Introduction to Commercial Building Audits

Course No. ENRG 50

Outline

A. Introduction to concept of commercial building energy auditing
   1. Why energy efficiency (EE) is important
   2. Energy use and waste in commercial building operations
   3. Prioritizing energy efficiency over renewable energy generation

B. Ordinances, policies and standards governing commercial building audits
   1. San Francisco Existing Commercial Buildings Performance Ordinance
   2. State of California energy goals
   3. ASHRAE standards, including Building Energy Assessment Professional (BEAP)
   4. Other audit standards

C. Three ASHRAE audit levels
   1. Preliminary energy use analysis
   2. Level 1, Walk-through analysis
   3. Level 2, Intermediate, energy survey and energy analysis
   4. Level 3, Detailed analysis of capital-intensive modifications

D. Developing the scope of work in a commercial building audit
   1. Objectives of the audit, including needed data and resources
   2. Assessment management
   3. Responsibilities of audit team members

E. Elements in preliminary analysis of building performance data
   1. Engineering and architectural document review
   2. Geographical and climatic review
   3. Review and analysis of current energy use and costs
   4. Benchmarking procedures

F. Factors in on-site building assessment
   1. Common safety hazards and field safety techniques
   2. Occupant interviews and assessment of building operations
   3. Building envelope
   4. Electrical systems
   5. HVAC&R systems
   6. Lighting systems and use
   7. Miscellaneous other energy use systems
   8. Domestic water systems and use
   9. Indoor environmental quality

G. Analysis of data collected
   1. Identify opportunities for efficiency improvement
   2. Calculate value of efficiency improvements and return on investment
   3. Prioritize options based on client criteria

H. Audit completion activities
   1. Prepare and present written report
   2. Assist with development of implementation plan

F. Factors in on-site building assessment

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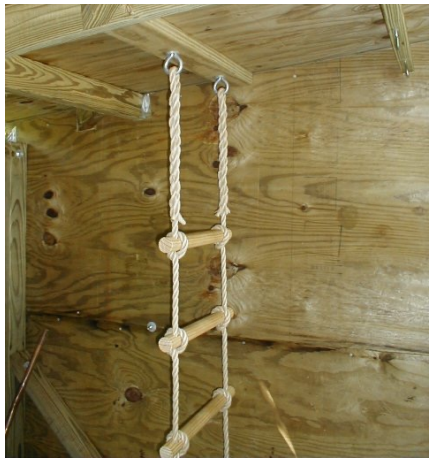
Common safety hazards and field safety techniques

- Prepared during the day of on-site survey, you may:
  - climb a ladder
  - enter a interstitial space or get on roof
  - check the roof
  - work in hot, cold, freezing, noisy and/or dark space
  - be exposed to chemical hazard if for laboratory
- Dress appropriately
  - avoid loose clothing and jewelry;
  - avoid open-toe shoes
  - wear glasses/gargle when necessary

Safety tips

- Work in group or in pair if possible
- Get familiar with the building and emergency exit
- Wear eye and ear protection if necessary
- Make sure all ladders are secure
- Do not touch equipment and ask facility staff to help if needed



http://www.johnderbyshire.com

Site Visit Safety Activity

- Aspects of facilities where safety is a concern:
  - Hard to reach equipment (require ladders)
  - Rotary equipment
  - Hot surfaces
  - Combustion gases
  - Pipes and other low-hanging equipment
  - Keyed entries and automated door locks
  - pressurized spaces

information source: PG&E Energy Auditing Techniques

Site Visit Safety Activity

- Environmental/behavior factors that add to risk:
  - Need to move quickly
  - Move on sloped surface/roof
  - Low Lighting in some areas
  - Noisy environments
  - Extreme hot or cold conditions
  - Wet/slick floors
  - Code compliance issues (electrical, gas, refrigerant…)

information source: PG&E Energy Auditing Techniques

F. Factors in on-site building assessment

1. Common safety hazards and field safety techniques
2. Occupant interviews and assessment of building operations
3. Building envelope
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Occupant interviews and assessment of building operations

- Who should be interviewed? (if applicable)
  - executive team
  - energy manager
  - facility manager
  - facility staff
  - facility users/customers

Occupant interviews and assessment of building operations

What questions should be asked?

Homework of Chapter D, you have already generate a questionnaire for on-line energy interview.

Practice to ask those questions to the facility manager and finish the questionnaire report.

F. Factors in on-site building assessment

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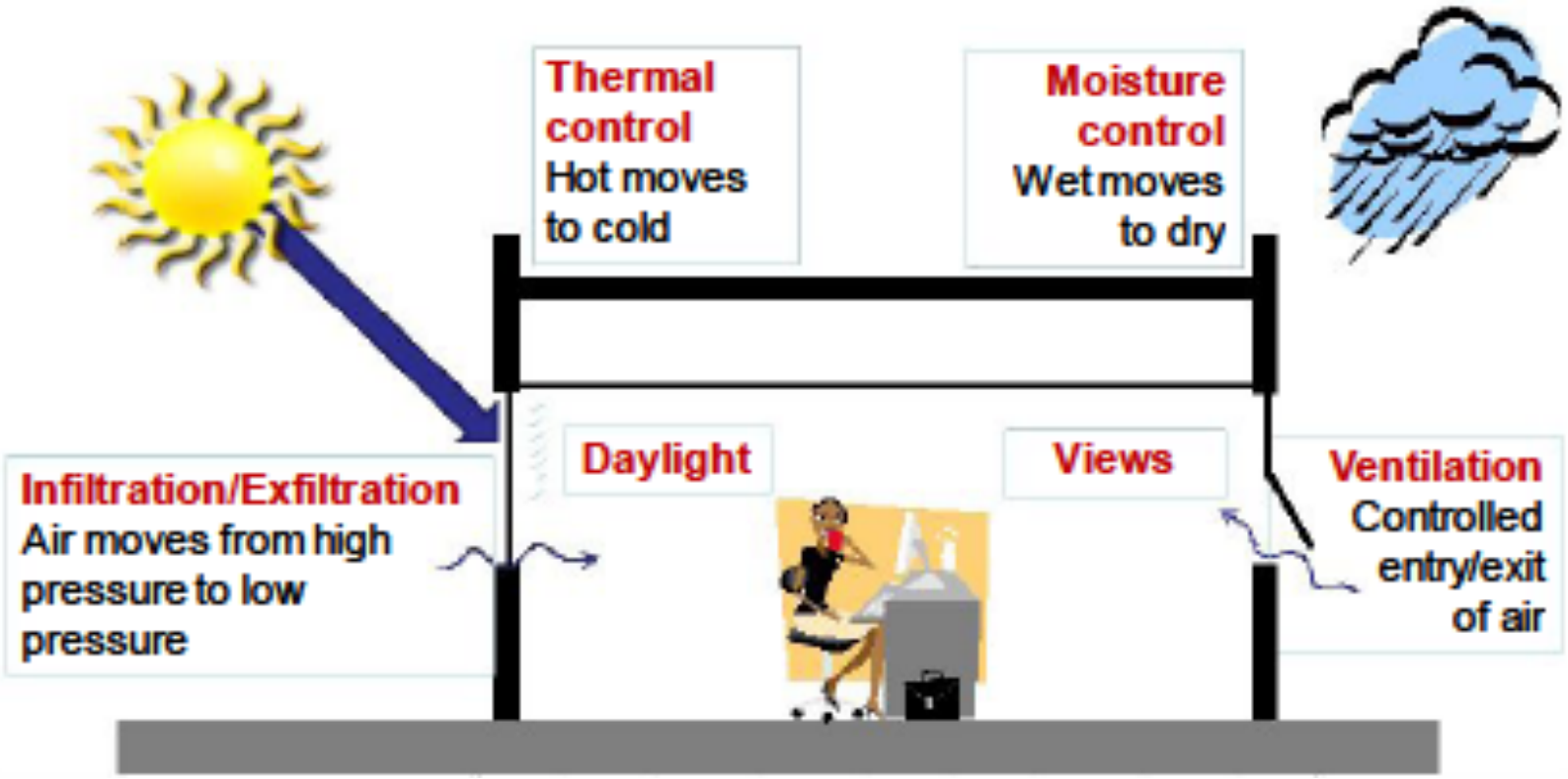
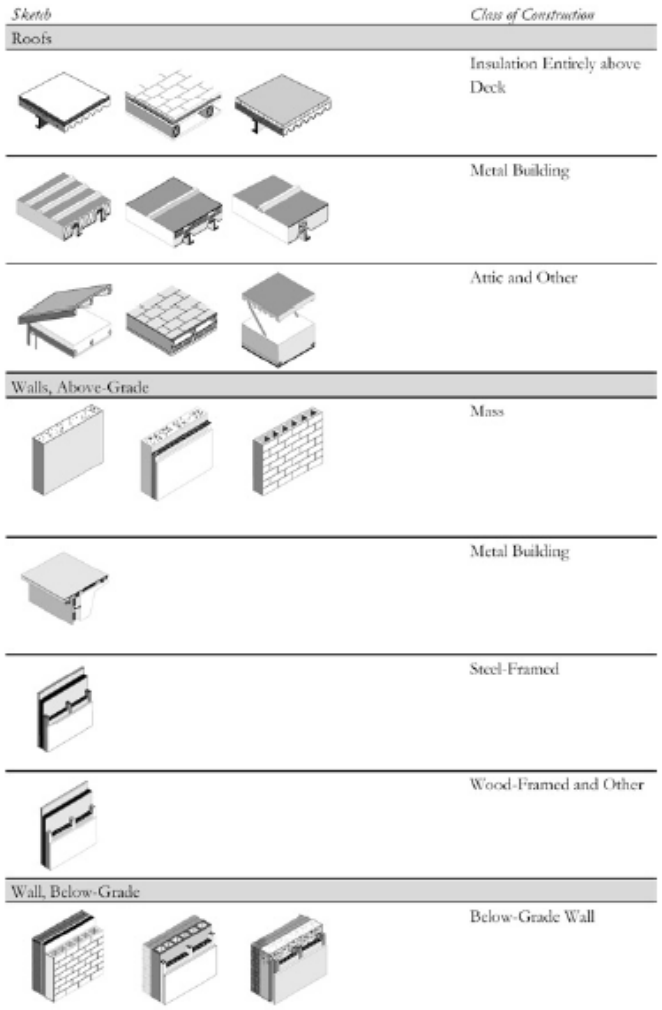
Building envelope system

Opaque enclosure – wall, roof, floor
Fenestration – windows, skylights, shading devices



Opaque classes of construction

- Roofs
  - Insulation above roof decks
  - Metal building roofs
  - Attic roofs with wood/steel framing
- Above-grade walls
  - Mass walls
  - Metal building walls
  - Steel frame walls
  - Wood frame walls
- Below-grade walls



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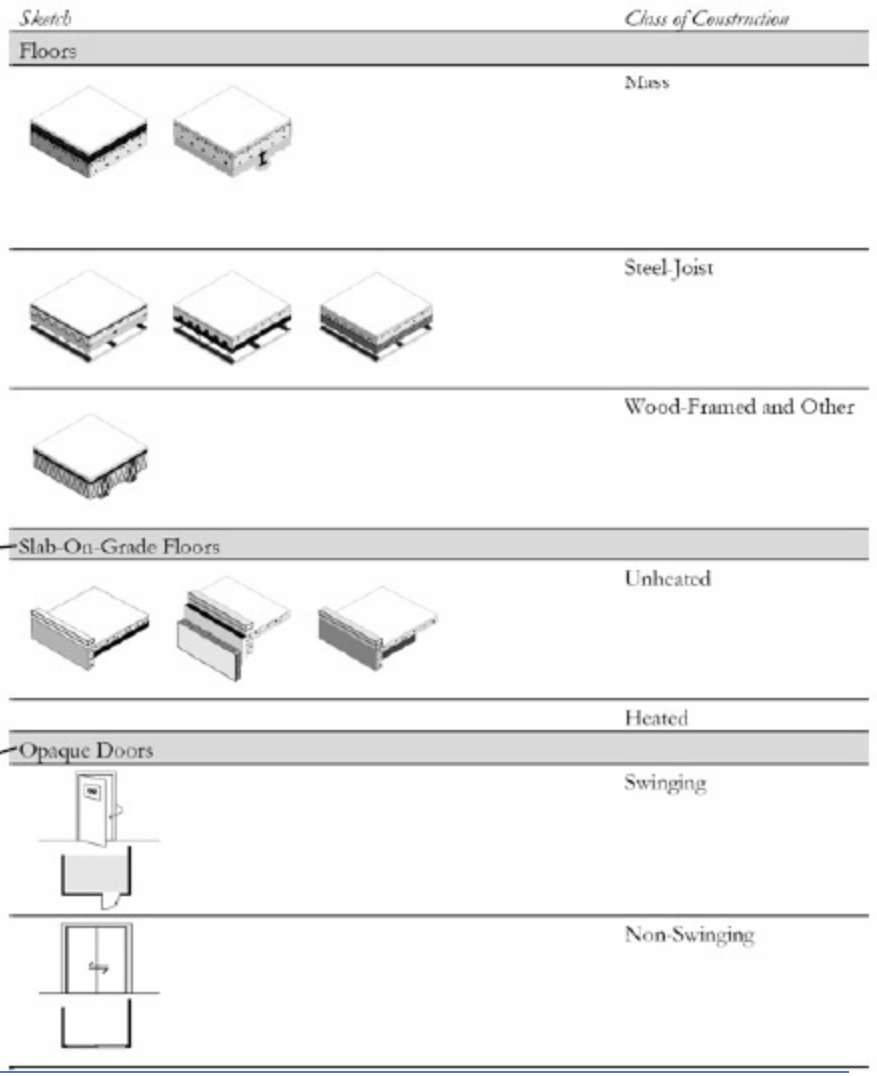
Opaque classes of construction

- Floors
  - Mass floors
  - Steel joist floors
  - Wood framed & other floors
- Slab-on-grade floors
  - Heated
  - Unheated
- Opaque Doors



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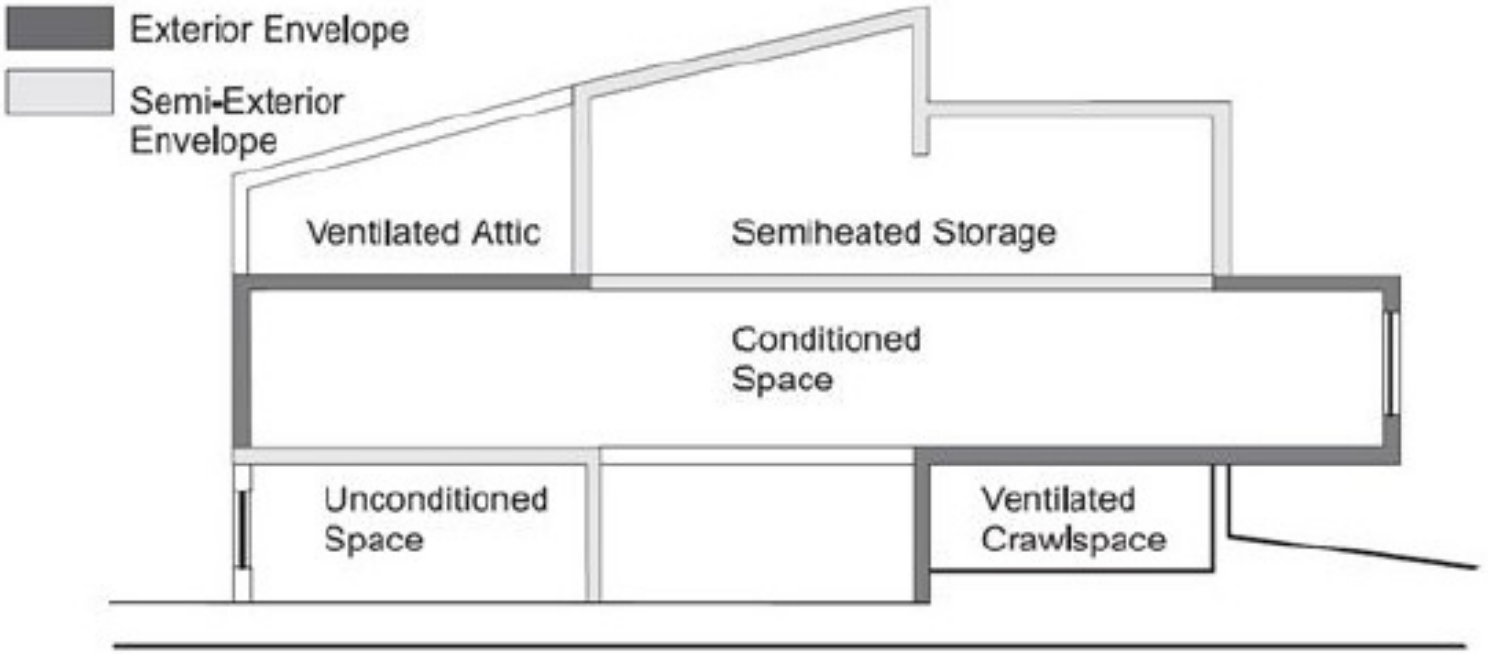
ASHRAE Standard 90.1 – Envelope classifications



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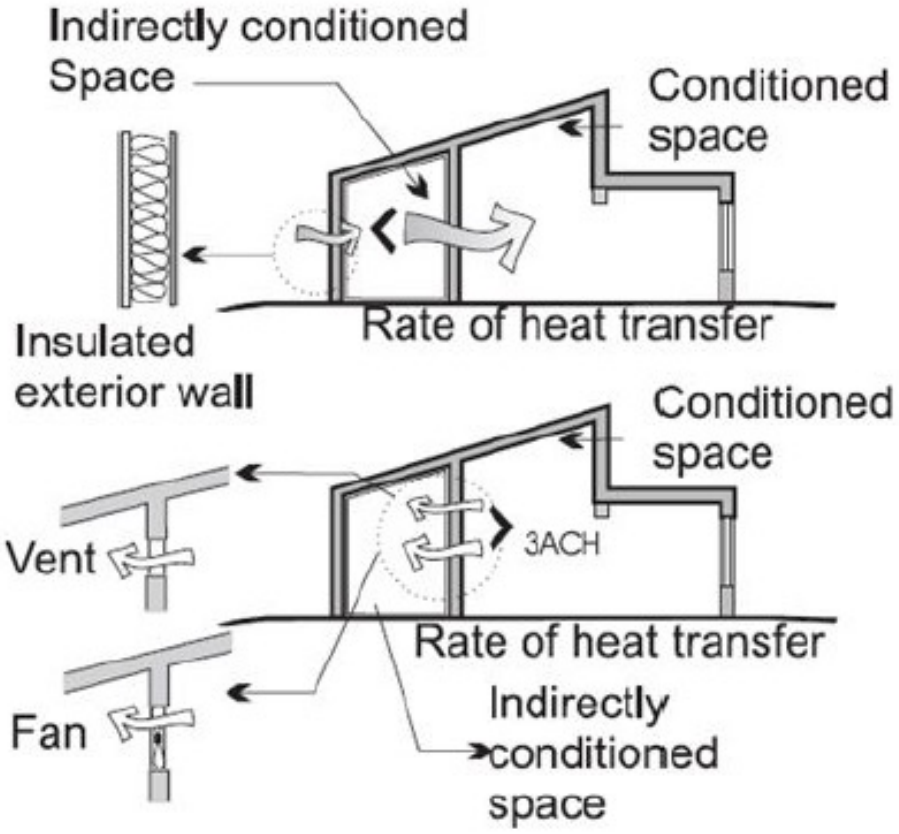
Indirectly conditioned space



Principal Criterion

Optional Criterion

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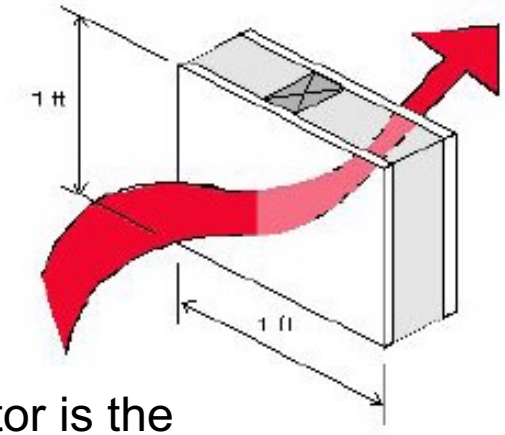
Opaque enclosure heat transfer

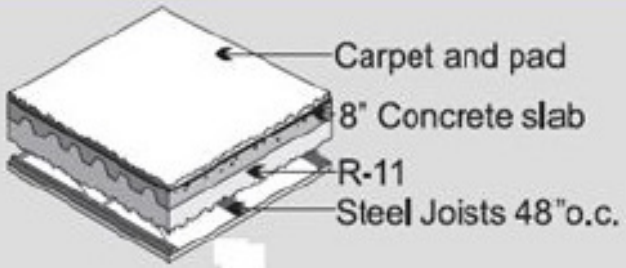
- R-value
  - Thermal resistance
  - Add layers for total R-value
  - Larger R-value has greater thermal resistance

- U-factor
  - Thermal transmittance
  - = 1/R-value
  - IP unites = Btu/hr-°F-ft^2
  - SI units = W/°C-m^2



U-Factor is the rate of heat flow in Btu/h through one ft^2 area when one side is 1° F warmer

U-Factor calculation – concrete floor



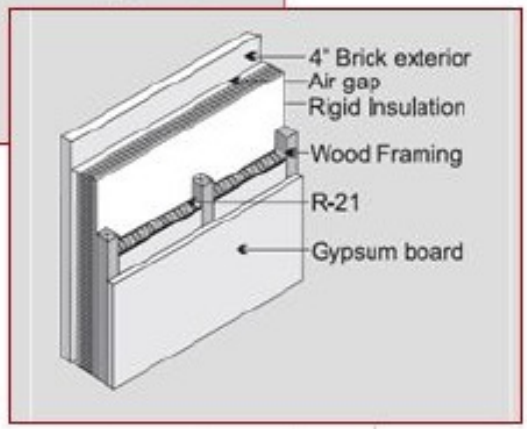
Layer	R-value	Data Source
Inside air film	0.92	§ A9.4.1
Carpet and pad	1.23	Table A9.4D
0.5 in. concrete (85 lb/ft³)	0.35	Table A3.1B (use Rc / 2)
8.0 in. concrete (144 lb/ft³)	0.50	Table A3.1B (use Rc)
Insulation/framing	10.01	Table A9.2A
Semi-exterior air film	0.46	§ A9.4.1
Total R-value	13.47	
U-factor	0.0742	

Series Method

U-Factor calculation – wood framed wall – parallel path

	Cavity	Studs	Headers	Data Source
Exterior air film	0.17	0.17	0.17	*Standard 90.1-2007* (§ A9.4.1)
4 in. face brick	0.25	0.25	0.25	ASHRAE *Handbook*
0.75 in. air space	0.90	0.90	0.90	*Standard 90.1-2007* (Table A9.4A)
Rigid insulation	7.00	7.00	7.00	Manufacturer's data
0.625 in. gypsum board	0.56	0.56	0.56	*Standard 90.1-2007* (Table A9.4D)
Cavity insulation	25.00	n.a.	n.a.	Manufacturer's data
Wood studs	n.a.	9.06	n.a.	*Standard 90.1-2007* (Table A9.4D)
Wood header	n.a.	n.a.	1.88	ASHRAE *Handbook*
Rigid insulation	n.a.	n.a.	17.50	Manufacturer's data
Wood header	n.a.	n.a.	1.88	ASHRAE *Handbook*
0.625 in. gypsum board	0.56	0.56	0.56	*Standard 90.1-2007* (Table A9.4D)
Interior air film	0.68	0.68	0.68	*Standard 90.1-2007* (§ A9.4.1)
Total thermal resistance	35.12	18.18	31.38	
U-factor	0.0285	0.0521	0.0319	
Weight	78%	18%	4%	

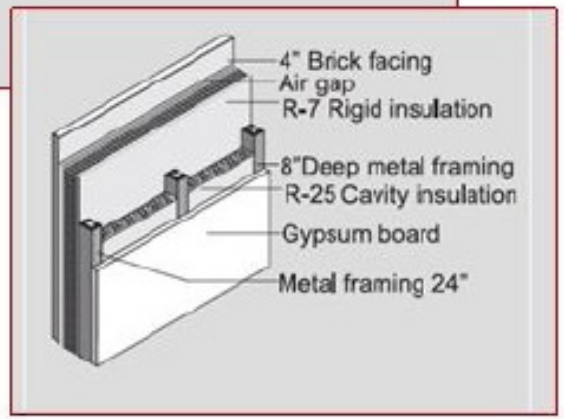
Parallel Path Method



U-Factor calculation – steel framed wall

Layer	R-value	Source of Data
Exterior air film	0.17	*Standard 90.1-2007* (§ A9.4.1)
4 in. face brick	0.25	*ASHRAE Handbook*
0.75 in. air space	0.90	*Standard 90.1-2007* (Table A9.4A)
Rigid insulation	7.00	Manufacturer's data
0.625 in. gypsum board	0.56	*Standard 90.1-2007* (Table A9.4D)
Framing/cavity	9.60	*Standard 90.1-2007* (Table A9.2B)
0.625 in gypsum board	0.56	*Standard 90.1-2007* (Table A9.4D)
Interior air film	0.68	*Standard 90.1-2007* (§ A9.4.1)
Total	*19.72*	
U-factor	*0.051*	

Isothermal Planes Method



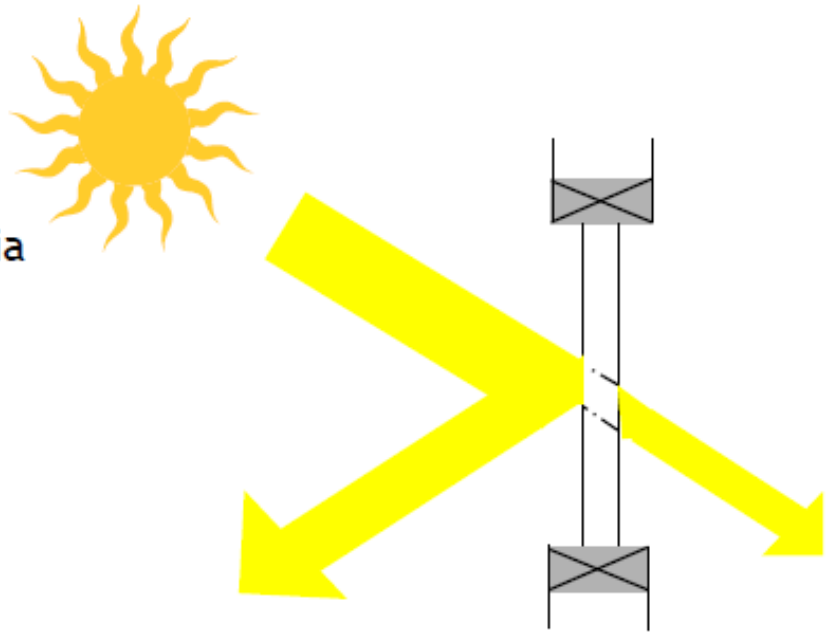
Application of U-Factor calculation methods

	Acceptable Calculation Methods					
Construction Classes	Testing	Series Calculation Method	Parallel Path Calculation Method	Isothermal Planes	Modified Zone Method	Two-dimensional Calculation Meth
Roofs						
Insulation Entirely above Deck	✓	✓				✓
Metal Building	✓					✓
Attic (wood joists)	✓		✓			✓
Attic (steel joists)	✓			✓ (1)	✓	✓
Attic (concrete joists)	✓	✓ (2)		✓ (3)		✓
Other	✓					✓
Walls, Above-Grade						
Mass	✓			✓		✓
Metal Building	✓					✓
Steel-Framed	✓			✓ (1)	✓	✓
Wood-Framed	✓		✓			✓
Other	✓					✓
Wall, Below-Grade						
Mass	✓			✓		✓
Other	✓					✓
Floors						
Mass	✓	✓ (2)		✓ (3)		✓
Steel-Joist	✓			✓ (1)	✓	✓
Wood-Framed	✓		✓	✓		✓
Other	✓					✓
Slab-On-Grade Floors						
Unheated						✓
Heated						✓

Fenestration prescriptive requirements

Items Covered:

- Compliance Method
  - SHGC and U-value criteria
  - Rated - NFRC standards
  - Unrated - Alternate procedures provided
- Credits / Exceptions
  - Credit for permanent external shading
  - Street Level Fenestration exempt from SHGC requirements, if several conditions are met.



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Fenestration & doors

The following are mandatory provisions for fenestration and doors:

- Rating of fenestration products
- Labeling of fenestration products
- Labeling of doors
- U-factor
- Solar heat gain coefficient
- Visible light transmittance

Fenestration & Doors

NFRC-National Fenestration Rating Council:

a non-profit organization that administers the only uniform, independent rating and labeling system for the energy performance of windows, doors, skylights, and attachment products.

http://www.nfrc.org/default.aspx

Fenestration & Doors

U-factor:
- measures how well a product prevents heat from escaping.
- 0.20 ~ 1.20
- the lower, the better its insulting value

Solar Heat Gain Coefficient:
- measures how well a product blocks heat caused by sunlight
- 0~1
- the lower, the less solar heat it transmits

Visible Transmittance:
- measured how much light comes through a product
- 0~1
- the higher, the more light is transmitted

Air Leakage:
- indicated by an air leakage rating expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/sq ft)

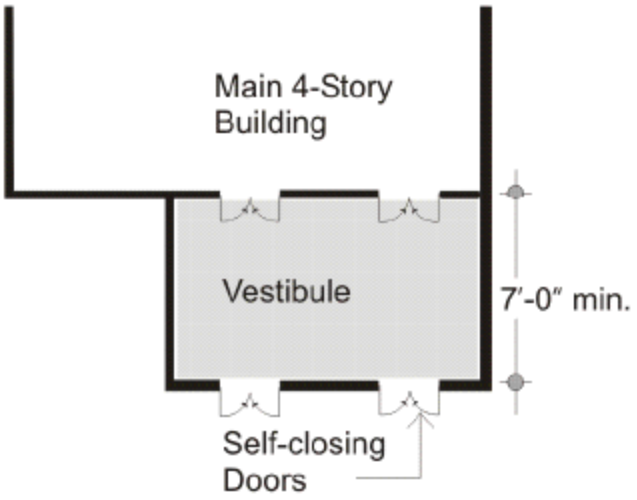
Condensation Resistance:
- measured the ability of a product to resist the formation of condensation on the interior surface of that product.
- 1~100

http://www.nfrc.org/default.aspx

Air leakage: Vestibules

Applies to:
- doors that separate conditioned space from the exterior.

Requirements:
- such doors shall be protected with an enclosed vestibule.
- all doors opening into or out of the vestibule shall be equipped with self-closing devices
- interior and exterior doors shall:
  1) not be required to be open at the same time
  2) be separated by a minimum distance of 7 ft, when closed.



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Climate Zone 1A, Fenestration Elements only

Space Conditioning Categories

Categories of Construction

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-1.20		U-1.20		U-1.20	
Metal framing (curtainwall/storefront)[d]	U-1.20	SHGC-0.25 all	U-1.20	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (entrance door) [d]	U-1.20		U-1.20		U-1.20	
Metal framing (all other)[d]	U-1.20		U-1.20		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	Uall-1.98	SHGCall-0.36	Uall-1.98	SHGCall-0.19	Uall-1.98	SHGCall-NR
2.1%–5.0%	Uall-1.98	SHGCall-0.19	Uall-1.98	SHGCall-0.16	Uall-1.98	SHGCall-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	Uall-1.90	SHGC all-0.34	Uall-1.90	SHGC all-0.27	Uall-1.90	SHGC all-NR
2.1%–5.0%	Uall-1.90	SHGCall-0.27	Uall-1.90	SHGCall-0.27	Uall-1.90	SHGCall-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	Uall-1.36	SHGC all-0.36	Uall-1.36	SHGC all-0.19	Uall-1.36	SHGC all-NR
2.1%–5.0%	Uall-1.36	SHGCall-0.19	Uall-1.36	SHGCall-0.19	Uall-1.36	SHGCall-NR

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Climate Zone 2(A, B) Fenestration Elements only

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.75	SHGC-0.25 all	U-0.75	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.70		U-0.70		U-1.20	
Metal framing (entrance door)[d]	U-1.10		U-1.10		U-1.20	
Metal framing (all other)[d]	U-0.75		U-0.75		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	$U_{all-1.98}$	$SHGC_{all-0.36}$	$U_{all-1.98}$	$SHGC_{all-0.19}$	$U_{all-1.98}$	$SHGC_{all-NR}$
2.1%–5.0%	$U_{all-1.98}$	$SHGC_{all-0.19}$	$U_{all-1.98}$	$SHGC_{all-0.19}$	$U_{all-1.98}$	$SHGC_{all-NR}$
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	$U_{all-1.90}$	$SHGC_{all-0.39}$	$U_{all-1.90}$	$SHGC_{all-0.27}$	$U_{all-1.90}$	$SHGC_{all-NR}$
2.1%–5.0%	$U_{all-1.90}$	$SHGC_{all-0.34}$	$U_{all-1.90}$	$SHGC_{all-0.27}$	$U_{all-1.90}$	$SHGC_{all-NR}$
Skylight without Curb, All, % of Roof						
0%–2.0%	$U_{all-1.36}$	$SHGC_{all-0.36}$	$U_{all-1.36}$	$SHGC_{all-0.19}$	$U_{all-1.36}$	$SHGC_{all-NR}$
2.1%–5.0%	$U_{all-1.36}$	$SHGC_{all-0.19}$	$U_{all-1.36}$	$SHGC_{all-0.19}$	$U_{all-1.36}$	$SHGC_{all-NR}$

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Climate Zone 4 (A,B) Fenestration Elements only

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.40		U-0.40		U-1.20	
Metal framing (curtainwall/storefront)[d]	U-0.50	SHGC-0.40 all	U-0.50	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (entrance door)[d]	U-0.85		U-0.85		U-1.20	
Metal framing (all other)[d]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	Uall-1.17	SHGCall-0.49	Uall-0.98	SHGCall-0.36	Uall-1.98	SHGCall-NR
2.1%–5.0%	U all-1.17	SHGC all-0.39	U all-0.98	SHGC all-0.19	U all-1.98	SHGC all-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	Uall-1.30	SHGCall-0.65	Uall-1.30	SHGCall-0.62	Uall-1.90	SHGCall-NR
2.1%–5.0%	U all-1.30	SHGC all-0.34	U all-1.30	SHGC all-0.27	U all-1.90	SHGC all-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	Uall-0.69	SHGCall-0.49	Uall-0.58	SHGCall-0.36	Uall-1.36	SHGCall-NR
2.1%–5.0%	U all-0.69	SHGC all-0.39	U all-0.58	SHGC all-0.19	U all-1.36	SHGC all-NR

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Climate Zone 6(A,B) Fenestration Elements only

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.35		U-0.35		U-0.65	
Metal framing (curtainwall/storefront)[d]	U-0.45	SHGC-0.40 all	U-0.45	SHGC-0.40 all	U-0.60	SHGC-NR all
Metal framing (entrance door) [d]	U-0.80		U-0.80		U-0.90	
Metal framing (all other)[d]	U-0.55		U-0.55		U-0.65	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U all-1.17	SHGC all-0.49	U all-0.98	SHGC all-0.46	U all-1.98	SHGC all-NR
2.1%–5.0%	uall-1.17	SHGCall-0.49	uall-0.98	SHGCall-0.36	uall-1.98	SHGCall-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U all-0.87	SHGC all-0.71	U all-0.74	SHGC all-0.65	U all-1.90	SHGC all-NR
2.1%–5.0%	uall-0.87	SHGCall-0.58	uall-0.74	SHGCall-0.55	uall-1.90	SHGCall-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U all-0.69	SHGC all-0.49	U all-0.58	SHGC all-0.49	U all-1.36	SHGC all-NR
2.1%–5.0%	uall-0.69	SHGCall-0.49	uall-0.58	SHGCall-0.39	uall-1.36	SHGCall-NR

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Glazing types

Solar Heat Gain Coefficient (SHGC)

- Significantly greater energy savings are realized when sun penetration is blocked before entering the windows.
- Glass facing east and west should be significantly limited.

Visual Light Transmission (VLT)

- Higher VLTs (0.50 - 0.70):
  - Use in glazing between 6 ft above the floor up to the ceiling.
  - Are preferred in predominantly overcast climates.
- Lower VLTs (0.35 - 0.50)
  - Acceptable in view windows below 6 ft.
  - May be required to prevent glare, especially on the east or west facades or for higher window-wall ratios.

U-Factors

- U-factors for windows are to be measured over the entire window assembly, not just the center of glass.

http://ali.ashrae.biz/2012winterconferencecourses/std90-1envelope/Complying_90-1-2010_Env_Ltg_Chicago_2012_Final_Slides.pdf

Credit for external shading

- Credit is limited to overhangs
- Credit is not provided for other external shading devices such as:
  - Vertical fins, or
  - Non-permanent devices such as awnings.
- Shading effects from geometry of some devices, such as shown at the right, may be converted to equivalent overhang, with approval of building official.

http://ali.ashrae.biz/2012winterconferencecourses/std90-1envelope/Complying_90-1-2010_Env_Ltg_Chicago_2012_Final_Slides.pdf

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