2022 MO COMMERCIAL ENERGY CODE TRAINING

Southface MEEA MIDWEST ENERGY EFFICIENCY ALLIANCE

Commercial Envelope

INTRODUCTIONS

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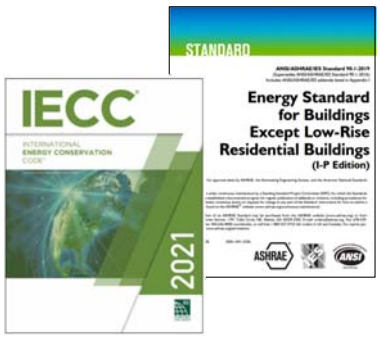

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INTRODUCTIONS

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ABOUT SOUTHFACE

Building Science & Energy Code

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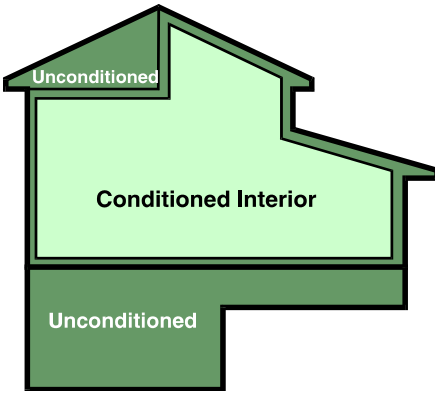
BUILDING SCIENCE FUNDAMENTALS

Understand Building as a System

Control Flow of
- Heat
- Air
- Moisture

The **building thermal envelope** separates conditioned space from unconditioned (or outside) and consists of two elements: an air barrier and insulation that must be continuous and touching



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BUILDINGS ARE SYSTEMS

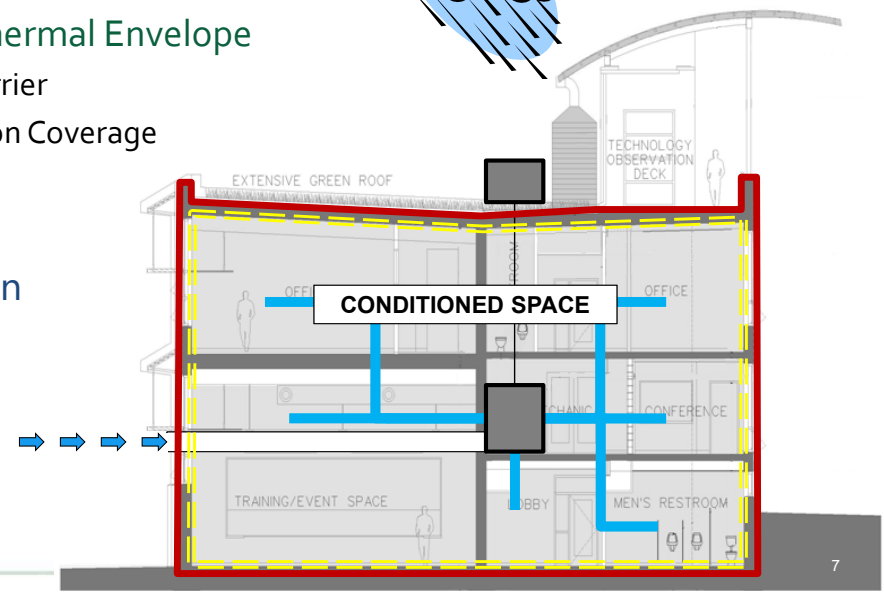
Complete Building Thermal Envelope

- Continuous Air Barrier
- Complete Insulation Coverage

Proper Heating & Cooling Systems

Controlled Ventilation

Deal with Moisture!



HEAT TRANSFER CONCEPTS

Heat always moves from a warmer place to a cooler place

Types of Heat Transfer

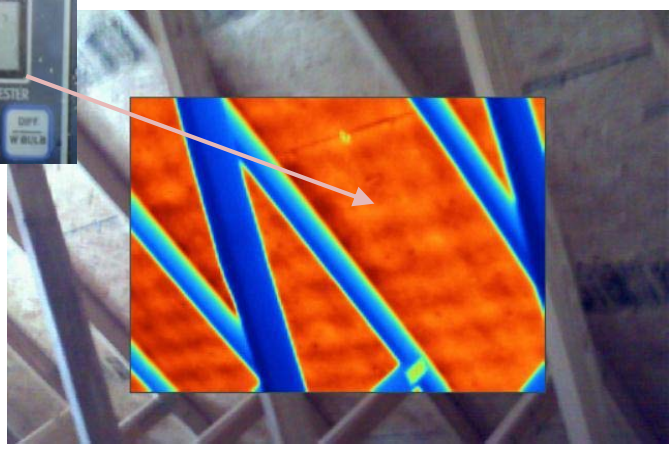
- Radiation – heat flow from hot to cool surface
- Conduction – heat flow through solids
- Convection – heat flow through fluids

BUILDING SCIENCE: HEAT TRANSFER

- Heat is a form of energy
- Heat moves from hot to cold
- 3 methods of heat transfer:
  - **Radiation:**
    Heat emits from a hot surface or hot object, e.g. hot coals
  - **Conduction:**
    Heat moves through a material by contact, e.g. the grill grates
  - **Convection:**
    Heat energy carried by a fluid, e.g. the air inside the covered grill

HEAT TRANSFER: RADIATION

- Low-emitting surfaces slow radiation



Radiation - heat transfer from a hot surface to a cool surface

RADIATION

$$q = \varepsilon\sigma A(T^4 - T_0^4)$$

Radiation is the movement of heat from a hot surface to a cold surface with nothing solid or opaque in between (low-emitting surfaces slow radiation)

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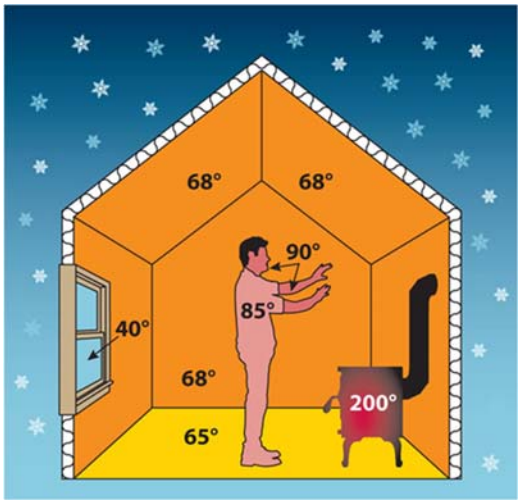
MEAN RADIANT TEMPERATURE

$$q = \varepsilon\sigma A(T^4 - T_0^4)$$

- When the surfaces in a building (walls, floors, ceilings, windows, and doors), are different than the room air temperature, additional body heat can be lost or gained through radiation.
- This can have a major impact on comfort



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$(T_H\text{^}4 - T_L\text{^}4) = ([200+460]\text{^}4 - [90+460]\text{^}4) = (190\text{Billion} - 91\text{Billion}) = 100\text{Billion}$

$\sigma \approx 1.714\times10^{-9}$

CONDUCTION

- Conduction is heat flowing through a solid material
- Insulation slows conduction



CONDUCTION HEAT FLOW CALCULATION

Heat transfer through a solid object: the formula for calculating transmission heat loss is:

$$\mathbf{q = U \times A \times \Delta T}$$

q = heat flow (Btu/hr)

U = inverse of R-Value [U=1/R, R=1/U] (Btu/hr ft^2°F)

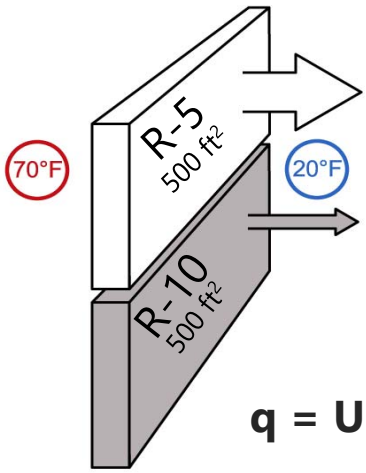
U is referred to as the *Conductance* or *Thermal Transmittance*

A = area (square feet)

ΔT = temperature difference across component (°F)

Btu = British Thermal Unit

CONDUCTION EXAMPLE



q = U x A x ΔT

Low R-value (R-5)

(1/5) x 500 x (70-20) = 5,000 Btu/hr

High R-value (R-10)

(1/10) x 500 x (70-20) = 2,500 Btu/hr

Total = 7,500 Btu/hr

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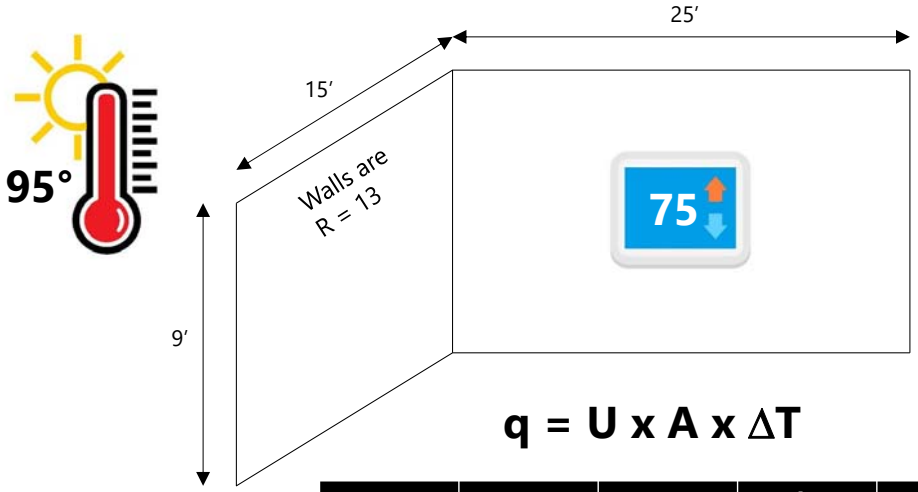
CONDUCTION – GROSS WALL AREA EXAMPLE



q = U x A x ΔT

R	U	Area	Delta T	q
13	.077	360	20	554 Btu/hr

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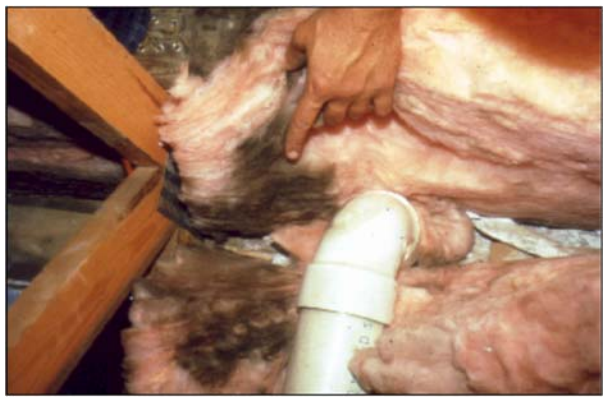
CONVECTION

- Convection is the transfer of heat by the movement of a fluid (gas or liquid)
- Air barriers limit convection

Fiberglass and certain other "air permeable" insulation does not stop air flow!



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AIR LEAK AT SILL (BOTTOM) PLATE

Dirty carpet on **exterior** wall indicates leak at wall sill plate

On **interior** wall indicates wall leaking to attic

Bottom Plate Sealed
(but batt installation fails!)

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CONVECTION

Heat transfer through a fluid (liquid or gas) – usually air.
For air, the formula for calculating convective heat transfer is

$q = 1.08 \times CFM \times \Delta T$ = convective heat flow (Btu/hr)

CFM = Cubic Feet per Minute of air being transported

ΔT = temperature difference of entering air and ambient air (°F)

Example:
A supply fan delivers 200 cfm of OA into a 75°F building when the ambient is 90°F.
Sensible heat added is q = 1.08 x 200 x (15) = 3,240 Btu / hr

SCIENCE OF AIR MOVEMENT

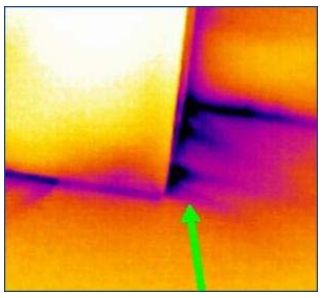
Basic Principle of Air Leakage

High or "+" Pressure → Low or "-" Pressure

Air will **always** move from an area of high pressure to an area of low pressure

When air moves out of a building, the same amount has to come in and vice-versa

CFMout = CFMin

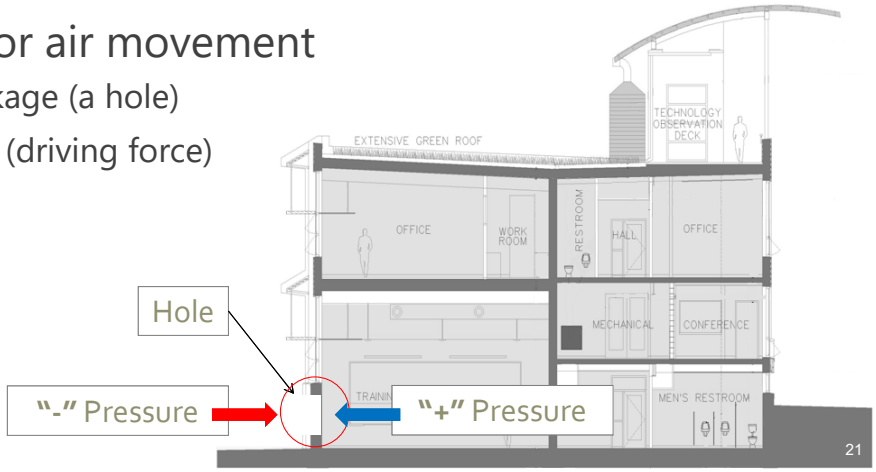


SCIENCE OF AIR FLOW (INFILTRATION)

Basic Principles of Air Infiltration

Two requirements for air movement

1. Pathway for air leakage (a hole)
2. Pressure difference (driving force)



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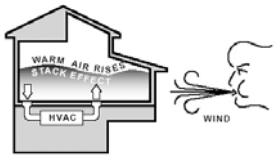
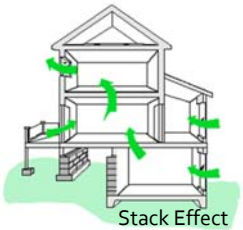
AIR LEAKAGE: DRIVING FORCES

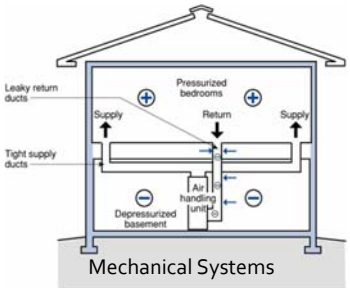
Three forces create pressure differences in a building:

- Wind
- Stack Effect
- Mechanical Fans




Wind


Stack Effect



Mechanical Systems

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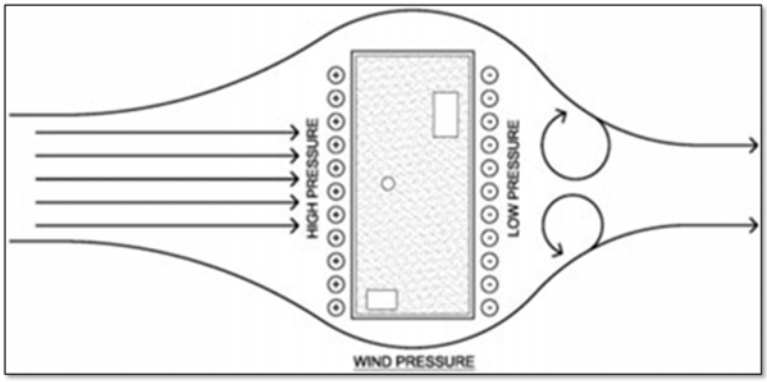
Wind

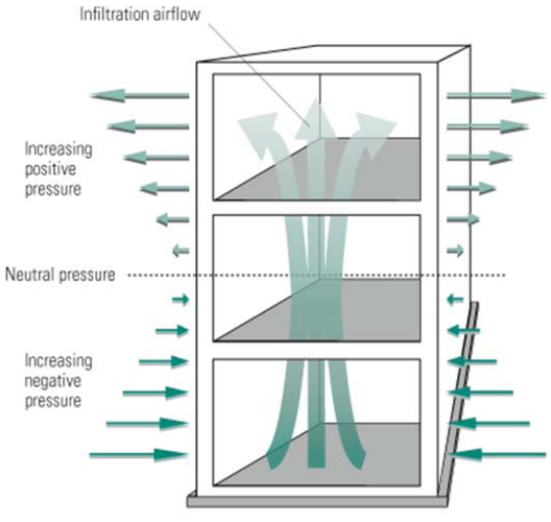
Air leaks across envelope assemblies driven by the pressure differential due to wind

Air enters the building on the windward side (infiltration) and exits on the leeward side (exfiltration)



Stack Effect

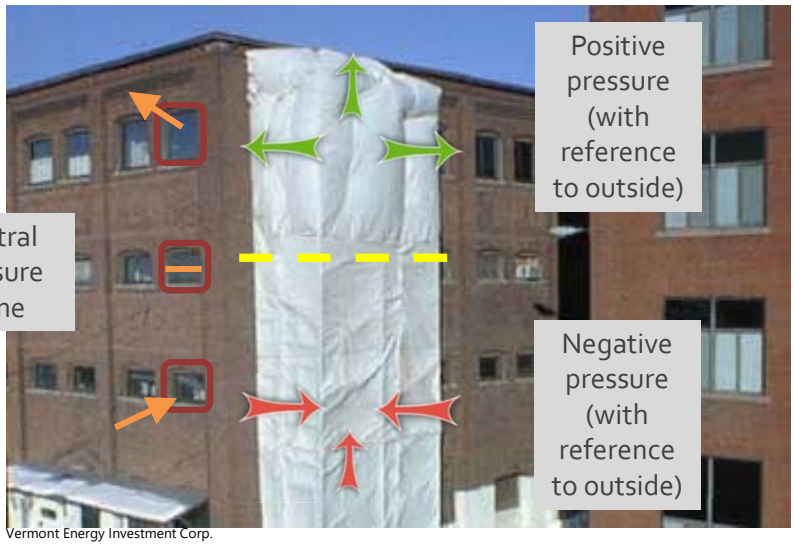
- The stack effect causes air movement due to the buoyancy of heated air
- The greater the thermal difference and the height of the structure, the greater the buoyancy force



STACK EFFECT

Function of

- Building Height
- Temperature difference



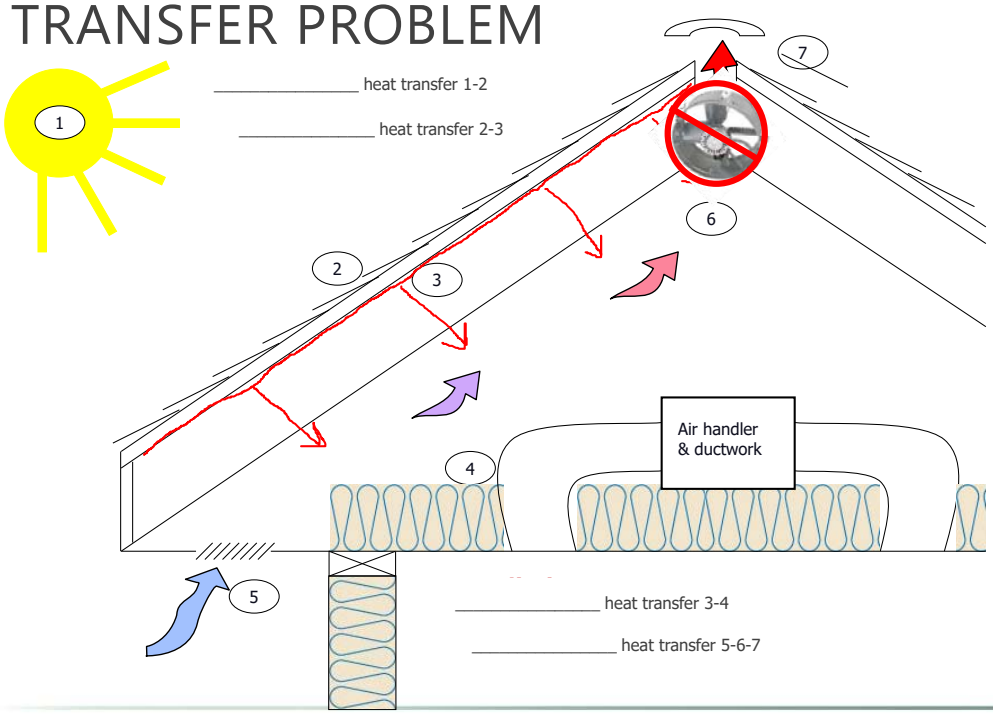
Vermont Energy Investment Corp.

PRESSURES / DRIVING FORCES

Mechanical Fans

Mechanical fans in a building can create significant pressure differences which drive air exchanges.

HEAT TRANSFER PROBLEM



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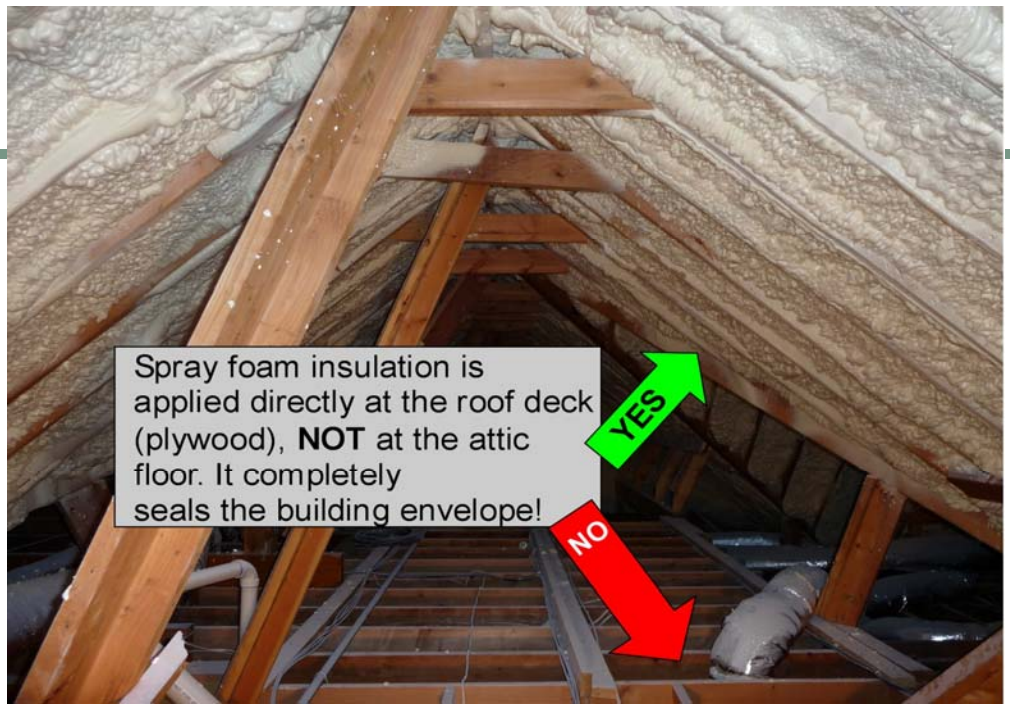

MOISTURE

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BUILDING SCIENCE: MOISTURE TRANSPORT

- Moisture moves from wet to dry
- Liquid water flows downhill (but can be wicked up)
- Water vapor diffuses from high concentration to lower concentration
- Air movement can carry lots of humidity

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FORMS OF MOISTURE FLOW

LIQUID and **VAPOR**

Bulk
Liquid water (rain, drainage, plumbing leaks)

Capillarity
Wicking through porous materials (concrete, wood, paper drywall, fiberglass and cellulose insulation)

Diffusion
Molecules of water moving through porous materials

Infiltration
Moisture laden air brought into the house

Wet → Dry

MANAGING BULK MOISTURE

- Foundation waterproofing
- Proper site drainage
  - Gutters channel water away from foundation
- Drainage planes with proper flashing in walls allows water to escape (e.g. behind brick)

MANAGING BULK MOISTURE

Foundation waterproofing

- Plastic under slab
  - Gravel base under plastic
- Waterproofing foundation wall
  - Drainage mat, dimpled with filter, then backfill
- Footing
  - Wrap footing in plastic –tie into other plastic and waterproofing
  - OR waterproof top of footing before stem wall is poured
- Foundation drain tile
  - Adjacent to footing (better than on top)
  - Routed to daylight or sump pump
- Positive exterior drainage
  - Gutters, downspouts, grading slopes away from foundation
- Capillary break at top of stem wall

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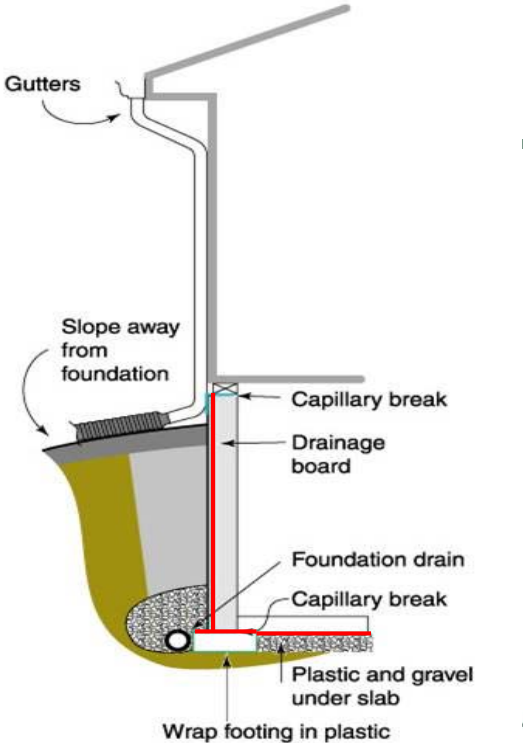
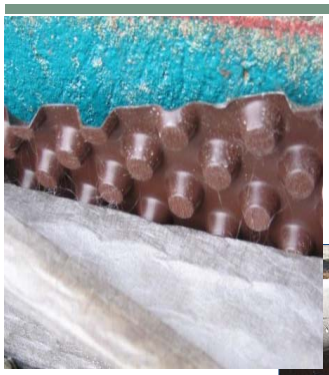


BULK MOISTURE – FOUNDATION WATERPROOFING



Dimpled drainage mat with filter

Drainage system

Spray on water-proofing plus drainage board

Plastic wrapped beneath footing

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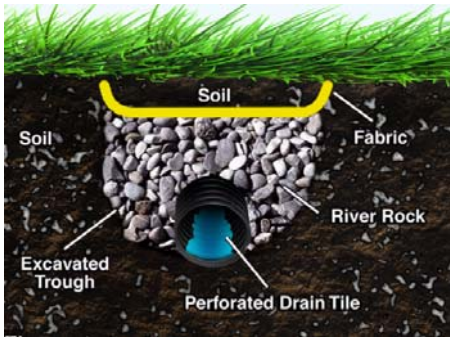
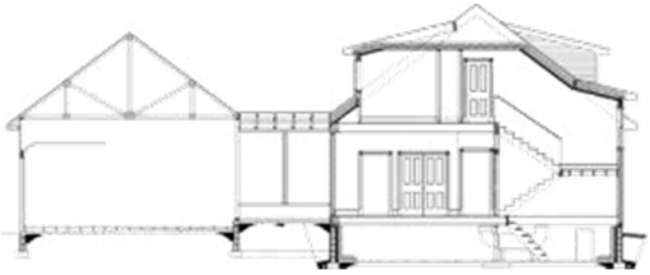
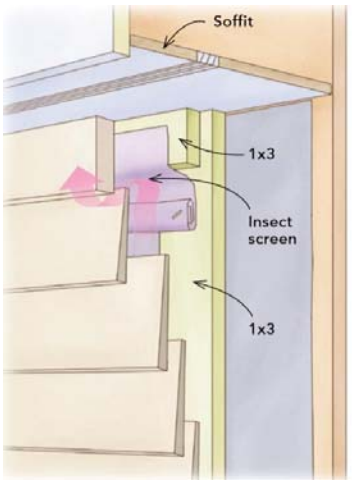
BULK MOISTURE CONTROL

- Proper site drainage
  - Swales
  - Grading with positive slope
  - French drains

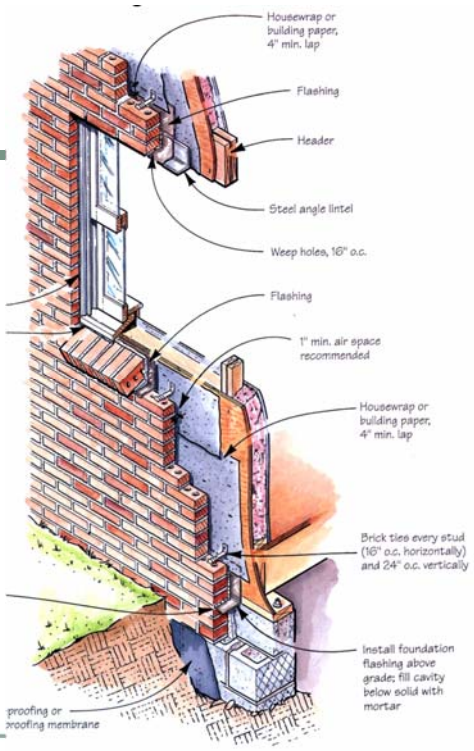


MOISTURE TRANSPORT DRAINAGE PLANES AND CLADDING

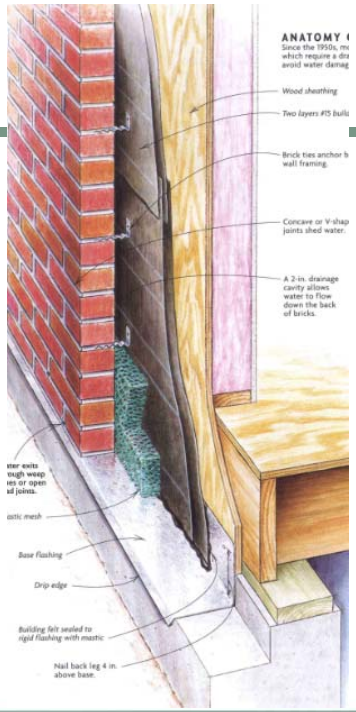




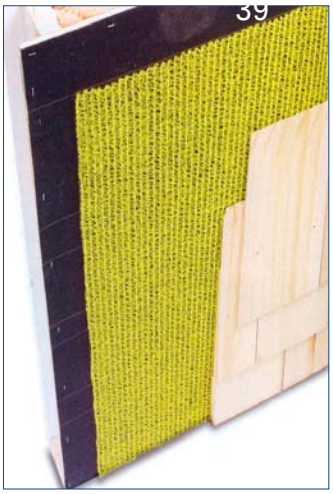
Cladding -Brick Veneer

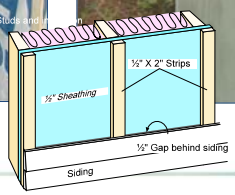


Brick Veneer



Rain Screen / Drainage Plane





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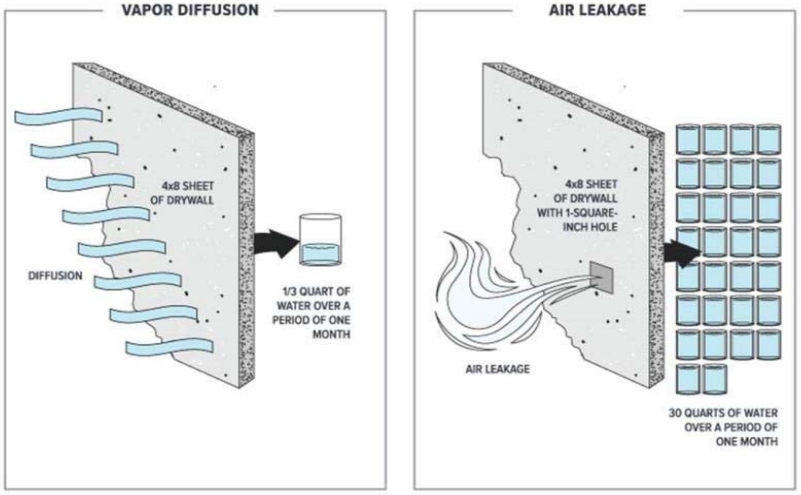
VAPOR DIFFUSION VS. AIR LEAKAGE



VAPOR DIFFUSION VS. AIR LEAKAGE

INTERIOR TEMPERATURE = 70° F
RELATIVE HUMIDITY = 40%

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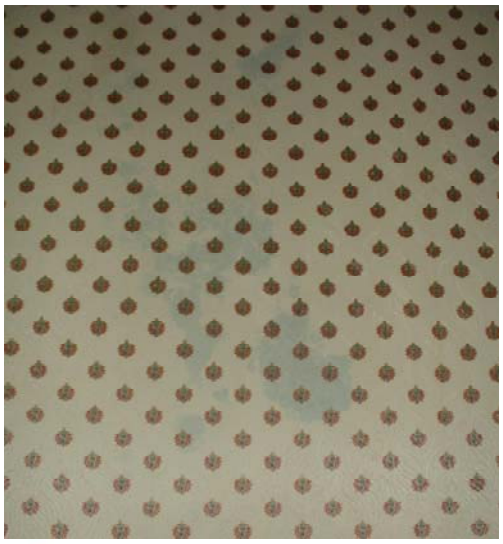
VAPOR DIFFUSION RETARDERS



Appropriate measures for moisture control are essential!

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Commercial Energy Codes

Photo: Jonathan Hillyer, 2009

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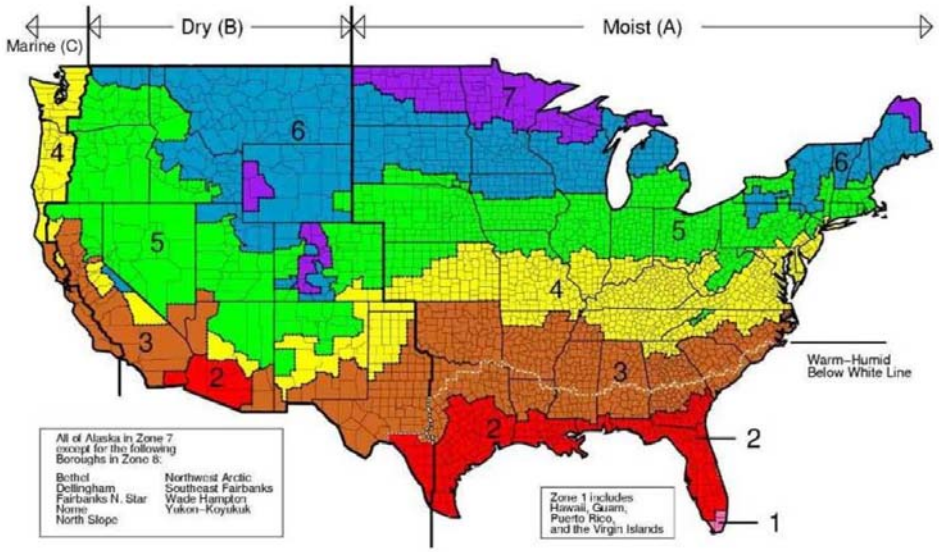
OLD 2018 IECC CLIMATE ZONES

MO is CZ4-5



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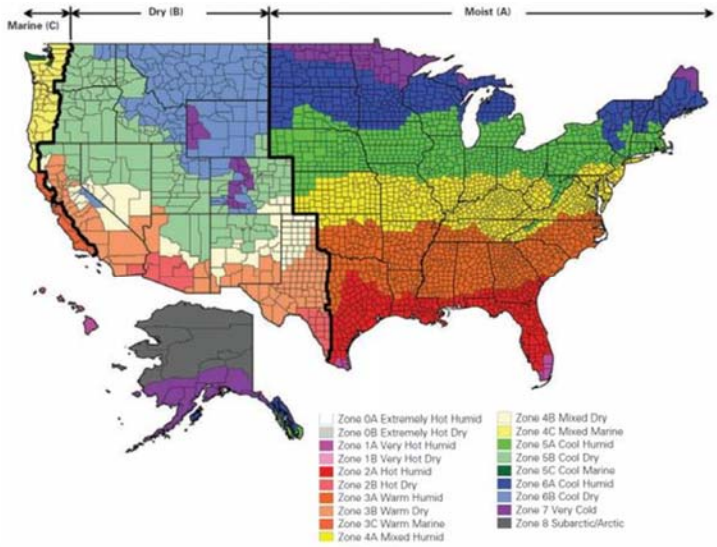
HOW ARE ENVELOPE REQUIREMENTS DETERMINED?

Requirements for building energy codes are linked to the dominate climate within a given jurisdiction, determined by a 30-year average of local surface observations.

Note: Climate zones change! Climate zones change! ASHRAE 90.1-2019 & IECC 2021 have important changes, including a new climate zone (CZ0) and shifts in county designations.

Question: Why should you (or a building owner/operator) care?



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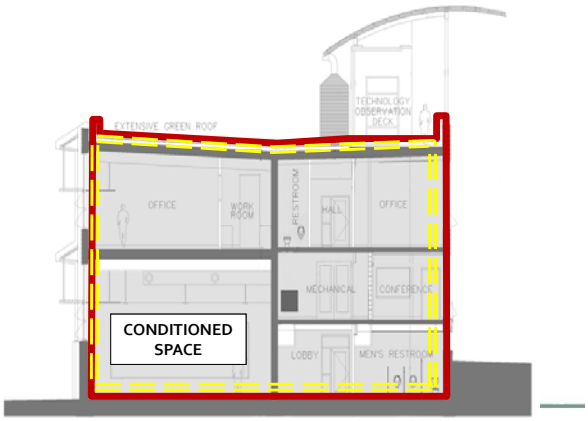
WHAT IS THE BUILDING THERMAL ENVELOPE?

These assemblies can comprise the building thermal envelope if they **separate conditioned from unconditioned space or outside air**

- Roof/Ceiling Assembly
- Wall Assembly
- Vertical Fenestration and Skylights
- Floor Assembly
- Slab Edge
- Below-Grade Wall Assembly

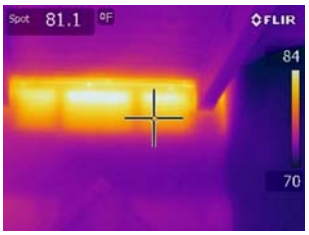


WHY THE SCIENCE MATTERS

You can't really appreciate the impact of the building envelope if you don't understand some basic science behind it.

We will briefly mention these topics as they relate to envelope:

- Solar orientation
- Heat transfer (radiation, conduction, convection)
- Thermal mass
- Air pressure (stack effect)
- Moisture flow



SPACE CONDITIONING CATEGORIES

Envelope requirements are specified by space-conditioning categories

Conditioned space must be:

- a cooled space with a cooling system sensible cooling output capacity larger than 3.4 Btu/h·ft^2 of floor area
- a heated space with a heating system output capacity larger than that specified in table provided
- Or, an indirectly conditioned space

Heating Output, Btu/h·ft^2	Climate Zone
>5	0, 1, 2
>9	3A, 3B
>7	3C
>10	4A, 4B
>8	4C
>12	5
>14	6
>16	7
>19	8

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SPACE CONDITIONING CATEGORIES

Separate envelope component requirements apply to three types of conditioned spaces

- 90.1: *Nonresidential* – IECC: "All other"
- 90.1: *Residential* – IECC: "Group R"
- 90.1: *Semiheated* – spaces are heated, but not to comfort levels, and not cooled.
  (Only if approved by the building official - Uncommon)

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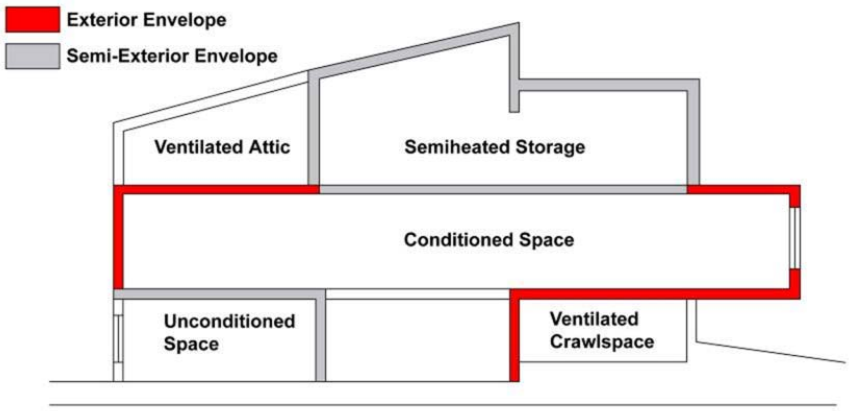
SEMI-EXTERIOR ENVELOPE



**IECC does not have a definition for semiheated*

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SPACE CONDITIONING CATEGORIES

A semiheated space has a heating system with a capacity ≥ 3.4 Btu/h.ft^2 of floor area but is not conditioned space

Spaces are assumed to be conditioned space and comply with requirements of conditioned space at time of construction regardless of whether the mechanical or electrical equipment is included in the building permit application or installed at that time

Exceptions:

Space is designated as semiheated or unconditioned and approved as such by the building official

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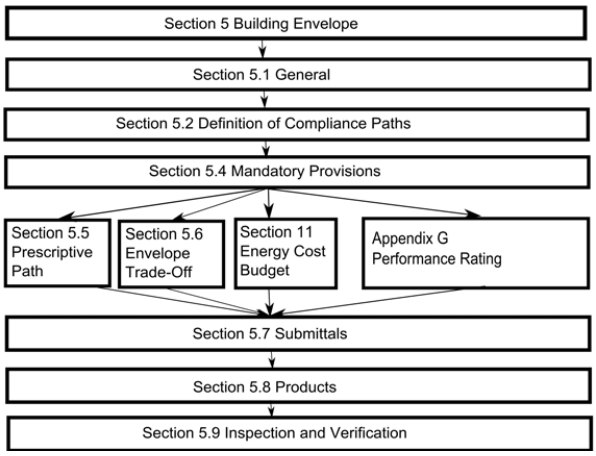
COMPLIANCE OPTIONS

- Mandatory provisions apply to all compliance pathways
- Prescriptive is a recipe that you have to follow
- Other pathways require energy modeling



COMPLIANCE OPTIONS - PRESCRIPTIVE

Building must comply with

- C402 Envelope
- C403 Mech
- C404 SWH
- C405 Lighting
- Plus pick one additional efficiency package

ADDITIONAL EFFICIENCY PACKAGE OPTIONS

One additional efficiency feature must be selected to comply with the IECC

- C406.2 More efficient **HVAC** performance, OR
- C406.3 Reduced **lighting** power density system, OR
- C406.4 Enhanced lighting **controls**, OR
- C406.5 On-site supply of **renewable** energy
- C406.6 Dedicated outdoor air system (**DOAS**), OR
- C406.7 More efficient SWH (**hot water**) OR
- C406.8 Enhanced **envelope** performance OR
- C406.9 Reduced air **infiltration**

COMPLIANCE OPTIONS - PERFORMANCE

C407 Total Building Performance

- Building energy cost to be less than 85% of standard reference design building
- C402.5 Air Leakage
- C403.2 Provisions applicable to all mechanical
- C404 SWH
- Mandatory Lighting C405.2, C405.3, C405.4, C405.6

INSULATION – PRESCRIPTIVE REQUIREMENTS

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MANDATORY PROVISIONS - INSULATION

- Insulation must be in substantial contact with inside surface in a permanent manner
- No loose-fill insulation in attic when ceiling is steeper than 3:12 slope
- Dams & baffles at eave vents to deflect incoming air
- Recessed equipment – effect on insulation
- Insulation protected from sunlight, moisture, landscaping operations, equipment maintenance, and wind
- Stagger joints of multilayered rigid insulation

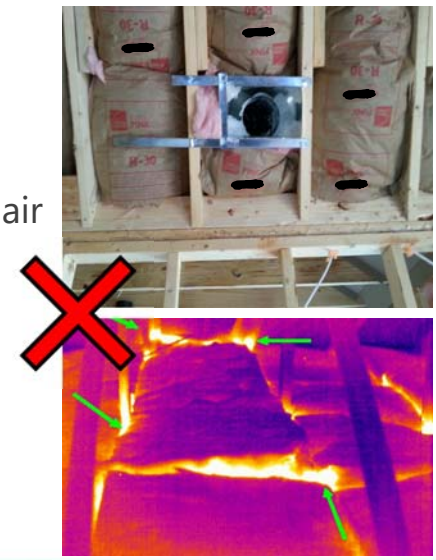

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TABLE C402.1.3 OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Roofs														
Insulation entirely above roof deck	R-20ci	R-25ci	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-60	R-60
Walls, above grade														
Mass[f]	R-5.7ci[c]	R-5.7ci[c]	R-5.7ci[c]	R-7.6ci	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci
Metal building	R-13 + R-6.5ci	R-13 + R-6.5ci	R13 + R-6.5ci	R-13 + R-13ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-17ci	R-13 + R-19.5ci
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	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-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R20 + R3.8ci	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[d]	NR	NR	NR	NR	NR	NR	R-7.5ci	R-10ci	R-7.5ci	R-10ci	R-10ci	R-15ci	R-15ci	R-15ci
Floors														
Mass[e]	NR	NR	R-6.3ci	R-8.3ci	R-10ci	R-10ci	R-14.6ci	R-16.7ci	R-14.6ci	R-16.7ci	R-16.7ci	R-16.7ci	R-20.9ci	R-20.9ci
Joist/framing	R-13	R-13	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-38	R-38	R-38	R-38
Slab-on-grade floors														
Unheated slabs	NR	NR	NR	NR	NR	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-20 for 24" below	R-20 for 24" below	R-20 for 48" below	R-20 for 24" below	R-20 for 48" below
Heated slabs[g]	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below+ R-5 full slab	R-10 for 24" below + R-5 full slab	R-10 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	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

TABLE C402.1.4 OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, *U*-FACTOR METHOD[a, b]

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Roofs																
Insulation entirely above roof deck	U-0.048	U-0.039	U-0.039	U-0.039	U-0.039	U-0.039	U-0.032	U-0.032	U-0.032	U-0.032	U-0.032	U-0.032	U-0.028	U-0.028	U-0.028	U-0.028
Metal buildings	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.031	U-0.029	U-0.029	U-0.029	U-0.026	U-0.026
Attic and other	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021	U-0.017	U-0.017	U-0.017	U-0.017
Walls, above grade																
Mass[f]	U-0.151	U-0.151	U-0.151	U-0.123	U-0.123	U-0.104	U-0.104	U-0.090	U-0.090	U-0.080	U-0.080	U-0.071	U-0.071	U-0.071	U-0.037	U-0.037
Metal building	U-0.079	U-0.079	U-0.079	U-0.079	U-0.079	U-0.052	U-0.052	U-0.050	U-0.050	U-0.050	U-0.050	U-0.050	U-0.044	U-0.039	U-0.039	U-0.039
Metal framed	U-0.077	U-0.077	U-0.077	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.055	U-0.055	U-0.049	U-0.049	U-0.049	U-0.042	U-0.037	U-0.037
Wood framed and other[c]	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.051	U-0.051	U-0.051	U-0.051	U-0.051	U-0.051	U-0.032	U-0.032
Walls, below grade																
Below-grade wall[c]	C-1.140[e]	C-1.140[e]	C-1.140[e]	C-1.140[e]	C-1.140[e]	C-1.140[e]	C-0.119	C-0.092	C-0.119	C-0.092	C-0.092	C-0.063	C-0.063	C-0.063	C-0.063	C-0.063
Floors																
Mass[d]	U-0.322[e]	U-0.322[e]	U-0.107	U-0.087	U-0.074	U-0.074	U-0.057	U-0.051	U-0.057	U-0.051	U-0.051	U-0.051	U-0.042	U-0.042	U-0.038	U-0.038
Joist/framing	U-0.066[e]	U-0.066[e]	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027
Slab-on-grade floors																
Unheated slabs	F-0.73[e]	F-0.73[e]	F-0.73[e]	F-0.73[e]	F-0.73[e]	F-0.54	F-0.52	F-0.52	F-0.52	F-0.51	F-0.51	F-0.434	F-0.51	F-0.434	F-0.434	F-0.424
Heated slabs	F-0.69	F-0.69	F-0.69	F-0.69	F-0.66	F-0.66	F-0.62	F-0.62	F-0.62	F-0.62	F-0.62	F-0.602	F-0.602	F-0.602	F-0.602	F-0.602
Opaque doors																
Nonswinging door	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31
Swinging door[g]	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37
Garage door < 14% glazing[h]	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31	U-0.31

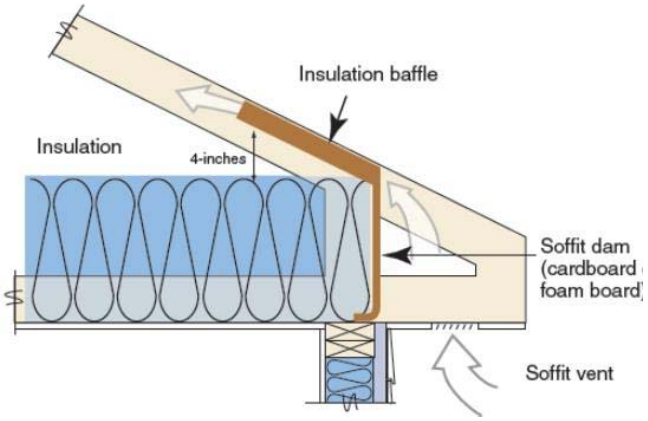
ASHRAE 90.1-2019 ENVELOPE REQUIREMENTS CLIMATE ZONE 4

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

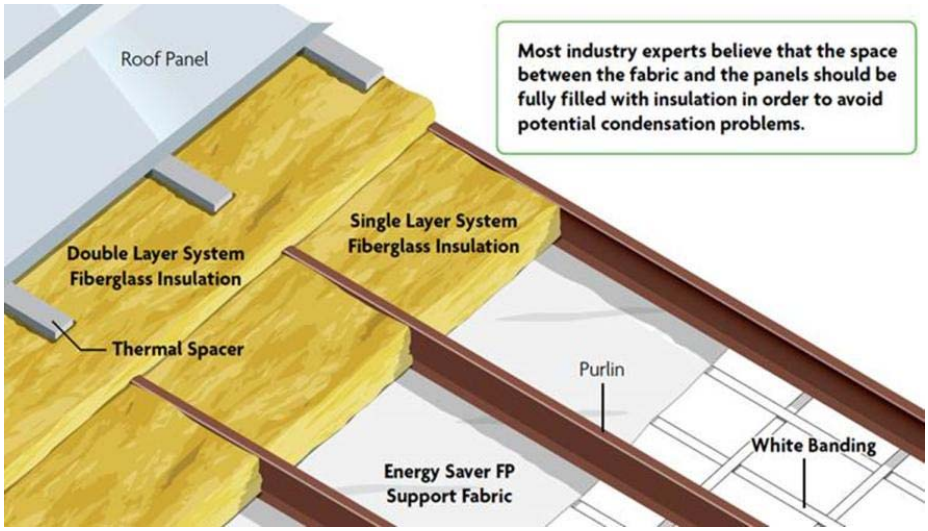
Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal building[a]	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.082	R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel-framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood-framed and other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

MANDATORY PROVISIONS - INSULATION

- Extent of insulation – full component area



METAL BUILDING ROOF INSULATION



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METAL BUILDING ROOF INSULATION

Good – Has *thermal spacer block* to slow down thermal bridging

Better – Has thermal spacer block and the cavity is filled with insulation

Diagrams courtesy of North American Insulation Manufacturers Association (NAIMA)

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INSULATION

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INSULATION

Substantial contact?

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ENVELOPE MINIMUM REQUIREMENTS

Poor wall insulation details

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ENVELOPE MINIMUM REQUIREMENTS

Poor wall insulation detail

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ENVELOPE MINIMUM REQUIREMENTS

Good wall insulation details

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ENVELOPE MINIMUM REQUIREMENTS

Good wall / floor insulation details

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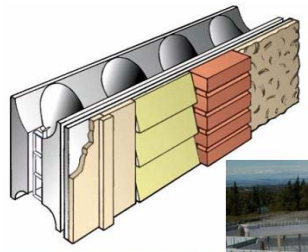
HIGH PERFORMANCE WALLS - ICF'S

CONTINUOUS AIR, THERMAL
& MOISTURE BARRIERS

- ICF's are resource efficient & reduce waste
- Cost effective alternative to light gauge steel
- 40% recycled fly ash and slag to "green" the concrete



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ROOFS

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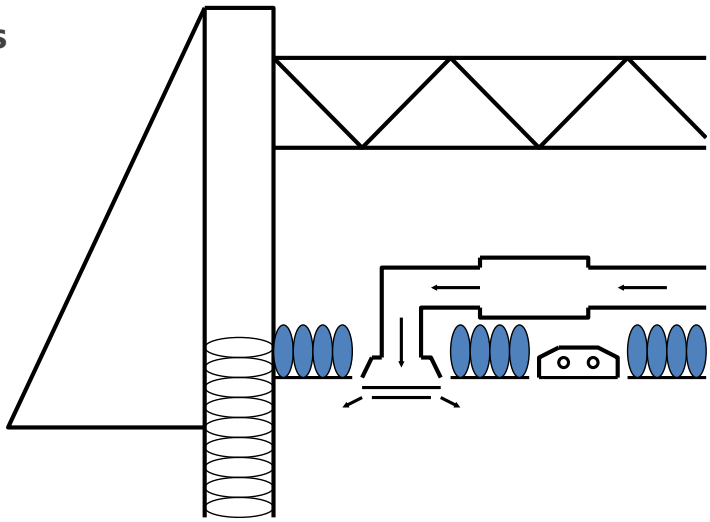
UNACCEPTABLE ROOF DESIGN

Batts over suspended ceiling tiles

Poor pressure boundary caused by tile grid, porous tiles, lighting vent holes

Poor durability – maintenance disrupts batts, exposure to fiberglass dust

Many thermal breaks due to ductwork, light fixtures, grid and support wires



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SUSPENDED CEILINGS

The roof insulation shall not be installed on a suspended ceiling with removable ceiling panels.

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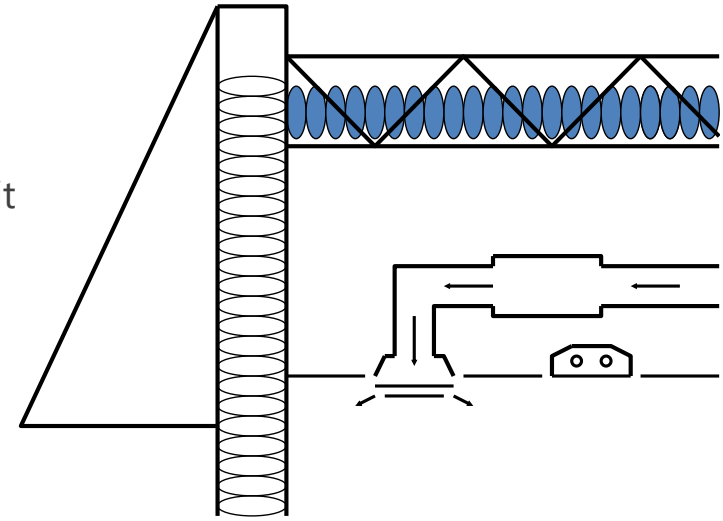
GOOD ROOF DESIGN

Insulation above hard ceiling

Example: taped gypsum; similar to residential construction

Ductwork is inside but must limit and seal HVAC, plumbing, and electrical penetrations through pressure boundary

Thermal bridging from metal roof trusses



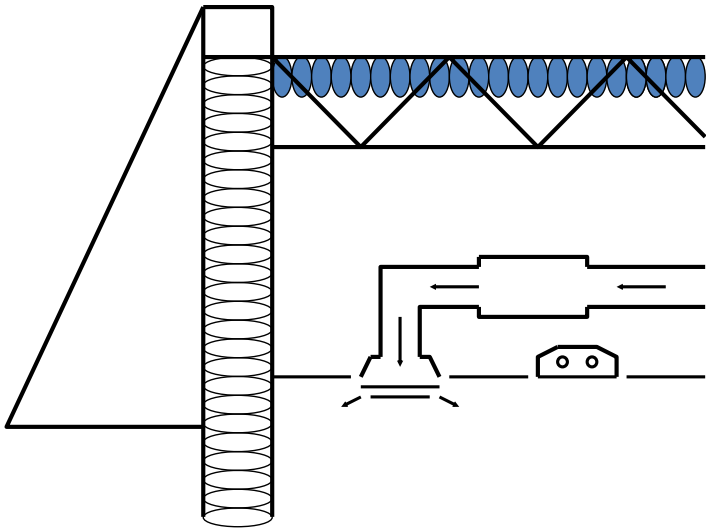
BETTER ROOF DESIGN

Spray foam insulation against underside of roof deck

Minimal thermal breaks and continuous pressure boundary

HVAC equipment and ductwork located within

- Good durability
- Preferred for retrofits



CASE STUDY - PRESCHOOL

Sprayed foam to R20 against underside of roof deck
(+ new lighting fixtures)

HVAC load reduced 33%

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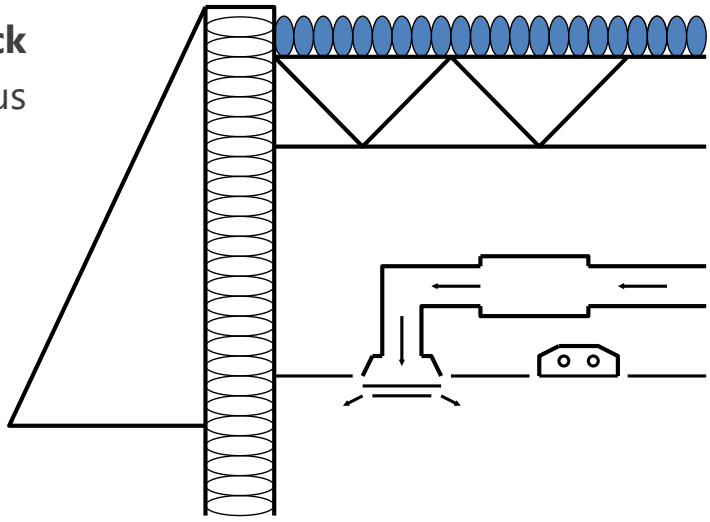
BEST ROOF DESIGN

Rigid insulation above roof deck

No thermal breaks and continuous pressure boundary

HVAC equipment and ductwork located within conditioned space

Good durability



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INSULATION ABOVE ROOF DECK

- Insulation considered continuous
- Continuous insulation board to have > 2 layers and the edge joints between each layer shall be staggered.

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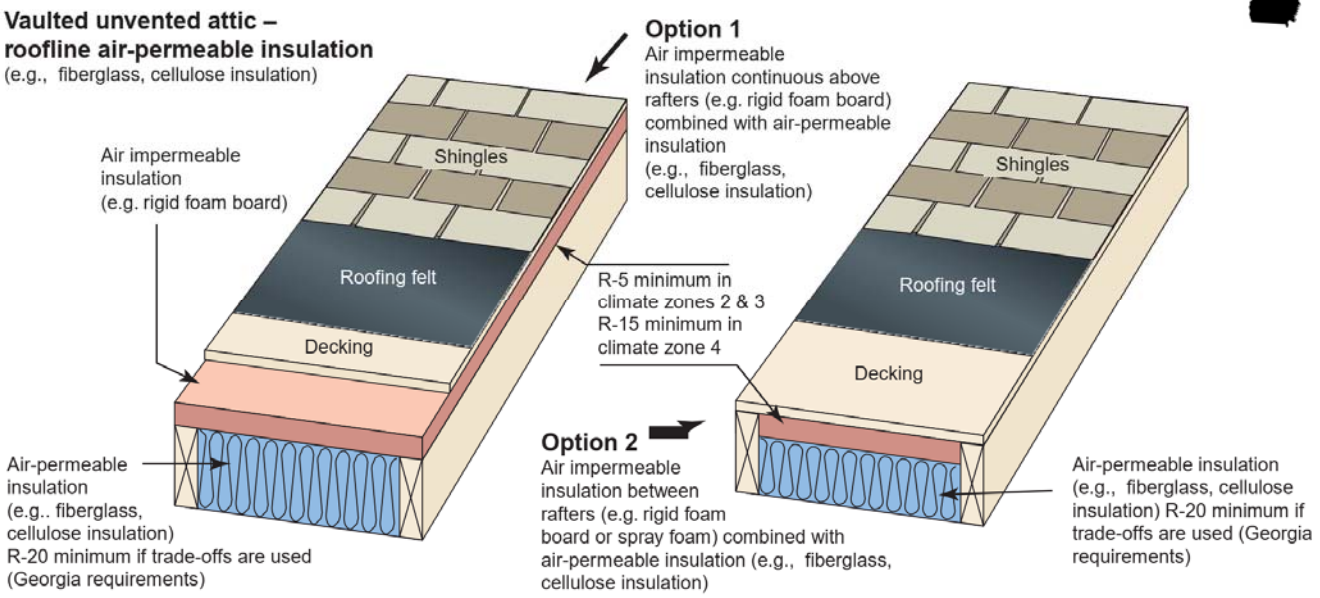
PEACHCREST COMMUNITY CENTER

HYBRID INSULATION APPROACHES



5.3. Where preformed insulation board is used as the air-impermeable insulation layer, it shall be sealed at the perimeter of each individual sheet interior surface to form a continuous layer.

IRC/IBC 806.5 UNVENTED ROOF ASSEMBLIES

- To reduce risk of condensation, install a certain amount of "air-impermeable" insulation before using an "air-permeable" product in an unvented roof assembly

TABLE R806.5
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM RIGID BOARD ON AIR-IMPERMEABLE INSULATION R-VALUE[a, b]
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

a. Contributes to but does not supersede the requirements in Section N1102.

b. Alternatively, sufficient continuous insulation shall be installed directly above the structural roof sheathing to maintain the monthly average temperature of the underside of the structural roof sheathing above 45°F (7°C). For calculation purposes, an interior air temperature of 68°F (20°C) is assumed and the exterior air temperature is assumed to be the monthly average outside air temperature of the three coldest months.

HIGH ALBEDO ROOFS

Required in climate zones 0-3

(not required in CZ4-5 but still a good idea!)

TABLE C402.3
MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]

Three-year aged solar reflectance[b] of 0.55 and 3-year aged thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for either solar reflectance or thermal emittance shall be assigned both a 3-year-aged solar reflectance in accordance with Section C402.3.1 and a 3-year-aged thermal emittance of 0.90.

b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-1 Standard.

c. Aged thermal emittance tested in accordance with ASTM C1371 or ASTM E408 or CRRC-1 Standard.

d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h · ft²·°F (12W/m²· K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

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TABLE 5.5.3.1.1 – INCREASED ROOF INSULATION VALUES

Roofs	*Nonresidential*		*Residential*	
Opaque Elements	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Climate Zone 0				
Insulation entirely above deck	U-0.027	R-36 c.i.	U-0.027	R-36 c.i.
Metal buildings	U-0.028	R-35		
Climate Zones 1 to 3				
Insulation entirely above deck	U-0.030	R-33 c.i.	U-0.029	R-34 c.i.
Metal buildings	U-0.028	R-35		

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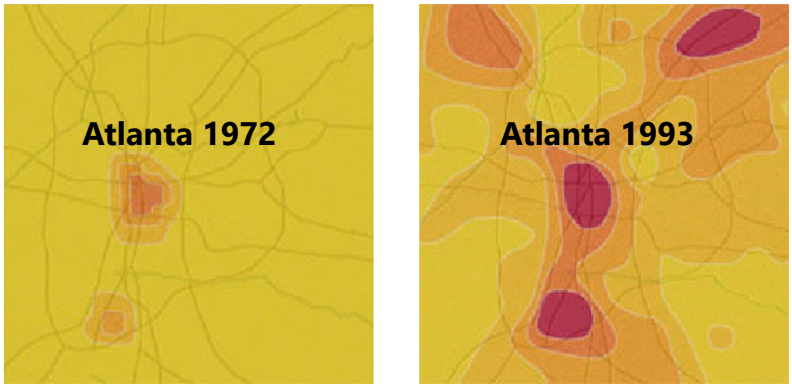
URBAN HEAT ISLAND EFFECT

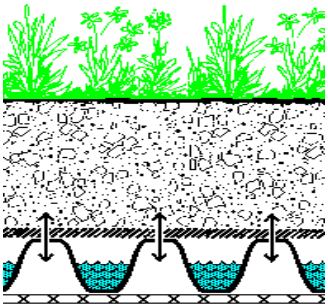


ROOF OPTIONS - IRMA

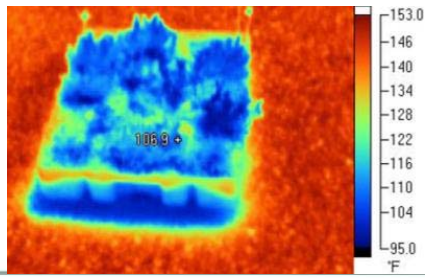
Inverted Roof Membrane Assembly

- Membrane is covered by insulation
- Insulation is protected from sun (concrete or vegetated)
- Result is extended life of roof membrane

VEGETATIVE ROOFS



- Reduces heat island
- Insulates
- Extends life of roof membrane
- Absorbs storm water



UNINTENTIONAL GREEN ROOFS

AIR BARRIER

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CONTINUOUS AIR BARRIER

Continuous air barrier required except in:

- Semiheated spaces in climate zones 0-6
- Single wythe concrete masonry buildings in climate zone 2B

The air barrier shall be designed and noted

- Air barrier components identified or noted in construction documents
- Joints, intersections, and penetrations of air barrier components (incl. lighting fixtures) detailed
- Air barrier must extend over all surfaces of building envelope at lowest floor, exterior walls, and ceiling or roof
- Designed to resist positive and negative pressures from wind, stack effect, and mechanical ventilation

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AIR BARRIER MATERIALS

Materials that have an air permeance not exceeding 0.004 cfm/ft^2 under a pressure differential of 0.3 in. of water (1.57 psf) when tested in accordance with ASTM E2178. The following materials meet these requirements:

Material	Thickness (minimum)
Plywood	3/8 in.
Oriented strand board	3/8 in.
Extruded polystyrene insulation board	½ in.
Foil-faced urethane insulation board	½ in.
Exterior gypsum sheathing or interior gypsum board	½ in.
Cement board	½ in.
Built up roofing membrane	
Modified bituminous roof membrane	
Single-ply roof membrane	
A Portland cement/sand parge, stucco, or gypsum plaster	½ in.
Cast-in-place and precast concrete	
Sheet metal	
Closed cell 2 lb/ft^3 nominal density spray polyurethane foam	1 in.

AIR BARRIER INSTALLATION

The following areas are to be wrapped, sealed, caulked, gasketed, or taped:

- Joints around fenestration and door frames (both manufactured and site-built)
- Junctions between walls
  - And foundations
  - At building corners
  - And roofs or ceilings
- Penetrations for roofs, walls, and floors
- Building assemblies used as ducts or plenums
- Joints, seams, connections between planes, and other changes in continuous air barrier materials

RECESSED EQUIPMENT

Lighting fixtures; heating, ventilating, and air-conditioning equipment, including wall heaters, ducts, and plenums; and other equipment shall not be recessed in such a manner as to affect the insulation thickness unless:

a) the total combined area affected (including necessary clearances) is less than 1% of the opaque area of the assembly,
b) the entire roof, wall, or floor is covered with insulation to the full depth required, or
c) the effects of reduced insulation are included in calculations using an area-weighted average method and compressed insulation values obtained from Table A9.4.3.

In all cases, air leakage through or around the recessed equipment to the conditioned space shall be limited in accordance with Section 5.4.3.

RECESSED LIGHTING

All recessed luminaires installed in the building thermal envelope must be IC rated and have the following:

- Sealed with gasket or caulk between housing and interior wall or ceiling covering
- Labeled in accordance with ASTM E 283 to allow ≤2.0 cfm of air movement between conditioned and unconditioned spaces

MAJOR AIR LEAKAGE LOCATIONS

- Cavities above suspended ceilings
- Plenum return spaces (Highly depressurized)
- Ventilated walls
- Equipment tunnels and chases
- Mechanical rooms and mezzanines
- Unconditioned adjacent space (storage, plant, warehouse, etc.)

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AIR SEALING IS MANDATORY

Roof leak or something else?

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NO OR POOR QUALITY AIR SEALING

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GETTING BETTER

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HOW TO ASSESS AIR SEALING

Look up!
Sometimes behind a drop ceiling.

VERIFYING AN ENERGY EFFICIENT BUILDING ENVELOPE

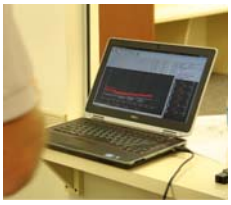
Blower Door Testing – Recognized by IECC

- Prove Air Sealing
- Envelope Integrity

C402.5 Air leakage—thermal envelope (Mandatory). The *thermal envelope* of buildings shall comply with Sections C402.5.1 through C402.5.8, or the building *thermal envelope* shall be tested in accordance with ASTM E 779 at a pressure differential of 0.3 inch water gauge (75 Pa) or an equivalent method approved by the code official and deemed to comply with the provisions of this section when the tested air leakage rate of the building thermal envelope is not greater than 0.40 cfm/ft^2 (0.2 L/s · m^2). Where compliance is based on such testing, the building shall also comply with Sections C402.5.5, C402.5.6 and C402.5.7.

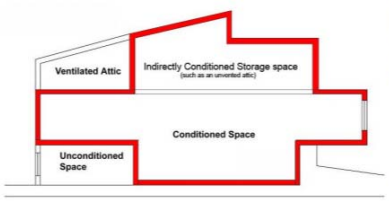
$$ELR_{75} = \frac{CFM_{75}}{\text{shell area}}$$

$$ELR_{75} \leq 0.40$$



ENVELOPE LEAKAGE RATIO @ 75 PA "ELR75" – A BETTER METRIC

- Leakage occurs through shell of building (not through volume)
- Normalizing leakage at 75Pa (0.3 in w.c.) based on shell area is most common for commercial buildings



Building Thermal Envelope

The building thermal envelope is the portion of the building envelope that is comprised of the continuous air barrier and insulation and separates conditioned space from unconditioned space.

Example Calculation

A 7,600 square foot building (First floor: 3,600 square feet and second floor: 4,000 square feet) has a shell area of 13,920 square feet. The blower door test measures a flow of 3,340 CFM_{75}.

What is the Envelope Leakage Ratio at 75 Pa?

ELR75 is calculated by dividing the measured CFM75 by the total shell area of the envelope.

$$\textbf{Shell Area} = 4000ft^2 + 4000ft^2 + 5920ft^2 = \mathbf{13{,}920}ft^2$$

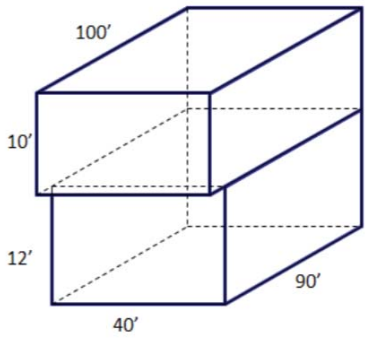
$$\textbf{BD Fan Flow Measurement} = \mathbf{3{,}340}\ CFM_{75}$$

$$ELR_{75} = \frac{CFM_{75}}{Shell\ Area}$$

$$ELR_{75} = \frac{3{,}340\ CFM_{75}}{13{,}920\ sf}$$

$$ELR_{75} = \mathbf{0.24}$$

Envelope passes program requirement and earns additional points



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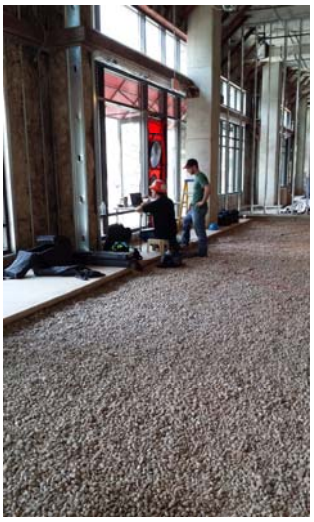
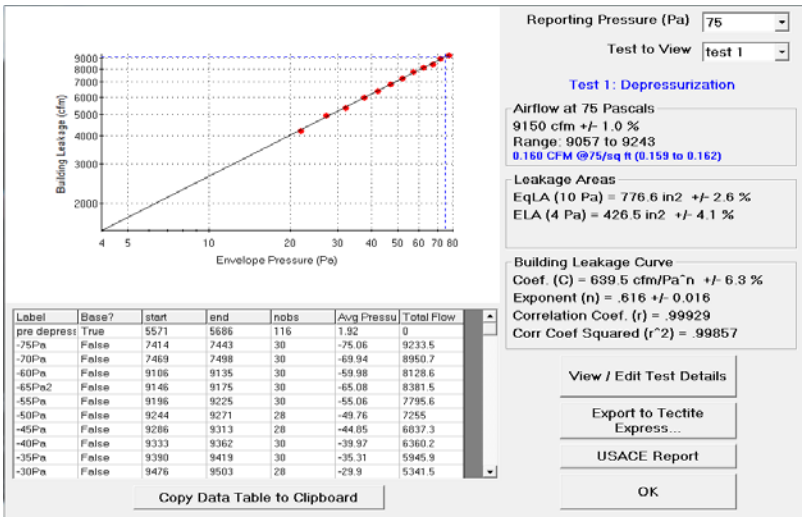
MULTI-BLOWER DOOR – ENVELOPE LEAKAGE TEST





Label	Base?	start	end	nobs	Avg Pressu	Total Flow
pre depress	True	5571	5686	116	1.92	0
-75Pa	False	7414	7443	30	-75.06	9233.5
-70Pa	False	7469	7498	30	-69.94	8950.7
-60Pa	False	9106	9135	30	-59.98	8128.6
-65Pa2	False	9146	9175	30	-65.08	8381.5
-55Pa	False	9196	9225	30	-55.06	7795.6
-50Pa	False	9244	9271	28	-49.76	7255
-45Pa	False	9286	9313	28	-44.85	6837.3
-40Pa	False	9333	9362	30	-39.97	6360.2
-35Pa	False	9390	9419	30	-35.31	5945.9
-30Pa	False	9476	9503	28	-29.9	5341.5

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BONUS - REDUCED AIR INFILTRATION

Air infiltration verified by whole-building pressurization test

- Per ASTM E779 or ASTM E1827
- By an independent third party

Measured air-leakage rate not to exceed 0.25 cfm/ft^2 under pressure differential of 0.3 inches w.c. (75 Pa), with calculated surface area the sum of above- and below-grade building envelope

Submit report to code official and building owner, including: tested surface area, floor area, air by volume, stories above grade, and leakage rates

Exception: Buildings over 250,000 ft^2 of conditioned floor area don't need testing on whole building, can test representative above-grade sections. Tested areas to total not less than 25% of conditioned floor area and tested per C406.9

BUILDING ENVELOPE

Case Study Overview

- Dining Hall
  - o One Story; 4,615 sf; climate zone 3A
  - o SFBE 14,668 sf; CMU with brick veneer
- House of Worship
  - o One Story; 12,864 sf; climate zone 3A
  - o SFBE 36,845 sf; metal stud with EIFS

BUILDING ENVELOPE

Findings of Case Study

- Dining Hall
  - o VE effort to save on materials led to increased cost and time on new envelope solution
  - o Following manufacturer material installation recommendations did not always happen

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BUILDING ENVELOPE

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BUILDING ENVELOPE

Findings of Case Study

- House of Worship
  - o Designate materials that will act as air barrier
  - o Create material transition location details to link one air barrier material to the next

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BUILDING ENVELOPE

Case Study Findings

- Inline Retail
  - o Envelope Transitions

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UTILITY CHASE

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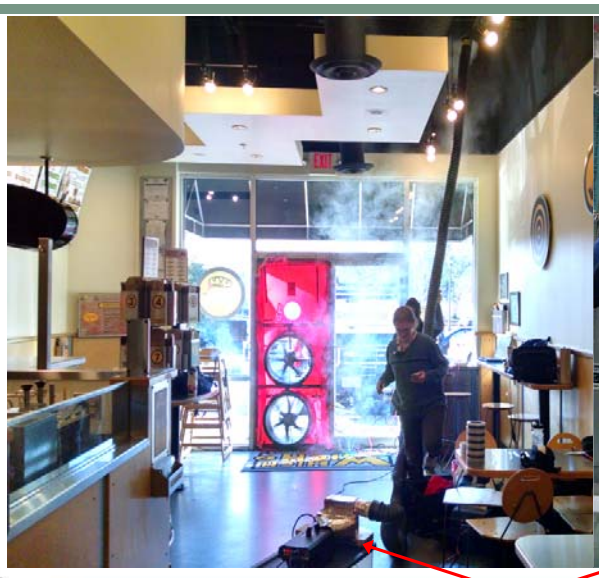
HOW TO GET FOG IN THE RIGHT PLACE



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RTU ENVELOPE PENETRATIONS

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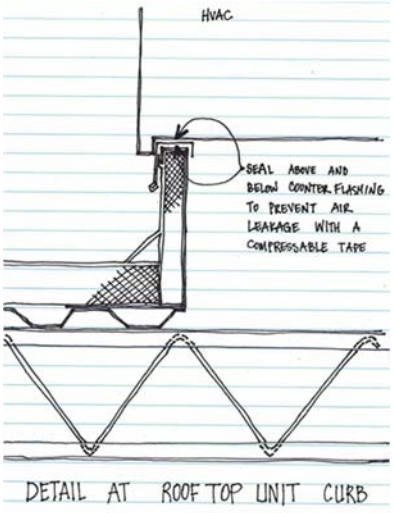
RTU ENVELOPE PENETRATIONS



Wall and roof penetration require sealing at curb and equipment

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ROOF MEMBRANE CONNECTIONS

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PARAPET LEAK

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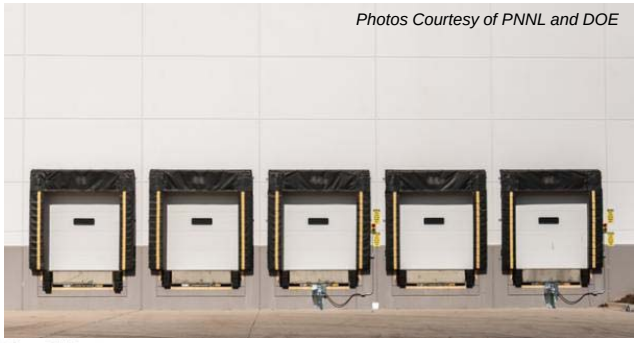
LOADING DOCK WEATHERSEALS

Cargo and loading door openings must be equipped with weatherseals to restrict infiltration and provide direct contact with vehicles along top and sides



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LOADING DOCK WEATHERSEALS

ASHRAE 90.1 2019

Exception – Climate zones 1-3

IECC 2021

No exceptions for warmer climate zones.

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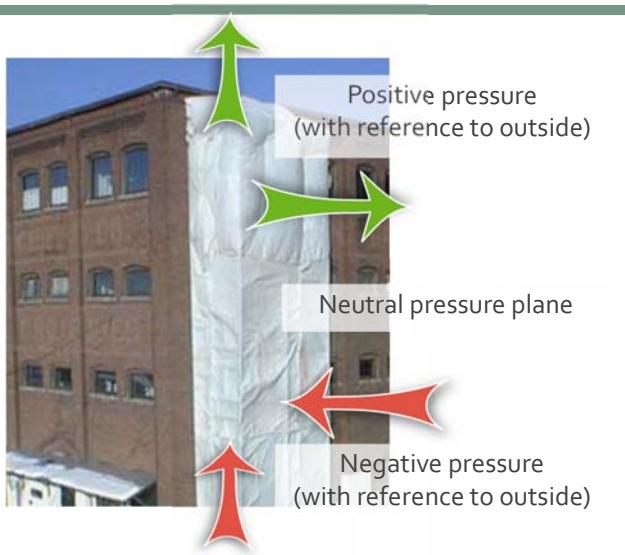
VESTIBULES

Required for both codes with many exceptions

The taller the building, the greater the need for vestibules

Both codes vary greatly on requirements based on zones and other inputs



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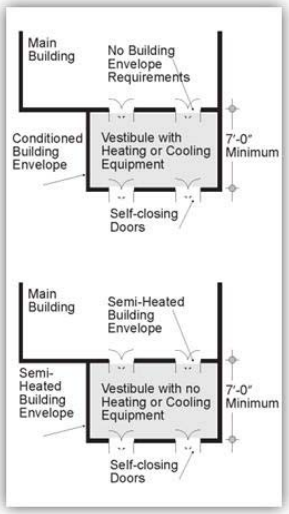
VESTIBULES

Vestibules must have

- Self-closing doors
- Interior and exterior doors not open at the same time
- Distance between interior and exterior doors not < 7 ft when in closed position
- *Floor* area of each vestibule to not exceed the greater of 50 ft^2 or 2% of the gross *conditioned floor area* for that level of the *building*
- Exterior envelope of conditioned vestibule comply with *conditioned space* requirements
- Interior/exterior envelope of unconditioned vestibule comply with *semiheated space* requirements



VESTIBULES DETAILS

Building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

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VESTIBULES EXCEPTIONS

1. Buildings in Climate Zones 1 and 2.
2. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
3. Doors opening directly from a sleeping unit or dwelling unit.
4. Doors that open directly from a space less than 3,000 square feet (298 m^2) in area.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. Doors that have an air curtain with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3.

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90.1 - VESTIBULES EXCEPTIONS

- Non-entrance *doors* or *doors* opening from *dwelling unit*
- *Building entrances* with revolving *doors*
- All *building entrances* in climate zones 1 and 2 **OR** in *buildings* in climate zone 3 < 4 stories and < 10,000 ft^2 in gross conditioned floor area **OR** in buildings < 1000 ft^2 in *gross conditioned floor area* in climate zones 0 and 4-8
- All *doors* that open from *spaces* < 3000 ft^2 and separate from *building entrance*
- *Semiheated spaces*
- Enclosed elevator lobbies for *building entrances* directly from parking garages

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90.1 VESTIBULES FOR LARGE SPACES

Vestibules opening into large *conditioned spaces* (large retail)

- *spaces* having a *gross conditioned floor area* for that level of the *building* of 40,000 ft^2 and greater,
- and when the *doors* opening into and out of the vestibule are equipped with automatic, electrically driven, self-closing devices, the interior and exterior *doors* shall have a minimum distance between them of not less than 16 ft.

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2022 MISSOURI ENERGY CODE ENVELOPE QUIZ

A 3 story 25,000 ft^2 office building is located in CZ4. The primary public entrance doors open into the main lobby which is 4000 ft^2 and has a centrally located security desk; each hallway off this lobby has double swinging doors.

Is this building required to have a vestibule?

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SECTION 6 – 6.4.3.9
HEATING AND COOLING IN VESTIBULES

Include automatic controls to shut off heating system when

- OA temps are > 45°F
- Also controlled by a thermostat in the vestibule with setpoint limited to maximum of 60°F

Note: a single heating thermostat in the vestibule limited to 45°F would meet the requirements

Shut off vestibule cooling system when

- Controlled by a thermostat in the vestibule with setpoint limited to minimum of 85°F

Exceptions, vestibules:

- heated or cooled by site-recovered energy
- tempered with transfer air that would otherwise be exhausted

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CONDITIONED VESTIBULES?

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FENESTRATION

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FENESTRATION PRODUCT RATING

How Do You Meet the Requirement?

- Fenestration product rating in accordance to NFRC 100 (Windows, Doors, Skylights)
- Labeled and certified by the manufacturer
- Non-NFRC 100 rated fenestration
  - Default Glazed Fenestration U-factor Table C303.1.3(1)

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NATIONAL FENESTRATION RATING COUNCIL
LABEL CERTIFICATE

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: ***XYZ-001*** **Issuance Date:** mm/dd/yyyy

NFRC CERTIFIED PRODUCT RATING INFORMATION:*

The NFRC Certified Product Rating Information listed here is to be used to verify that the ratings meet applicable energy code requirements.

PRODUCT LISTING:

						CERTIFIED Performance Rating at NFRC Model Size		
CPD ID	Total Area	Name	Framing Ref	Glazing Ref	Spacer Ref	U**	SHGC**	VT**
	ft²					Btu/ hr·ft²·°F	-	-
P-PL-010	88.89	PL-2200 / PL-2210	FA-PL2210	GA-TT-001	SA-AM-001	0.53	0.58	0.66
P-PL-005	192.67	PL-3400 / PL-3401	FA-PL3401	GA-TT-001	SA-AM-002	0.56	0.57	0.65
P-PL-012	382.22	PL-5700 / PL-5720	FA-PL5720	GA-TO-002	SA-AM-001	0.52	0.21	0.30
P-PL-002	60.00	PL-1100 / PL-1152	FA-PL1152	GA-TT-001	SA-AM-001	0.42	0.51	0.62
P-PL-022	525.00	PL-9900 / PL-9915	FA-PL9915	GA-TO-003	SA-AM-002	0.45	0.15	0.19

FRAME, GLAZING and SPACER ASSEMBLIES:

FRAMING LISTING:

FRAMING REF	SUPPLIER ID	DESCRIPTION
FA-PL2210		Single Casement Thermally Broken Aluminum
FA-PL3401		Projecting (Awning) Thermally Broken Aluminum
FA-PL5720		Vertical Slider PVC reinforced with Steel
FA-PL1152		Vertical Slider Thermally Broken Aluminum
FA-PL9915		Fixed Thermally Broken Aluminum

GLAZING LISTING:

GLAZING REF	SUPPLIER ID	DESCRIPTION
GA-TT-001		1" Double Glazed, 1/4" HC Low-e, 1/4" Clear, Argon (90%), 1/2" gap
GA-TT-002		1" Triple Glazed, 1/8"Clear, Coated film, 1/8"SC, Argon (90%), 3/8" gap
GA-TT-003		1" Double Glazed, 1/4" Bronze, 1/4" SC Low-e, Argon (90%), 1/2" gap

SPACER LISTING:

SPACER REF	SUPPLIER ID	DESCRIPTION
SA-AM-001		250P Mill Finish Aluminum Low profile (1/2")
SA-AM-002		15A Polymer Spacer (3/8")

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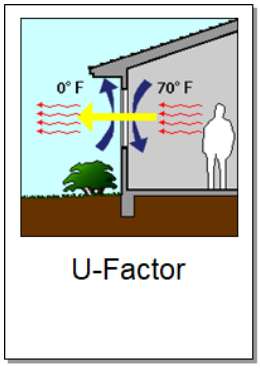
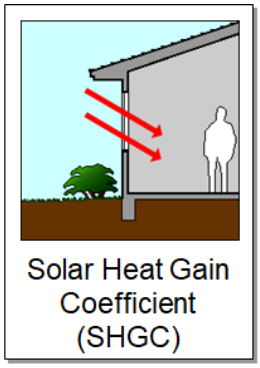
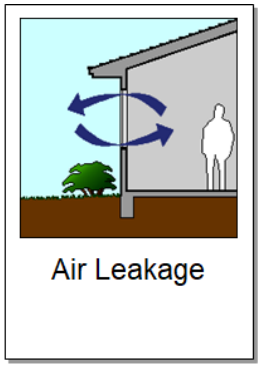
ENERGY PERFORMANCE OF GLAZING

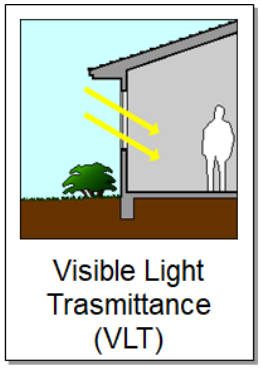
Fenestration Terminology



U-Factor


Solar Heat Gain Coefficient (SHGC)


Air Leakage


Visible Light Trasmittance (VLT)

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ASHRAE FENESTRATION REQUIREMENTS FOR CZ4

	Nonresidential			*Residential*			Semiheated		
Fenestration	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*	Assembly Max. U	Assembly Max. SHGC	Assembly Min. *VT/SHGC*	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*
Vertical Fenestration, 0% to 40% of *Wall*									
Fixed	0.36	0.36	1.10 (for all types)	0.36	0.36	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.45	0.33		0.45	0.33		0.65		
Entrance door	0.63	0.33		0.63	0.33		0.77		
Skylight, 0% to 3% of *Roof*									
All types	0.50	0.40	NR	0.50	0.40	NR	0.75	NR	NR

IECC FENESTRATION REQUIREMENTS

TABLE C402.4 BUILDING ENVELOPE FENESTRATION MAXIMUM *U*-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
							Vertical fenestration									
							U-factor									
Fixed fenestration	0.50		0.45		0.42		0.36		0.36		0.34		0.29		0.26	
Operable fenestration	0.62		0.60		0.54		0.45		0.45		0.42		0.36		0.32	
Entrance doors	0.83		0.77		0.68		0.63		0.63		0.63		0.63		0.63	
							SHGC									
	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable
PF < 0.2	0.23	0.21	0.25	0.23	0.25	0.23	0.36	0.33	0.38	0.33	0.38	0.34	0.40	0.36	0.40	0.36
0.2 ≤ PF < 0.5	0.28	0.25	0.30	0.28	0.30	0.28	0.43	0.40	0.46	0.40	0.46	0.41	0.48	0.43	0.48	0.43
PF ≥ 0.5	0.37	0.34	0.40	0.37	0.40	0.37	0.58	0.53	0.61	0.53	0.61	0.54	0.64	0.58	0.64	0.58
							Skylights									
U-factor	0.70		0.65		0.55		0.50		0.50		0.50		0.44		0.41	
SHGC	0.30		0.30		0.30		0.40		0.40		0.40		NR		NR	

NR = No Requirement. PF = Projection Factor.

FENESTRATION PRODUCT RATING

- Unlabeled fenestration is required to use the default U-factor and SHGC values.

Table A8.2 Assembly *U-Factors*, Assembly *SHGCs*, and Assembly Visible Transmittances (*VTs*) for Unlabeled *Vertical Fenestration*

		Unlabeled *Vertical Fenestration*					
		Clear Glass			*Tinted* Glass		
Frame Type	Glazing Type	*U-Factor*	*SHGC*	*VT*	*U-Factor*	*SHGC*	*VT*
All frame types	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	NA	NA	NA
Wood, vinyl, or fiberglass frames	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame types	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

- Those values are very poor and ***will not comply*** with the prescriptive compliance path.

MAXIMUM AREA

Fenestration: All areas (including frames) that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than half glass, and glass block walls

The vertical fenestration area shall not be greater than **30 percent** of the gross above-grade wall area.

The skylight area shall not be greater than 3 percent of the gross roof area.

- Can increase skylight area to **5 percent** with the use of daylight responsive lighting controls

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INCREASED FENESTRATION AREA

In Climate Zones 1 through 6, not more than **40 percent** of the gross above-grade wall area shall be permitted to be vertical fenestration, provided **all** of the following requirements are met:

1. 1-2 story buildings - At least 50 percent of the net floor area is within a daylight zone.
2. 3 stories or more - At least 25 percent of the net floor area is within a daylight zone.
3. Daylight responsive controls complying with Section C405.2.3.1 are installed in daylight zones.
4. Visible transmittance (VT) of vertical fenestration is not less than 1.1 times solar heat gain coefficient (SHGC).

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MAXIMUM AREA

Fenestration: Skylights, roof windows, vertical windows (fixed or moveable), *opaque doors*, glazed doors, glazed block, and combination opaque/glazed doors

- The vertical fenestration area shall not be greater than **40 percent** of the gross above-grade wall area.
- The skylight area shall not be greater than 3 percent of the gross roof area.
  - Can increase skylight area to **6 percent** with the use of daylight responsive lighting controls

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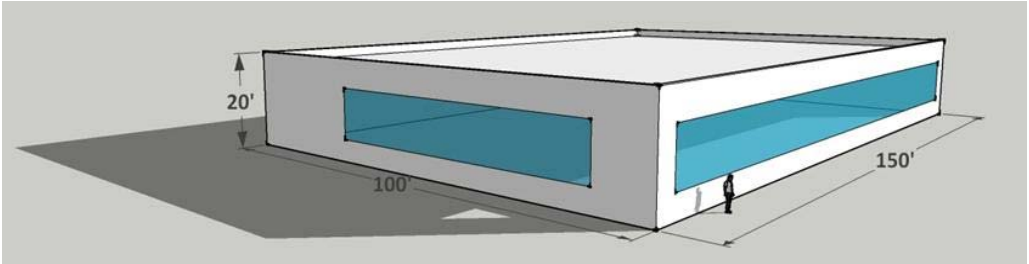
PERCENT GLAZING AREA EXAMPLE

Glazing Example

% Glazing = Fenestration Area / Gross Wall Area

What is the % Glazing for a 100'x150' building with 20' high walls and 3,000 sq ft of windows and glass doors?



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MAXIMUM SKYLIGHT AREA

IECC

Can increase skylight area from 3 percent to **5 percent** with the use of daylight responsive lighting controls

ASHRAE

Can increase skylight area from 3 percent to **6 percent** with the use of daylight responsive lighting controls

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90.1 DAYLIGHTING DETAILS

5.5.4.2.2 Max. Skylight Fenestration Area

- Total skylight area shall not exceed 3% of gross roof area
- May go to 6% of gross roof area provided design meets all criteria

5.5.4.2.3 Minimum Skylight Fenestration Area

- for any enclosed space in a building (all of the following):
  - ≥2,500 sq. ft.
  - Directly under a roof with ceiling heights greater than 15 feet
  - One of the following space types: office, lobby, atrium, concourse, corridor, warehouse, gym, convention center, courtroom automotive service, fire station engine room, manufacturing, retail, library, distribution/sorting, transportation baggage and seating, or workshop
- Minimum 50% of floor area is daylit area and either:
  - Provide skylight to daylight area of 3% and VT of 0.4
  - Minimum skylight effective aperture of 1%
- Many exceptions based on LPD, space type, and side daylighting

Exceptions to Section 5.5.4.2.3

1. *Enclosed spaces* in Climate Zones 6 through 8
2. *Enclosed spaces* where it is documented that existing structures or natural objects block direct-beam sunlight on at least half of the *roof* over the *enclosed space* for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
3. *Enclosed spaces* where the *daylight area under roof monitors* is greater than 50% of the *enclosed space floor* area.
4. *Enclosed spaces* where it is documented that 90% of the *skylight* area is shaded on June 21 in the Northern Hemisphere (December 21 in the Southern Hemisphere) at noon by permanent architectural features of the *building*.
5. *Enclosed spaces* where the total area minus the *primary sidelighted area* and *secondary sidelighted area* is less than 2500 ft^2 and where the lighting is controlled according to sidelighting requirements described in Section 9.4.1.1(e).

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BREAKOUT QUESTION

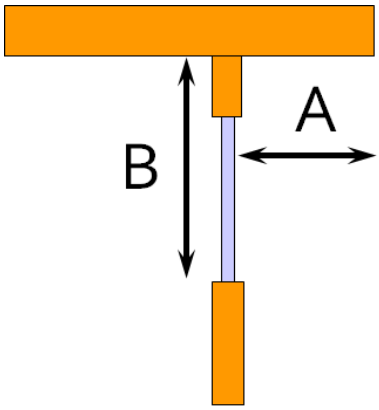
A retail "big box" store in KC has a total floor area of 50,000 ft^2 and a ceiling height of 25 ft.

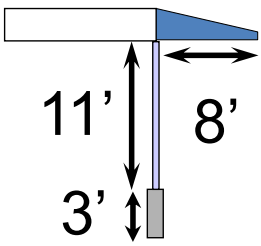
What is the minimum area (ft^2) required for the "daylight zone" in this building (from skylights or other)?

What is maximum % of skylight area allowed?

PROJECTION FACTOR (PF)

The ratio of overhang projection divided by height from windowsill to bottom of overhang (must be permanent)





PF = 8/11 = 0.73

For S, E or W glazing SHGC multiplier (from next slide) = **0.51**

If glass SHGC = 0.48, it effectively becomes 0.24 due to overhang

SHGC MULTIPLIERS

Projection Factor	SHGC Multiplier (South, East, and West Orientations)
0 to 0.10	1.00
>0.10 to 0.20	0.91
>0.20 to 0.30	0.82
>0.30 to 0.40	0.74
>0.40 to 0.50	0.67
>0.50 to 0.60	0.61
>0.60 to 0.70	0.56
>0.70 to 0.80	0.51
>0.80 to 0.90	0.47
>0.90 to 1.00	0.44

Vertical fenestration that is north oriented shall be permitted to have an SHGC equal to or less than the area-weighted average SHGC of the south-east-, and west-oriented vertical fenestration before any reductions made for permanent projections in Exceptions 1 and 2 of Section 5.5.4.4.1.

No credit for overhangs on North glazing

OVERHANGS

Must be permanent!

FENESTRATION ORIENTATION

Area of vertical fenestration on east and west facades may not exceed 25% of total area of vertical glazing with some exceptions for permanent shading

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SECTION 5.5.4.6: VT/SHGC RATIO

Where automatic daylighting controls are required, the Visible Transmittance / SHGC ratio shall be ≥ 1.1

Exceptions to Section 5.5.4.6

1. A *light-to-solar-gain ratio* (*LSG*) of not less than 1.25 is allowed to be used as an alternative to *VT*/*SHGC*. When using this option, the center-of-glass *VT* and the center-of-glass *SHGC* shall be determined in accordance with NFRC 300 and NFRC 301, determined by an independent laboratory or included in a database published by a government agency, and certified by the *manufacturer*.
2. *Fenestration* not covered in the scope of the NFRC 200.
3. *Enclosed spaces* where the *daylight area under roof monitors* is greater than 50% of the *enclosed space floor* area.
4. *Enclosed spaces* with *skylights* that comply with Section 5.5.4.2.3.
5. *Enclosed spaces* where the *sidelighting effective aperture* is greater than or equal to 0.15.
6. For *dynamic glazing*, the *VT*/*SHGC* ratio and the *LSG* shall be determined using the maximum *VT* and maximum *SHGC*. *Dynamic glazing* shall be considered separately from other *fenestration*, and area-weighted averaging with other *fenestration* that is not *dynamic glazing* shall not be permitted.

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ENERGY CODE TRAINING
BUILDING ENVELOPE TRADE OFFS

https://vimeo.com/169382048/c973625071

Commercial Envelope Part 2

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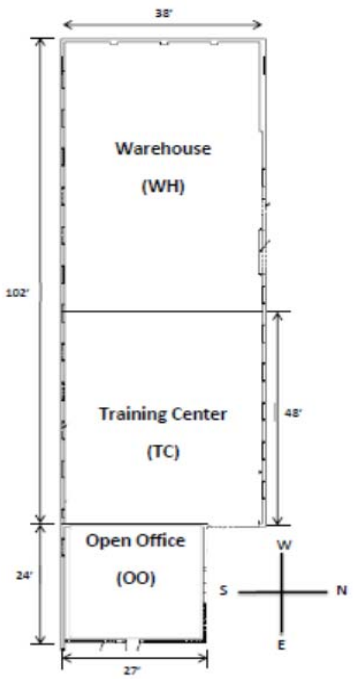
SWEET NEW – USING COMCHECK

Review pdf of SWEET NE



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EAZEE BUILDING COMCHECK
ENVELOPE HW PROBLEM

Small 10’ Strip Retail Building

East Wall: R-19 2x6, 16” o.c. all metal curtain-wall glazing is on the Front (East) façade and shaded by a 6’ overhang (500 s.f.)

- East Glazing 410 s.f. U-0.36, SHGC-0.44, VT-0.50
- East Glass Entry 40 s.f. U-0.31, SHGC-0.38, VT-0.50

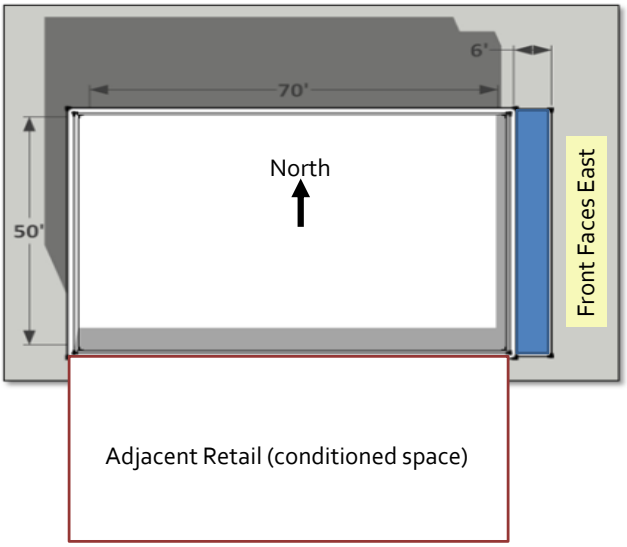
South Wall: 8” CMU’s - adjacent “interior” (700 s.f.)

North Wall: 8” CMU’s with R-10 c.i. (700 s.f.)

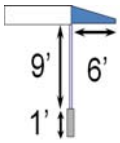
West Wall: 8” CMU’s with R-10 c.i. (500 s.f.)

- Rear Opaque Doors 80 s.f. U-0.32

Enter the building dimensions into COMCheck and locate it in your city in MO. Slab on grade, R-10, Ceiling R-30 continuous above roof decking. Select/adjust insulation values that will make it pass 90.1-2019



INSTRUCTIONS
Enter all envelope surfaces into COMCheck
Use 90.1-2019 or IECC 2021 as code.
Account for overhang shading front glass
Adjust wall R-values, etc. until design passes



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CONCLUSION

Go to www.energycodes.gov and pull up COMCheck web – establish a user’s account & feel free to play with it

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