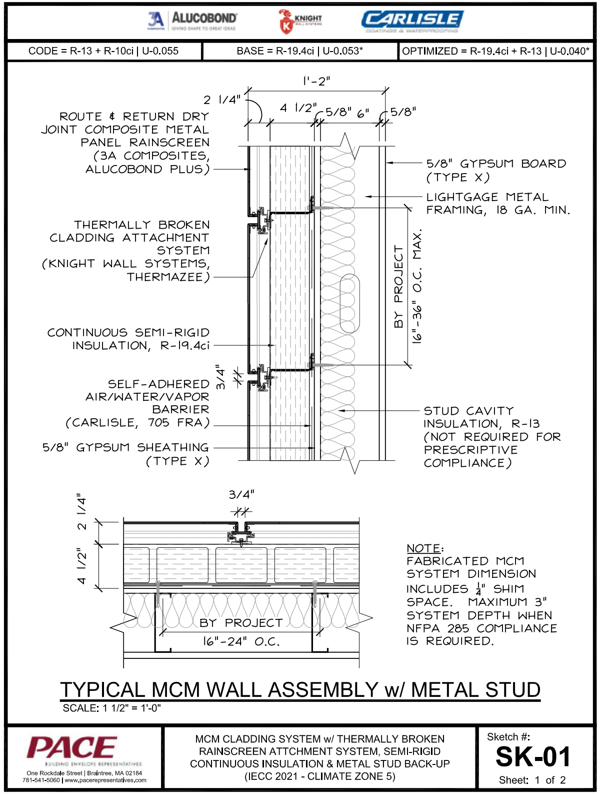
Actual

R-15.1ci = U-0.064 *(modelled)*

R-13 + R-15.1ci = U-0.047 *(modelled)*

SOLUTIONS

AIA Continuing Education



Reference detail. Registered professional in responsible charge to review prior to use | Revised: September 2023
* Assembly U-Factor based on manufacturer's 3D thermal modeling for cladding attachment system and 24" o.c. spacing

IECC 2021 – Metal Stud

R-13 + R-10ci | U-0.055

Proposed

4 1/2" mineral wool (R-19.4ci) w/ Knight Wall ThermaZee (24" o.c.)

optional R-13 cavity insulation

ASHRAE Appendix A

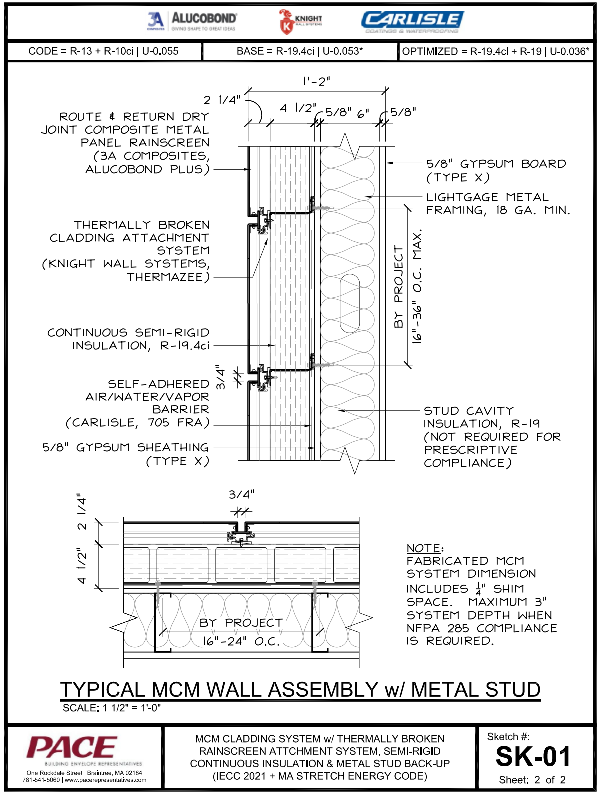
N/A

MA Stretch Code – 10th Edition

R-19.4ci = U-0.092 *(prescriptive)*

R-19.4ci = U-0.053 *(modelled)*

R-13 + R-15.1ci = U-0.047 *(modelled)*



Reference detail. Registered professional in responsible charge to review prior to use | Revised: September 2023
* Assembly U-Factor thermal derating based on manufacturer's 3D thermal modeling for cladding attachment system and 24" o.c. spacing

SOLUTIONS

Show Your Work - Prescriptive

R_o = >R-15

Derating Factor = 0.55 – (0.007 * R-19.4) = 0.414

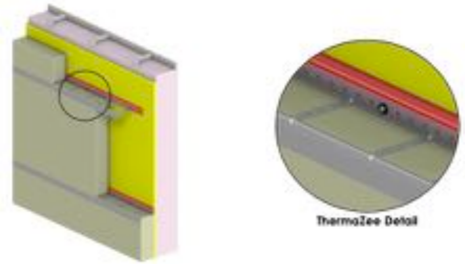
$R_{derated}$ = R-19.4 * 0.414 = R-8.03

ASHRAE 90.1 - Appendix A – Table A3.3

R-8ci = U-0.092

Show Your Work - Modelled

2. THERMAZEE WITH SPLIT INSULATED STEEL STUD ASSEMBLY



Component	Material	Thickness in (mm)	Thermal Conductivity Btu in / ft² h °F (W/m K)	Nominal Resistance ft² h °F / Btu (m² K/W)
Interior Film	-	-	-	R-0.7 (0.12 RSI)
Gypsum	Gypsum	1/2 (13)	1.1 (0.16)	R-0.5 (0.08 RSI)
Stud Cavity	R-19 Batt Insulation	6 (152)	-	R-19.0 (3.35 RSI)
Steel Stud	Galvanized Steel	18 ga.	430 (62)	-
Sheathing	Gypsum	5/8 (16)	1.1 (0.16)	R-0.6 (0.10 RSI)
Exterior Insulation	Rockwool Cavity Rock (R-4.3/in)	Varies	0.23 (0.034)	R-8.6 to R-17.2 (1.51 to 3.03 RSI)
Thermostop Isolation Strip	PVC	-	1.09 (0.157)	-
Fastener	Steel	0.28 (7.1) Ø	347 (50)	-
Isolation Washer	Polypropylene	-	1.5 (0.22)	-
ThermaZee	Galvanized Steel	18 ga.	430 (62)	-
Air Spaces[1]	Air	Varies	Varies	-
Exterior Film	-	-	-	R-0.7 (0.12 RSI)
Overall Wall Assembly 1D	-	-	-	R-30.0 to R-38.6 (5.28 to 6.80 RSI)

[1] The thermal conductivities of the air spaces were determined according to ISO 10077-2

SUMMARY

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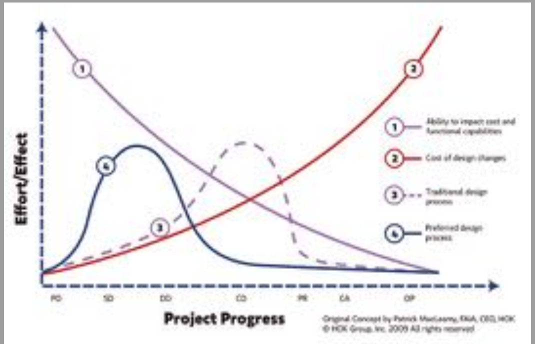

Image Credit: HOK Group, Inc.

- The building envelope influences over 50% of the energy end use of a commercial building
- Establishing envelope performance targets early in design allow design team to maximize the tradeoffs between the envelope and other building systems
- Material selection should account for performance, durability and compatibility
- Water + Path + Force = Leak
- The design and detailing of control layers should be kept as simple as possible, but no simpler
- A properly designed building envelope will reduce energy use, improve indoor environmental quality and assembly durability

REFERENCES & RESOURCES

AIA Continuing Education

- Building Science Corporation
- ASHRAE Fundamentals Handbook
- National Institute of Building Sciences – Whole Building Design Guide
- US Energy Information Administration
- New Buildings Institute
- Payette Research – Thermal Performance of Façades
- Morrison Hershfield - Thermal Performance of Building Envelope Details (1365-RP)
- Morrison Hershfield – BC Hydro Thermal Bridging Guide v1.6

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