Building Envelope Standard 90.1-2004

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General Design Considerations

- Building envelope does not use energy
- Design affects heating and cooling loads
- Insulation affects the temperature of inside surfaces; comfort
- Daylighting can reduce electric lighting
- Integrated design approach saves energy

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General Design Considerations

- Standard 90.1 sets minimum level of thermal performance
- Limits solar gain through fenestration

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General Design Considerations

- Building envelope requirements address:
  - Opaque elements
    - Roofs, walls, floors, below-grade walls, slabs, opaque doors
  - Fenestration
    - Windows, doors, skylights

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Section 5 – Building Envelope

- General *(Section 5.1)*
  - Scope, Climate, Space-Conditioning Categories
- Compliance Paths *(Section 5.2)*
  - See chart
- Simplified Approach *(Section 5.3)*
  - reserved
- Mandatory Provisions *(Section 5.4)*
  - Insulation, Fenestration and Doors, Air Leakage
- Prescriptive Building Envelope Option *(Section 5.5)*
  - Opaque Areas
  - Fenestration
- Building Envelope Trade-Off Option (*Section 5.6)*
  - Software option
- Submittals *(Section 5.7)*
- Product Information *(Section 5.8)*

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General *(Section* 5.1.1)

- Requirements apply to the exterior building envelope, separating conditioned space from the exterior
- Requirements apply to three types of occupancies
  - Nonresidential
  - Residential
  - Semi-heated

AND

- Three types of spaces
  - Conditioned Space
  - Unconditioned Space
  - Semi-Heated Space

AND

- 8 Climate Zones

5

Semi-heated space Definition (section 3)

- Has a heating system with a capacity > 3.4 Btu/hr.ft^2 (10 W/m^2) of floor area but is not conditioned space

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Space Conditioning Categories (Section 5.1.2)

- All semi-heated and unconditioned spaces to be clearly indicated on floor plans
- In climates > 1800 HDD65 (climate zone 3), a space may be designated either semi-heated or unconditioned only if approved by the building official
  - Shell build outs

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Space Conditioning Categories (Section 5.1.2)

- Standard 90.1 assumes that all buildings will be heated in climates with more than 1,800 HDD65 (climate Zone 3).

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Envelope Alterations (section 5.1.3)

- Exempt from compliance provided no increase in energy usage
  - Installing storm windows over existing glazing
  - Replacing broken or damaged glazing in existing sash and frame
  - Altering roofs, ceilings, walls or floors that have cavities with insulation of at least R-3.0 per inch
  - Altering walls and floors that have no framing cavities

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Envelope Alterations (section 5.1.3)

- Exempt from compliance provided no increase in energy usage
  - Replacing a roof membrane, as long as no exposure of roof sheathing or existing insulation
  - Replacing exterior doors does not trigger the requirement for a vestibule or revolving door
  - Replacing existing fenestration as long as the area of fenestration is less than 25% of the total fenestration of the building

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General-(Section 5.1) Moisture control

- Standard 90.1 does not address moisture control or provide guidelines to prevent moisture migration

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Problem

- A 30,000 sq. ft. warehouse in Kensington, PA (near Philadelphia) will be used to store household appliances.
- A 2,700 sq. ft. office is attached to the warehouse.
- The warehouse is designed with two 100,000 Btu/h output unit heaters and is not air-conditioned.
- A packaged single-zone heating and cooling system will service the office.
- How do the building envelope standards apply?

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Answer

- Envelope standards apply to office.
- Warehouse heating system has a capacity of 6.7 Btu/ft^2 (200,000 Btu/h divided by 30,000 ft^2)
- Philadelphia has 4,954 HDD65— (CZ 4A)so heating system has to be larger than 15 Btu/h ft^2 to be considered conditioned space.
- The space is considered semi-heated since the heating system > 3.4 Btu/h ft^2.
- The walls and roofs separating the office from the outdoors are exterior (nonresidential criteria apply).
- The walls and roof that separate the warehouse from the exterior or from the office are semi exterior and the criteria for semi-heated spaces apply.

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Answer *con't*

- *Since Philadelphia has more than 1800 HDD65 (CZ 3), the building official must approve designation of the warehouse as a semi-heated space.*

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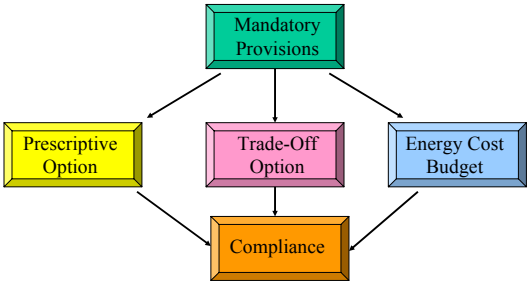
Envelope Compliance Methods *(Section 5.2)*



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Simplified Building *(Section 5.3)*

- Not Used Yet

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Mandatory Provisions *(Section 5.4)*

- Insulation
- Fenestration and Doors
- Air Leakage

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Building Envelope sealing
(Section 5.4.3.1)

- Seal, caulk, gasket, or weather-strip
  - Joints around fenestration and door frames
  - Junctions between walls and foundations, walls at building corners, between walls and structural floors or roofs, and between walls and roof or wall panels
  - Openings at penetrations of utility services through roofs, walls, and floors
  - Site-built fenestration and doors
  - Joints, seams, and penetrations of vapor retarders

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Fenestration and Doors
(Section 5.4.3.2)

- NFRC 400
- Labeled and certified by manufacturer
- Glazed swinging entrance doors and revolving doors – not to exceed 1.0 cfm/ft^2
- All other products – not to exceed 0.4 cfm/ft^2
- Exceptions
  - "Field-fabricated fenestration and doors"
  - Garage doors – NAGDM 105

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Loading Dock Weatherseals
(Section 5.4.3)

- > 3600 HDD65 (>climate zone 4)
  - "Cargo doors and loading dock doors shall be equipped with weatherseals"
    - To restrict infiltration when vehicles are parked in the doorway"

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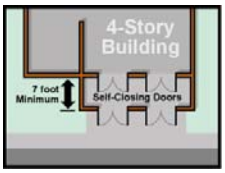
Vestibules
(Section 5.4.3.4)

- All exterior doors in tall buildings in cold climates must have a vestibule with
  - self-closing doors
  - interior and exterior doors must not be open at the same time
  - distance between interior and exterior doors not < 7 ft when in closed position (remember ADA!)



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Vestibules
(Section 5.4.3.4)

- Non-entrance doors (mechanical/electrical rooms)
- Vehicle and material handling doors and adjacent personnel doors **OR** revolving doors
- All doors in climates < 1800 HDD65 **OR** in buildings < 4 stories
- All doors that open into spaces < 3000 ft^2 **OR** into dwelling units

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Prescriptive Building Envelope Option *(Section 5.5)*

- 8 criteria sets for different Climate Zones *(26 90.1-2001, 90.1-1999)*
  - Single page that summarizes all prescriptive requirements
  - Insulation requirements for Opaque elements
    - Roofs, walls, floors, below-grade walls, slabs, opaque doors
  - U factor and SHGC for Fenestration
    - Windows, doors, skylights
  - Each envelope component must separately meet requirements

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Prescriptive Building Envelope Option *(Section 5.5)*

You need to know 4 things

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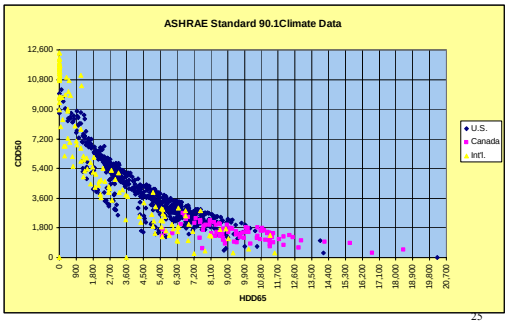
ASHRAE Standard 90.1 Climate Data



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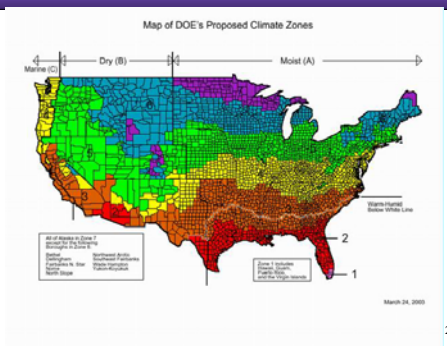
Climate Zones



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Prescriptive Building Envelope Option *(Section 5.5)*

- Nonresidential
- Residential
- Semi-Heated

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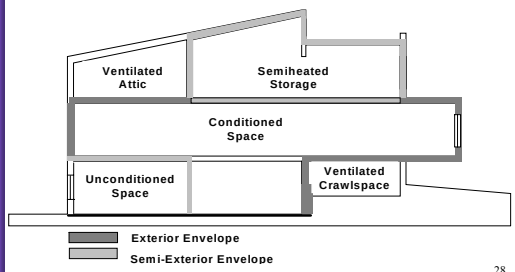
Prescriptive Building Envelope Option *(Section 5.5)*



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Prescriptive Building Envelope Option *(Section 5.5)*

- Prescriptive tables

	NONRESIDENTIAL		RESIDENTIAL		SEMIHEATED	
OPAQUE ELEMENTS	Assembly Maximum	Insulation Min. R-value	Assembly Maximum	Insulation Min. R-value	Assembly Maximum	Insulation Min. R-value
Roofs	U-factor	R-value	U-factor	R-value	U-factor	R-value
Walls, Above Grade	U-factor	R-value	U-factor	R-value	U-factor	R-value
Walls, Below Grade	C-factor	R-value	C-factor	R-value	C-factor	R-value
Floors	U-factor	R-value	U-factor	R-value	U-factor	R-value
Slab-on-Grade Floors	F-factor	R-value	F-factor	R-value	F-factor	R-value
Opaque Doors	U-factor	R-value	U-factor	R-value	U-factor	R-value
FENESTRATION	Assembly Max. U (Fixed/	Assembly Max. SHGC (All Orientations/	Assembly Max. U (Fixed/	Assembly Max. SHGC (All Orientations/	Assembly Max. U (Fixed/	Assembly Max. SHGC (All Orientations/

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Prescriptive Building Envelope Option *(Section 5.5)*

- Opaque Surfaces
  - R-value or U-factor
- Fenestration
  - Area
  - U-factor and SHGC
  - VLT

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Prescriptive Building Envelope Option *(Section 5.5)*

- Compliance
  - Meet or exceed minimum R-values in Table 5.3
    - Only R-value of insulation, not to include air films, etc

    OR
    - Meet maximum U-factor, C-factor, or F-factor for the entire assembly

    OR
    - Perform area-weighted average U-factor, C-factor, or F-factor
      - Only if there are multiple assemblies within a <u>single</u> class of construction for a <u>single</u> space-conditioning category

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Prescriptive Building Envelope Option *(Section 5.5)*

- Modifiers to Prescriptive tables
  - Shading
  - "cool roofs"
- Only applies to < 50% glazing

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Problem

- I am designing a 2 story school in Naperville, what are the requirements for the building envelope?
  - Masonry load bearing
  - Slab on grade
  - Steel bar joist roof and deck

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Answer

- We know the building will be heated beyond 15 btu/sq ft.
- Go to Appendix B which lists DuPage County as Climate Zone 5
- For the nonresidential space category, U-factor for the wall assembly is 0.123 btu/h*ft^2*F or R-7.6ci
- The floor slab has NR
- The roof requires R-15.0ci
- Assuming we are between 40%- 50% glazing, the window U-factor would be .46 for fixed units and .47 for operable units
- The SHGC would be .26 for N, E and W orientations and .36 for South

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Roof Insulation *(5.5.3.1)*

- 3 Primary classes of roof construction

Insulation above

Metal buildings

Attic + Other

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Roof Insulation *(5.5.3.1)*

- All roofs shall have a rated R-value not less than that specified in the appropriate prescriptive table.
- "Skylight curbs insulated to level of roofs with insulation entirely above deck or R-5, whichever is less"
- Roofs with insulation entirely above deck the R-value is for continuous insulation

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Roof Insulation *(5.5.3.1)*

- Single rafter roof exception, (appendix A, A2.4.2.4)

TABLE A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d*(actual)		
	$d \leq 8$ in.	$8 < d \leq 10$ in.	$10 < d \leq 12$ in
1-7	R-19 U-0.055	R-30 U-0.036	R-38 U-0.028
8	R-21 U-0.052	R-30 U-0.036	R-38 U-0.028

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Roof Insulation *(5.5.3.1)*

- 'Cool roof' – un vented
- Solar Reflectance > .70
- Thermal emittance > .75

- $U_{roofadj} = U_{roofproposed}$ X Multiplier
  (table5.3.1.1b)

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Above-Grade Wall Insulation *(5.5.3.2)*

- All above-grade walls, including mass walls, metal building walls, steel-framed walls, and wood-framed walls shall have a rated R-value not less than the appropriate prescriptive table.

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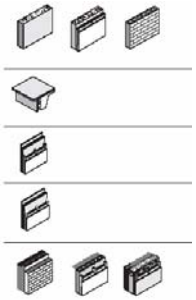
Above-Grade Wall Insulation *(5.5.3.2)*

- 4 Classes of wall construction



Mass

Metal Building

Metal Stud

Wood Stud

Below Grade

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Above-Grade Wall Insulation *(5.5.3.2)*

- Mass walls
  - R-value is for continuous insulation uninterrupted by framing other than 20 gauge 1 in. metal clips spaced no closer than 24 in. on center horizontally and 16 in. on center vertically (A3.1.2.2)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Mass walls
  - Framing via metal/wood studs based on assembly U-factor (A3.1.2.3)
  - Continuous insulation required throughout the panel for concrete sandwich panels using rated R-value (A3.1.2.4)
  - Mass walls with integral insulation shall meet the criteria when U-factors $\leq$ the requirement for thickness and density in the "Partly Grouted Insulated" column(A3.1.3.1)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Mass Walls Exception (A3.1.3.1)
  - Indicated by superscript [a]
  - Maximum assembly U of 0.151 for ASTM C90 concrete block walls, ungrouted or partially grouted filled with material having a maximum thermal conductivity of 0.44 Btu-in/hour x ft^2 ºF. (perlite-filled)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Metal building walls
  - First rated R-value is for insulation compressed between metal wall panels and the steel structure; second rated R-value is for insulation installed from the inside, covering the girts. (A3.2.2.1 - 2)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Metal building walls
  - Insulation boards are installed on the inside of the girts and uninterrupted by the framing members (A3.2.2.3)
  - Insulation exposed to conditioned or semiheated spaces shall have a facing and seams shall provide continuous air barrier. (A3.2.2.4)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Steel-framed walls
  - First rated R-value is for uncompressed insulation installed in the cavity between steel studs; second R-value is for continuous insulation uninterrupted by framing to be installed in addition to the first insulation. (A3.3.2.1 – 2)

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Above-Grade Wall Insulation *(5.5.3.2)*

- Steel-framed walls
  - Opaque mullions in spandrel glass shall be covered with insulation. (A3.3.2.3)
  - Options for 24" o.c. see appendix

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Above-Grade Wall Insulation *(5.5.3.2)*

- Wood-framed walls
  - The first rated R-value is for uncompressed insulation installed in the cavity between wood studs; the second rated R-value is for continuous insulation uninterrupted by framing to be installed in addition to the first insulation (A3.4.2.1 – 2)
  - Options for advanced framing see appendix

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Below-Grade Wall Insulation *(5.5.3.3)*

- Rate R-value of insulation not less than that specified in the appropriate prescriptive table.
- R-value is for continuous insulation
- If framing is used, compliance is based on maximum assembly C-factor

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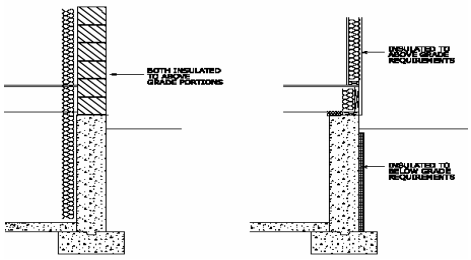
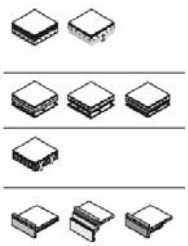
Above/Below Grade Wall Insulation *(5.5.3.2)*

- When a wall consists of both above-grade and below-grade insulation, the entire wall in that story requires insulation on either the exterior or interior or be integral.



Floor Insulation
(5.5.3.4)

- 4 Classes of floor construction



Mass

Steel Joist

Wood Joist

Slab on Grade Heated/Unheated

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Floor Insulation
(5.5.3.4)

- All floors, including mass floors, steel joist floors, and wood-framed and other floors shall have a rated R-value of insulation not less than the appropriate prescriptive table.
- Mass Floors
  - The rated R-value of insulation is for continuous insulation uninterrupted by framing. Where framing, including metal and wood joists, is used, compliance shall be based on the maximum assembly U-factor. (A5.2.2.1-2).

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Floor Insulation
(5.5.3.4)

- Mass floors
  - For waffle-slab floors, the floor shall be insulated either on the interior above the slab or on all exposed surfaces of the waffle. (A5.2.2.3)
  - For floors with beams that extend below the floor slab, the floor shall be insulated either on the interior above the slab or on the exposed floor and all exposed surfaces of the beams that extend 24 in. and less below the exposed floor. (A5.2.2.4)

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Floor Insulation
(5.5.3.4)

- Steel joist floors
  - The first rated R-value of insulation is for uncompressed insulation installed in the cavity between steel joists or for spray-on insulation. (A5.3.2.1)
  - Continuous insulation OK; installed either on the interior above the floor structure or below a framing cavity completely filled with insulation. (A5.3.2.2)

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Floor Insulation
(5.5.3.4)

- Wood-framed and other floors
  - The first rated R-value of insulation is for uncompressed insulation installed in the cavity between wood joists. (A5.4.2.1)
  - Continuous insulation OK; installed either on the interior above the floor structure or below a framing cavity completely filled with insulation. (A5.4.2.2)

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Floor Insulation
(5.5.3.4)

- Slab on Grade
  - All slab-on-grade floors, including heated slab-on-grade floors and unheated slab-on-grade floors, shall have a rated R-value of insulation (or an assembly F-factor)not less than the appropriate prescriptive table and shall be installed around the perimeter of the slab-on-grade floor to the distance specified.

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Floor Insulation
(5.5.3.4)

- Perimeter insulation installed inside the foundation wall shall extend downward from top of slab a minimum distance specified or to the top of the footing, whichever is less
- Perimeter insulation installed outside the foundation wall shall extend from top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum distance specified"

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Floor Insulation
(5.5.3.4)

- In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10" thick.

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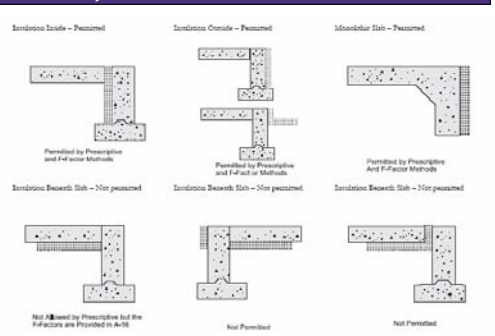
Floor Insulation
(5.5.3.4)



Opaque Doors
(5.5.3.6)

- All opaque doors, including swinging doors and non-swinging doors shall have a U-factor not greater than the appropriate prescriptive table.
  - From NFRC 100 (a7) or
  - A7.1

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Fenestration
(5.5.4)

- Criteria apply to fenestration, including windows, glass doors, glass block, plastic panels, and skylights
- Compliance
  - Meet or exceed maximum U-factors in table
  - Meet or exceed minimum SHGC in table
  - Use NFRC ratings or default values in Appendix A
- Treat space conditioning categories separate
- Use area weighted values for multiple assemblies in one space conditioning category.

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Fenestration Area
(5.5.4.2)

- Total vertical fenestration area to be < 50% of gross wall area
  - including both fixed and operable vertical fenestration
  - Exception for street level windows
- Total skylight area to be < 5% of gross roof area
  - glass skylights
  - plastic skylights with a curb
  - all skylights without a curb

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Fenestration U-factor *(5.5.4.3)*

- Use NFRC values or meet or exceed maximum default U-factors in A-17
- Exception
  - Street level windows allowed to have U-factor not greater than U-factor specified for 40% of the gross wall area"

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Fenestration SHGC *(5.5.4.4.1)*

- Vertical fenestration
- Skylights
  - SHGC values < Tables 5.5-1 thru 5.5-8 for appropriate total vertical fenestration area

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Fenestration SHGC *(5.5.4.4.1)*

- Exception
  - In latitudes > 10°, SHGC for north-oriented vertical fenestration shall be calculated separately

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Fenestration SHGC
(5.5.4.4.1)

- Exception
  - For demonstrating compliance for vertical fenestration only, the SHGC in the proposed building can be reduced by using the multipliers in Table 5.3.2.3 for each product shaded by permanent projections

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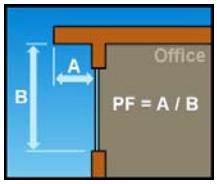
Fenestration SHGC
(5.5.4.4.1)

- Standard credits permanent overhangs by adjustment to SHGC
- Size of overhang is determined by projection factor



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Fenestration SHGC
(5.5.4.4.1)

- Exception
  - Street level vertical fenestration
  - Street side does not exceed 20' in height
  - Fenestration has a continuous overhang with a weighted average projection factor > 0.5
  - Fenestration area < 75% of the gross wall area
  - When these criteria are met, separate calculations are to be performed

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Problem

- A 2-story building in Camden is sited on a sloping site such that the first floor of the north wall is below grade. The first floor of the east and west walls are partially below grade, as the ground slopes. The building is rectangular with a 200' ft. dimension in the east-west direction and a 100' dimension in the north-south direction. The floor-to-floor height is 12 ft. What is the gross wall area for this building?

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Answer

- The gross wall area includes both above-grade walls and below-grade walls.
- The gross wall area is the perimeter of the building (200 + 100 + 200 + 100)times the 24 ft height = 14,400 ft^2.

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Problem

- A commercial wood-framed building in Climate Zone 6 will be insulated to comply with the Standard.
- East façade is almost entirely glass—but other walls don't have a lot of glass. Total fenestration area is 37% of the gross exterior wall area.
- Windows are wood-framed and double-glazed with a low-e coating on the third surface. They have an NFRC rating of 0.52 (U-factor), 0.55 (SHGC). The glass is clear and there are no overhangs? *Will it comply?*

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Answer

- Go to Table 5.5-6. For the nonresidential space category, the vertical fenestration criteria calls for a U-factor of 0.57 for fixed windows and a 0.67 for operable windows.
- The maximum SHGC is 0.49 for north orientations and 0.39 for other orientations.
- These criteria are taken for a window-wall ratio 30.1-40%.
- *The building complies with the U-factor (0.52 < 0.57) but not for SHGC (0.55 > 0.49 or .39).*

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Answer

- *Choices to consider for the designer:*
- *Use another glazing material.*
- *Add overhangs.*

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Problem

- Philadelphia travel agency has typical windows on all sides with a window-wall ratio of 32%.
- Windows are 5' x 10' with an overhang that projects 3' from the surface of the glass, and is positioned 6 in. above the window head.
- Windows have NFRC rating for SHGC of 0.6.
- Does the building comply with the nonresidential SHGC fenestration criteria?

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Answer

- Go to Table (Appendix B) to determine appropriate criteria table for Philadelphia.
- Go to Table 5.5-5. SHGC criteria for the 30.1%-40% window-wall ratio range is 0.49 for north-facing orientations and 0.39 for other.
- The windows qualify for overhang credit.
- To determine the credit, calculate the overhang projection factor (PF).

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Answer

- The PF is the ratio of the 3 ft. projection to the distance from the windowsill to the bottom of the overhang (5.5 ft.) PF is then 3/5.5 = .54.
- From Table 5.5.4.4.1, the overhang multiplier is 0.61 for non-north orientations and 0.81 for north.
- The effective SHGC on non-north orientations is 0.61 x 0.6 = .37. For north, 0.81 x 0.6 = 0.49. *Both are lower than the criteria so the building meets the requirements of the standard.*

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Submittals
(Section 5.7)

- Refers one to Section 4
- Requires labeling of *Space Conditioning Categories*

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Insulation
(Section 5.8.1)

- Insulation General
  - Installation
  - Substantial contact
  - Recessed equipment
  - Location of roof insulation
  - Insulation protection

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Insulation
(Section 5.8.1)

- Clearly labeled
- Installed per manufacturer's instructions
  - Exception: Metal buildings
    - If roof and wall insulation is "compressed between roof or wall skin and the structure
- No open-blown or poured loose-fill insulation in attic roofs where slope > 3 in 12.
- If eave vents installed
  - Provide baffling of air vents

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Insulation
(Section 5.8.1)

- Install insulation in a "permanent manner in substantial contact with inside surface"
- Flexible batt insulation in floor cavities
  - to be "supported in a permanent manner by supports no more than 24 in. o.c."

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Insulation
(Section 5.8.1)

- Exception
  - Insulation materials that rely on air spaces adjacent to reflective surfaces for their rated performance.

81

Insulation
(Section 5.8.1)

- Do not recess equipment so that the insulation thickness is affected
  - Lighting fixtures
  - HVAC equipment (includes wall heaters, ducts, and plenums)
  - Other

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Insulation
(Section 5.8.1)

- When
  - "Total combined area affected (include necessary clearances) is < 1% of opaque area of the assembly, **OR**
  - Entire roof, wall, or floor is covered with insulation to the full depth required, **OR**
  - Effects of reduced insulation are included in area-weighted calculations"

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Insulation
(Section 5.8.1)

- Not "installed on a suspended ceiling with removable ceiling panels"

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Insulation
(Section 5.8.1)

- Cover exterior insulation with protective material
  - Sunlight, moisture, landscaping operations, equipment maintenance, wind
- Access to attics and mechanical rooms without damaging or compressing insulation
- "Insulation materials in ground contact to have a water absorption rate no greater than 0.3% (ASTM C272)"

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Fenestration and Doors
(Section 5.8.2)

- Fenestration performance determined from production line units or representative of units as purchased
- U-factors determined according to NFRC 100
- SHGC determined according to NFRC 200
- Visible Light Transmittance determined according to NFRC 200

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National Fenestration Rating Council (NFRC)

- NFRC Products Directory-lists more than 81,000 products
- 1995-Site-built fenestration program developed for field glazed/assembled products
- Label Certificate form replaces the temporary and permanent labels in the residential certification program

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THE NFRC Label

- U-factor
- SHGC
- VT
- Air Leakage

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Visible Light Transmittance
(Section 5.8.2.6)

- No criteria in the Prescriptive Building Envelope Option, but there are "minimum criteria in the Building Envelope Trade-Off Option"

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Building Envelope Trade-Off Option (5.6)

- EnvStd
  - Envelope Standard
- Must use if > 50% glazing
- Comes with User's Guide
- Cannot be used to by-pass Mandatory requirements
- Can only be used to make trade-offs between Envelope components
- Considers both heating and cooling energy

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Building Envelope Trade-Off Option (5.6)

- Building complies if
  - It satisfies the provisions of 5.1, 5.4, 5.7 and 5.8
  - $\text{EPF}_{\text{Proposed Building}} < \text{EPF}_{\text{Budget Building}}$

EPF = envelope performance factor

EPF is calculated using Normative Appendix C

"Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems to be the same for proposed building and budget building"

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ENVStd Software

Demonstration of software

Step 1: Start program
Step 2: Enter project properties
Step 3: The Project Explorer
Step 4: Create the Opaque Constructions Schedule
Step 5: Create the Fenestration Products Schedule
Step 6: Add the Spaces
Step 7: Add Surfaces
Step 8: Add Openings
Step 9: Project Explorer
Step 10: View/print reports

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Users Manual

- ✓Reference Section
- ✓Examples
- ✓Figures
- ✓Terminology/definitions
- ✓Building Envelope Compliance Work sheets

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Thank you.

Thanks to the U.S. Department of Energy for assistance with this presentation