BUILDING ENERGY CODES PROGRAM

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# ANSI/ASHRAE/IES Standard 90.1-2016: Envelope

March 2017 – PNNL-SA-124574

# Compliance Paths
## Building Envelope

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

### Building System

- Envelope
- HVAC
- SWH
- Power
- Lighting
- Other

**Mandatory Provisions**
(required for all compliance options)

### Compliance Options

- Prescriptive Option
- Trade Off Option
- Energy Cost Budget
- Performance Rating Method

## Energy Code Compliance

Separate envelope component requirements apply to three types of conditioned spaces

- *Nonresidential*
- *Residential*
- *Semiheated* - *New*

*Semiheated spaces* are heated, but not to comfort levels, and not cooled

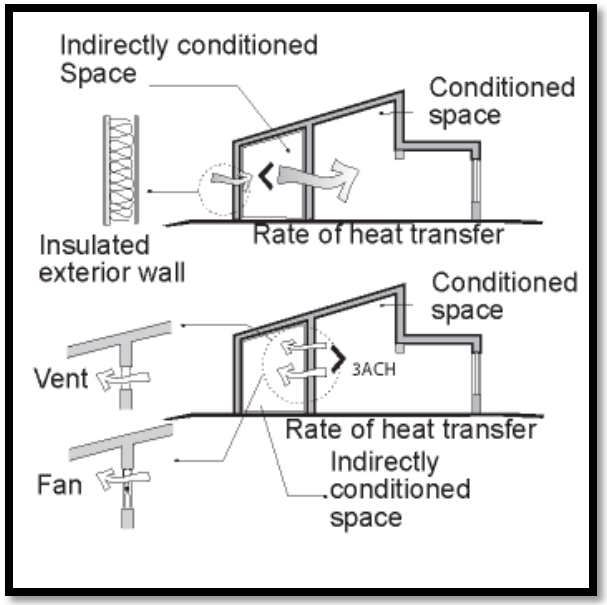



Figure 5-A

Examples of Indirectly Conditioned Spaces

*(User's Manual – 90.1.-2013)*

# 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 below
  - 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 |

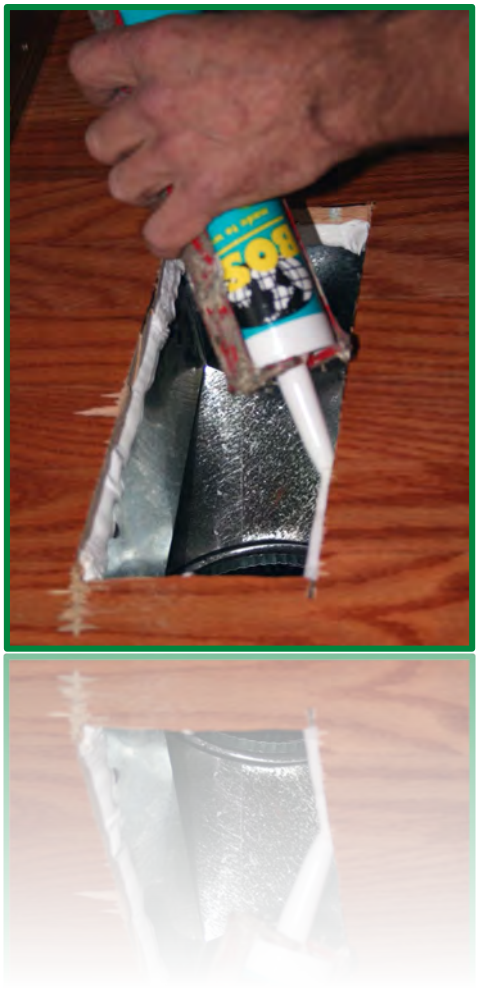
- ✓ Fenestration and *Doors (Section 5.4.2 that refers to 5.8.2)*
- ✓ Air Leakage *(Section 5.4.3)*

Photo courtesy of Ken Baker, K energy

- Continuous air barrier
- Fenestration and doors
- Loading dock weather seals
- Vestibules

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



## **Option 1**: Whole-Building Testing [5.4.3.1.3(a) Whole-*building* pressurization testing]

### Buildings > 50,000 sf

Can comply by testing only (and all) the following portions and area-weighting measured air leakage:

a) Floor areas under roof or with building entrances
b) Representative above-grade wall sections totaling at least 25% of wall area, not including floor area in (a)

### Buildings < 50,000 sf

Must comply by testing entire building

1. Building complies if measured air leakage rate is less than 0.40 cfm/ft$^2$ at 0.30 in. of water
2. If measured air leakage rate is greater than 0.40 cfm/ft$^2$ but less than 0.60 cfm/ft$^2$
   - Perform diagnostic evaluation (smoke tracer, infrared imaging, etc.) and seal identified leaks
   - Perform visual inspection of air barrier and seal identified leaks
   - Submit report to code official and building owner identifying corrective actions taken to seal leaks

# **Option 2**: Materials Testing [5.4.3.1 (b)]

Materials with an air permeance of < 0.004 cfm/ft$^2$ under pressure differential of 0.3 in. of $H_2O$ when tested in accordance with ATM E 2178

These 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. |

**Option 3**: Assemblies of Materials Testing [5.4.3.1 (c)]

Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage < 0.04 cfm/ft$^2$ under a pressure differential of 0.3 in. of $H_2O$ when tested in accordance with ASTM E 2357, 1677, 1680, or 283.

The following assemblies meet these requirements:

Concrete masonry *walls* that are

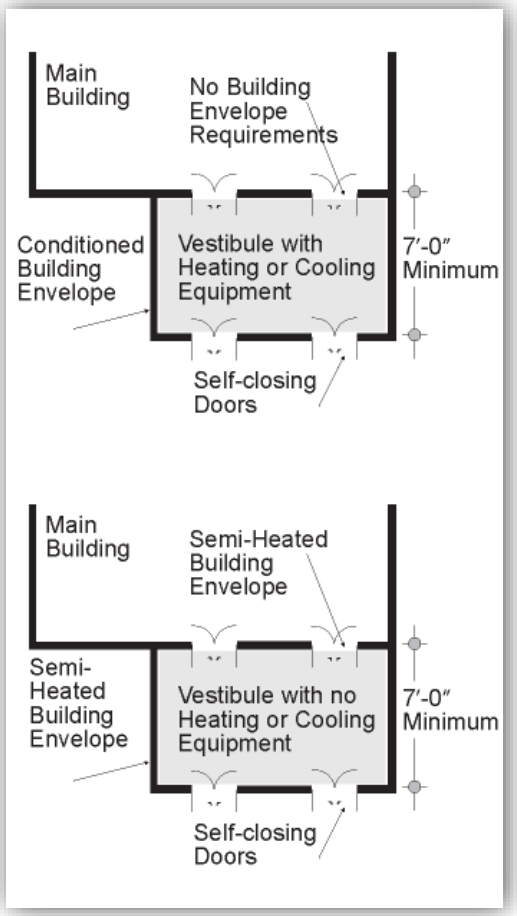
a. Fully grouted, or
b. Painted to fill the pores.

Cargo doors and loading dock doors equipped with weatherseals

- To restrict infiltration when vehicles are parked in the loading dock/doorway


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



- Non-entrance *doors* or *doors* opening from *dwelling unit*
- *Building entrances* with revolving *doors*
- All *building entrances* in buildings < 1000 $ft^2$ in *gross conditioned floor area*
- 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

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.

# Compliance Approach
## Building Envelope

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## Energy Code Compliance

# Current Oregon Opaque Envelope Requirements

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

| CLIMATE ZONE | All Other | Group R |
|---|---|---|
| **Roofs** | | |
| Insulation entirely above deck | R-20ci | R-20ci |
| Metal buildings (with R-3.5 thermal blocks) | R-13 + R-13 | R-19 |
| Attic and other | R-38 | R-38 |
| **Walls, Above Grade** | | |
| Mass | R-11.4ci | R-13.3ci |
| Metal building | R-13 + R-5.6ci | R-13 + R-5.6 ci |
| Metal framed | R-13 + R-7.5ci | R-13 +R-7ci |
| Wood framed and other | R-13 + R-3.8ci or R-21 | R-13 +R-3.8ci or R-21 |

| CLIMATE ZONE | All Other | Group R |
|---|---|---|
| **Walls, Below Grade** | | |
| Below grade wall | R-7.5ci | R-7.5ci |
| **Floors** | | |
| Mass | R-10ci | R-12.5ci |
| Joist/Framing (steel/wood) | R-30 | R-30 |
| **Slab-on-Grade Floors** | | |
| Unheated slabs | NR | R-10 for 24 in. below |
| Heated slabs | R-15 for 24 in. below | R-15 for 24 in. below |
| **Opaque Doors** | | |
| Swinging | U-0.70 | U-0.70 |
| Roll-up or sliding | U-0.50 | U-0.50 |

**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 |

**Table 5.5-5 *Building Envelope* Requirements for Climate Zone 5 (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-0.063 | R-15 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-0.090 | R-11.4 c.i. | U-0.080 | R-13.3 c.i. | U-0.151[b] | R-5.7 c.i.[b] |
| *Metal building* | U-0.050 | R-0 + R-19 c.i. | U-0.050 | R-0 + R-19 c.i. | U-0.094 | R-0 + R-9.8 c.i. |
| *Steel-framed* | U-0.055 | R-13 + R-10 c.i. | U-0.055 | R-13 + R-10 c.i. | U-0.084 | R-13+R-3.8 c.i. |
| *Wood-framed and other* | U-0.051 | R-13 + R-7.5 c.i. or R-19 + R-5 c.i. | U-0.051 | R-13 + R-7.5 c.i. or R-19 + R-5 c.i. | U-0.089 | R-13 |

**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* |
| *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 | |

**Table 5.5-5 *Building Envelope* Requirements for Climate Zone 5 (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* |
| *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-0.510 | R-20 for 24 in. | F-0.730 | NR |
| *Heated* | F-0.688 | R-20 for 48 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 | |

# Current Oregon Fenestration Requirements



| CLIMATE ZONE | 4 AND MARINE 4 |
|---|---|
| **Vertical fenestration (30% maximum of above-grade wall)** | |
| Fenestration type | U-factor |
| **Framing materials other than metal with or without metal reinforcement or cladding** | |
| **Fixed, operable, and doors with greater than 50% glazing** | 0.35 |
| **Metal framing with or without thermal break** | |
| Fixed: including curtain wall/storefront | 0.45 |
| Entrance door | 0.80 |
| All other | 0.46 |
| **SHGC-all frame types** | 0.40 |
| **Skylights (3% maximum of roof area)** | |
| U-factor | 0.60 |
| SHGC | 0.40 |

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

| | *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* | | (for all frame types) | | | (for all frame types) | | | (for all frame types) | |
| *Nonmetal framing*, all | 0.31 | 0.36 | 1.10 | 0.31 | 0.36 | 1.10 | 0.51 | NR | NR |
| *Metal framing, fixed* | 0.38 | | | 0.38 | | | 0.73 | | |
| *Metal framing, operable* | 0.46 | | | 0.46 | | | 0.81 | | |
| *Metal framing, entrance door* | 0.68 | | | 0.68 | | | 0.77 | | |
| *Skylight*, 0% to 3% of *Roof* | | | | | | | | | |
| All types | 0.50 | 0.40 | NR | 0.50 | 0.40 | NR | 1.15 | NR | NR |

**Table 5.5-5 *Building Envelope* Requirements for Climate Zone 5 (A,B,C)***

| | *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* | | (for all frame types) | | | (for all frame types) | | | (for all frame types) | |
| *Nonmetal framing*, all | 0.31 | 0.38 | 1.10 | 0.31 | 0.38 | 1.10 | 0.45 | NR | NR |
| *Metal framing, fixed* | 0.38 | | | 0.38 | | | 0.62 | | |
| *Metal framing, operable* | 0.46 | | | 0.46 | | | 0.70 | | |
| *Metal framing, entrance door* | 0.68 | | | 0.68 | | | 0.77 | | |
| *Skylight*, 0% to 3% of *Roof* | | | | | | | | | |
| All types | 0.50 | 0.40 | NR | 0.50 | 0.40 | NR | 0.98 | NR | NR |

Total *vertical fenestration area* to be smaller 40% for all climate zones

- Including both fixed and operable *vertical fenestration*
- Exception: street-level *vertical fenestration* (5.5.4.4.1)

Total *skylight* area smaller than specified in Tables 5.5-0 through 5.5-8 (3% of roof area for all climate zones)

- Permitted to be no greater than 6% of *gross roof area* provided criteria in exception 1 to *skylight SHGC* requirements are met (5.5.4.4.2) and *daylight area under skylights* is more than or equal to half the *floor* area of the *space*

Minimum *skylight* area must be provided in *enclosed spaces* that are

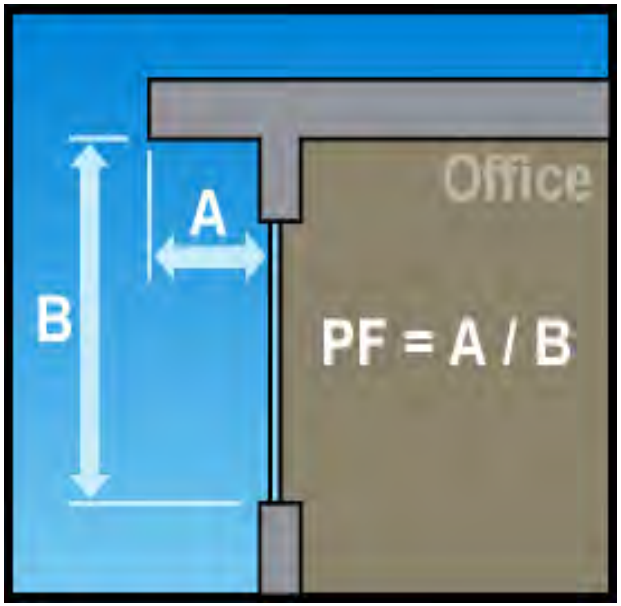
- ≥ 2,500 $ft^2$
- In spaces with ceiling height > 15 ft and
- Space types

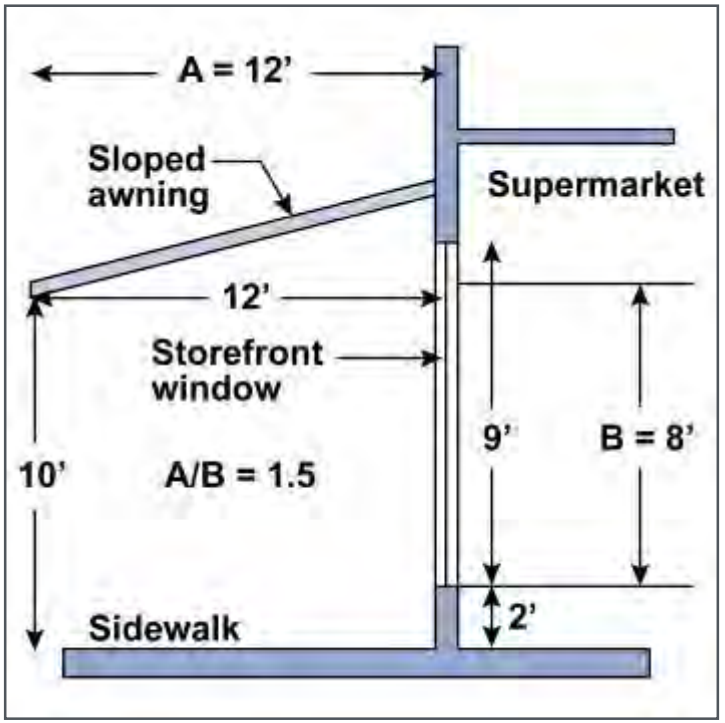
- Office
- Lobby
- Atrium
- Concourse
- Corridor
- Storage (incl. nonrefrigerated warehouse)
- Gymnasium/fitness /exercise area
- Playing area
- Gymnasium seating area
- Convention exhibit/event space
- Courtroom
- Automotive service
- Fire station engine room
- Manufacturing
- Corridor/transition and bay areas
- Retail
- Library reading and stack areas
- Distribution/sorting area
- Transportation
- Baggage and seating areas
- Workshop

# Information – Overhangs

Standard credits permanent overhangs by adjustment to *SHGC*

Size of overhang is determined by projection factor



# Information – Overhangs



**Table 5.5.4.4.1 *SHGC* Multipliers for Permanent Projections**

| 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 |

Two options to comply for *vertical fenestration*:

(a) For Climate Zones 0 - 8

$A_W \leq (A_T)/4$ *and* $A_E \leq (A_t)/4$

**OR**

(b) For Climate Zones 0 – 3

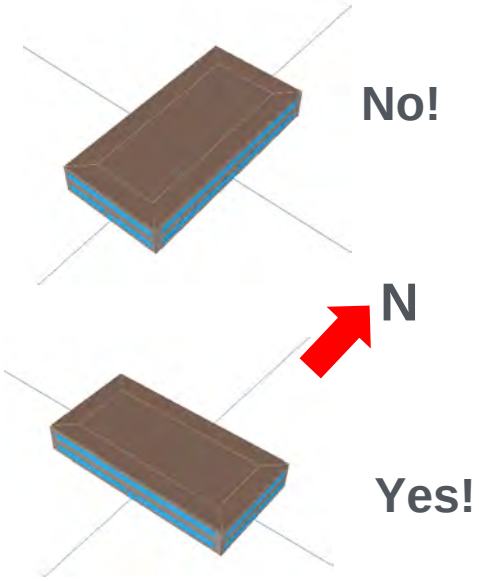
$A_W \times SHGC_W \leq (A_T \times SHGC_C)/4$ *and*

$A_E \times SHGC_E \leq (A_T \times SHGC_C)/4$

For Climate Zones 4 – 8

$A_W \times SHGC_W \leq (A_T \times SHGC_C)/5$ *and*

$A_E \times SHGC_E \leq (A_T \times SHGC_C)/5$




Where,

$A_W$ and $SHGC_W$ = west-oriented *vertical fenestration area* and SHGC

$A_E$ and $SHGC_E$ = east-oriented *vertical fenestration area* and SHGC

$A_T$ = total *vertical fenestration area*

$SHGC_C$ = SHGC criteria in Tables 5.5-0 through 5.5-8

**Exceptions**

- Complies with Exception 3 of Section 5.5.4.4.1
- *Buildings* with shade on 75% of the west and east
- *Alterations* and additions that don't increase *vertical fenestration area*
- *Buildings* where west- and east-oriented *vertical fenestration area* < 20% of *gross wall area* for each of those facades and SHGC on those facades < 90% of $SHGC_c$
- *Buildings* in Climate Zone 8