

Building Envelope Thermal Performance

Calculation Methods & Standards - ASHRAE 90.1-2022

Document: BEC-ASHRAE-2025-002 | Standard: ASHRAE 90.1-2022 | Date: November 2025 | Revision: 4.1

1. Wall U-Value Calculation Method

$$U\text{-value} = 1 / R_{\text{total}}$$

$$R_{\text{total}} = R_{\text{inside}} + \sum R_{\text{layers}} + R_{\text{outside}}$$

Multi-Layer Wall Assembly Analysis:

Layer Description	Thickness (mm)	Conductivity (W/m·K)	R-Value (m²·K/W)
Inside Air Film	-	-	0.130
Gypsum Plasterboard	12.5	0.25	0.050
Concrete Masonry Unit	200	1.70	0.118
XPS Insulation	100	0.034	2.941
Air Gap (ventilated)	25	-	0.180
Clay Brick	100	0.77	0.130
Outside Air Film	-	-	0.040

Calculation Steps:

- Sum all R-values: $0.130 + 0.050 + 0.118 + 2.941 + 0.180 + 0.130 + 0.040$
- $R_{\text{total}} = 3.589 \text{ m}^2\cdot\text{K}/\text{W}$
- $U\text{-value} = 1 \div 3.589 = 0.279 \text{ W}/\text{m}^2\cdot\text{K}$

Final U-Value: 0.279 W/m²·K

ASHRAE 90.1 Limit (Climate Zone 4): 0.35 W/m²·K

Status: COMPLIANT ✓

2. Thermal Bridging Correction

$$U_{\text{corrected}} = U_{\text{clear wall}} + \Delta U_{\text{thermal bridges}}$$

$$\Delta U_{\text{thermal bridges}} = \Sigma(\psi \times l) / A_{\text{wall}}$$

Thermal Bridge Analysis:

Linear Thermal Bridges:

- Steel studs (16" o.c.): $\psi = 0.15 \text{ W/m}\cdot\text{K}$, Length = 120 m
- Window perimeter: $\psi = 0.08 \text{ W/m}\cdot\text{K}$, Length = 180 m
- Floor slab edge: $\psi = 0.25 \text{ W/m}\cdot\text{K}$, Length = 80 m
- Balcony connections: $\psi = 0.45 \text{ W/m}\cdot\text{K}$, Length = 24 m

Calculation:

$$\Delta U = [(0.15 \times 120) + (0.08 \times 180) + (0.25 \times 80) + (0.45 \times 24)] \div 2400$$

$$\Delta U = [18 + 14.4 + 20 + 10.8] \div 2 \quad \Delta U = [18 + 14.4 + 20 + 10.8] \div 2400$$

$$\Delta U = 63.2 \div 2400 = 0.026 \text{ W/m}^2\cdot\text{K}$$

$$\text{Corrected U-Value: } 0.279 + 0.026 = 0.305 \text{ W/m}^2\cdot\text{K}$$

Still within ASHRAE 90.1 limit ✓

Overall Window U-Value:

$$U_{\text{window}} = (A_{\text{glass}} \times U_{\text{glass}} + A_{\text{frame}} \times U_{\text{frame}} + L_{\text{edge}} \times \psi_{\text{edge}}) / A_{\text{total}}$$

Double-Glazed Window Analysis:

Component	Area/Length	U-Value/ ψ -Value	Heat Loss (W/K)
Glass Area	1.8 m ²	1.4 W/m ² ·K	2.52
Frame Area	0.7 m ²	2.8 W/m ² ·K	1.96
Edge Seal	5.2 m	0.06 W/m·K	0.31

Overall Calculation:

Total Heat Loss = 2.52 + 1.96 + 0.31 = 4.79 W/K

Total Window Area = 1.8 + 0.7 = 2.5 m²

$U_{\text{window}} = 4.79 \div 2.5 = 1.92 \text{ W/m}^2\cdot\text{K}$

4. Solar Heat Gain Coefficient (SHGC)

$SHGC = \text{Solar Heat Gain} / \text{Incident Solar Radiation}$

$\text{Solar Heat Gain} = \text{Direct Transmission} + \text{Inward Flowing Fraction}$

Low-E Glazing SHGC Calculation:

Glass Properties:

- Solar Transmittance (τ): 0.42
- Solar Absorptance outer pane (α_1): 0.15
- Solar Absorptance inner pane (α_2): 0.08
- Inward flowing fraction outer: 0.12
- Inward flowing fraction inner: 0.89

SHGC Calculation:

Direct transmission = 0.42
Absorbed heat flow = $(0.15 \times 0.12) + (0.08 \times 0.89)$
Absorbed heat flow = $0.018 + 0.071 = 0.089$
SHGC = $0.42 + 0.089 = 0.509$

Calculated SHGC: 0.51

ASHRAE 90.1 Limit (South-facing, Zone 4): 0.40

Status: REQUIRES EXTERNAL SHADING

5. Climate Zone Requirements

Zone 1 (Hot)

Wall U-Value: 0.89
Window U-Value: 1.22
SHGC: 0.25

Zone 2 (Hot)

Wall U-Value: 0.89
Window U-Value: 0.65
SHGC: 0.25

Zone 3 (Warm)

Wall U-Value: 0.89
Window U-Value: 0.57
SHGC: 0.25

Zone 4 (Mixed)

Wall U-Value: 0.35
Window U-Value: 0.48
SHGC: 0.40

Zone 5 (Cool)

Wall U-Value: 0.35
Window U-Value: 0.48
SHGC: NR

Zone 6 (Cold)

Wall U-Value: 0.35
Window U-Value: 0.48
SHGC: NR

Note: All U-values in W/m²·K. SHGC values are dimensionless. NR = No Requirement. Values shown are for non-residential buildings per ASHRAE 90.1-2022.

6. Air Leakage Calculations

$$\text{Air Leakage Rate} = Q / A_{\text{envelope}}$$

$$Q = C \times \Delta P^n$$

Where: C = flow coefficient, ΔP = pressure difference, n = flow exponent

Blower Door Test Results:

Test Conditions:

- Test Pressure: 75 Pa
- Measured Airflow: 8,500 CFM
- Building Envelope Area: 25,000 ft²
- Flow Exponent (n): 0.65

Calculation:

Air Leakage Rate = 8,500 CFM ÷ 25,000 ft²
Air Leakage Rate = 0.34 CFM/ft²
ASHRAE 90.1 Limit = 0.40 CFM/ft²

Measured: 0.34 CFM/ft² @ 75 Pa
Required: ≤ 0.40 CFM/ft² @ 75 Pa
Status: COMPLIANT ✓