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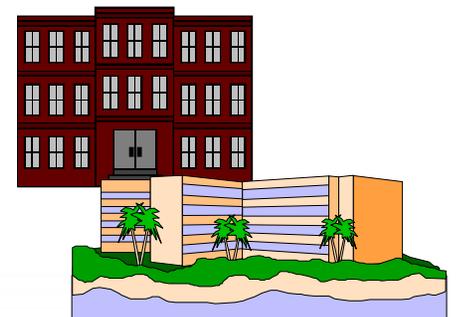
**BUILDING** TECHNOLOGY,

STATE AND COMMUNITY PROGRAMS

# Commercial Provisions of the 2000 International Energy Conservation Code

U.S. Department of Energy  
Office of Codes and Standards

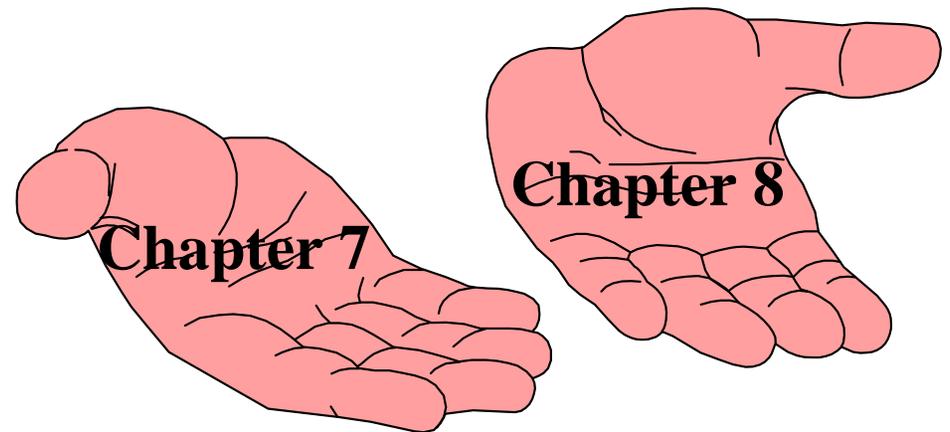
Produced by the Pacific Northwest National Laboratory



# Chapter 7 Compared to Chapter 8

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- Envelope compliance
- Mechanical compliance
- Service water heating compliance
- Lighting compliance



# Structure of the IECC

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- Chapter 1 Administrative & Enforcement
- Chapter 2 Definitions
- Chapter 3 Design Conditions
- Chapter 4 Residential - Systems Analysis
- Chapter 5 Residential - Component Performance
- Chapter 6 Simplified Prescriptive
- **Chapter 7 *ASHRAE 90.1* Reference**
- **Chapter 8 Design by Acceptable Practice for Commercial Buildings**
- Chapter 9 Referenced Standards

# Building Envelope

## Chapter 8 Scope

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### **Chapter 8**

#### Section 802

- $\leq 50\%$  glazing area

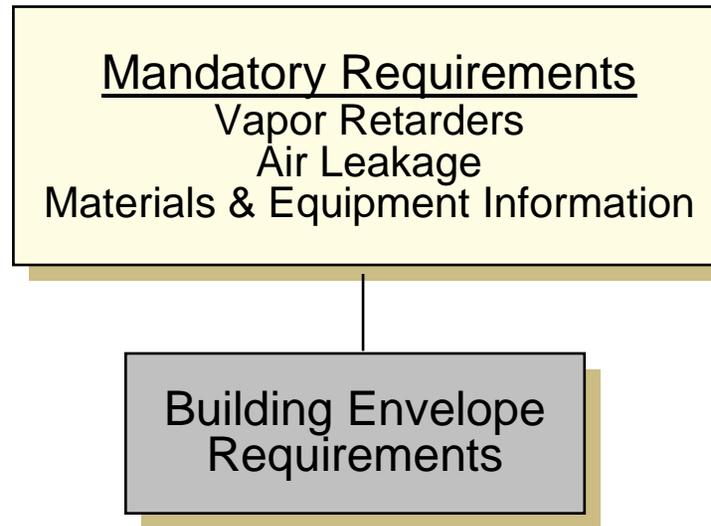
### **Chapter 7**

#### Section 402

# IECC Scope

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- Envelope requirements

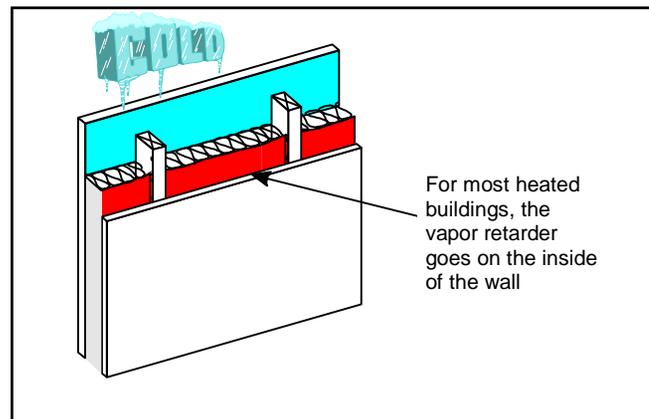


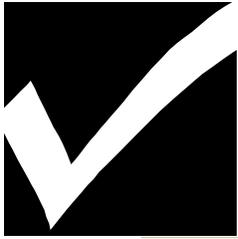
# Vapor Retarder

(Section 802.1.2)



- Install in nonvented framed ceilings, walls, floors
- Must have a Perm Rating of  $<1.0$
- Install on the “warm-in-winter” side of insulation



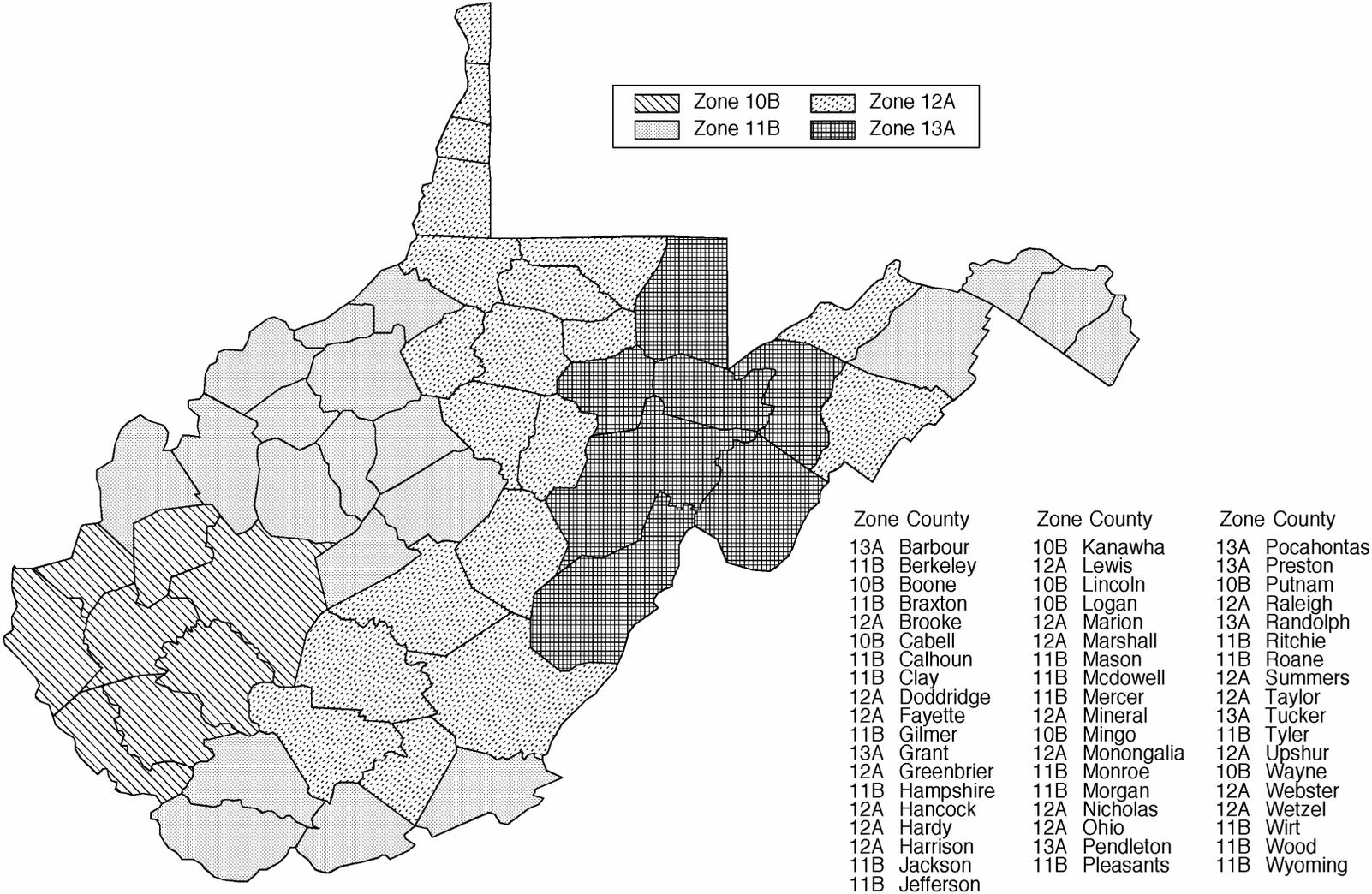


# Vapor Retarder

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- Exceptions
  - Climate Zones 1 through 7
    - IECC Chapter 3

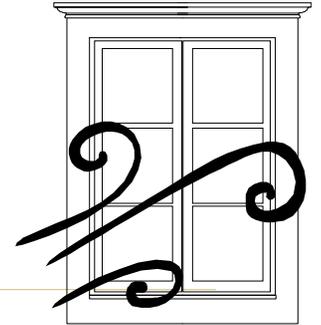
# WEST VIRGINIA



# Air Leakage

*(Section 802.3)*

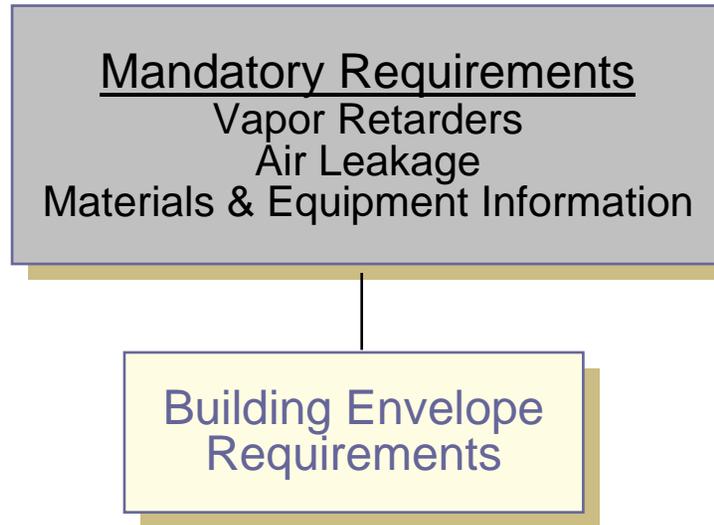
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- Manufactured window and door air leakage rates
  - Labeled windows and doors enforced at point of manufacturer
  - Meet AAMA/WDMA 101 windows and doors
  - Meet ASTM E283
  - Non-labeled windows and doors ~ use manufacturers test results

# Building Envelope Compliance

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# Envelope Requirements

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- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - Skylights
  - Floors
  - Slabs on grade
  - Below-grade walls

# Terms Used in Each Code

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<u>Component</u>	<u>IECC</u>	<u>90.1</u>
Roofs	R-Value	U-Factor
Above Grade Walls	R-Value	U-Factor
Raised Floors	R-Value	U-Factor
Windows	U-Factor	U-Factor
Skylights	U-Factor	U-Factor
Slab-on-Grade	R-Value	R-Value
Below Grade Walls	R-Value	R-Value

# Terms R-Values

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## •Terms

### •Requirements

- Walls
- Windows
- Roofs
- Skylights
- Floors
- Slabs on Grade
- Below-Grade Walls

- Thermal resistance to heat flow
- The larger the number the better
- The R-value of layers in a construction can be added together

# Terms

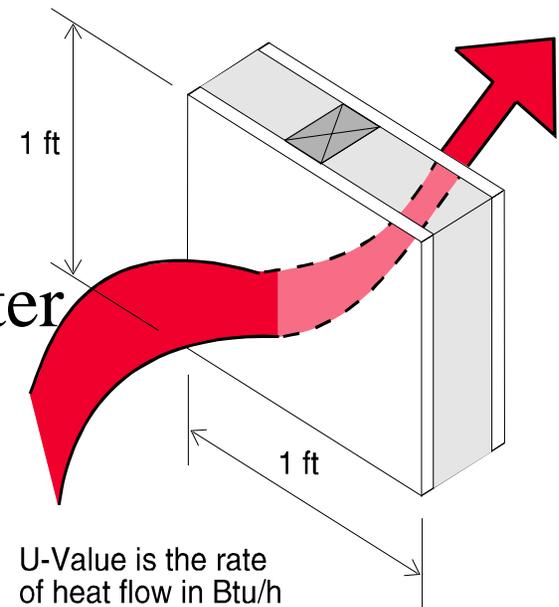
## U-Factors

### •Terms

#### •Requirements

- Walls
- Windows
- Roofs
- Skylights
- Floors
- Slabs on Grade
- Below-Grade Walls

- The amount of heat in Btu (British thermal units) that flows each hour through one square foot, when there is a  $1^{\circ}\text{F}$  temperature difference across the surface
- The smaller the number the better



U-Value is the rate of heat flow in Btu/h through one  $\text{ft}^2$  area when one side is  $1^{\circ}\text{F}$  warmer

## Terms

# Relationship Between R-values and U-factors

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### •Terms

#### •Requirements

- Walls
- Windows
- Roofs
- Skylights
- Floors
- Slabs on Grade
- Below-Grade  
Walls

$$U - Factor = \frac{1}{R - Value}$$



# Building Envelope Requirements

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- For buildings  $\leq 50\%$  glazing to gross wall area
- Minimal calculations
- Based on:
  - Climate zone
  - Window wall ratio
  - Construction assembly
- All components must meet or exceed building envelope requirements

# IECC Chapter 8

# IECC Table

GLAZING AREA OVER 10 PERCENT BUT NOT GREATER THAN 25 PERCENT OF ABOVE-GRADE WALL AREA			
ELEMENT	CONDITION/VALUE		
Skylights ( <i>U</i> -value)	0.8		
Slab or below-grade wall ( <i>R</i> -value)	R-0		
Windows and glass doors	SHGC	<i>U</i> -value	
PF < 0.25	0.5	0.6	
0.25 ≤ PF < 0.50	0.6	0.6	
PF ≥ 0.50	0.7	0.6	
Roof assemblies ( <i>R</i> -value)	Insulation between framing	Continuous insulation	
All-wood joist/truss	R-25	R-19	
Metal joist/truss	R-25	R-20	
Concrete slab or deck	NA	R-19	
Metal purlin with thermal block	R-30	R-20	
Metal purlin without thermal block	X	R-20	
Floors over outdoor air or unconditioned space ( <i>R</i> -value)	Insulation between framing	Continuous insulation	
All-wood joist/truss	R-19	R-12	
Metal joist/truss	R-19	R-13	
Concrete slab or deck	NA	R-13	
Above-Grade Walls ( <i>R</i> -value)	No Framing	Metal Framing	Wood Framing
Framed			
<i>R</i> -value cavity	NA	R-11	R-11
<i>R</i> -value continuous	NA	R-0	R-0
CMU, ≥ 8 in, with integral insulation			
<i>R</i> -value cavity	NA	R-11	R-11
<i>R</i> -value continuous	R-5	R-0	R-0
Other Masonry Walls			
<i>R</i> -value cavity	NA	R-11	R-11
<i>R</i> -value continuous	R-5	R-0	R-0

# Building Envelope Requirements

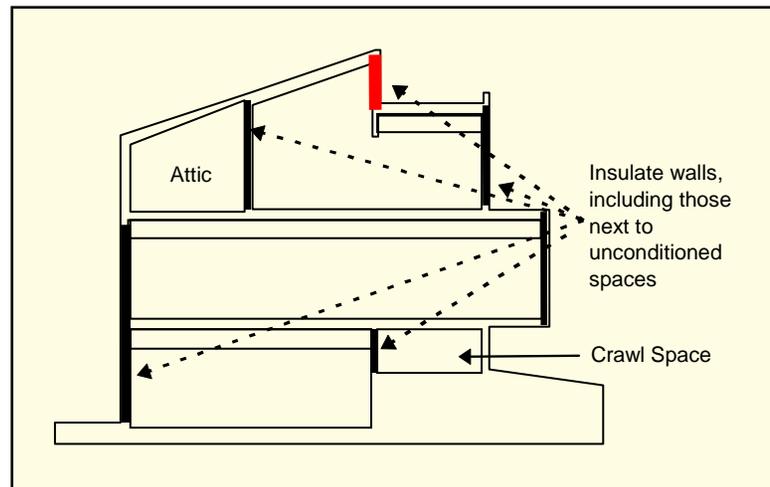
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- Glazing percentage to above grade wall
  - Gross window area / gross wall area
  - Gross wall area includes
    - Above-grade walls
    - Band joist and subfloor between floors
    - Area of all doors and windows

Envelope Requirements  
**Walls**  
*(Section 802.2.1)*

- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - Skylights
  - Floors
  - Slabs on Grade
  - Below-Grade Walls

- Meet or exceed R-value requirement
- Insulation between framing R-value
- Continuous R-value





## Envelope Requirements **Windows** *(Section 802.2.3)*

- Terms
- Requirements
  - Walls
  - **Windows**
  - Roofs
  - Skylights
  - Floors
  - Slabs on Grade
  - Below-Grade Walls

- Requirements based on
  - Solar Heat Gain Coefficient
  - Maximum U-value

# Windows - SHGC

- Solar Heat Gain Coefficient (SHGC)
  - Requirements dependent on projection factor
  - National Fenestration Rating Council (NFRC) tested
  - Default SHGC range diagrams
  - $SHGC = SC \times .87$

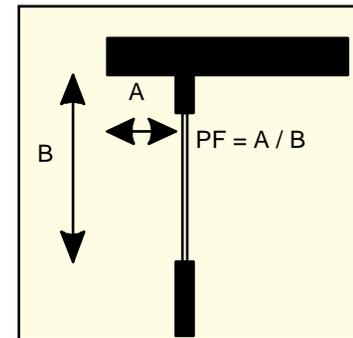


TABLE 102.3(3)  
SHGC DEFAULT TABLE FOR FENESTRATION

PRODUCT DESCRIPTION	SINGLE GLAZED				DOUBLE GLAZED			
	Clear	Bronze	Green	Gray	Clear + Clear	Bronze + Clear	Green + Clear	Gray + Clear
Metal frames								
Operable	0.75	0.64	0.62	0.61	0.66	0.55	0.53	0.52
Fixed	0.78	0.67	0.65	0.64	0.68	0.57	0.55	0.54
Nonmetal frames								
Operable	0.63	0.54	0.53	0.52	0.55	0.46	0.45	0.44
Fixed	0.75	0.64	0.62	0.61	0.66	0.54	0.53	0.52

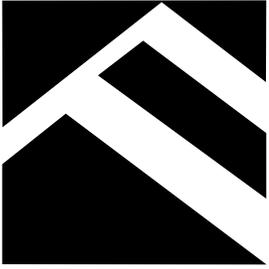
# Windows – U-Factor

**TABLE 102.3(1)**  
**U-VALUE DEFAULT TABLE FOR WINDOWS,**  
**GLAZED DOORS AND SKYLIGHTS**

FRAME MATERIAL AND PRODUCT TYPE <sup>a</sup>	SINGLE GLAZED	DOUBLE GLAZED
Metal without thermal break		
Operable (including sliding and swinging glass doors)	1.27	0.87
Fixed	1.13	0.69
Garden window	2.60	1.81
Curtain wall	1.22	0.79
Skylight	1.98	1.31
Site-assembled sloped/overhead glazing	1.36	0.82
Metal with thermal break		
Operable (including sliding and swinging glass doors)	1.08	0.65
Fixed	1.07	0.63
Curtain wall	1.11	0.68
Skylight	1.89	1.11
Site-assembled sloped/overhead glazing	1.25	0.70
Reinforced vinyl/metal clad wood		
Operable (including sliding and swinging glass doors)	0.90	0.57
Fixed	0.98	0.56
Skylight	1.75	1.05
Wood/vinyl/fiberglass		
Operable (including sliding and swinging glass doors)	0.89	0.55
Fixed	0.98	0.56
Garden window	2.31	1.61
Skylight	1.47	0.84

For SI: 1 inch = 25.4 mm.  
<sup>a</sup> Glass block assemblies with mortar but without reinforcing or framing shall have a U-value of 0.60.

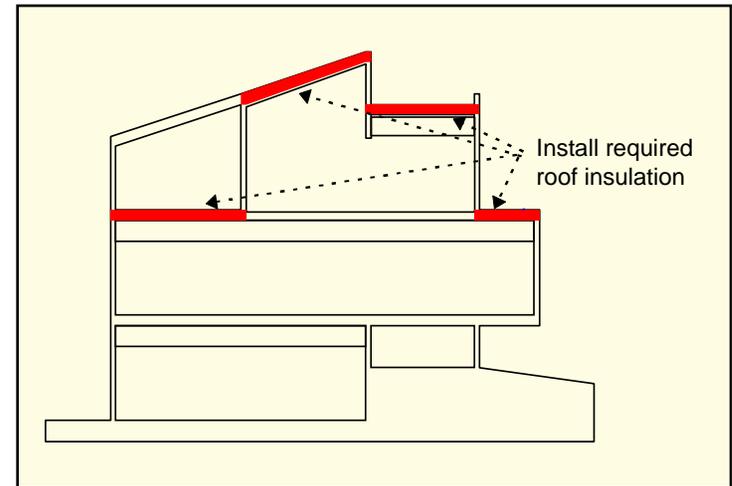
- U-values
  - NFRC tested and certified or default window U-value range
- Use assembly U-value
- All windows must meet or exceed



Envelope Requirements  
**Roofs**  
*(Section 802.2.4)*

- Terms
- Requirements
  - Walls
  - Windows
  - **Roofs**
  - Skylights
  - Floors
  - Slabs on Grade
  - Below-Grade Walls

- Requirements based on
  - Assembly type
  - Continuous insulation
  - Insulation between framing
- All R-values must meet or exceed



Envelope Requirements  
**Skylights**  
*(Section 802.2.5)*

- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - **Skylights**
  - Floors
  - Slabs on Grade
  - Below-Grade Walls

- Restricted to  $\leq 3\%$  of roof area
- Requirements based on
  - U-value ~ NFRC tested or default U-value table

TABLE 102.3(1)  
 U-VALUE DEFAULT TABLE FOR WINDOWS,  
 GLAZED DOORS AND SKYLIGHTS

FRAME MATERIAL AND PRODUCT TYPE <sup>a</sup>	SINGLE GLAZED	DOUBLE GLAZED
Metal without thermal break		
Operable (including sliding and swinging glass doors)	1.27	0.87
Fixed	1.13	0.69
Garden window	2.60	1.81
Curtain wall	1.22	0.79
Skylight	1.98	1.31
Site-assembled sloped/overhead glazing	1.36	0.82
Metal with thermal break		
Operable (including sliding and swinging glass doors)	1.08	0.65
Fixed	1.07	0.63
Curtain wall	1.11	0.68
Skylight	1.89	1.11
Site-assembled sloped/overhead glazing	1.25	0.70
Reinforced vinyl/metal clad wood		
Operable (including sliding and swinging glass doors)	0.90	0.57
Fixed	0.98	0.56
Skylight	1.75	1.05
Wood/vinyl/fiberglass		
Operable (including sliding and swinging glass doors)	0.89	0.55
Fixed	0.98	0.56
Garden window	2.31	1.61
Skylight	1.47	0.84

For SI: 1 inch = 25.4 mm.

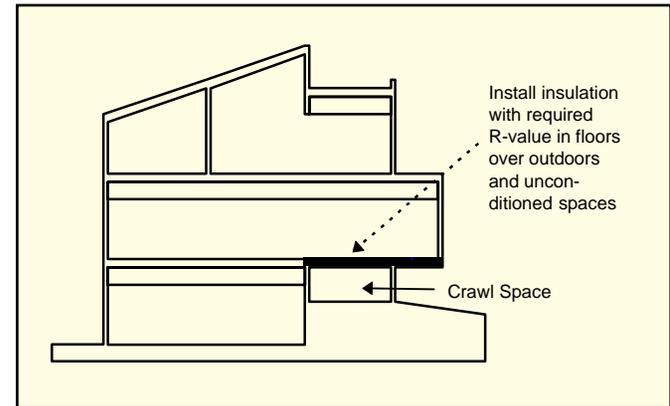
<sup>a</sup> Glass block assemblies with mortar but without reinforcing or framing shall have a U-value of 0.60.

Envelope Requirements

**Floors**  
*(Section 802.2.6)*

- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - Skylights
  - **Floors**
  - Slabs on Grade
  - Below-Grade Walls

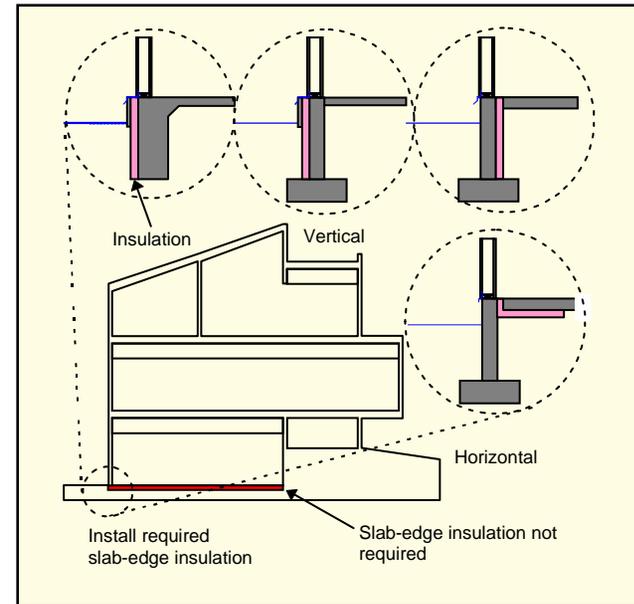
- Requirements based on
  - Assembly type
  - Continuous insulation
  - Insulation between framing
- Raised floor insulation
  - Meet or exceed



Envelope Requirements  
**Slabs on Grade**  
*(Section 802.2.7)*

- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - Skylights
  - Floors
  - **Slabs on Grade**
  - Below-Grade Walls

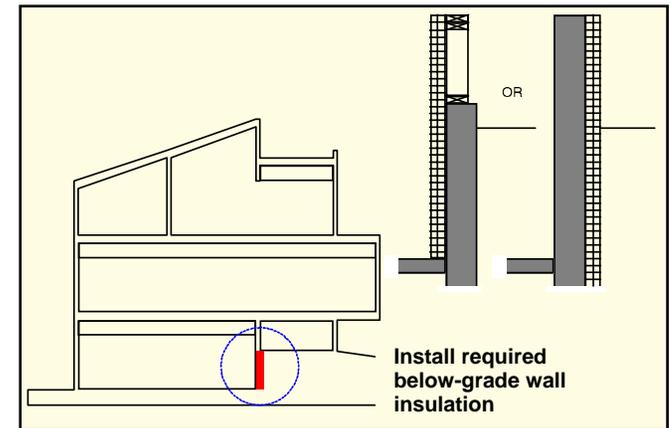
- Slab edge insulation
  - Proposed R-value must meet or exceed



Envelope Requirements  
**Below-Grade Walls**  
*(Section 802.2.8)*

- Terms
- Requirements
  - Walls
  - Windows
  - Roofs
  - Skylights
  - Floors
  - Slabs on Grade
  - **Below-Grade Walls**

- $\geq 85\%$  below grade
- Proposed R-value(s) must meet or exceed required R-value



# Building Envelope

## Chapter 7 Scope

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**Chapter 8**  
Section 802

**Chapter 7**

Section 402

- >50% glazing area
- 4 stories and above

# Contrast with Simple Average

## Area-Weighted Averages

$$\text{Simple Average} = \frac{\text{U - factor}_1 + \text{U - factor}_2}{2}$$

$$\text{Area - Weighted Average} = \frac{\text{Area}_1 \times \text{U - factor}_1 + \text{Area}_2 \times \text{U - factor}_2}{\text{Area}_1 + \text{Area}_2}$$

# Thermal Performance

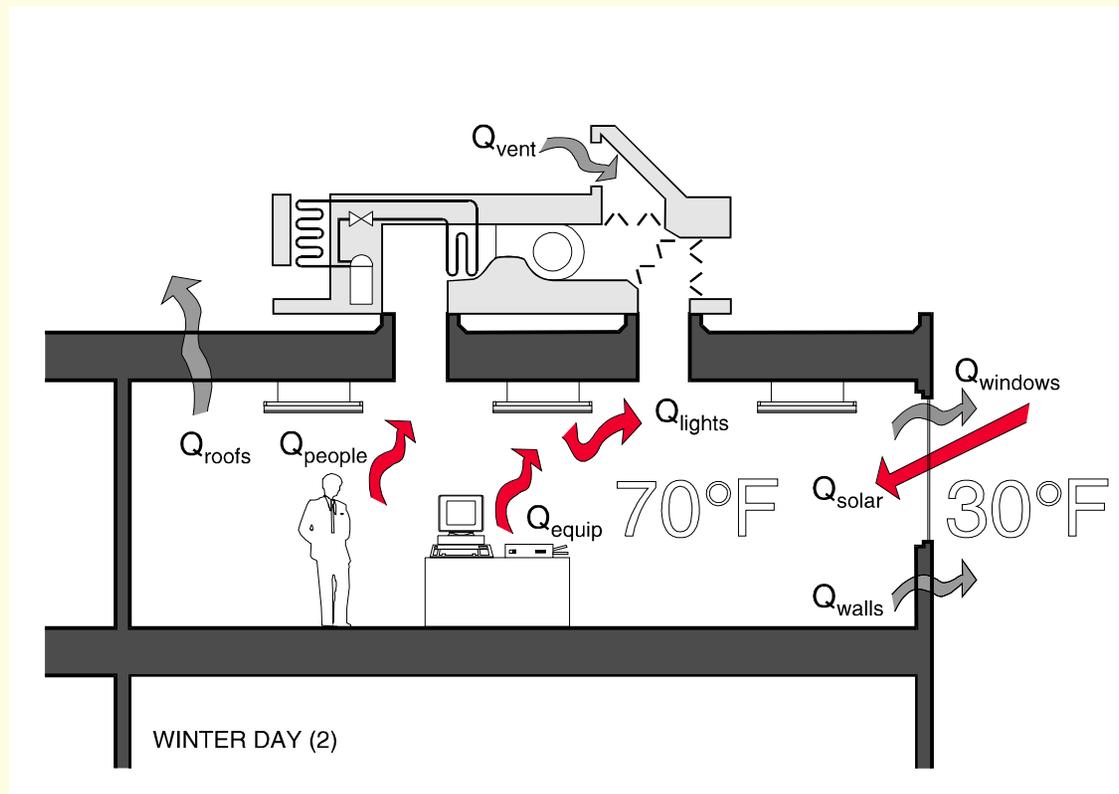
## Table 402.4.1.2

ASHRAE/IES 90.1 Code		October 1993	
Boston, MA		#31	

TABLE 402.4.1.2 MAXIMUM WINDOW WALL RATIO (WWR)								
Internal Load Density (ILD) Range	Projection Factor (PF) Range	Shading Coefficient (SCx) Range	Penetration U-Factor (Uof)					
			Base Case			Perimeter Daylighting		
			0.68 to 0.46	0.45 to 0.39	0.38 to 0	0.68 to 0.46	0.45 to 0	0.38 to 0
0.00 - 1.50	0.00 - 0.25	1.00 - 0.72	23	26	27	24	28	29
		0.71 - 0.61	26	31	32	26	32	34
		0.60 - 0.51	28	35	37	29	36	39
		0.50 - 0.39	31	39	42	31	41	44
		0.38 - 0.26	34	46	51	34	47	53
	0.25 - 0.00	38	55	63	38	55	64	
	0.26 - 0.50	1.00 - 0.72	29	36	38	30	37	40
		0.71 - 0.61	32	41	44	32	42	47
		0.60 - 0.51	34	45	50	34	46	52
		0.50 - 0.39	36	50	55	36	51	58
		0.38 - 0.00	39	56	64	38	56	65
	0.50 +	1.00 - 0.72	34	44	48	34	45	50
		0.71 - 0.61	36	49	54	36	50	57
		0.60 - 0.51	38	53	60	37	54	62
		0.50 - 0.00	39	57	66	39	57	67
1.51 - 3.00	0.00 - 0.25	1.00 - 0.72	20	22	23	24	28	30
		0.71 - 0.61	23	27	27	27	33	35
		0.60 - 0.51	26	30	32	30	37	40
		0.50 - 0.39	29	35	37	33	42	46
		0.38 - 0.26	33	42	46	36	49	55
	0.25 - 0.00	39	53	60	41	59	68	
	0.26 - 0.50	1.00 - 0.72	26	31	32	31	38	41
		0.71 - 0.61	30	36	38	33	43	48
		0.60 - 0.51	32	40	43	36	48	54
		0.50 - 0.39	35	45	49	38	52	60
		0.38 - 0.00	39	53	59	41	59	69
	0.50 +	1.00 - 0.72	31	38	41	35	46	52
		0.71 - 0.61	35	44	48	37	51	59
		0.60 - 0.51	37	49	53	39	55	65
		0.50 - 0.00	40	54	60	41	59	70
3.01 - 3.50	0.00 - 0.25	1.00 - 0.72	18	20	20	24	28	29
		0.71 - 0.61	21	24	25	27	32	35
		0.60 - 0.51	24	27	28	29	36	40
		0.50 - 0.39	27	32	33	32	41	45
		0.38 - 0.26	31	38	41	36	48	54
	0.25 - 0.00	37	49	55	40	58	68	
	0.26 - 0.50	1.00 - 0.72	24	27	28	30	37	40
		0.71 - 0.61	27	32	34	33	42	47
		0.60 - 0.51	30	37	39	35	47	53
		0.50 - 0.39	33	41	45	37	51	59
		0.38 - 0.00	37	49	54	40	57	68
	0.50 +	1.00 - 0.72	29	35	36	34	45	51
		0.71 - 0.61	32	40	43	37	50	58
		0.60 - 0.51	35	44	48	38	54	64
		0.50 - 0.00	37	49	55	40	58	69

# Heat Flows in Buildings

## Internal Heat Gain



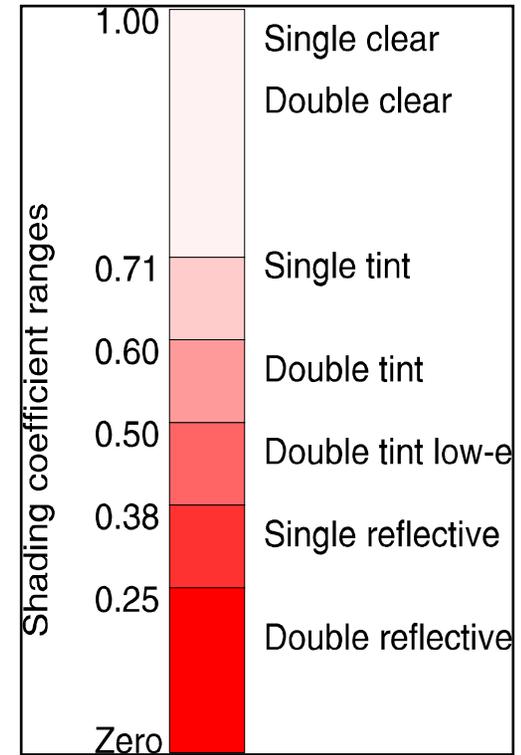
Thermal Performance  
**Internal Gain Ranges**

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- 0.00 - 1.50 W/ft<sup>2</sup> use for residential, hotel/motels, and warehouses
- 1.51 - 3.00 W/ft<sup>2</sup> use for all other
- 3.01 - 3.50 W/ft<sup>2</sup> use for small retail (<2,000 ft<sup>2</sup>) and vocational education schools (<10,000 ft<sup>2</sup>)

Thermal Performance  
**Shading Coefficient ( $Sc_x$ )**

- A number between zero and one that indicates the amount of solar heat gain that will pass through fenestration
- Can account for
  - Glazing material
  - Interior shade
  - Exterior shade



# Thermal Performance Default SC and VLT Values

	Unc coated Glass		Low-E Glass		Medium Reflective		High Reflective	
	SC	VLT	SC	VLT	SC	VLT	SC	VLT
<b>Single Glazing (1/4 in.)</b>								
Clear	0.95	0.88	n.a.	n.a.	0.65	0.43	0.23	0.08
Bronze	0.71	0.53	n.a.	n.a.	0.52	0.25	0.26	0.05
Gray	0.71	0.45	n.a.	n.a.	0.40	0.13	0.26	0.04
Green	0.71	0.75	n.a.	n.a.	0.50	0.33	0.25	0.07
High Performance Tint	0.58	0.66	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
<b>Double Glazing (1 in.)</b>								
Clear	0.81	0.78	0.72	0.73	0.56	0.41	0.16	0.06
Bronze Outer Lite	0.57	0.47	0.48	0.44	0.40	0.23	0.16	0.05
Gray Outer Lite	0.57	0.41	0.46	0.36	0.40	0.18	0.16	0.04
Green Outer Lite	0.57	0.66	0.49	0.62	0.38	0.30	0.15	0.06
High Performance Tint	0.47	0.64	0.39	0.59	n.a.	n.a.	n.a.	n.a.
<b>Single Acrylic</b>								
Clear	0.97	0.92	-	-	-	-	-	-
Bronze	0.53	0.27	-	-	-	-	-	-
High White	0.76	0.82	-	-	-	-	-	-
Medium White	0.68	0.53	-	-	-	-	-	-
Low White	0.45	0.32	-	-	-	-	-	-
<b>Double Acrylic</b>								
Clear	0.89	0.89	-	-	-	-	-	-
Bronze	0.43	0.25	-	-	-	-	-	-
High White	0.72	0.75	-	-	-	-	-	-
Medium White	0.63	0.49	-	-	-	-	-	-
Low White	0.40	0.29	-	-	-	-	-	-
<b>Triple Acrylic</b>								
Clear	0.82	0.85	-	-	-	-	-	-
Bronze	0.36	0.27	-	-	-	-	-	-
High White	0.68	0.69	-	-	-	-	-	-
Medium White	0.58	0.45	-	-	-	-	-	-
Low White	0.35	0.23	-	-	-	-	-	-

Notes:

- All glass is assumed to be 1/4-in. thick.
- Double glass is assumed to consist of two 1/4-in. panes separated by a 1/2-in. air space.
- The medium performance reflective coating is typical of pyrolytic coatings. These are coatings that are applied when the glass is in a hot, semi-molten state.
- The high performance reflective coating is typical of "SS08" coatings. SS08 is a generic name used by many manufacturers to indicate a stainless steel (SS) coating with a visible light transmission of 8% when applied to clear glass.
- Reflective coatings are assumed to be placed on the second surface.
- The low-e coating is typical of many products on the market, having an emissivity of about 0.15. This coating is assumed to be placed on the third surface.

# SC Adjustments for Interior Shading

Shading Coefficient of Glass	Light Colored Blind	Medium Colored Blind	Light Colored Drapery	Medium Colored Drapery	Dark Colored Drapery
0.90 - 1.00	0.57	0.67	0.57	0.64	0.73
0.80 - 0.89	0.68	0.75	0.61	0.65	0.76
0.70 - 0.79	0.76	0.81	0.65	0.68	0.77
0.60 - 0.69	0.77	0.82	0.69	0.74	0.81
0.50 - 0.59	0.80	0.84	0.76	0.78	0.85
0.40 - 0.49	0.83	0.85	0.80	0.85	0.93
< 0.40	0.86	0.89	0.83	0.86	0.92

Thermal Performance  
**Fenestration Area**

---

- Entire glazing area including the frame
- Typically the rough opening

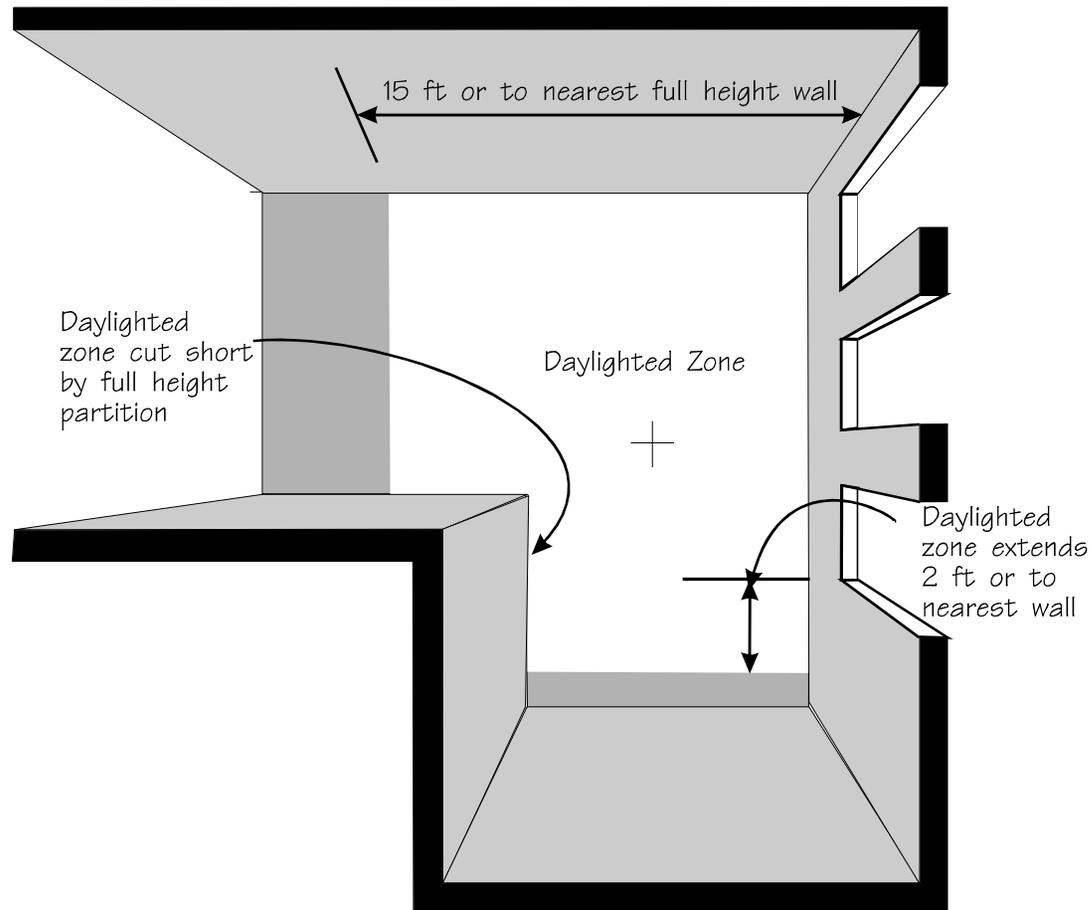
Thermal Performance  
Perimeter Daylighting Parameters

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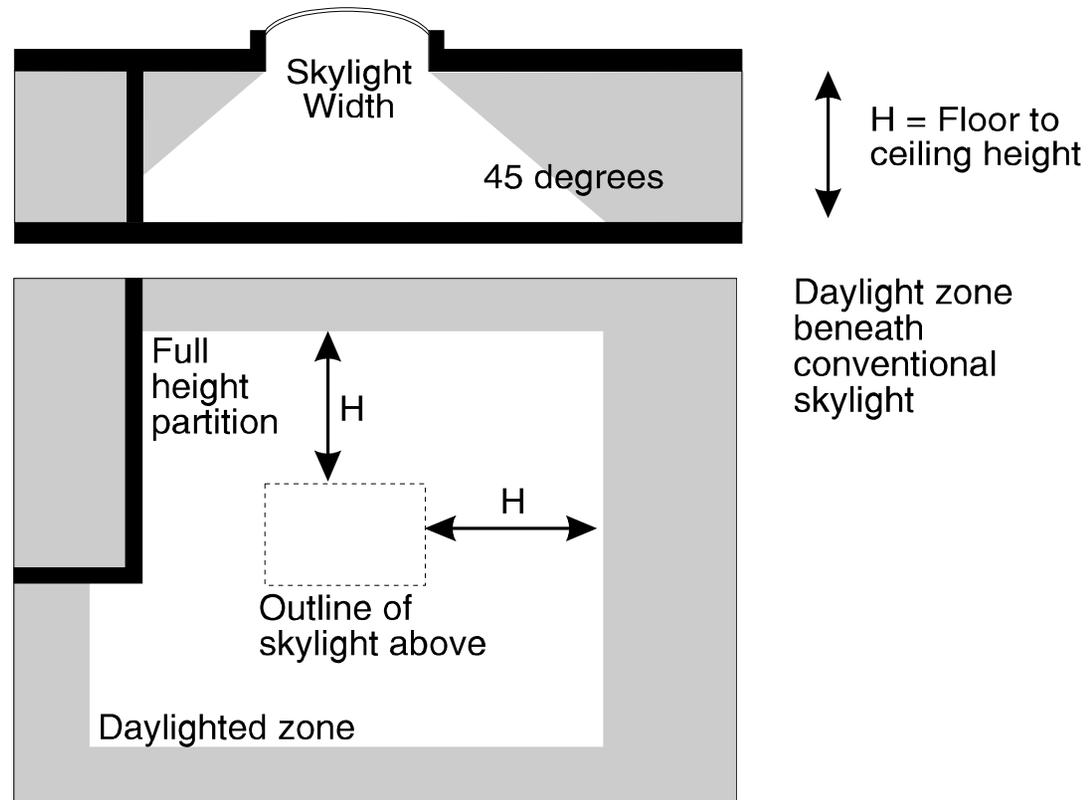
- Daylighted zone
- Visible light transmission

Thermal Performance  
**Daylighted Zone – Vertical Glazing**

---

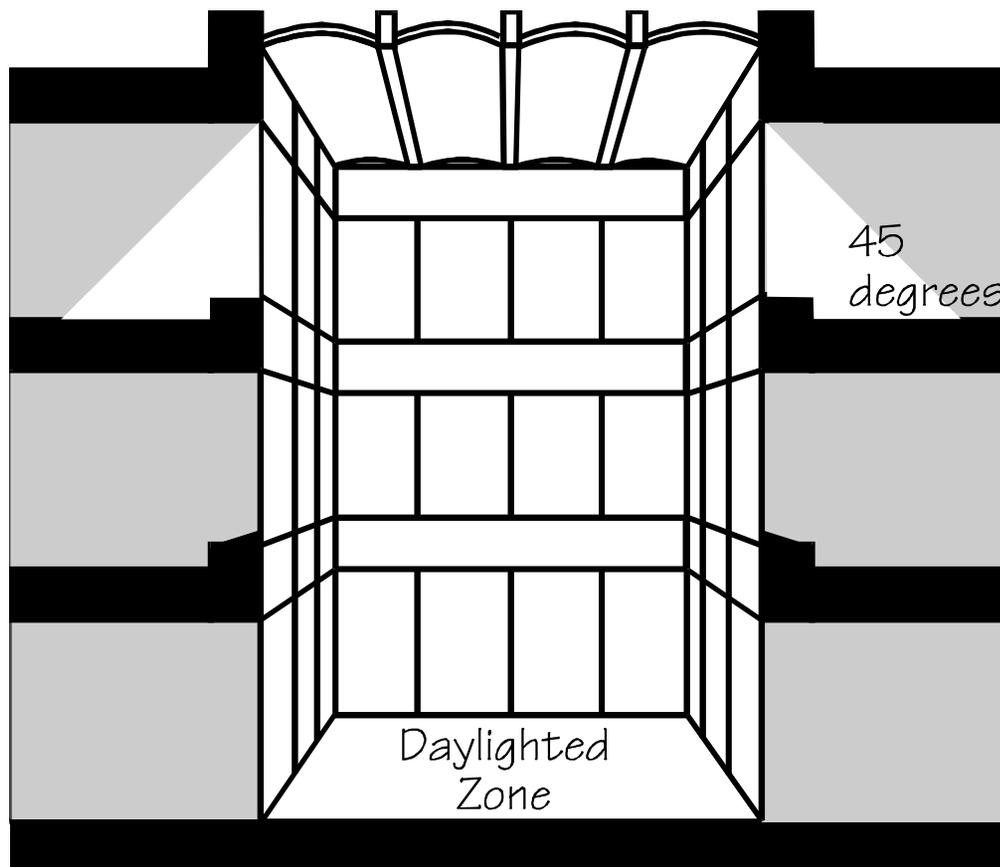


# Thermal Performance Daylighted Zone – Skylights



Thermal Performance  
**Daylighted Zone – Atrium**

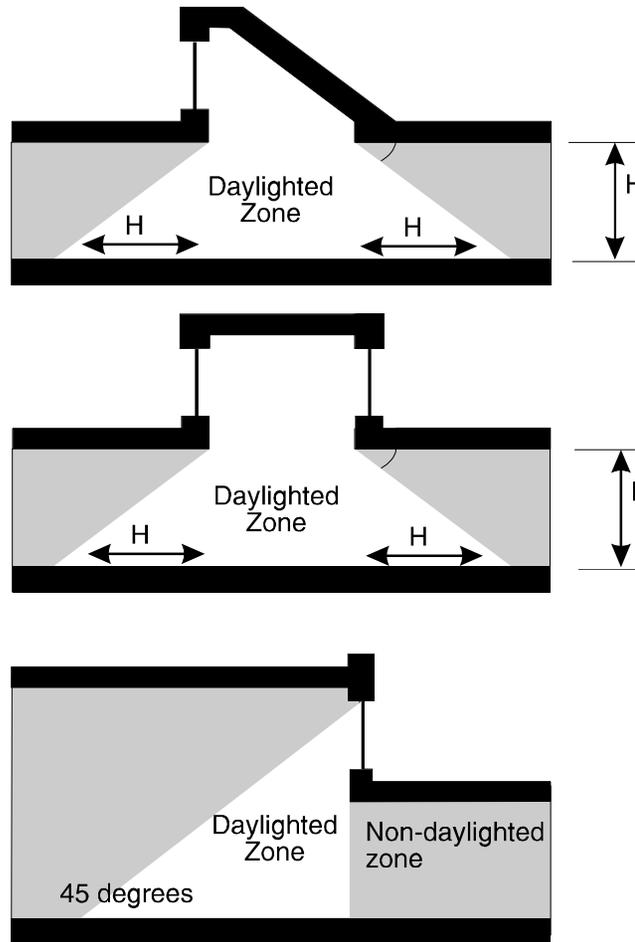
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Daylighted zone includes floor of atrium and the top floor next to the atrium

Thermal Performance  
**Daylighted Zone – Clerestories  
and Roof Monitors**

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# Thermal Performance

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- Daylighted zone
- Visible Light Transmission (VLT)
- Fraction of solar radiation in the visible spectrum that passes through fenestration
- Only significant for perimeter daylighting

# Thermal Performance

## Table 301.1

ASHRAE/IES 90.1 Code	December 1994
<b>Boston, MA #31</b>	

<b>TABLE 301.1 EXTERIOR DESIGN CONDITIONS</b>	
WINTER Design Dry Bulb: 6°F;	HDD65: 5775
SUMMER Design Dry Bulb: 88°F; Mean Coincident Wet Bulb: 71°F; CDD65: 695	
Annual Operating Hours, 8AM - 4PM when 55°F ≤ T ≤ 69°F: 713	

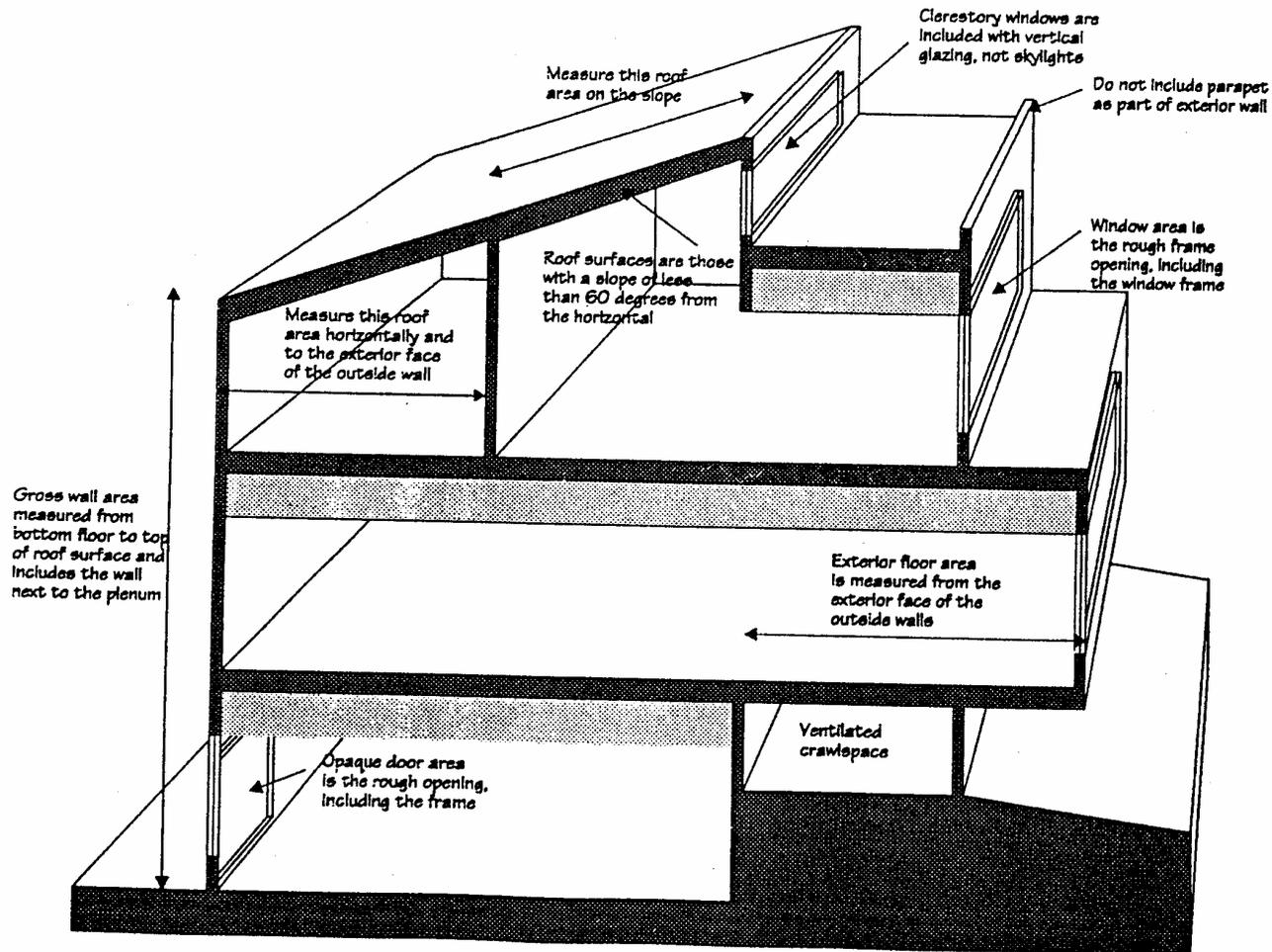
<b>TABLE 402.3.1(A) MAX. THERMAL TRANSMITTANCE (U)</b>	
Roof	0.058
Wall adjacent to unconditioned space	0.141
Floor over unconditioned space	0.054

<b>TABLE 402.3.1(B) MAX. EXEMPT SKYLIGHT AREA AS % OF ROOF AREA</b>					
Visible Light Transmittance (VLT)	Light level Ft. Candles	Range of Lighting Power Densities			
		<1.00	1.00 - 1.50	1.51 - 2.00	>2.00
0.75	30	2.3	3.4	4.5	5.6
	50	2.5	4.0	5.5	7.0
	70	2.8	4.6	6.4	8.2
0.50	30	3.6	5.1	6.6	8.1
	50	3.9	6.0	8.1	10.2
	70	4.2	6.9	9.6	12.3

<b>TABLE 402.3.2 MINIMUM THERMAL RESISTANCE (R-VALUE)</b>				
Slab on grade:	Unheated / Heated:	24 inches	36 inches	48 inches
	Horizontal	R-16/R-18	R-14/R-16	R-11/R-13
	Vertical	R-8/R-10	R-6/R-8	R-4/R-6
Wall below grade:		R-9		

<b>TABLE 402.4.1.1 MAX. WALL THERMAL TRANSMITTANCE (U<sub>w</sub>)</b>				
ILD Range	WWR	HC Range	Insulation Position	
			Interior/Integral	Exterior
All	0 to 100	0.0 - 4.9	0.089	
		5.0 - 9.9	0.095	0.117
		10.0 - 14.9	0.103	0.129
0.00 to 1.50	23	15.0 +	0.110	0.134
		5.0 - 9.9	0.094	0.112
		10.0 - 14.9	0.100	0.121
	67	15.0 +	0.106	0.125
		5.0 - 9.9	0.096	0.126
		10.0 - 14.9	0.107	0.144
1.51 to 3.00	20	15.0 +	0.117	0.151
		5.0 - 9.9	0.094	0.115
		10.0 - 14.9	0.102	0.127
	70	15.0 +	0.108	0.131
		5.0 - 9.9	0.096	0.129
		10.0 - 14.9	0.108	0.149
3.01 to 3.50	18	15.0 +	0.120	0.157
		5.0 - 9.9	0.094	0.116
		10.0 - 14.9	0.102	0.128
	69	15.0 +	0.109	0.133
		5.0 - 9.9	0.094	0.116
		10.0 - 14.9	0.102	0.128

# How to Measure Surface Areas



# Thermal Performance Roofs

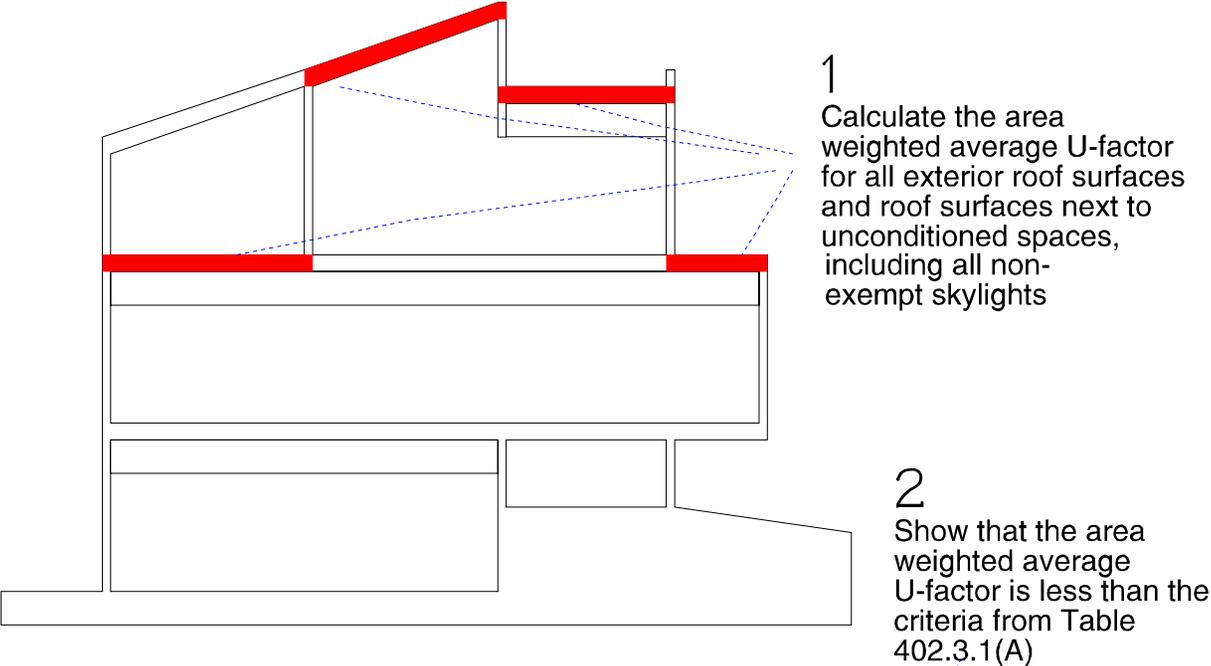
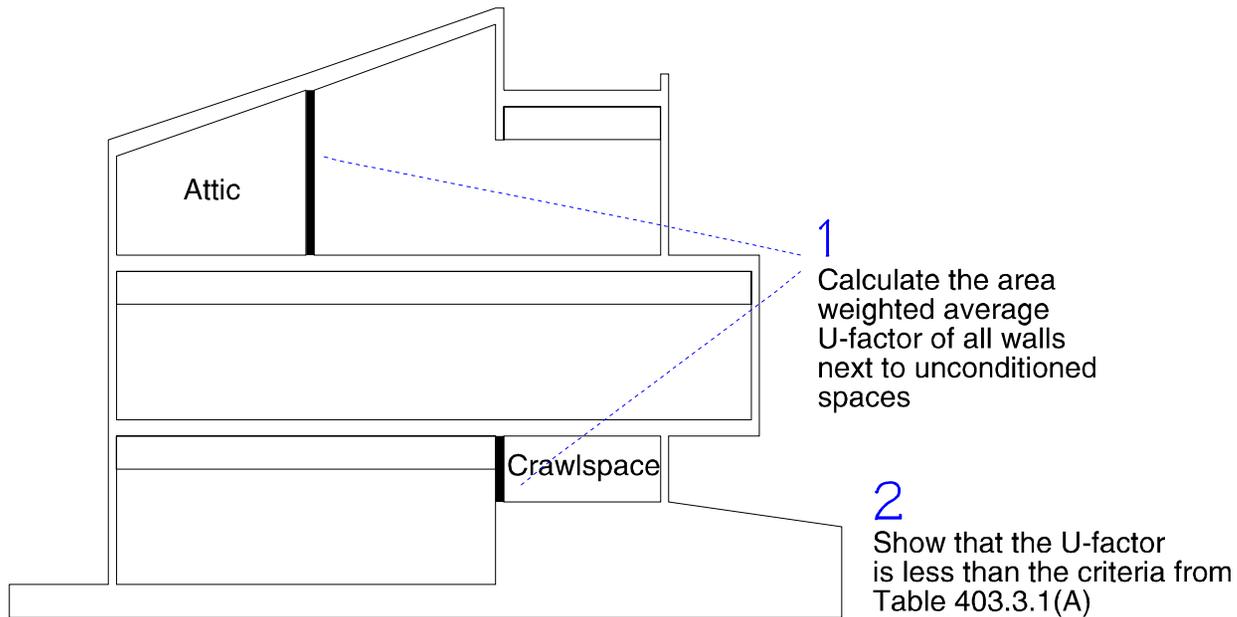


TABLE 402.3.1(A) MAX. THERMAL TRANSMITTANCE (U)

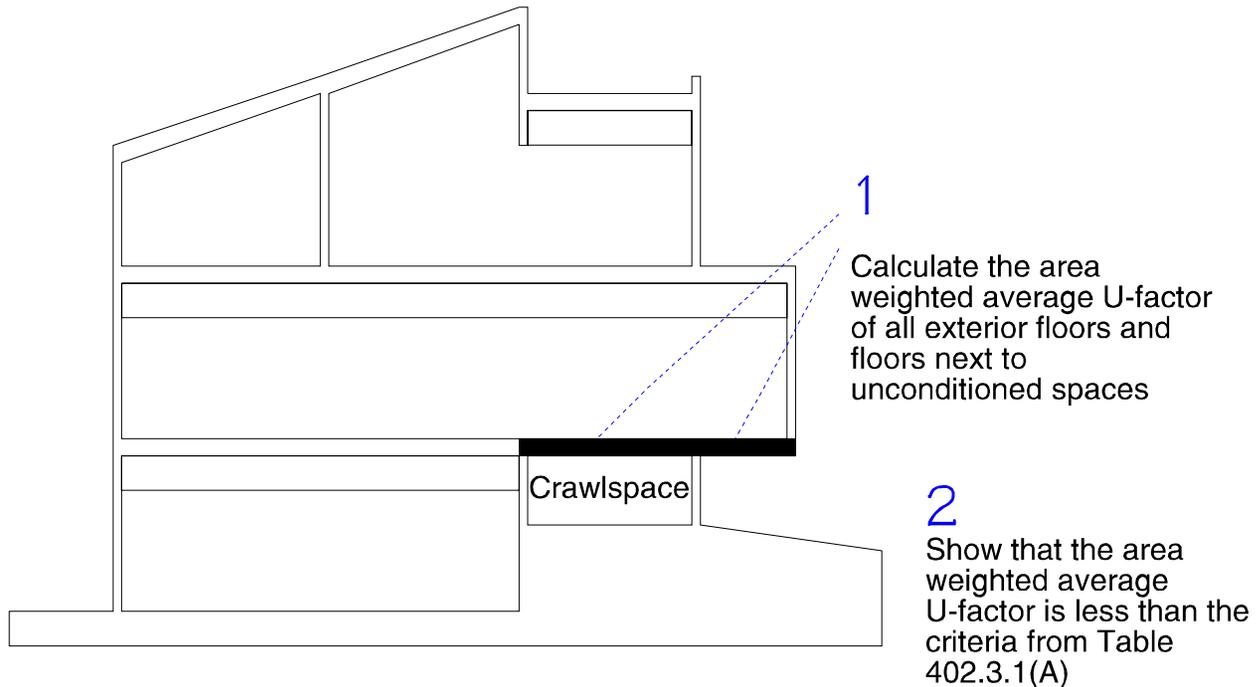
Roof	0.061
Wall adjacent to unconditioned space	0.161
Floor over unconditioned space	0.069

# Thermal Performance Walls Adjacent to Unconditioned Space



Roof	0.061
Wall adjacent to unconditioned space	0.161
Floor over unconditioned space	0.069

# Thermal Performance Floors Over Unconditioned Space



Roof	0.061
Wall adjacent to unconditioned space	0.161
Floor over unconditioned space	0.069

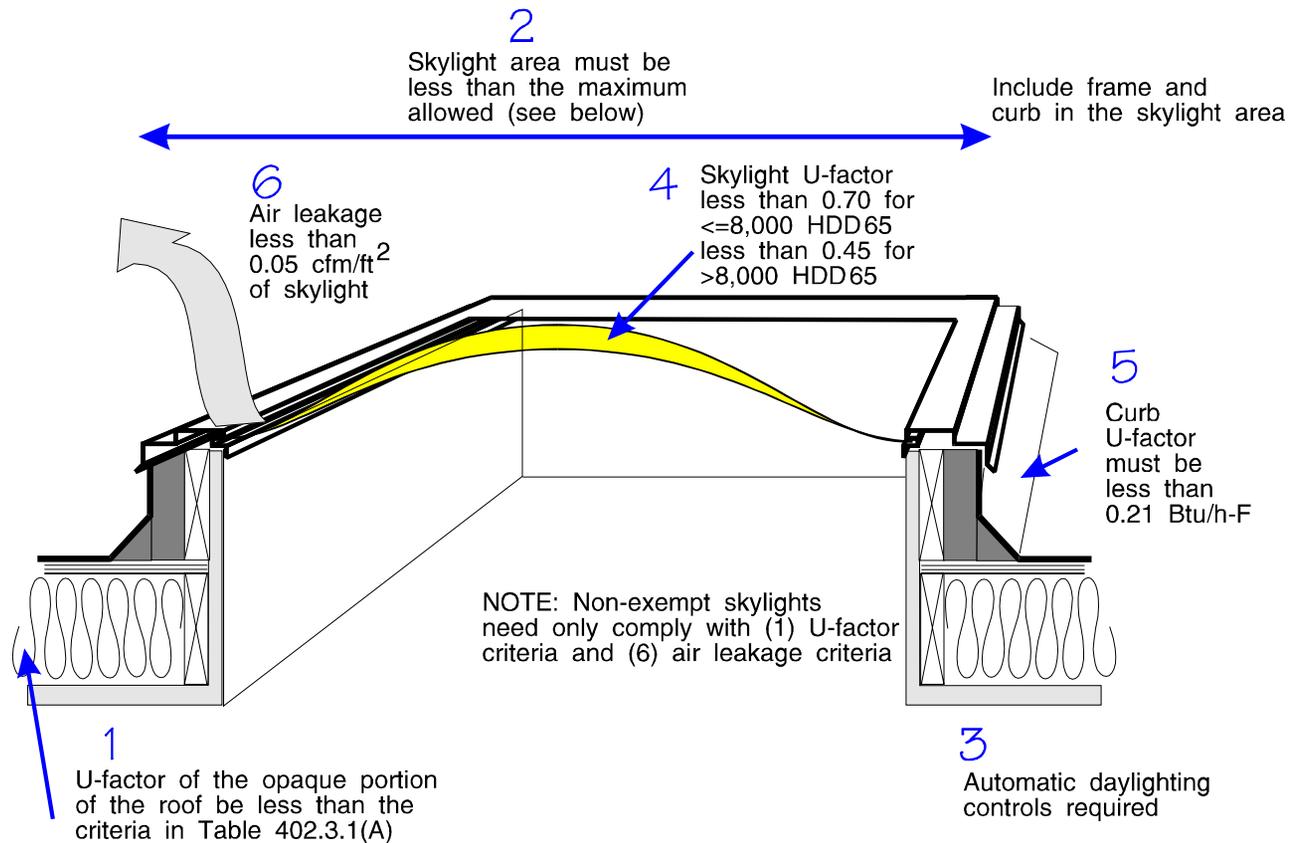
Thermal Performance  
**Skylight Exception**

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- Qualifying skylights may be excepted from the roof U-factor, provided six conditions are met

# Thermal Performance Skylight Exception *(cont'd)*

## • The Six Conditions



# Thermal Performance Skylight Exception *(cont'd)*

## • Maximum Area Allowed to be Exempt

MAXIMUM AREA ALLOWED TO BE EXEMPT

TABLE 402.3.1(B) MAX. EXEMPT SKYLIGHT AREA AS % OF ROOF AREA

2a Choose the appropriate design illumination  
2b Select a range for the lighting power density

Visible Light Transmittance (VLT)	Light Level Ft. Candles	Lighting Power Density (LPD) Range			
		<1.00	1.00-1.50	1.51-2.00	>2.00
0.75	30	2.3	3.1	4.5	5.6
	50	2.5	4.0	5.5	7.0
	70	2.8	4.5	6.4	8.2
0.50	30	3.6	5.1	6.6	8.1
	50	3.9	6.0	8.1	10.2
	70	4.2	6.9	9.6	12.3

2d Interpolate the results for the VLT of the skylights in the proposed building if it is between 0.50 and 0.75

2c Look up the allowed skylight area for a VLT of both 0.50 and 0.75

2e Increase the maximum exempt skylight area by 50% if skylights are shaded (see right)

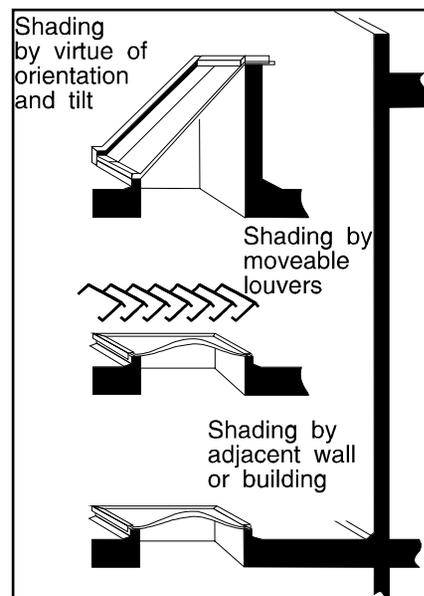
Thermal Performance  
**Skylight Exception** (*cont'd*)

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- **Area Increase for Shading**

Skylight exception - 50% increase in exempt area

- When shading devices block more than 50% of solar gains during peak cooling conditions



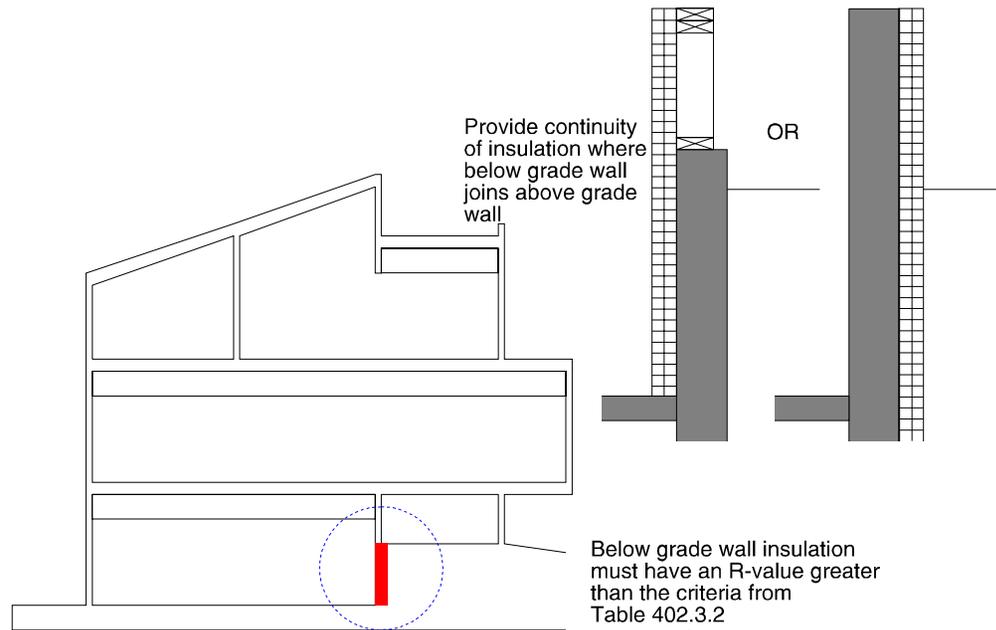
Thermal Performance  
**Skylight Exception** (*cont'd*)

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- Automatic Daylighting Controls
  - Luminaires located within daylighted area must be automatically controlled
  - Qualifying automatic controls
    - On/Off
    - Multiple stepped
    - Dimming
  - Must be capable of reducing lighting power by 50% when adequate daylighting is available

# IECC Chapter 7

## Thermal Performance Below-Grade Walls



Slab on grade:	Unheated / Heated:	24 inches	36 inches	48 inches
	Horizontal	R-14/R-16	R-12/R-14	R-10/R-12
	Vertical	R-7/R-9	R-6/R-8	R-4/R-6
Wall below grade:			R-8	

# Thermal Performance Slabs-On-Grade

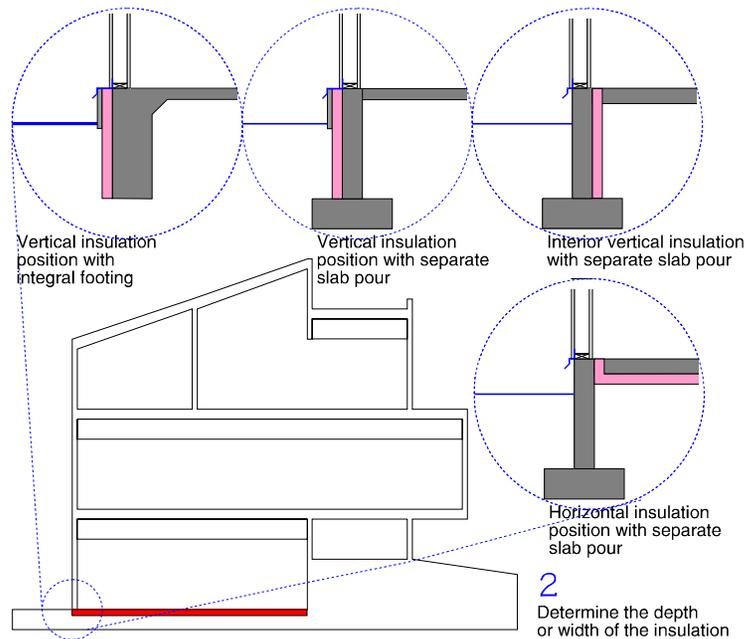


TABLE 402.3.2 MINIMUM THERMAL RESISTANCE (R-VALUE)

Slab on grade:	Unheated / Heated:	24 inches	36 inches	48 inches
	Horizontal	R-14/R-16	R-12/R-14	R-10/R-12
	Vertical	R-7/R-9	R-6/R-8	R-4/R-6
Wall below grade:		R-8		

1 Determine the position of the insulation

3 Look up the criteria. The first value is for unheated slabs and the second value is for heated slabs.

Thermal Performance  
**Compliance Methods**

---

- Prescriptive Criteria
  - Opaque walls
  - Vertical fenestration
- Systems Performance Method (ENVSTD)
  - Considers opaque walls and fenestration together

Thermal Performance  
**Heat Capacity**

---

- The heat capacity per square foot of wall are (Btu/ft<sup>2</sup>-F)

$$\text{HC (approx)} = \text{Wall Weight} \times 0.2$$

# Prescriptive Criteria

## Table B-6

**Table B-6:**  
**Properties of Solid Unit Masonry and Solid Concrete Walls**

Type		Layer Thickness, inches									
		3	4	5	6	7	8	9	10	11	12
LW CMU	U	na	0.71	0.64	na						
	Rt	na	1.4	1.6	na						
	HC	na	7.00	8.75	na						
MW CMU	U	na	0.76	0.70	na						
	Rt	na	1.3	1.4	na						
	HC	na	7.67	9.58	na						
NW CMU	U	0.89	0.82	0.76	na						
	Rt	1.1	1.2	1.3	na						
	HC	6.25	8.33	10.42	na						
Clay Brick	U	0.80	0.72	0.66	na						
	Rt	1.3	1.4	1.5	na						
	HC	6.30	8.40	10.43	na						
Concrete	U	0.96	0.91	0.86	0.82	0.78	0.74	0.71	0.68	0.65	0.63
	Rt	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6
	HC	7.20	9.60	12.00	14.40	16.80	19.20	21.60	24.00	26.40	28.80

**Notes:**

LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 105 PCF density

MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 115 PCF density

NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 125 PCF density

Clay Brick is a Clay Unit per ASTM C 62, Calculated at 130 PCF density

Concrete is structural poured or precast concrete, Calculated at 144 PCF density

Calculations based on Energy Calculations and Data, CMAACN, 1986

Values include air films on inner and outer surfaces.

[Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada]

# Prescriptive Criteria

## Table B-5

**Table B-5:**  
**Properties of Hollow Unit Masonry Walls**

Thickness/ Material Type		Core Treatment	Core Treatment		
			Solid Grout	Partly Grouted with Empty	Ungrouted Cells Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rt	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		R	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rt	1.8	2.0	2.8
		HC	24.8	16.5	16.5
10"	LW CMU	U	0.55	0.46	0.34
		Rt	1.8	2.2	2.9
		HC	18.9	12.6	12.6
	MW CMU	U	0.59	0.49	0.37
		R	1.7	2.1	2.7
		HC	19.7	13.4	13.4
	NW CMU	U	0.62	0.52	0.41
		Rt	1.6	1.9	2.4
		HC	20.5	14.2	14.2
8"	LW CMU	U	0.62	0.50	0.37
		Rt	1.6	2.0	2.7
		HC	15.1	9.9	9.9
	MW CMU	U	0.65	0.53	0.41
		R	1.5	1.9	2.4
		HC	15.7	10.5	10.5
	NW CMU	U	0.69	0.56	0.44
		Rt	1.4	1.8	2.3
		HC	16.3	11.1	11.1
Clay Unit	U	0.57	0.47	0.39	
	R	1.8	2.1	2.6	
	HC	15.1	11.4	11.4	
6"	LW CMU	U	0.68	0.54	0.44
		Rt	1.5	1.9	2.3
		HC	10.9	7.9	7.9
	MW CMU	U	0.72	0.58	0.48
		R	1.4	1.7	2.1
		HC	11.4	8.4	8.4
	NW CMU	U	0.76	0.61	0.52
		Rt	1.3	1.6	1.9
		HC	11.9	8.9	8.9
Clay Unit	U	0.65	0.52	0.45	
	R	1.5	1.9	2.2	
	HC	11.1	8.6	8.6	

**Notes:**

LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90, Calculated at 105 PCF density  
 MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90, Calculated at 115 PCF density  
 NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90, Calculated at 125 PCF density  
 Clay Unit is a Hollow Clay Unit per ASTM C 652, Calculated at 130 PCF density  
 Values include air films on inner and outer surfaces.

Calculations based on Energy Calculations and Data, CMACN, 1986

Grouped Cells at 32" X 48" in Partly Grouted Walls

[Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada]

# System Performance

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- Features of ENVSTD
  - More complicated
  - Requires a computer and ENVSTD program
  - Permits tradeoffs between windows and walls

# System Performance

- Values to use in ENVSTD 2.1

**TABLE 402.4.2**  
**EQUIP Default Values for ENVSTD21**

Occupancy	Default Equipment Power Density*	Default Occupant Load Adjustment*	Default Adjusted Equipment Power Density
Assembly	0.25	0.75	1.00
Health/Institutional	1.00	- 0.26	0.74
Hotel/Motel	0.25	- 0.33	0.00
Warehouse/Storage	0.10	- 0.60	0.00
Multi-Family High-Rise	0.75	N/A	0.00
Office	0.75	- 0.35	0.40
Restaurant	0.10	0.07	0.17
Retail	0.25	- 0.38	0.00
School	0.50	0.30	0.80

\* Defaults as defined in RS-1 from Section 8.6.10.5, Table 8-4, and Sections 8.6.10.6 and 13.7.2.1, Table 13-2.

# System Performance

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- For Other Building Types
  - $ILD = LPD + EPD + OLA$ 
    - where:
      - ILD is the internal load density
      - LPD is the lighting power density
      - OLA is the occupant load adjustment
  - Three ways to determine LPD
    - Prescriptive
    - Systems performance
    - Installed power
  - EPD from Table 402.4.2 or installed power
  - OLA from Table 402.4.2 or assume zero

# Mechanical Systems

## Chapter 8 Scope

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### **Chapter 8**

#### Section 803

- Unitary or packaged HVAC equipment and most other HVAC equipment

### **Chapter 7**

#### Section 403

# Scope

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- IECC Chapter 8 encourages efficient mechanical design by:
  - Requiring minimum equipment efficiency
  - Minimizing distribution losses in ductwork
  - Optimizing system controls
  - Requiring acceptable levels of outdoor ventilation

# Mechanical System Use Table

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## Section 803.2

## Section 803.3 or Chapter 7

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Unitary packaged cooling system

Split system cooling

Packaged terminal A/C

Heat pump cooling

Unitary packaged heating

Split system heating

Packaged terminal heat pump

Fuel-fired furnace

Electrical resistance heating

Packaged VAV reheat

Built-up VAV reheat

Built-up single-fan dual-duct VAV

Built-up or packaged dual-fan,  
dual-duct VAV

Four-pipe fan coil system with  
central plant

Hydronic heat pump with central  
plant

Any other multiple-zone system

Hydronic space heating system

# Equipment Efficiency

*(Section 803.2.2)*

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- Meet efficiency levels in Tables 803.2.2
- Most packaged equipment is covered by NAECA and must meet the requirements before it can be sold



# Efficiency Terms

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- EER
  - Energy Efficiency Ratio
  - Ratio of the net cooling capacity, in Btu/h to the total rate of electric input in watts
  - Calculated at full load conditions
  - Units Btu/h per watt

# Efficiency Terms *(cont'd)*

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- Part Load Performance
  - Annual Fuel Utilization Efficiency (AFUE)
  - Heating Seasonal Performance Factor (HSPF)
  - Seasonal Energy Efficiency Ratio (SEER)

# NAECA

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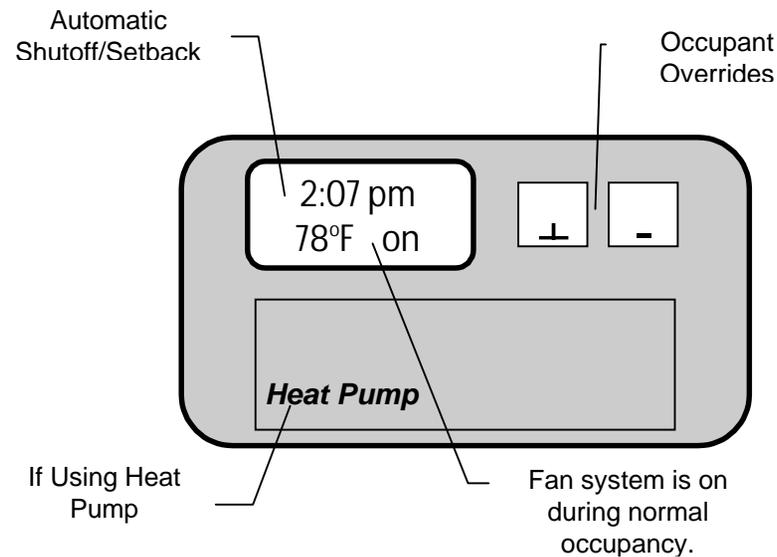
- National Appliance Energy Conservation Act
- Specifies equipment performance of heating and cooling equipment, water heaters, and other equipment
- Applicable equipment must meet NAECA before it can be sold in the United States - *No need to enforce at the building department counter*

# Heating and Cooling System Controls

*(Section 803.2.3)*

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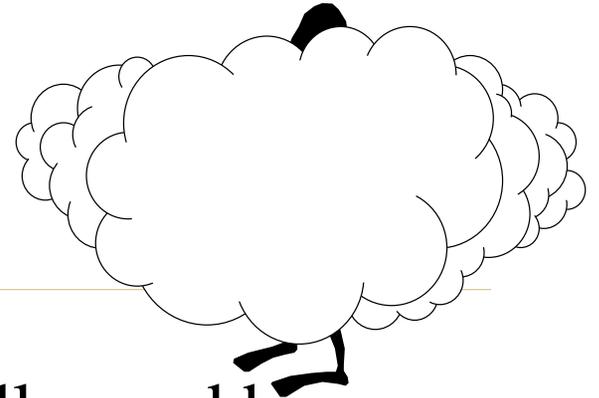
- Each system must have a thermostat to control heating and/or cooling to each zone



# Ventilation

*(Section 803.2.5)*

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- Applies to all enclosed spaces normally used by humans
- Spaces must be ventilated
  - Mechanically
  - Naturally
- Use Chapter 4 of the ICC International Mechanical Code (IMC)

# Mechanical Ventilation

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- Requirements for mechanically ventilated spaces
  - Minimum ventilation rates
  - System controls
  - Dampers

# Mechanical Ventilation

- Minimum ventilation rates (Chapter 4 of the IMC)

TABLE 403.3  
REQUIRED OUTDOOR VENTILATION AIR

OCCUPANCY CLASSIFICATION	ESTIMATED MAXIMUM OCCUPANT LOAD, PERSONS PER 1,000 SQUARE FEET <sup>a</sup>	OUTDOOR AIR [cubic feet per minute (cfm) per person] UNLESS NOTED <sup>b</sup>
<b>Correctional facilities</b>		
Cells	20	20
Dining halls	100	15
Guard stations	40	15
<b>Dry cleaners, laundries</b>		
Coin-operated dry cleaner	20	15
Coin-operated laundries	20	15
Commercial dry cleaner	30	30
Commercial laundry	10	25
Storage, pick up	30	35
<b>Education</b>		
Auditoriums	150	15
Classroom	50	15
Corridors	—	0.10 cfm/ft. <sup>2</sup>
Laboratories	30	20
Libraries	20	15
Locker rooms	—	0.50 cfm/ft. <sup>2</sup>
Music rooms	50	15
Smoking lounges <sup>b</sup>	70	60
Training shops	30	20
<b>Food and beverage service</b>		
Bars, cocktail lounges	100	30
Cafeteria, fast food	100	20
Dining rooms	70	20
Kitchens (cooking) <sup>f</sup>	20	15
<b>Hospitals, nursing and convalescent homes</b>		
Autopsy rooms <sup>g</sup>	—	0.50 cfm/ft. <sup>2</sup>
Medical procedure rooms	20	15
Operating rooms	20	30
Patient rooms	10	25
Recovery and ICU	20	15
20	15	
<b>Hotels, motels, resorts and dormitories</b>		
Assembly rooms	120	15
Bathrooms <sup>h</sup>	—	35 cfm per room
Bedrooms	—	30 cfm per room
Conference rooms	50	20
Dormitory sleeping areas	20	15
Gambling casinos	120	30
Living rooms	—	30 cfm per room
Lobbies	30	15
<b>Offices</b>		
Conference rooms	50	20
Office spaces	7	20
Reception areas	60	15
Telecommunication centers and data entry	60	20

(continued)

TABLE 403.3—continued  
REQUIRED OUTDOOR VENTILATION AIR

OCCUPANCY CLASSIFICATION	ESTIMATED MAXIMUM OCCUPANT LOAD, PERSONS PER 1,000 SQUARE FEET <sup>a</sup>	OUTDOOR AIR [cubic feet per minute (cfm) per person] UNLESS NOTED <sup>b</sup>
<b>Private dwellings, single and multiple</b>		
Living areas <sup>c</sup>	—	Based upon number of bedrooms. 0.35 air changes per hour <sup>c</sup> or 15 cfm per person, whichever is greater
Kitchens	—	100 cfm intermittent or 25 cfm continuous
Toilet rooms and bathrooms	—	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous
Garages, separate for each dwelling	—	100 cfm per car
Garages, common for multiple units <sup>b</sup>	—	1.5 cfm/ft. <sup>2</sup>
<b>Public spaces</b>		
Corridors and utilities	—	0.05 cfm/ft. <sup>2</sup>
Elevators <sup>d</sup>	—	1.00 cfm/ft. <sup>2</sup>
Locker and dressing rooms <sup>e</sup>	—	0.5 cfm/ft. <sup>2</sup>
Toilet rooms <sup>b,e</sup>	—	75 cfm per water closet or urinal
60	60	
Smoking lounges <sup>b</sup>	70	60
<b>Retail stores, sales floors and showroom floors</b>		
Basement and street	—	0.30 cfm/ft. <sup>2</sup>
Dressing rooms	—	0.20 cfm/ft. <sup>2</sup>
Malls and arcades	—	0.20 cfm/ft. <sup>2</sup>
Shipping and receiving	—	0.15 cfm/ft. <sup>2</sup>
Smoking lounges <sup>b</sup>	70	60
Storage rooms	—	0.15 cfm/ft. <sup>2</sup>
Upper floors	—	0.20 cfm/ft. <sup>2</sup>
Warehouses	—	0.05 cfm/ft. <sup>2</sup>
<b>Specialty shops</b>		
Automotive service stations	—	1.5 cfm/ft. <sup>2</sup>
Barber	25	15
Beauty	25	25
Clothing, furniture	—	0.30 cfm/ft. <sup>2</sup>
Florists	8	15
Hardware, drugs, fabrics	8	15
Pet shops	—	1.00 cfm/ft. <sup>2</sup>
Reducing salons	20	15
Supermarkets	8	15

(continued)

TABLE 403.3—continued  
REQUIRED OUTDOOR VENTILATION AIR

OCCUPANCY CLASSIFICATION	ESTIMATED MAXIMUM OCCUPANT LOAD, PERSONS PER 1,000 SQUARE FEET <sup>a</sup>	OUTDOOR AIR [cubic feet per minute (cfm) per person] UNLESS NOTED <sup>b</sup>
<b>Theaters</b>		
Auditoriums	150	15
Lobbies	150	20
Stages, studios	70	15
Ticket booths	60	20
<b>Transportation</b>		
Platforms	100	15
Vehicles	150	15
Waiting rooms	100	15
<b>Workrooms</b>		
Bank vaults	5	15
Darkrooms	—	0.50 cfm/ft. <sup>2</sup>
Duplicating, printing	—	0.50 cfm/ft. <sup>2</sup>
Meat processing <sup>a</sup>	10	15
Pharmacy	20	15
Photo studios	10	15
<b>Sports and amusement</b>		
Ballrooms and discos	100	25
Bowling alleys (seating areas)	70	25
Game rooms	70	25
Ice arenas	—	0.50 cfm/ft. <sup>2</sup>
Playing floors (gymnasiums)	30	20
Spectator areas	150	15
Swimming pools (pool and deck area)	—	0.50 cfm/ft. <sup>2</sup>
<b>Storage</b>		
Repair garages, public garages (enclosed) <sup>d</sup>	—	1.5 cfm/ft. <sup>2</sup>
Warehouses	—	0.05 cfm/ft. <sup>2</sup>

5

# Mechanical Ventilation

## *(Section 803.2.7)*

---

- Shutoff Dampers
  - Required for outdoor-air and exhaust systems with design air flow rates  $> 3000$  CFM
  - Must automatically close during periods of non-use
  - Exceptions
    - Where restricted by health and life safety codes
    - Where serving areas designed for continuous operation
    - Systems with readily accessible manual dampers

# Economizers

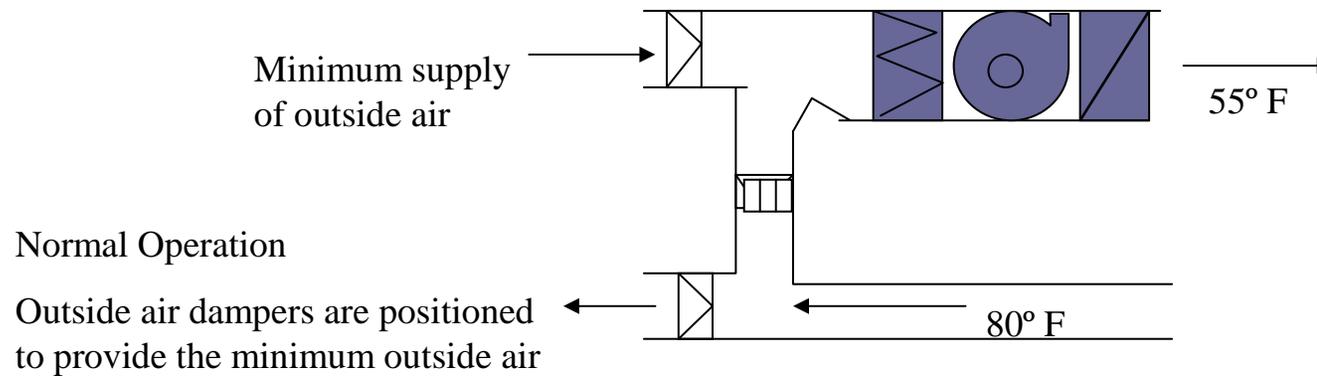
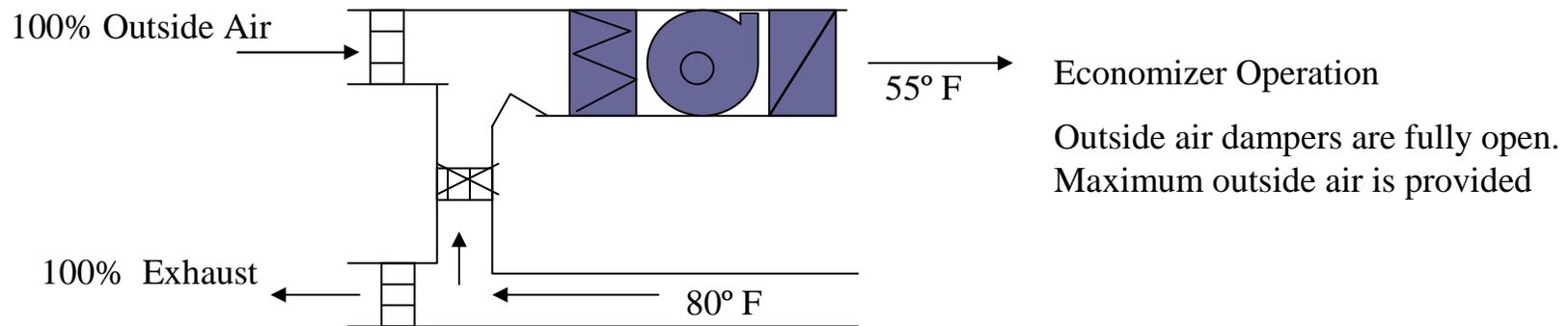
*(Section 803.2.6)*

---

- Air economizers required on systems
  - Cooling capacity > 90,000 Btu/h
- Not required in climate zones 1a, 1b, 2a, 2b, 3b
  - Check your location
- Not required if the cooling of proposed equipment meets or exceeds the EER listed in Table 803.2.6

# Air-Side Economizers

- Use dampers to increase outside air when outside air cool system requires cooling



# Economizers

- Trade-off high cooling efficiency for economizer
  - Total cooling capacity
  - Climate zones
  - Equipment efficiency (EER)

Total Cooling Capacity of Equipment	Building Location		
	Zones 6a, 9a, 10a, 11a, 12a, 12b, 13a, 13b, 14a, 14b, 15, 19	Zones 3a, 4a, 7a, 8, 9b, 10b, 11b	Zones 4b, 5a, 5b, 6b, 7b
90,000 Btu/h to 134,999 Btu/h	N/A	11.4 EER	10.4 EER
135,000 Btu/h to 759,999 Btu/h	N/A	10.9 EER	9.9 EER
760,000 Btu/h or more	N/A	10.5 EER	9.6 EER

# Duct and Plenum Insulation

*(Section 803.2.8)*

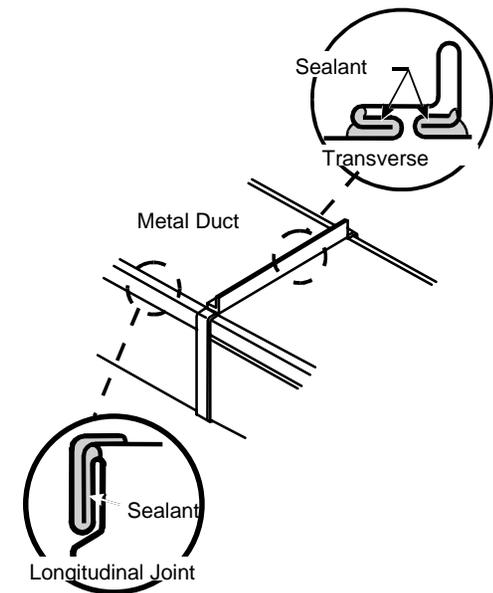
---

- Required for supply and return ducts and plenums
  - Located in unconditioned space - R5
  - Located outside the building envelope - R8

# Duct Sealing

(Section 803.2.8)

- Seal and securely fasten all joints, longitudinal and transverse seams and connections with:
  - welds
  - gaskets
  - mastics
  - mastic-plus-embedded fabric systems
  - tapes



# Mechanical Requirements

---

- Complex systems (*Section 803.3*)
  - Heating and cooling loads
  - HVAC equipment performance requirement
  - System controls
    - Thermostatic controls
    - Set point overlap restriction
    - Off-hour controls
    - Shutoff damper controls
    - Economizers
    - Variable air volume fan control
    - Hydronic systems controls
  - Multiple zone systems
  - Ventilation
  - Duct and plenum insulation and sealing
  - Piping insulation
  - HVAC system completion

# Equipment and System Sizing

## *(Section 803.3.1.1)*

### Complex systems

#### –Heating and cooling loads

–HVAC equipment performance requirement

–System controls

- Thermostatic controls

- Set point overlap restriction

- Off-hour controls

- Shutoff damper controls

- Economizers

- Variable air volume fan control

- Hydronic systems controls

–Multiple zone systems

–Ventilation

–Duct and plenum insulation and sealing

–Piping insulation

–System completion

- To not exceed 803.2.1
- Exceptions
  - Standby equipment to have controls and devices to operate automatically when primary equipment is not operating
  - Multiple units with combined capacities that exceed design load to have controls to sequence the operation



# Equipment Efficiency

*(Section 803.3.2)*

## Complex systems

–Heating and cooling loads

–**HVAC equipment performance requirement**

–System controls

•Thermostatic controls

•Set point overlap restriction

•Off-hour controls

•Shutoff damper controls

•Economizers

•Variable air volume fan control

•Hydronic systems controls

–Multiple zone systems

–Ventilation

–Duct and plenum insulation and sealing

–Piping insulation

–System completion

- If components from different manufacturers are used
  - Supply calculations and supporting data to demonstrate combined efficiency meets requirements
- If unitary or prepackaged equipment is used in complex systems not covered by 803.3.2, meet 803.2.2

# Thermostatic Controls

## *(Section 803.3.3.1)*

### Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls**
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Individual controls capable of responding to temperature within each zone
- If humidification or dehumidification or both
  - At least one control for each control system

# Thermostatic Controls

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls**
    - Set point overlap restriction
    - Off-hour controls
    - Shutoff damper controls
    - Economizers
    - Variable air volume fan control
    - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Exceptions
  - Independent perimeter systems
- Heat pump supplementary electric resistance heat
  - Controls to prevent supplementary heat operation when heat pump can meet the heating load (except defrost cycle)



# Set Point Overlap Restriction

(Section 803.3.3.2)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Controls to have a temperature range or deadband of at least 5°F
- Exception
  - Thermostats requiring manual changeover between heating and cooling modes



# Off-hour Controls

(Section 803.3.3.3)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Each zone to have setback controls with
  - Automatic time clock or
  - Programmable control system
- Exceptions
  - Continuously-operated zones
  - Zones with full HVAC load demand not exceeding 6800 Btu/hr with a readily accessible manual shutoff switch



# Shutoff Damper Controls

## *(Section 803.3.3.4)*

### Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls**
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Same requirements as in 803.2

# Economizers

(Section 803.3.3.5)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers**
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Required on each system  $> 90,000$  Btu/h
- Exception
  - Water economizers that can
    - cool supply air by either direct or indirect evaporation or both and
    - provide up to 100% of expected system cooling load at outside air temperatures of  $50^{\circ}\text{F}$  dry bulb/ $45^{\circ}\text{F}$  wet bulb and below



# VAV Fan Control

(Section 803.3.3.6)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Individual fans with motors  $\geq 25\text{hp}$ 
  - Driven by a mechanical or electrical variable speed drive
  - Be a vane-axial fan with variable pitch blades OR
  - Have controls or devices to result in fan motor demand  $\leq 50\%$  of their design wattage at 50% of design airflow when static pressure set point =  $1/3$  of the total design static pressure

# Hydronic Systems Controls

(Section 803.3.3.7)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Individual units to have separate hot water and chilled water supply and return piping; not supply hot and chilled water concurrently
- Exception
  - Zones where special humidity levels are required to satisfy process needs



# Requirements for Complex Mechanical Systems Serving Multiple Zones

## *(Section 803.3.4)*

### Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems**
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Systems shall be VAV systems that are designed and capable of being controlled to reduce primary air supply to each zone to a minimum before reheating, recooling or mixing takes place
- Several exceptions



# Ventilation

*(Section 803.3.5)*

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation**
- Duct and plenum insulation and sealing
- Piping insulation
- System completion

- Requirements are in 803.2.5

# Duct and Plenum Insulation and Sealing

(Section 803.3.6)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing**
- Piping insulation
- System completion

- In accordance with 803.2.8
- Ducts designed to operate at static pressures  $> 3$  in. wg to be leak tested in accordance with SMACNA
- Furnish documentation that representative sections totaling at least 25% of the duct area have been tested and meet the requirements

# Piping Insulation

*(Section 803.3.7)*

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation**
- System completion

- In accordance with Table 803.3.7
- Exceptions
  - Factory-installed piping within equipment
  - Piping conveying fluids between 55°F and 105°F
  - Piping conveying fluids not heated or cooled through the use of fossil fuels or electric power
  - Runout piping not exceeding 4 ft in length and 1 in. in diameter between the control valve and HVAC coil



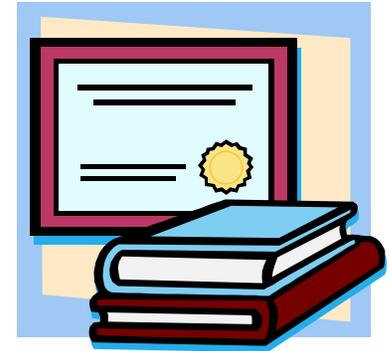
# HVAC System Completion

(Section 803.3.8)

## Complex systems

- Heating and cooling loads
- HVAC equipment performance requirement
- System controls
  - Thermostatic controls
  - Set point overlap restriction
  - Off-hour controls
  - Shutoff damper controls
  - Economizers
  - Variable air volume fan control
  - Hydronic systems controls
- Multiple zone systems
- Ventilation
- Duct and plenum insulation and sealing
- Piping insulation
- System completion**

- Before issuance of certificate of occupancy
  - Air system balancing
  - Hydronic system balancing
  - Manuals



# Mechanical Systems

## Chapter 7 Scope

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### **Chapter 8**

Section 803

### **Chapter 7**

Section 403

- Non-unitary or non-packaged HVAC equipment and systems
- Boilers and hydronic distribution systems

# Load Calculations

*(Section 403.2.1)*

---

- HVAC system designers must perform heating and cooling load calculations before selecting HVAC equipment

# Equipment Selection

---

- Equipment must be selected to provide no more than the heating and cooling design loads calculated
- Exceptions
  - Smallest size available within the desired equipment line
  - Intended for stand-by use only
  - Multiple pieces of the same equipment type with controls to sequence or otherwise optimally control the equipment in stages

# Separate Air Distribution Systems

## *(Section 403.2.3)*

---

- Separate air handling systems required for spaces with sensitive temperature or humidity requirements, e.g. computer rooms
- Single system providing comfort conditioning can be used for special spaces if supplementary equipment is used to maintain the additional process or equipment requirements
- Exceptions
  - Spaces requiring comfort conditioning use no more than 25% of the total system supply air quantity
  - Spaces requiring comfort conditioning do not exceed 1000 ft<sup>2</sup>

# Outside Air Ventilation

*(Section 403.2.4)*

---

- HVAC systems must be capable of supplying air at the minimum rate required by the applicable ventilation code
- Ventilation requirements vary from one local jurisdiction to another, but most are based on ASHRAE Standard 62
- Use Chapter 4 of the International Mechanical Code

# Economizers

*(Section 403.2.8)*

---

- Cooling systems in nonresidential buildings must be equipped with either an air or water economizer

# Economizer Exceptions

---

- Systems  $< 3,000$  cfm, or a total cooling capacity of  $< 90,000$  Btu/h at design conditions
- If the system needs extensive filtering of outside air
- If the economizer adversely affects the operation of other systems, such as supermarket refrigeration systems
- Systems that serve envelope-load dominated spaces
- Systems serving residential occupancies or hotel guest rooms

# Economizer Exceptions *(cont'd)*

---

- When at least 75% of the annual energy used for mechanical cooling is provided by energy recovery systems or site solar cooling systems
- Systems serving naturally ventilated spaces, defined as spaces that have operable openings with an area exceeding 5% of the floor area
- Systems in climates where the design outdoor wet-bulb temperature  $> 72^{\circ}\text{F}$  and HDD65 are  $< 2,000$  (see ACP Table)

# Integrated Economizers

---

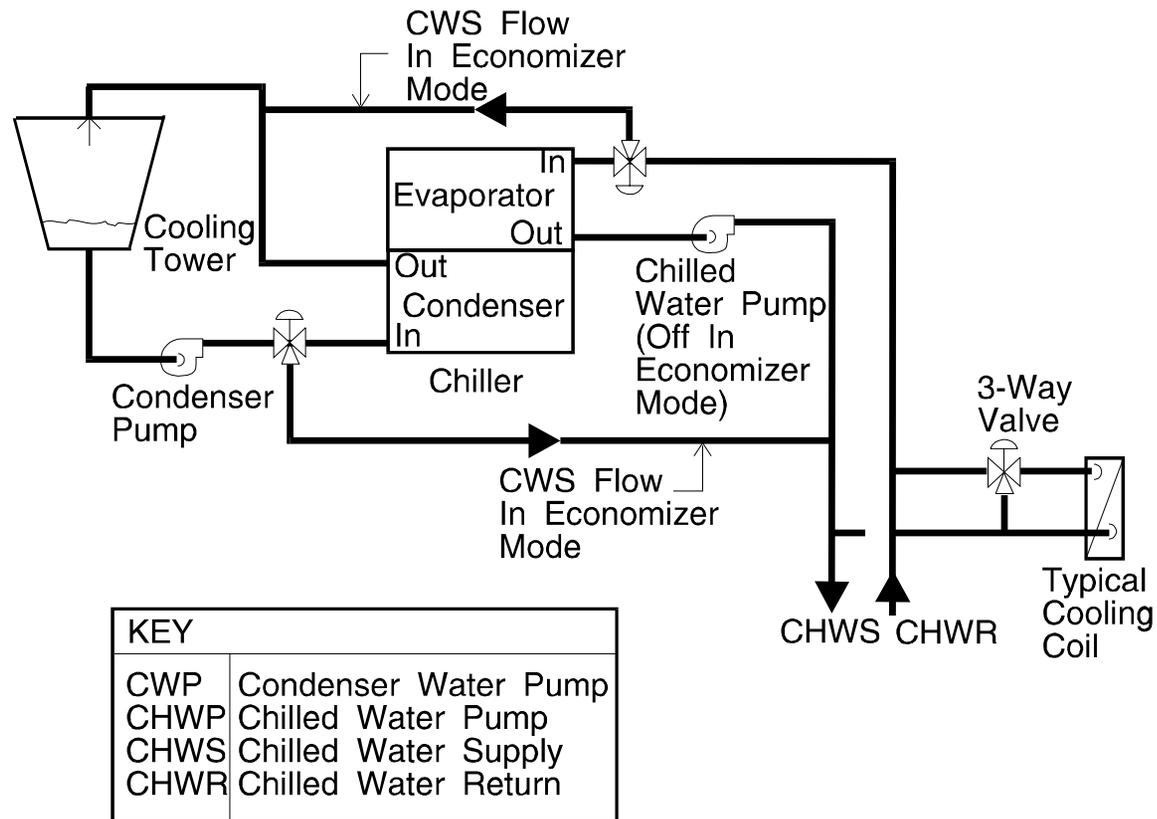
- Economizers must be able to operate simultaneously with the mechanical cooling system
- Exceptions:
  - DX systems with design capacities less than 15 tons
  - Systems located in climates where there are less than 750 hours during the typical weather year when the dry-bulb temperature is between 55°F and 69°F, inclusive, between 8:00 a.m. and 4:00 p.m. (see ACP Table)

# Water-Side Economizers

---

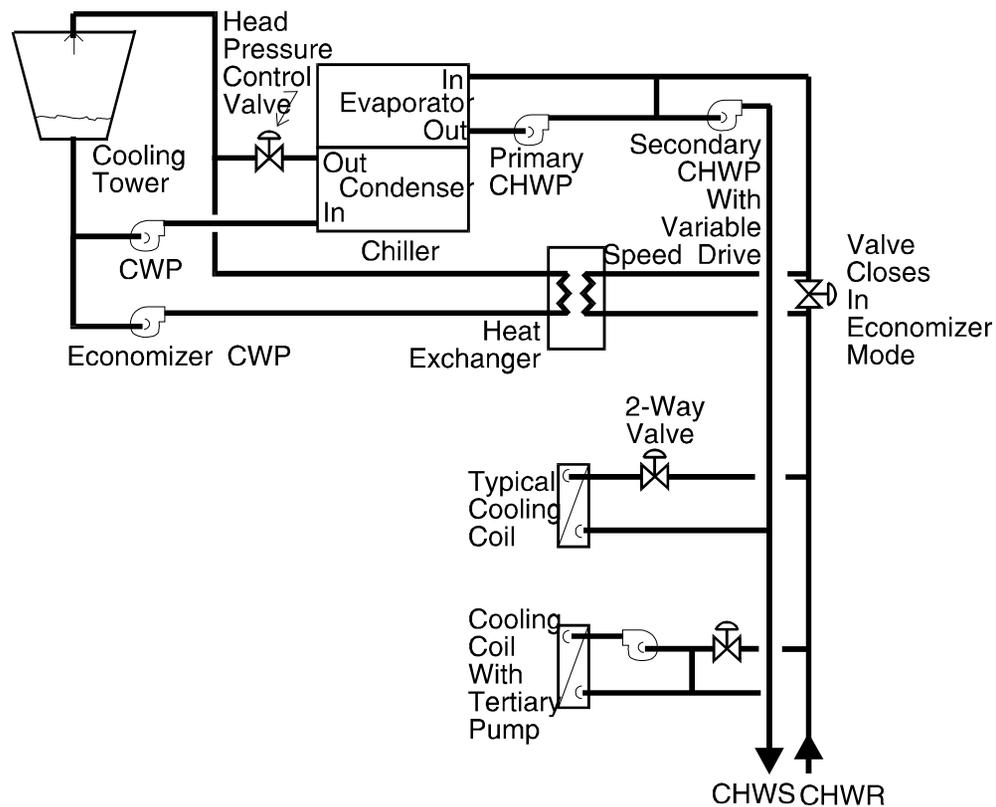
- Indirect and/or direct evaporative cooler
- Three popular types
  - “strainer-cycle” economizers
  - water precooling economizers
  - air precooling economizers

# Water Side Economizers "Strainer Cycle"

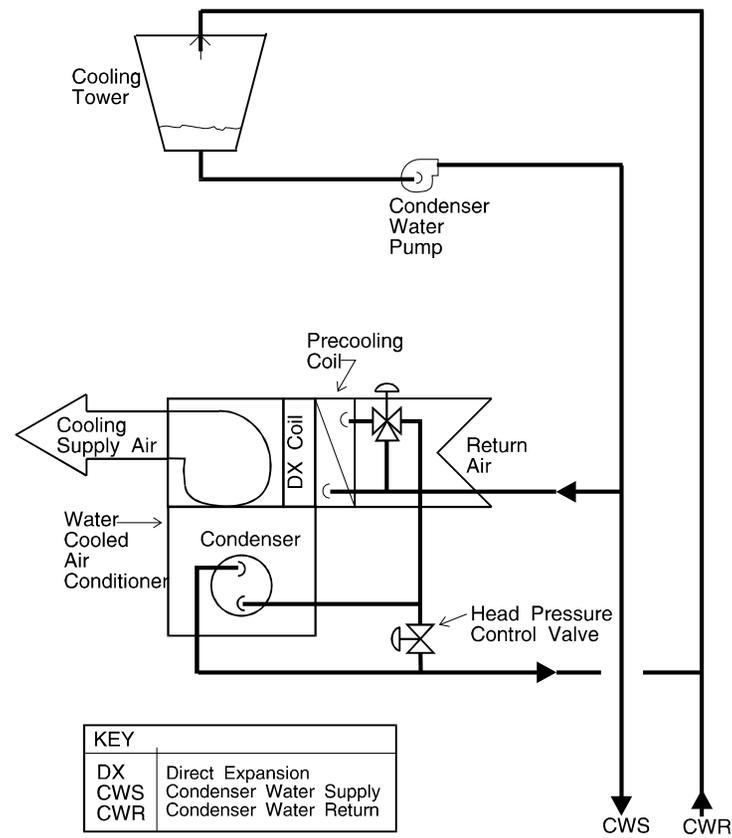


# Water Side Economizers

## Water Precooling Water Economizer with Two-Way Valves



# Water Side Economizers Air Precooling Water Economizer



# HVAC Piping

- Insulation (*Section 403.2.9.1*)
  - Table 403.2.9.1

	Insulation Conductivity <sup>a</sup>		Nominal Pipe Diameter (in.)					
	Conductivity Range Btu · in./- (h · ft <sup>2</sup> · °F)	Mean Rating Temperature °F	Runouts <sup>b</sup> up to 2	1 and less	1-1¼ to 2	2½ to 4	5 & 6	8 & up
<b>Heating systems (Steam, Steam Condensate, and Hot Water)</b>								
Fluid Design	0.32-0.34	250	1.5	1.5	2.5	3.0	3.5	3.5
Operating Temperature Range, °F	0.29-0.31	200	1.5	1.5	2.5	2.5	3.5	3.5
	0.27-0.30	150	1.0	1.0	1.5	2.0	2.0	3.5
	0.25-0.29	125	0.5	0.5	1.5	1.5	1.5	1.5
	0.24-0.28	100	0.5	0.5	1.0	1.0	1.0	1.5
<b>Domestic and Service Hot Water systems<sup>c</sup></b>								
105 and Greater	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
<b>Cooling systems (Chilled Water, Brine, and Refrigerant)<sup>d</sup></b>								
40-55	0.23-0.27	75	0.5	0.5	0.75	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

<sup>a</sup>For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:  $T = PR [(1 + t/PR)^{K/k} - 1]$ , where T = minimum insulation thickness for material with conductivity K, in.; PR = actual outside radius of pipe, in.; t = insulation thickness, in.; K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature; and k = the lower value of the conductivity range listed for the applicable fluid temperature.

<sup>b</sup>Runouts to individual terminal units not exceeding 12 ft in length.

<sup>c</sup>Applies to recirculating sections of service or domestic hot water systems and first 8 ft from storage tank for nonrecirculating systems.

<sup>d</sup>The required minimum thickness does not consider water vapor transmission and condensation.

# HVAC Piping

---

- Exceptions
  - Piping that is factory installed within equipment
  - Piping conveying fluids between 55°F and 105°F
  - Piping conveying fluids that have not been heated or cooled through the use of fossil fuels or electricity
  - Condensate drains and similar applications where insulation does not save energy

# Duct Insulation

## (Section 403.2.9.2)

- Table 403.2.9.2

Duct Location	Cooling <sup>b</sup>		Heating <sup>c</sup>	
	Annual Cooling Degree-Days Base 65°F	Minimum Insulation R-Value <sup>a</sup> (h · ft <sup>2</sup> · °F)/Btu	Annual Heating Degree-Days Base 65°F	Minimum Insulation R-Value <sup>a</sup> (h · ft <sup>2</sup> · °F)/Btu
Exterior of building	below 500	3.3	below 1500	3.3
	500 to 1150	5.0	1500 to 4500	5.0
	1151 to 2000	6.5	4501 to 7500	6.5
	above 2000	8.0	above 7500	8.0
Inside of building envelope or in unconditioned spaces <sup>f</sup>	TD <sup>d</sup> ≤ 15	None Req'd	TD <sup>d</sup> ≤ 15	None Req'd
	15 < TD <sup>d</sup> ≤ 40	3.3	15 < TD <sup>d</sup> ≤ 40	3.3
	TD <sup>d</sup> > 40	5.0 <sup>e</sup>	TD <sup>d</sup> > 40	5.0 <sup>e</sup>

<sup>a</sup>Insulation resistance measured on a horizontal plane in accordance with RS-6 at a mean temperature of 75°F at the installed thickness not including film resistance. The required minimum thicknesses do not consider water vapor transmission and condensation. For ducts that are designed to convey both heated and cooled air, duct insulation shall be as required by the most restrictive condition. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of this section or Section 402.

<sup>b</sup>Cooling ducts are those designed to convey mechanically cooled air or return ducts in such systems.

<sup>c</sup>Heating ducts are those designed to convey mechanically heated air or return ducts in such systems.

<sup>d</sup>TD is defined as the temp. difference at design conditions between the space within which the duct is located and the design air temperature in the duct.

<sup>e</sup>Insulation resistance for runouts to terminal devices less than 10 ft in length need not exceed 3.3 (h · ft<sup>2</sup> · °F)/Btu.

<sup>f</sup>Unconditioned spaces include crawl spaces and attics.

[Note: Enforcement agency can simplify table, upon adoption, in accordance with local weather data and default values of TD from Table D-1 in Appendix D. See example Table D-2. Enforcement agency to ensure that this requirement is consistent with local mechanical code requirements and amend, as necessary, to eliminate conflict.]

# Duct Insulation

## Common Duct Insulation Materials

---

R-Value (hr-°F-ft <sup>2</sup> )/Btu	Nominal Thickness, (in.)	Typical materials
3.3	1-1/2	1/2 to 1-1/2 lb./ft <sup>3</sup> fiberglass duct wrap
	1	3/4 to 3 lb./ft <sup>3</sup> fiberglass duct liner
	1-1/2	1/2 lb./ft <sup>3</sup> fiberglass duct liner
	1	fibrous glass duct board
	1	insulated flexible duct
5.0	3	1/2 lb./ft <sup>3</sup> fiberglass duct wrap
	2	3/4 to 1-1/2 lb./ft <sup>3</sup> fiberglass duct wrap
	1-1/2	3/4 to 2 lb./ft <sup>3</sup> fiberglass duct liner
	1	3 lb./ft <sup>3</sup> fiberglass duct liner
6.5	3	1/2 to 1-1/2 lb./ft <sup>3</sup> fiberglass duct wrap
	2	3/4 to 1-1/2 lb./ft <sup>3</sup> fiberglass duct liner
	1-1/2	2 to 3 lb./ft <sup>3</sup> fiberglass duct liner
8.0	4	1/2 to 3/4 lb./ft <sup>3</sup> fiberglass duct wrap
	3	1 to 1-1/2 lb./ft <sup>3</sup> fiberglass duct wrap
	3	3/4 to 1 lb./ft <sup>3</sup> fiberglass duct liner
	2	1-1/2 to 3 lb./ft <sup>3</sup> fiberglass duct liner

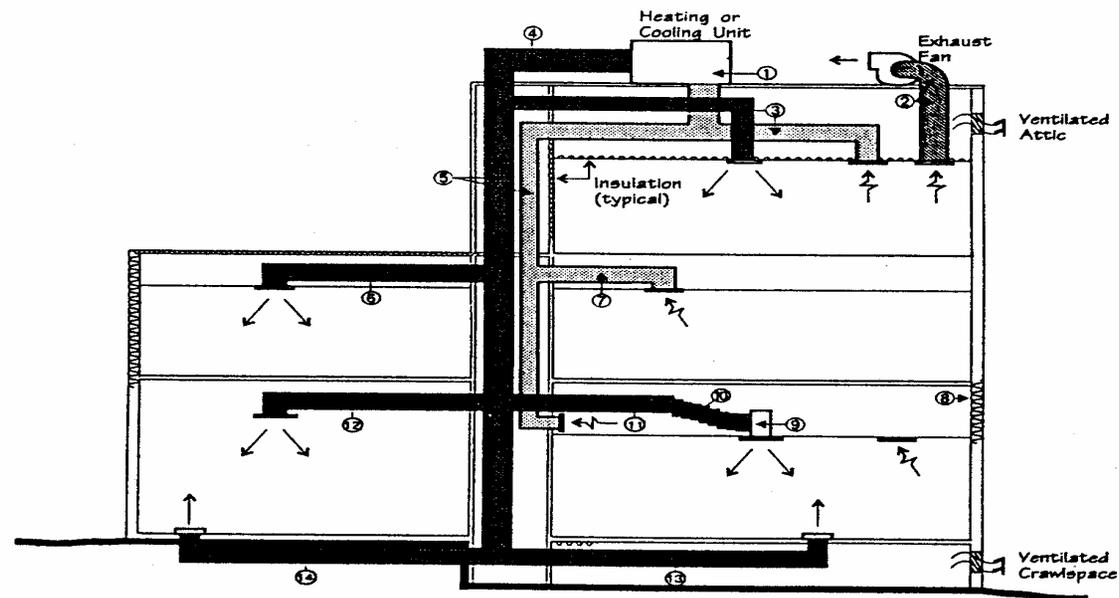
## Duct Insulation

# Example Duct Insulation Calculation

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- **Question:** The supply duct located on a roof of a building in Atlanta supplies both heating and cooling air. What is the R-value?
- **Answer:** The heating degree-days is 3070, so the R-value is  $5.0 \text{ h ft}^2 \text{ }^\circ\text{F/Btu}$ . The cooling degree-days is 1566, so the R-value is  $6.5 \text{ ft}^2 \text{ }^\circ\text{F/Btu}$ .
- The R-value for the duct would be  $6.5 \text{ ft}^2 \text{ }^\circ\text{F/Btu}$  since it is the most stringent

# Duct Insulation Common Applications



KEY	
1. Insulation of unit casing	5. Exterior wall of return plenum
2. Exhaust	9. Supply outlet in plenum
3. Supply & return in vented attic	10. Supply runoff in return plenum
4. Supply & return on exterior of building	11. Supply in return plenum
5. Supply & return in shaft	12. Supply & return in conditioned space
6. Supply & return in unvented attic	13. Supply & return in vented crawspace
7. Return in indirectly conditioned ceiling space	14. Buried supply

# Duct Construction

## *(Section 403.2.9.3)*

---

- Follow
  - SMACNA HVAC Duct Construction Standards - Metal and Flexible, 1985, and
  - SMACNA Fibrous Glass Duct Construction Standards, 1979, or equivalent
- In addition:
  - Supply ductwork designed to operate at static pressures from 1/4 to 2 in w.g., inclusive, must be sealed in accordance with SMACNA Seal Class C
    - Spiral joints do not require sealing (in any Seal Class)
    - Pressure sensitive tape must not be used as the primary sealant for ductwork designed to operate at 1 in, w.g. or greater

# Duct Construction *(cont'd)*

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- In addition
  - Ductwork designed to operate at static pressures in excess of 3 in w.g. must
    - be tested in accordance with the procedures outlined in Section 5 of the “SMACNA HVAC Air Duct Leakage Test Manual,” 1985
    - Tests may be made for representative sections

# Completion

---

- Operation and Maintenance Manuals  
(*Section 403.2.10.1*)
  - Must be provided to the building owner upon completion of construction
  - Must contain information for proper operation and maintenance of the system as a whole, not just each piece of equipment

# Completion

---

- Testing and Balancing
  - HVAC systems must be tested and balanced to insure proper operation
  - ASHRAE's Guideline 1-1989 Commissioning of HVAC Systems (Code 86801) is recommended, but not required for developing a commissioning plan
  - Air and hydronic systems should be balanced in accordance with
    - ASHRAE Standard 111-1988,
    - National Environmental Balancing Bureau (NEBB), or
    - Associated Air Balance Council (AABC)

# Applicability Matrix

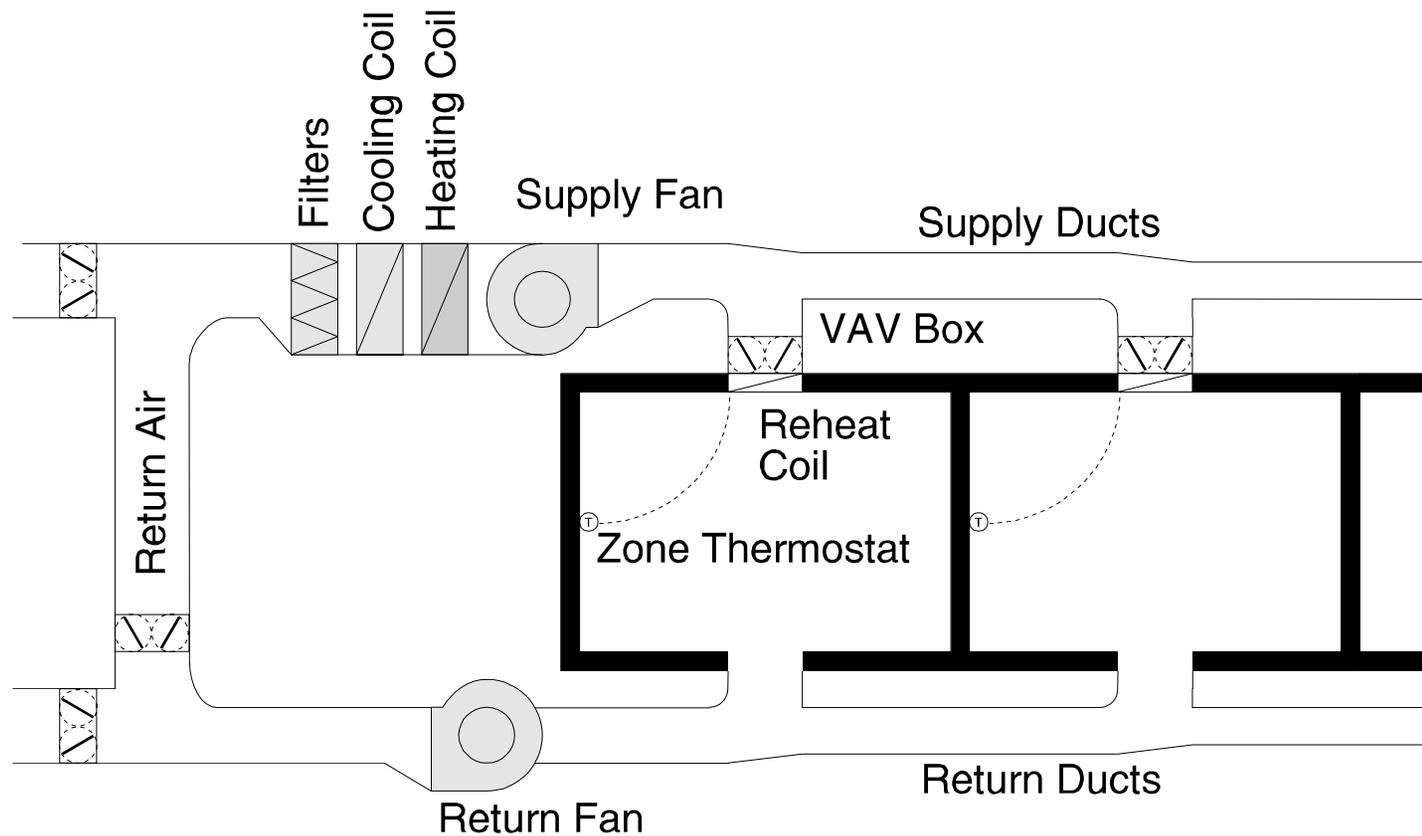
Requirement	Unitary		Hydronic	
	Single Zone	Multiple Zone	Single Zone	Multiple Zone
	Packaged rooftop or split system single zone > 7-1/2 tons	Packaged rooftop VAV	Chilled water 2-pipe or 4-pipe fan-coils	Chilled water VAV
Mechanical Equipment Efficiency (403.1)	Required	Required	Required	Required
Load Calculations (403.2.1)	Required	Required	Required	Required
Equipment/System Sizing (403.2.2)	Required	Required	Required	Required
Separate Air Distribution System (403.2.3)	Required	Required	Required	Required
Ventilation Capability (403.2.4)	Required	Required	Required	Required
Fan System Design (403.2.4)	Not required	Required	Not usually required	Required
Pumping System Design (403.2.5)	Not required	Not required	Required	Required
System Controls (403.2.6.1)	Systems comply inherently	Systems generally comply inherently	Systems comply inherently	Systems generally comply inherently
Zone Controls (403.2.6.2)	Systems comply inherently	Required	Systems comply inherently	Required
Zone Thermostatic Control Capability (403.2.6.3)	Required	Required	Required	Required
Heat Pump Auxiliary Heat (403.2.6.4)	Heat pump systems only	Not Required	Not Required	Not Required
Humidistats (403.2.6.5)	All humidification or active dehumidification systems	All humidification or active dehumidification systems	All humidification or active dehumidification systems	All humidification or active dehumidification systems
Simultaneous Heating and Cooling (403.2.6.6)	Not required except if reheat for dehumidification is used.	Required	Not required except if reheat for dehumidification is used.	Required
Air Temperature Reset (403.2.6.7)	Not required	Required	Not required	Required
Hydronic Temperature Reset (403.2.6.8)	Not required	Not required	Required	Required
Automatic Setback or Shutdown (403.2.7.1)	Required. Met with timeclock thermostat	Required	Required	Required
Shutoff Dampers (403.2.7.2)	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm
Zone Isolation (403.2.7.3)	Systems comply inherently	Required	Systems comply inherently	Required
Economizers (403.2.8)	Not required for systems less than 3,000 cfm or 7.5 tons	Required in most applications	Required in most applications	Required in most applications
Piping Insulation (403.2.9.1)	Required for split systems	Required for split systems	Required	Required
Duct and Plenum Insulation (403.2.9.2)	Required	Required	Required	Required
Duct and Plenum Construction (403.2.9.3)	Required	Required	Required	Required
Manuals (403.2.10.1)	Required	Required	Required	Required
Air System Balancing (403.2.10.2)	Required	Required	Required	Required
Hydronic System Balancing (403.2.10.3)	Not required	Not required	Required	Required
Control System Testing (403.2.10.4)	Required	Required	Required	Required

Table 403A Applicable Section 403 Requirements for Different HVAC Systems

Requirement	Unitary		Hydronic	
	Single Zone	Multiple Zone	Single Zone	Multiple Zone
	Packaged rooftop or split system single zone > 7-1/2 tons	Packaged rooftop VAV	Chilled water 2-pipe or 4-pipe fan-coils	Chilled water VAV
Mechanical Equipment Efficiency (403.1)	Required	Required	Required	Required
Load Calculations (403.2.1)	Required	Required	Required	Required
Equipment/System Sizing (403.2.2)	Required	Required	Required	Required
Separate Air Distribution System (403.2.3)	Required	Required	Required	Required
Ventilation Capability (403.2.4)	Required	Required	Required	Required
Fan System Design (403.2.4)	Not required	Required	Not usually required	Required
Pumping System Design (403.2.5)	Not required	Not required	Required	Required
System Controls (403.2.6.1)	Systems comply inherently	Systems generally comply inherently	Systems comply inherently	Systems generally comply inherently
Zone Controls (403.2.6.2)	Systems comply inherently	Required	Systems comply inherently	Required
Zone Thermostatic Control Capability (403.2.6.3)	Required	Required	Required	Required
Heat Pump Auxiliary Heat (403.2.6.4)	Heat pump systems only	Not Required	Not Required	Not Required
Humidistats (403.2.6.5)	All humidification or active dehumidification systems	All humidification or active dehumidification systems	All humidification or active dehumidification systems	All humidification or active dehumidification systems
Simultaneous Heating and Cooling (403.2.6.6)	Not required except if reheat for dehumidification is used.	Required	Not required except if reheat for dehumidification is used.	Required
Air Temperature Reset (403.2.6.7)	Not required	Required	Not required	Required
Hydronic Temperature Reset (403.2.6.8)	Not required	Not required	Required	Required
Automatic Setback or Shutdown (403.2.7.1)	Required. Met with timeclock thermostat	Required	Required	Required
Shutoff Dampers (403.2.7.2)	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm	Required if outside air intake exceeds 3000 cfm
Zone Isolation (403.2.7.3)	Systems comply inherently	Required	Systems comply inherently	Required
Economizers (403.2.8)	Not required for systems less than 3,000 cfm or 7.5 tons	Required in most applications	Required in most applications	Required in most applications
Piping Insulation (403.2.9.1)	Required for split systems	Required for split systems	Required	Required
Duct and Plenum Insulation (403.2.9.2)	Required	Required	Required	Required
Duct and Plenum Construction (403.2.9.3)	Required	Required	Required	Required
Manuals (403.2.10.1)	Required	Required	Required	Required
Air System Balancing (403.2.10.2)	Required	Required	Required	Required
Hydronic System Balancing (403.2.10.3)	Not required	Not required	Required	Required
Control System Testing (403.2.10.4)	Required	Required	Required	Required

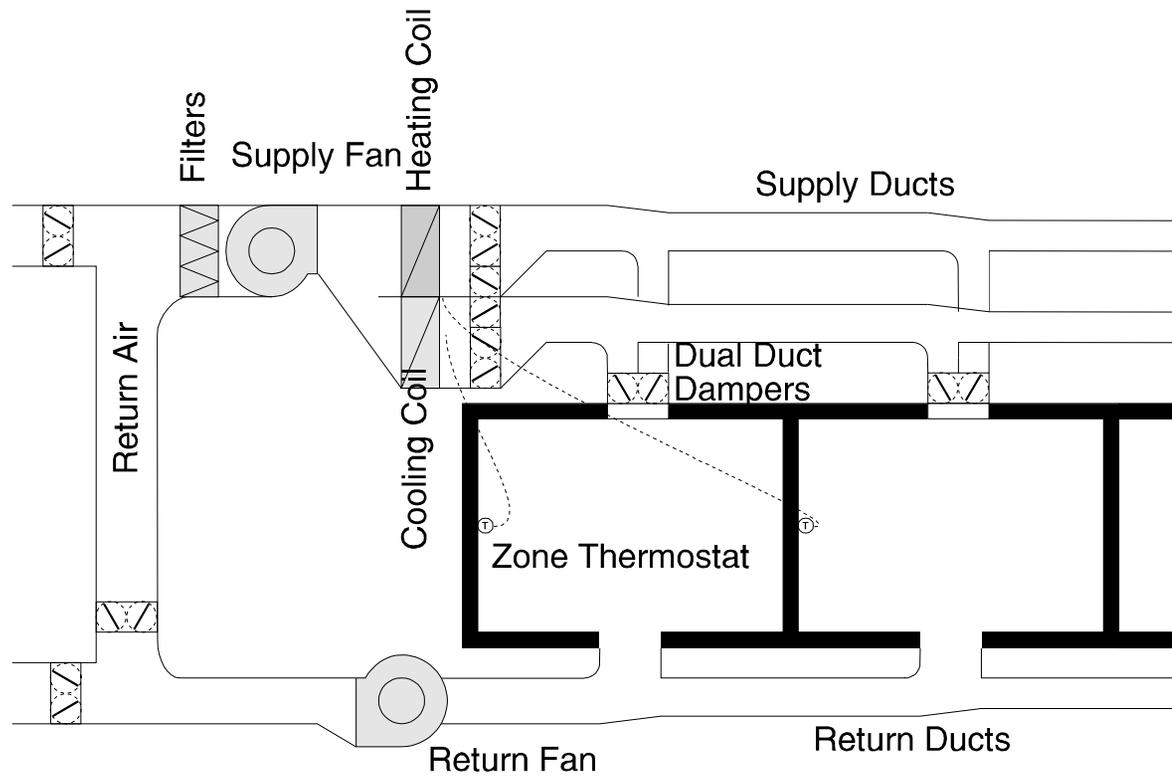
# System Types Variable Air Volume

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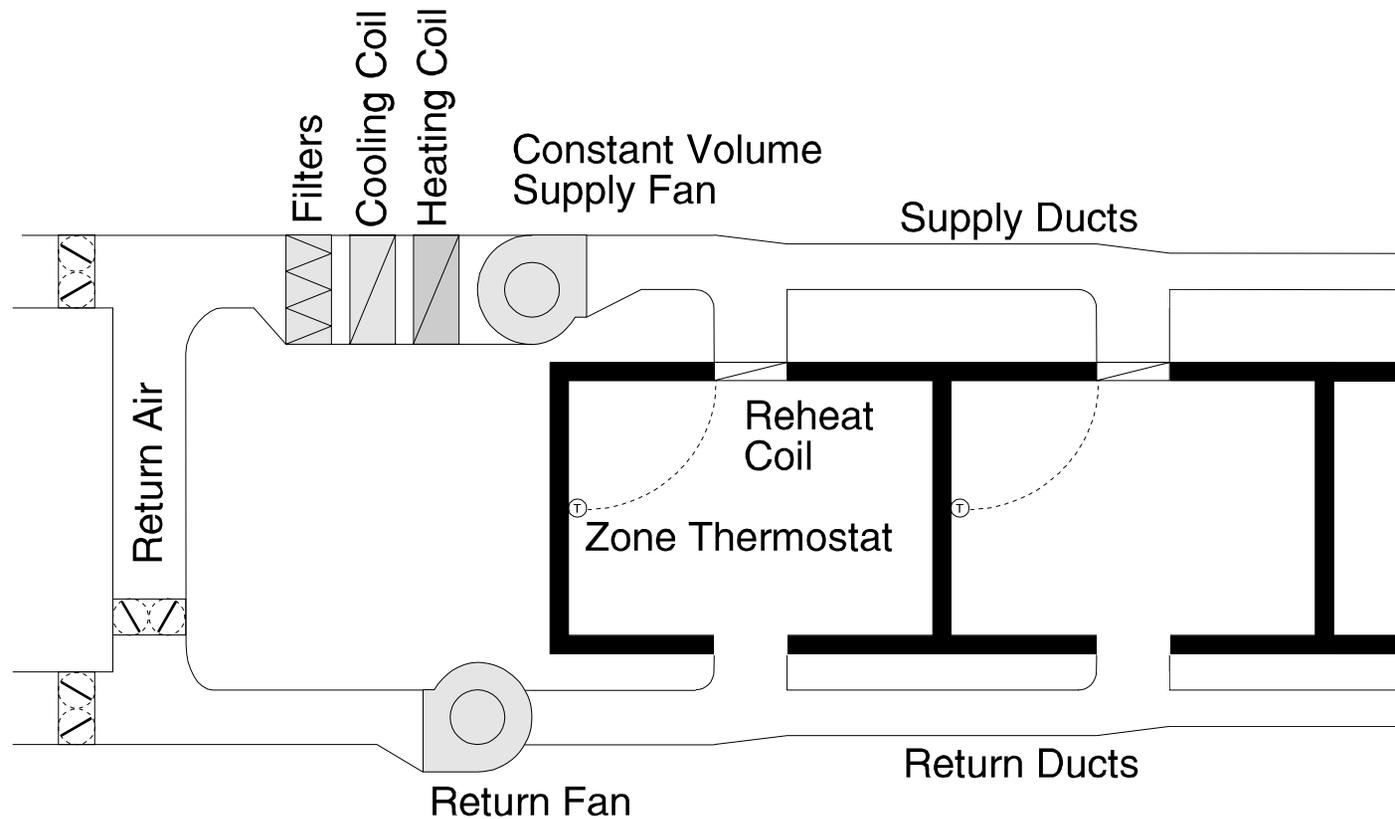


# System Types Dual Duct

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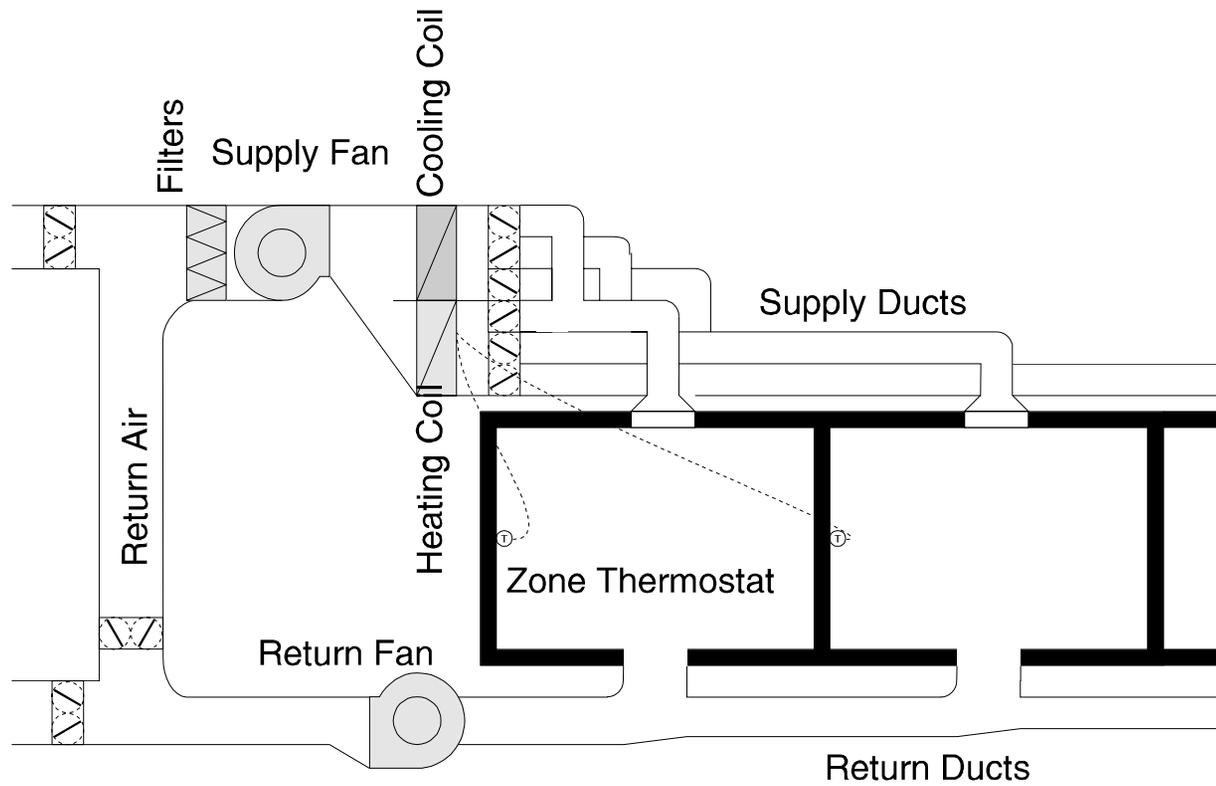


# System Types Constant Volume (Reheat)



# System Types Multi-Zone

---



# Equipment Efficiency

- Boilers and Chillers
- Table 403.1c and f
- Refer to Standard

TABLE 403.1c Water Chilling Packages, <i>Electrically Operated</i> , Minimum Efficiency Requirements				
Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency <sup>b</sup>	Test Procedure <sup>a</sup>
Air-Cooled Chiller, with Condenser	< 150 Tons		2.7 COP 2.8 IPLV	ARI 550 Centrifugal/ Rotary Screw (RS-30)
	≥ 150 Tons		2.5 COP 2.5 IPLV	
Air-Cooled Chiller, without Condenser	All Capacities		3.1 COP 3.2 IPLV	or
Water Cooled Chiller	< 150 Tons		3.8 COP 3.9 IPLV	ARI 590 Reciprocating (RS-31)
	≥ 150 Tons and < 300 Tons		4.2 COP 4.5 IPLV	
	≥ 300 Tons		5.2 COP <sup>c</sup> 5.3 IPLV <sup>c</sup>	

<sup>a</sup>See Chapter 5 for detailed references.

<sup>b</sup>Equipment must comply with all efficiencies when multiple efficiencies are indicated.

<sup>c</sup>These requirements are reduced to 4.7 COP and 4.8 IPLV, where R-22 is used or where refrigerants with *ozone depletion factors* less than or equal to that for R-22 are used.

# Fan Systems

---

- Fan Power Limits (*Section 403.2.4*)
  - Maximum of 0.8 W/cfm for constant volume fans
  - Maximum of 1.25 W/cfm for variable volume fans

## Fan Systems

# Applies to fans that

---

- Include either a heating or a cooling source
- Operate at “design conditions”
- Supply air from the heating or cooling source to the conditioned space
- Return air from the space to the heating or cooling source
- Exhaust air from the space to the outside

## Fan Systems

# General Exceptions to Fan Requirements

---

- Small fan systems with fan motor horsepower totaling 10 hp or less
- Fans in unitary equipment for which fan energy is included in the efficiency ratings, e.g. EER

Fan Systems  
**Fan Power Equation**

---

- $W = 746 \times \text{BHP} / (\eta_m \times \eta_d)$
- Where:

BHP = brake horsepower

$\eta_m$  = motor efficiency

$\eta_d$  = drive efficiency

# Fan Systems Typical Motor Efficiencies

---

<b>Nameplate Rating (hp)</b>	<b>90.1 Code Motor</b>	<b>High Efficiency Motor</b>
1/20	35	--
1/10	35	--
1/8	35	--
1/6	35	--
1/4	54	--
1/3	56	--
1/2	60	--
3/4	72	--
1	75	82.5
1-1/2	77	84.0
2	79	84.0
3	81	86.5
5	82	87.5
7-1/2	84	88.5
10	85	89.5
15	86	91.0
20	87	91.0
25	88	91.7
30	89	92.4
40	89	93.0
50	89	93.0
60	89	93.6
75	90	94.1
100	90	94.1
125	90	94.5
150 and up	91	95.0

(Open Motors, 1,800 RPM synchronous speeds, nominal efficiencies. High efficiency motors from Energy Policy Act of 1992, effective 1997. Standard motor data are from the ASHRAE Fundamentals Handbook, (1989), page 26.8)

## Fan Systems

# Adjustments for Special Filtering

---

- For air treatment or filtering equipment with pressure drops in excess of 1 in w.g.

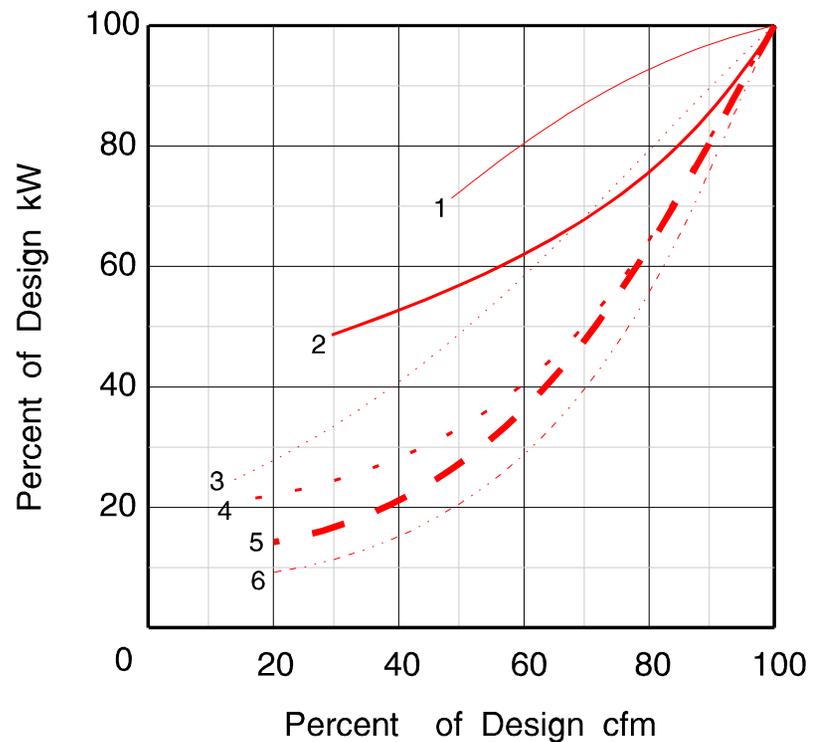
Fan Systems  
Fan Part Load Requirement

---

- Fan power may not exceed 50% of full load power at 50% flow
- Application: Variable speed drives required for individual VAV fans with 75 hp motors or larger

# Fan Systems

## Part Load Fan Curves



- ① Air foil or backward-inclined centrifugal fan with discharge dampers
- ② Air foil centrifugal fan with inlet vanes
- ③ Forward-curved centrifugal fan with discharge dampers or riding curve
- ④ Forward-curved centrifugal fan with inlet vanes
- ⑤ Vane-axial fan with variable pitch blades
- ⑥ Any fan with variable speed drive (mechanical drives will be slightly less efficient)

# Fan Systems Example Fan Power Calculation

---

*Q* Is the central VAV system described below in compliance with the fan power limits of Section 403.2.4?

Quantity	Fan Service	Design, cfm each	Brake Horsepower	Motor Horsepower
2	Supply fans with variable speed drives	75,000	70.5	75 high efficiency
4	Economizer relief fans	32,000	3.5	5
1	Toilet exhaust	6,750	2.7	3 high efficiency
1	Elevator machine room exhaust fan	5,000	unknown	3/4
2	Cooling tower exhaust fans	unknown	unknown	15
15	Conference room exhaust fans	500	240 watts	--
120	Series type fan-powered mixing boxes	1,300 (average)	unknown	1/3

# Fan Systems

## Example Fan Power Calculation

---

*Q* Is the central VAV system described below in compliance with the fan power limits of Section 403.2.4?

Quantity	Fan Service	Design, cfm each	Brake Horsepower	Motor Horsepower
2	Supply fans with variable speed drives	75,000	70.5	75 high efficiency
4	Economizer relief fans	32,000	3.5	5
1	Toilet exhaust	6,750	2.7	3 high efficiency
1	Elevator machine room exhaust fan	5,000	unknown	3/4
2	Cooling tower exhaust fans	unknown	unknown	15
15	Conference room exhaust fans	500	240 watts	--
120	Series type fan-powered mixing boxes	1,300 (average)	unknown	1/3

## Fan Systems

# Example Fan Power Calculation (*cont'd*)

---

**A** First, determine which fans to include in the fan wattage calculation.

<b>Fans</b>	<b>Included</b>	<b>Not Included</b>
supply fans	x	
economizer relief fans		x
toilet exhaust fan	x	
elevator exhaust fan		x
cooling tower fans		x
conference room exhaust fans		x
series type fan-powered VAV boxes	x	

The fans that are included and their power requirements are:

Fan Service	Quantity	Wattage Calculation	Power Each, watts	Total Power, watts
Supply fans	2	$746 \times 70.5 / (0.94 \times 0.97 \times 0.95)$	60,716	121,432
Toilet exhaust fan	1	$746 \times 2.7 / (0.86 \times 0.97)$	2,115	2115
Fan powered VAV boxes	120	$746 \times 1/3 / 0.56$	444	53,280
Total				176,827

# Pumps

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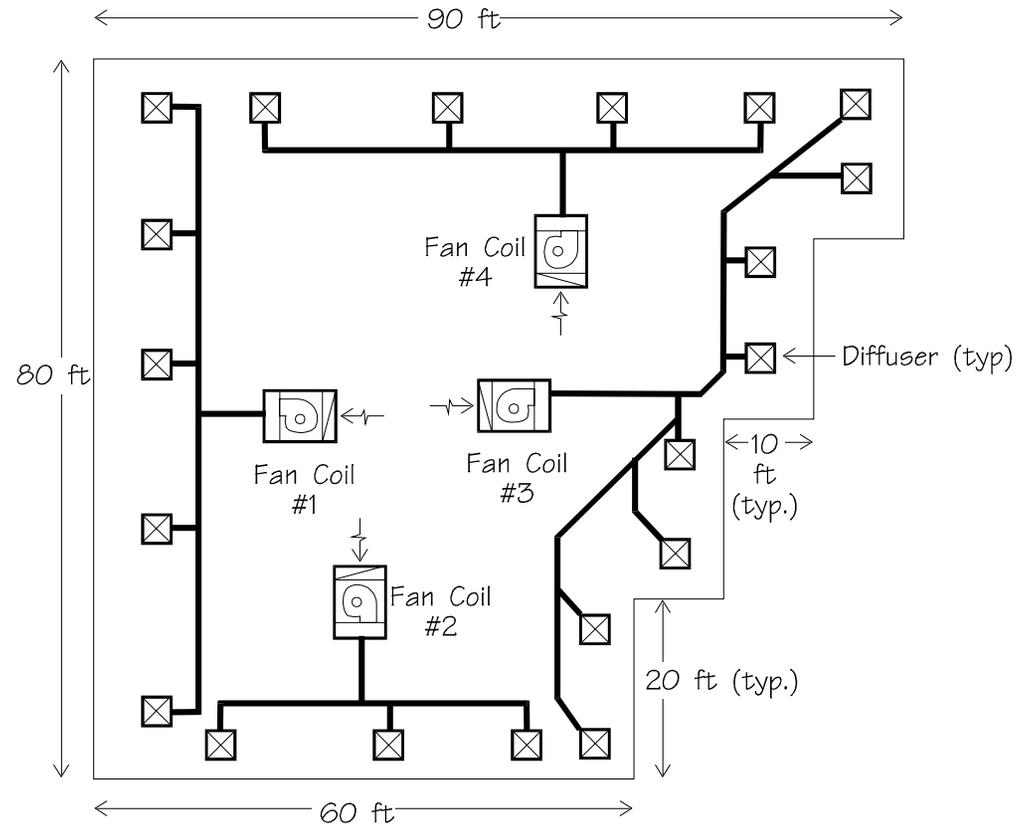
- Pumping System Design (*Section 403.2.5*)
  - Pumping systems with modulating or two-position controls must be designed for variable flow, capable of operating at 50% of design flow or lower
- Exceptions
  - Systems for which flow rates greater than 50% of design flow are required for proper operation, such as chillers, and some types of boilers
  - Systems with only one control valve
  - Pumping systems with total system pump motor horsepower less than or equal to 10 hp
  - Systems that include supply water temperature reset controls, in accordance with Section 403.2.6.8, without exception

Zone Control  
**Temperature Control**  
*(Section 403.2.6.1)*

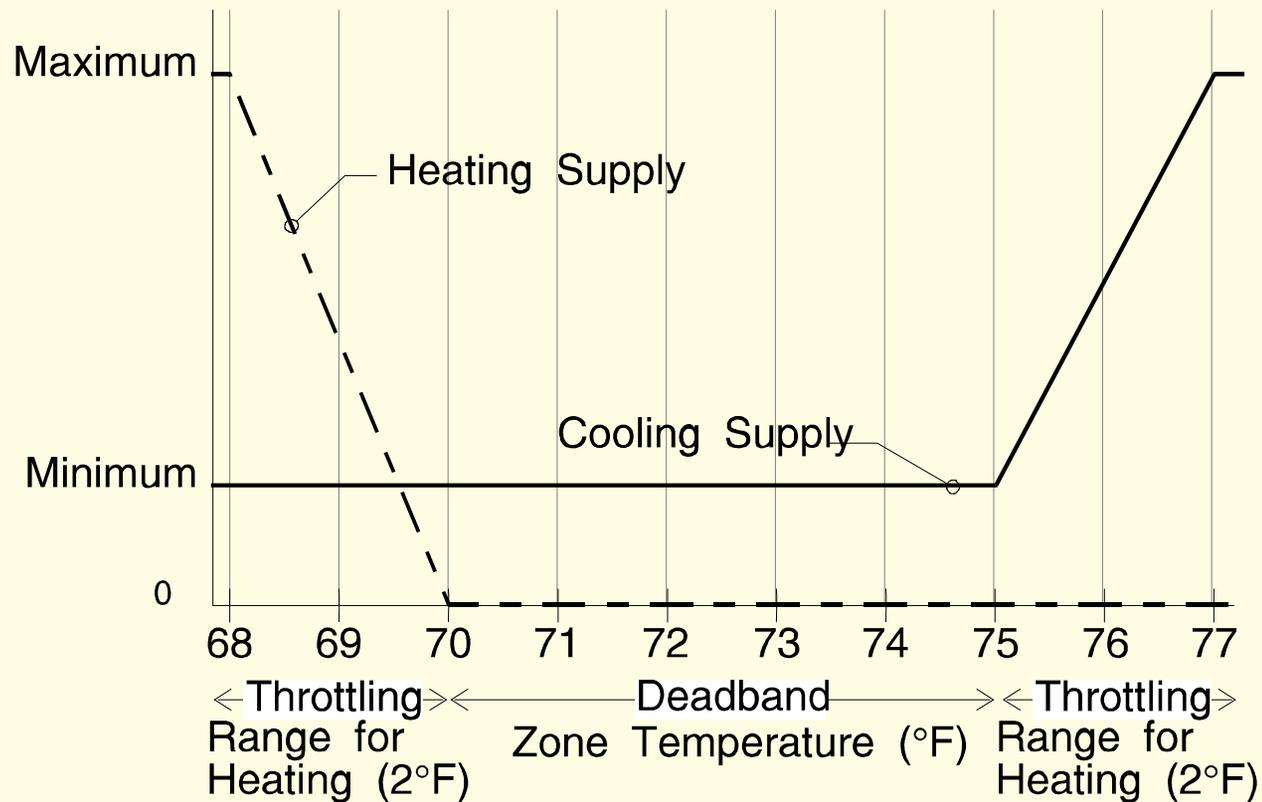
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- Each zone must be controlled by an individual temperature controller
- Dwelling units may be considered a single control zone
- Perimeter system zoning is permitted as long as:
  - The perimeter system has at least one zone for each major exposure (an exterior wall that faces 50 contiguous feet or more in one direction)
  - Each perimeter system zone is controlled by one or more thermostats located in the zones served

# Zone Control Independent Perimeter Zone Heating System



# Zone Control Deadband Thermostatic Controls (VAV Box)



# Simultaneous Heating and Cooling

*(Section 403.2.6.6)*

---

- Systems prohibited which reheat, recool, or mix mechanically heated or cooled air
- Exceptions:
  - 1 variable air volume systems that first reduce air to
    - 30% of the peak supply to space,
    - the minimum required to meet code (ventilation),
    - 0.4 cfm/ft<sup>2</sup>, or
    - 300 cfm

# Simultaneous Heating and Cooling *(cont'd)*

---

- Exceptions

- 2 Where special pressurization relationships or cross-contamination requirements make VAV impractical
- 3 Where at least 75% of the reheat energy is supplied by heat recovered from some process or equipment within the building
- 4 For zones where specific humidity levels must be maintained for non-comfort purposes
- 5 For zones with peak supply air quantities of 300 cfm or less

Controls for Part Load

# Supply Air Temperature Reset

*(Section 403.2.6.7)*

---

- Application: multiple zone systems
- Must have capability of adjusting the supply air temperature to the maximum (for cooling) or minimum (for heating) temperature that can satisfy the loads
- Must be reset by at least 25% of the design supply air to room air temperature difference
- Zones with relatively constant loads must be designed for the fully reset temperature

## Controls for Part Load

# Acceptable Basis for Resetting Supply Air Temperature

---

- The zone which requires the coldest (cooling systems) or warmest (heating systems) supply air temperature
- Peak, or representative zone requirements
- Load indicators such as return air temperature or fan static pressure
- Outside air temperature

Controls for Part Load

# Supply Air Temperature Reset Exceptions

---

- For systems which either require no simultaneous heating or cooling
- When simultaneous heating or cooling requirement is satisfied without using exceptions 1 or 2 of Section 403.2.6.6
  - 75% of reheat energy is recovered
  - Humidity control required for non-comfort purposes
  - Zones with 300 cfm or less of supply air

Controls for Part Load  
**Hydronic Temperature Reset**  
*(Section 403.2.6.8)*

---

- Application: chilled and hot water systems with design capacities  $> 600,000$  Btu/h (50 tons)
- Must have capability to reset the supply water temperature upward (for cooling) and downward (for heating) at low loads
- Must be reset by at least 25% of the design supply to return water temperature difference

Controls for Part Load

# Acceptable Basis for Resetting Hydronic Temperature

---

- The cooling or heating coil that requires the coldest (cooling systems) or warmest (heating systems) water
- Return water temperature
- Outside air temperature

# Hydronic Temperature Reset Exceptions

---

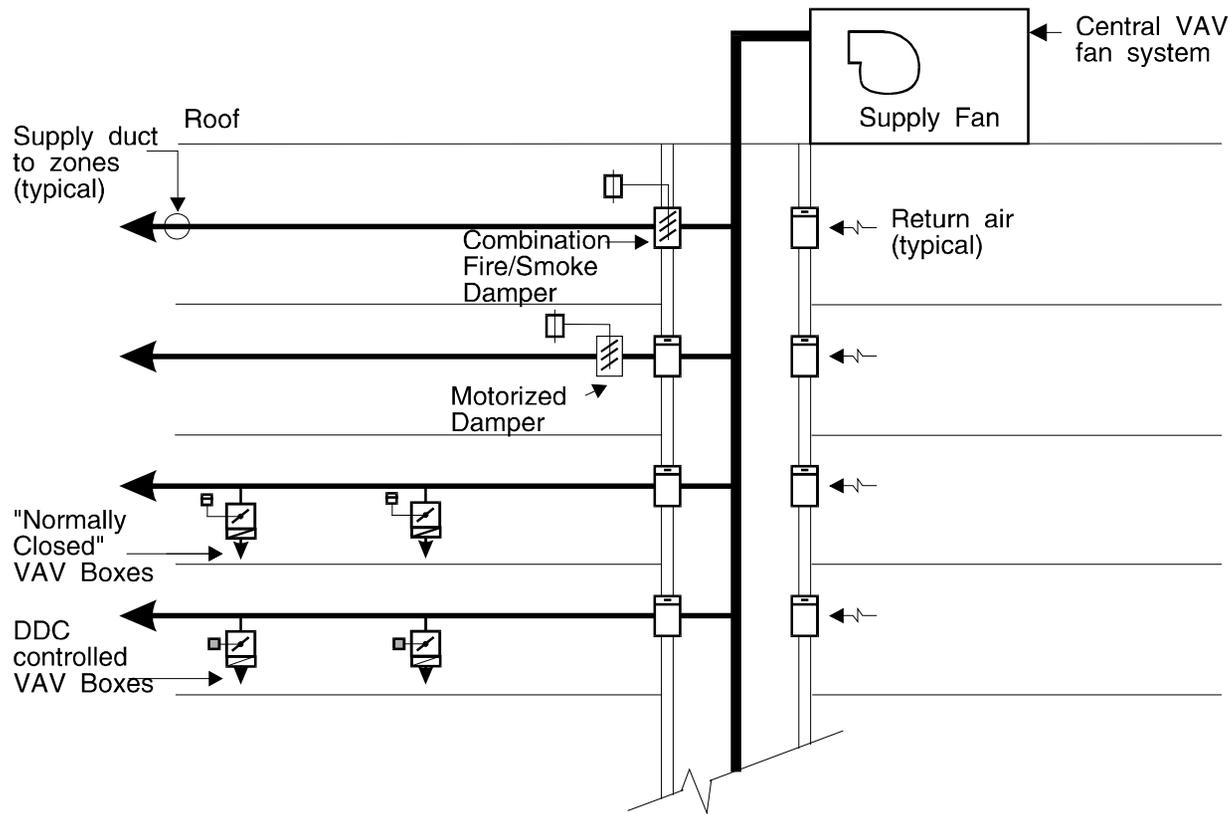
- Exceptions to Hydronic Temperature Reset Requirement
  - System is designed for variable flow in accordance with Section 403.2.5, without exception
  - Supply temperature reset will cause improper operation of heating, cooling, humidification, or dehumidification systems, usually humidity control.

Controls for Part Load  
**Zone Isolation**  
*(Section 403.2.7.3)*

---

- Application: multizone systems serving zones that can be expected to operate non-simultaneously for 750 hours or more per year
- Isolation devices and controls must be installed that allow each zone to be shut off or set back individually
- Common areas, such as lobbies, that are unoccupied only when all other spaces are unoccupied need not be isolated
- Zones may be grouped together provided:
  - Floor area of the group does not exceed 25,000 ft<sup>2</sup>
  - All zones in the group are on the same floor

# Controls for Part Load Zone Isolation Methods for a Central VAV System



# Service Water Heating

## Chapter 8 Scope

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### **Chapter 8**

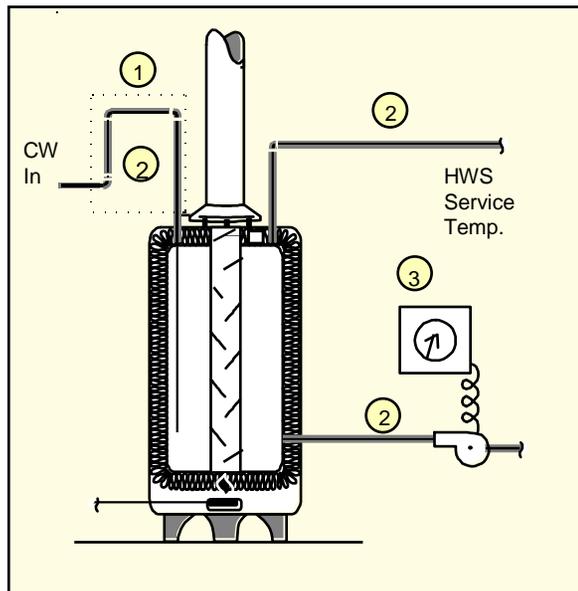
Section 804

### **Chapter 7**

Section 404

# Water Heating

- Summary of requirements



- ① Heat traps to reduce standby losses
- ② Pipe insulation to reduce distribution and standby losses

- ③ Circulation loop temperature controls to reduce distribution losses

# Equipment Efficiency

*(Section 804.2)*

---

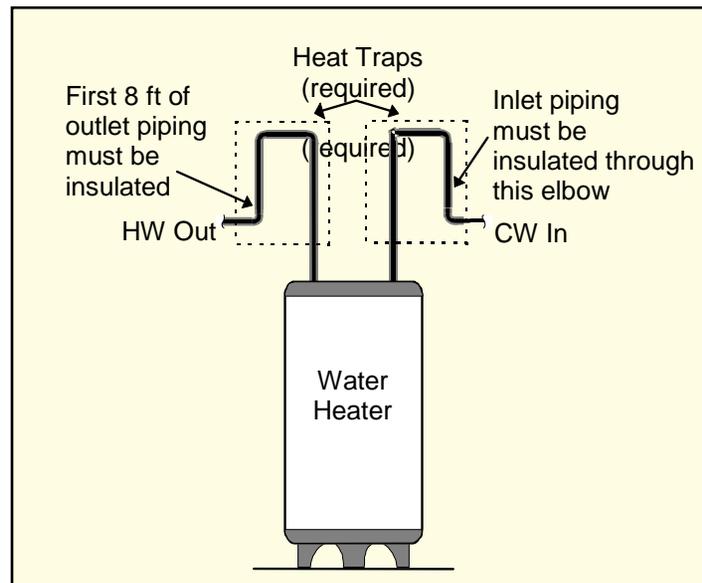
- NAECA regulated water heating equipment allowed under the IECC
  - Electric heaters
  - Fuel-fired storage
  - Packaged boilers
  - Instantaneous
  - Pool and spa heaters
- Non NAECA regulated water heating equipment
  - Gas/oil

# Heat Traps

*(Section 804.4)*

---

- Required on noncirculating hot water systems



# Pipe Insulation

*(Section 804.5)*

---

- Noncirculating system insulation requirements
  - First eight feet of outlet piping on systems with no integral heat traps
  - 1/2 inch of insulation required
- Circulating systems
  - 1 inch of insulation

# Hot Water System Controls

*(Section 804.6)*

---

- Application: circulating hot water systems
  - Automatic time switches required to turn off the pump and heat tracer tape when it is not in use

# Service Water Heating

## Chapter 7 Scope

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### **Chapter 8**

Section 804

### **Chapter 7**

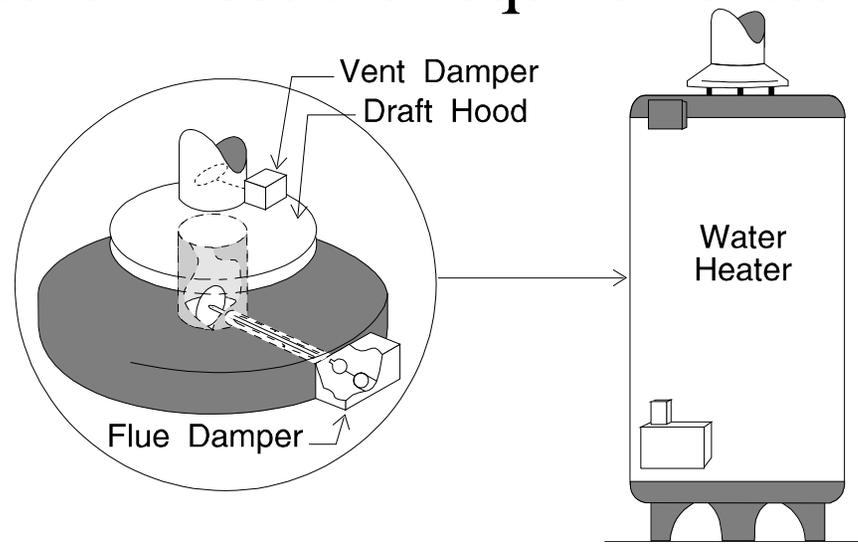
Section 404

- Swimming Pools
- Combined Service Water Heating & Space Heating

# Automatic Vent or Flue Dampers (Section 404.1)

---

- Required on fuel-fired systems which draw either combustion air or air for draft hood dilution from conditioned space.
- Integral dampers installed by the equipment manufacturer meet the requirements.



# Swimming Pools

*(Section 404.5)*

---

- Requirements
  - Pool heaters must meet the efficiency requirements in Table 404.1
- Readily accessible on/off switch
- Time switches, except for:
  - pumps that must operate continuously to meet public health standards
  - pumps that operate to use solar or waste heat recovery to heat the pool
- Pool covers required, unless more than 70% of operating energy is from solar energy or waste heat recovery

# Combined Service Water Heating and Space Heating Equipment (*Section 404.6*)

---

- Permitted when
  - Combined system capacity (input rating or storage volume) is not more than twice the size of smaller of the two loads
  - Input rating of the combined system must be less than 150,000 Btu/h
  - Service water heating portion meets Section 404
  - Space conditioning portion meets Section 403

# Lighting Systems

## Chapter 8 Scope

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### **Chapter 8**

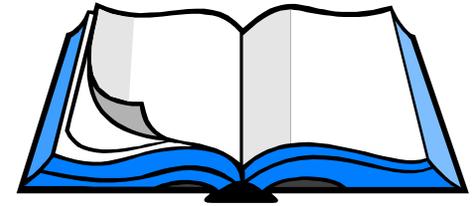
#### Section 805

- No lighting control credits
- High efficiency exterior lighting

### **Chapter 7**

#### Section 401

# Scope

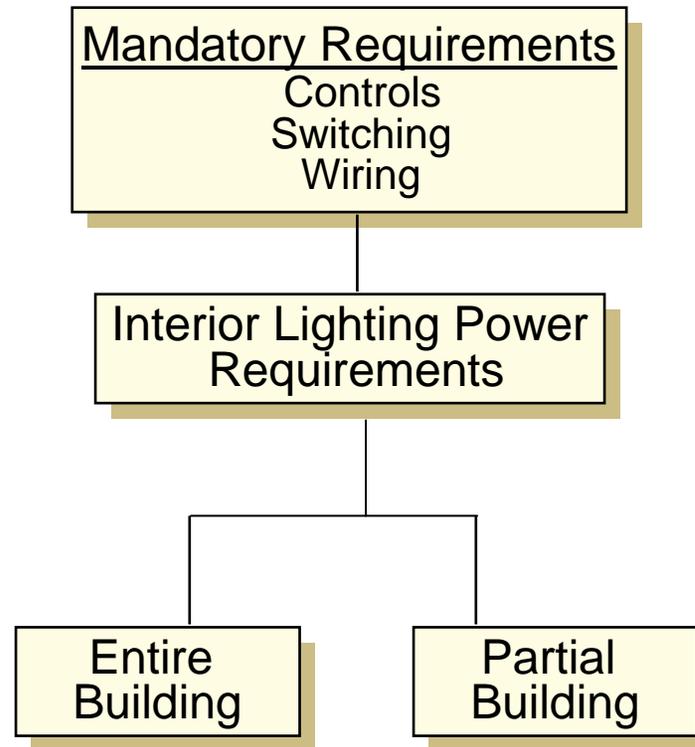


- 
- Applies to the design of the:
    - first installed lighting systems
    - altered system that increases the lighting load if change of occupancy
  - Lighting systems used for specialized commercial, display and emergency use purposes are exempt (*Section 805.4.1*)

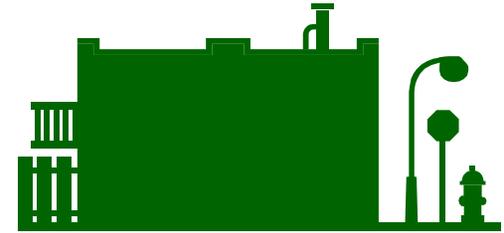
# Scope

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- Interior lighting requirements



# Scope



- Exterior lighting requirements

Mandatory Requirements  
Controls

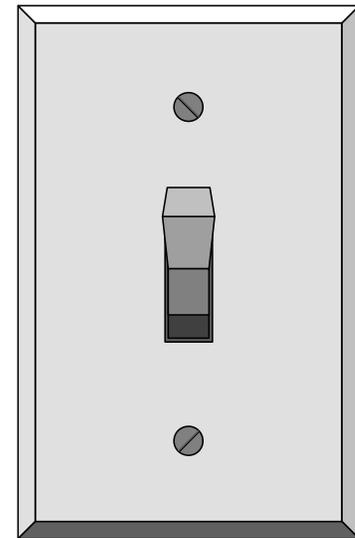
Exterior Lighting Requirements  
Energy Efficient Sources  
Use Limitations

# Independent Switching

*(Section 805.2.1)*

---

- Lighting controls required for each area enclosed by ceiling height partitions
- Switch locations
  - In view of lights
  - “On” or “off” indication from remote location
  - Occupancy sensor





# Independent Switching

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- Exceptions
  - Emergency/security lighting
  - Stairway or corridor lighting for egress

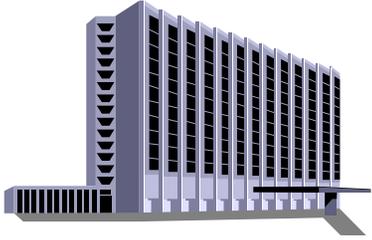


# Bi-Level Switching

*(Section 805.2.1.1)*

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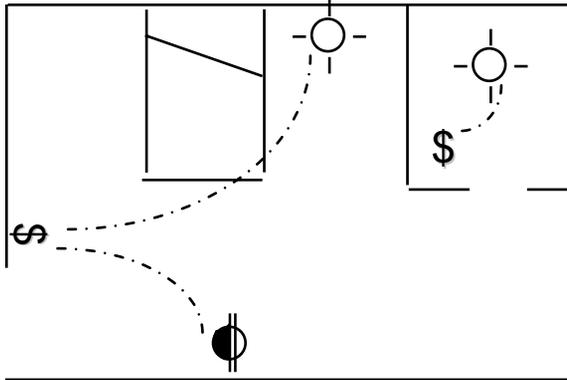
- Reduce connected lighting load uniformly by 50% for each space
- Exceptions
  - Area has one luminaire
  - Occupancy sensor controls area
  - Area is corridor, storage area, restroom, or main lobby



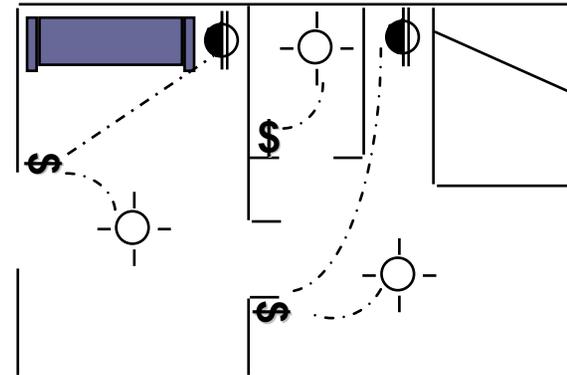
# Hotel/Motel Guest Room Switching

*(Section 805.2.1.2)*

- Master switch required at entry



Standard Room



Suite

# Exterior Lighting Controls

*(Section 805.2.2)*

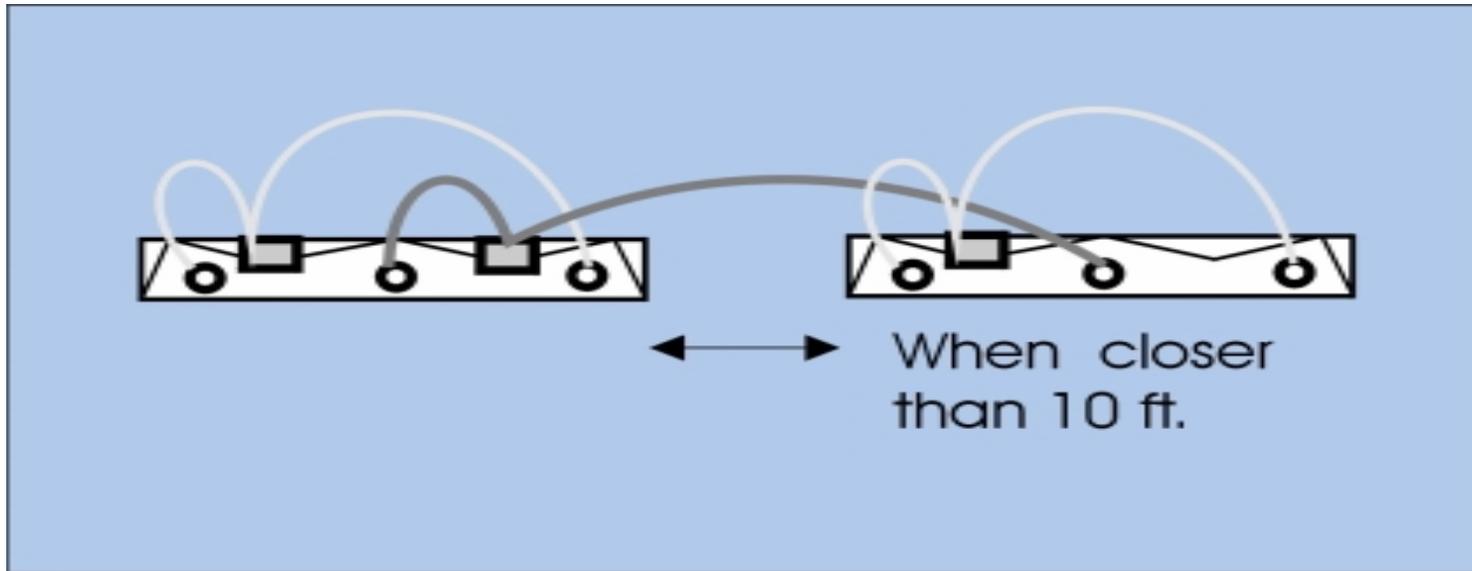
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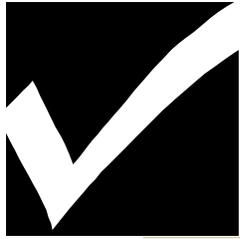
- Must be capable of automatically turning lights off when daylight is available
- Eligible controls
  - Directional photocell
  - Astronomical time switch
  - Building automation system with astronomical time switch capabilities
- Exceptions
  - Covered areas requiring illumination during daylight hours

# Tandem Wiring

*(Section 805.3)*

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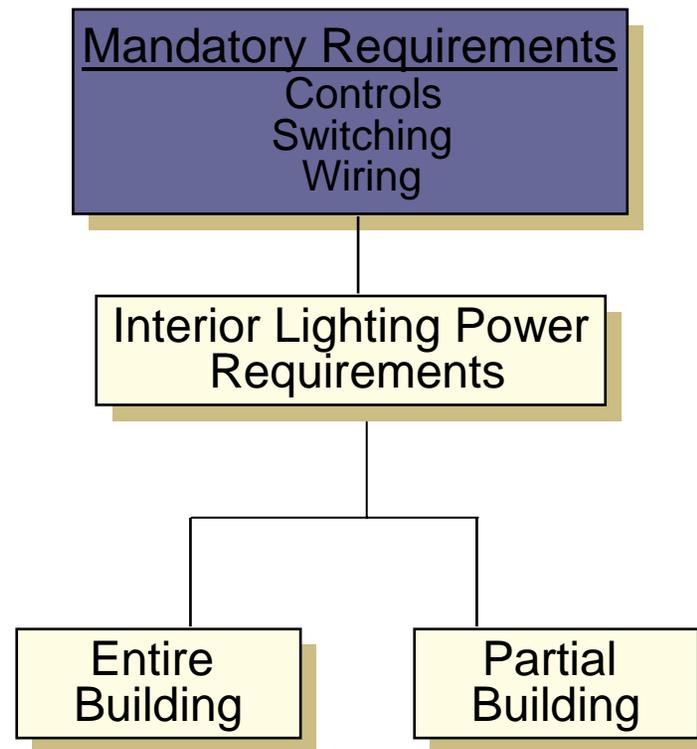
# Tandem Wiring

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- Exceptions
  - Luminaires with electronic high-frequency ballasts
  - Luminaires not on same switch controls or not in the same area

# Interior Lighting Requirements

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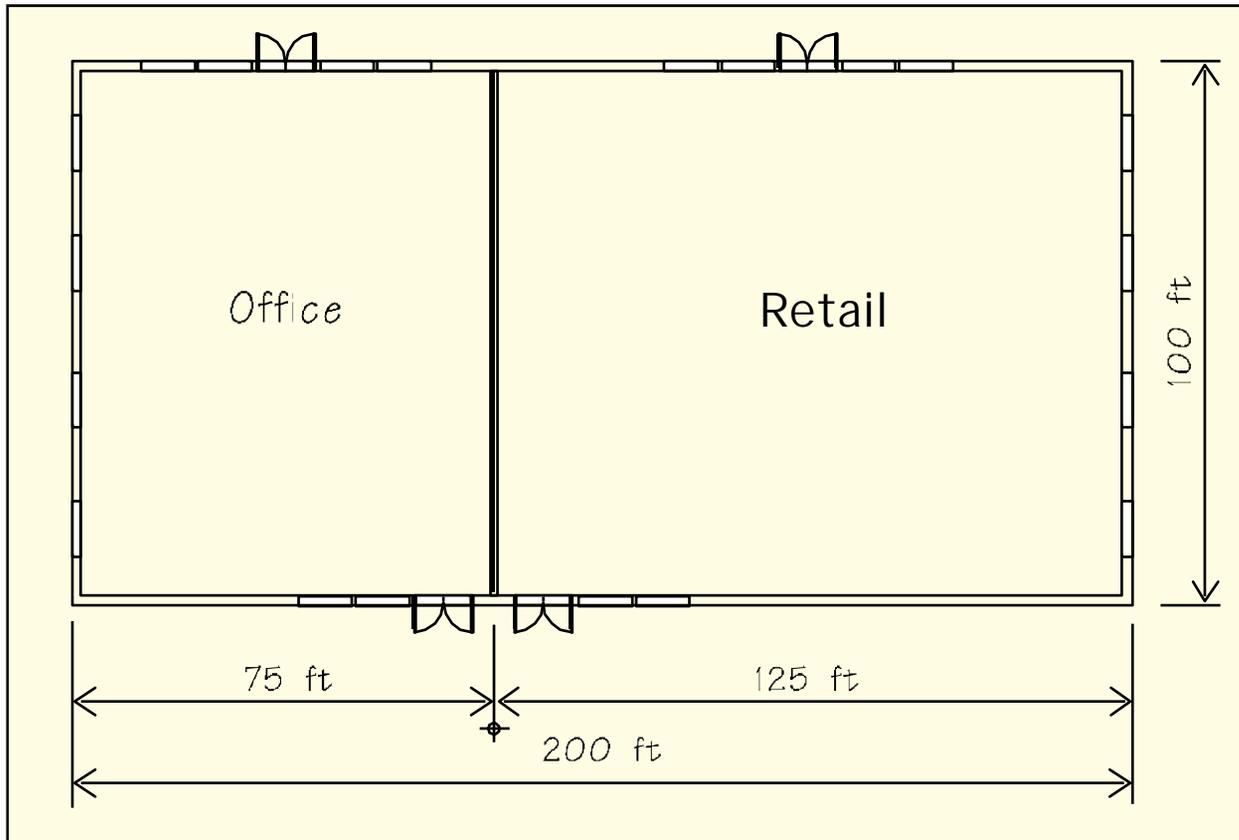
# Interior Lighting Power

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- Entire building
  - Building is all one occupancy or a majority occupancy exists (*Section 101.4.3*)
- Tenant area or portion of building
  - Use for tenant spaces in larger building or divide whole building into area types
- Table 805.4.2

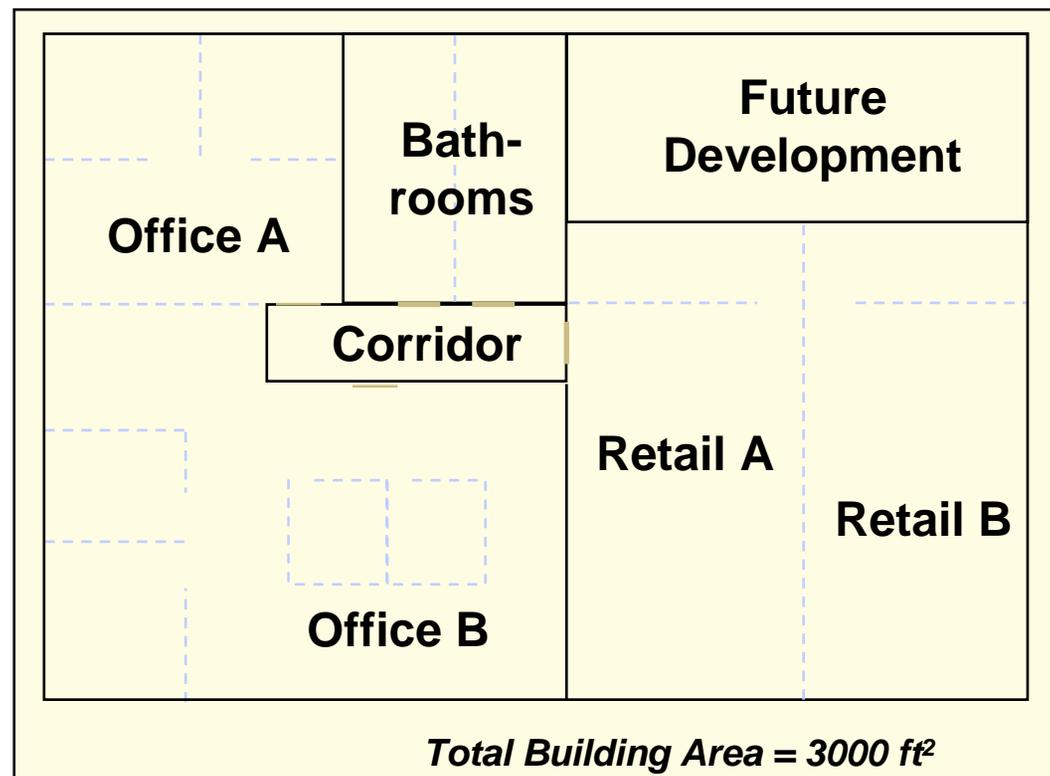
# What is the Interior Lighting Power Budget for this Building?

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# What is the Interior Lighting Power Budget for this Building?

<b>Office A:</b>	<b>400 ft<sup>2</sup></b>
<b>Office B:</b>	<b>850 ft<sup>2</sup></b>
<b>Bathrooms:</b>	<b>350 ft<sup>2</sup></b>
<b>Corridor:</b>	<b>50 ft<sup>2</sup></b>
<b>Retail A:</b>	<b>500 ft<sup>2</sup></b>
<b>Retail B:</b>	<b>500 ft<sup>2</sup></b>
<b>Future:</b>	<b>350 ft<sup>2</sup></b>



# Total Connected Power

---

- Total connected lighting wattage includes:
  - Lamp wattage
  - Ballast wattage
- Sources of bulb/ballast wattages
  - Manufacturer's literature
  - Industry default tables

# Does the Building Comply?

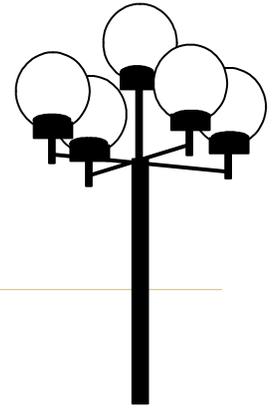
---

- Determine the total connected power in watts for the proposed lighting
- Determine the interior lighting power budget for the entire building or space
- Building complies if:
  - Interior lighting power budget - total connected power  $\geq 0$

# Exterior Lighting

*(Section 805.5)*

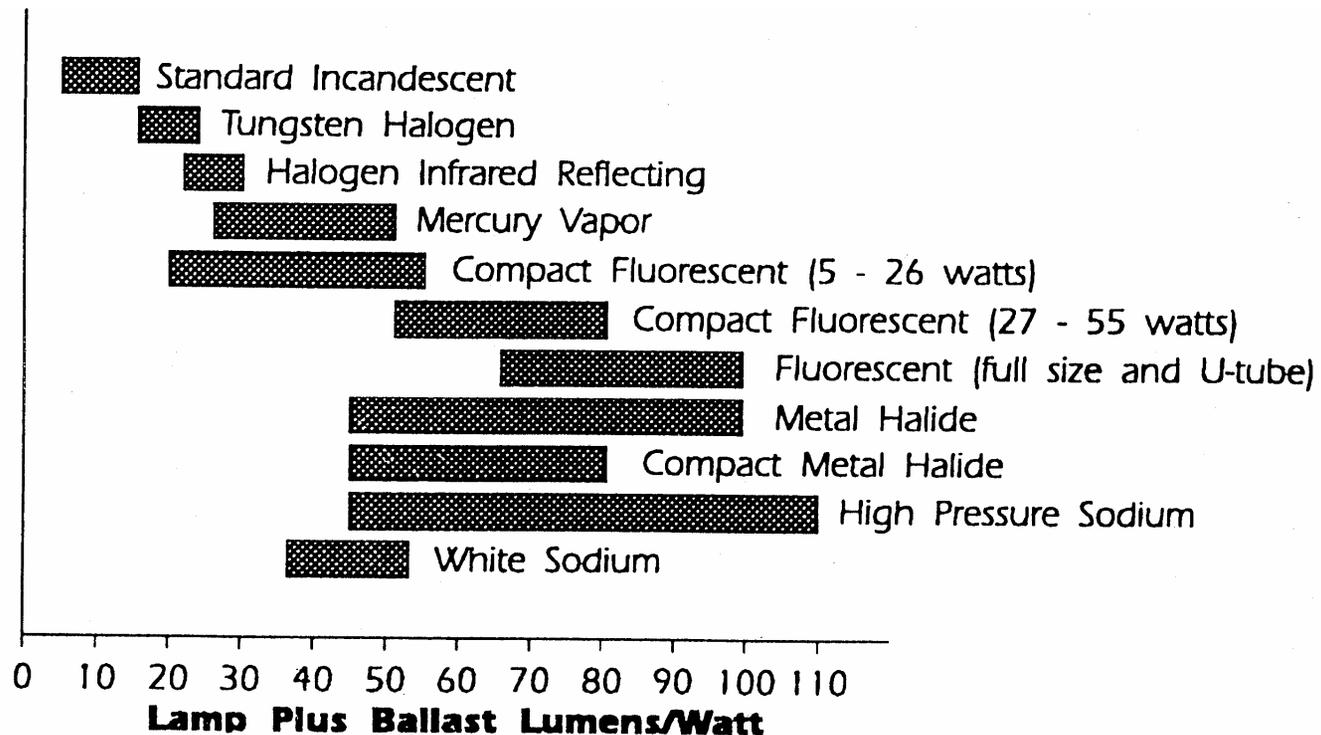
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- Criteria
  - Lighting power supplied through building electrical service
  - Must use energy-efficient lighting sources to highlight paths, walkways and parking areas
    - $\geq 45$  Lumens/Watt
    - Fluorescent
    - Compact Fluorescent
    - Metal Halide
    - High Pressure Sodium

# Energy-Efficient Lighting Sources

---



# Exterior Lighting

---

- Exceptions
  - Where approved because of the following considerations:
    - Historical
    - Safety
    - Signage
    - Emergency

# Electrical/Lighting

## Chapter 7 Scope

---

### **Chapter 8**

Section 805

### **Chapter 7**

Section 401

- Check metering
- Lighting control credits

# Electrical Power

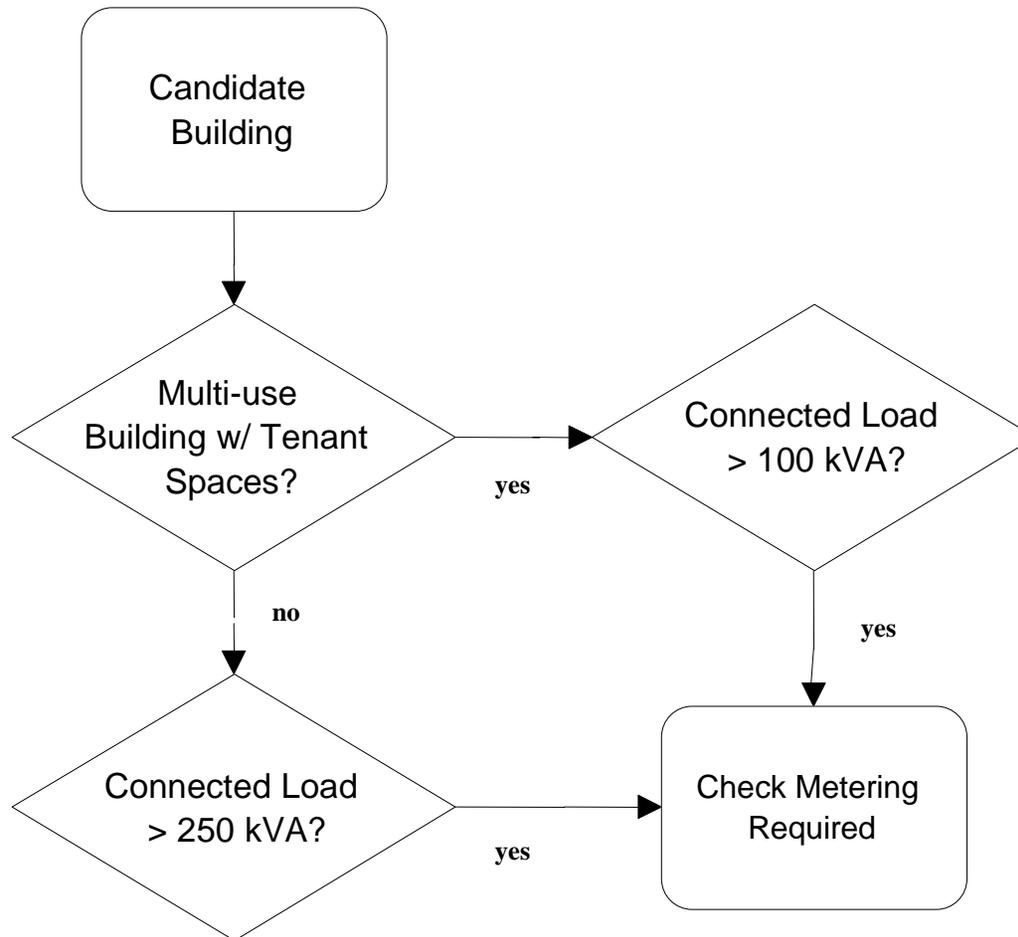
*(Section 401.1)*

---

- Check metering
- Minimum motor efficiency

# Check Metering

---



# Minimum Provisions for Check Metering

---

- Arrange electrical feeders so that a portable or permanent meter may be installed
- Not necessary to install meters or sensors

# Make Provisions to Check Meter Electricity Use

---

- By end-use (minimum)
  - HVAC
  - Lighting and receptacle
  - Other uses more than 20 kVA
- By tenant space (when  $> 100$  kVA)

# Intent of Check Metering

---

- Provide information that will enable intelligent energy management and monitoring

# Electric Motors

---

- **Minimum Motor Efficiency (*Section 401.2*)**

<b>Horsepower</b>	<b>Minimum Efficiency (%)</b>
1-4	78.5
5-9	84.0
10-19	85.5
20--49	88.5
50-99	90.2
100-124	91.7
125 or greater	92.4

# Electric Motors

---

- Exceptions
  - Multi-speed motors
  - Motors that are part of equipment meeting mechanical equipment requirements (most cases)
  - Less than 1 hp
  - Motors used 500 hours or less per year

# Electrical System Documentation to be Provided (Single-Line Diagram) (*Section 401.1.2*)

---

- Check-metering access locations
- Schematic diagrams non-HVAC control systems
- Operating and maintenance information
- Electrical Systems Summary form

# Exterior Lighting

*(Section 401.3.1)*

---

- Exterior Lighting Applies to
  - Building-mounted exterior lighting
  - Grounds, roads, parking lots, and other exterior lighting
  - Parking areas

# Exterior Lighting

---

- Exceptions for
  - Manufacturing, commercial greenhouses, and processing facilities
  - Sports lighting
  - Public monuments
  - Local code-required lighting
  - Lighting for designated high-risk security areas
  - Sign lighting
  - Lighting for retail storefronts
  - Exterior enclosed display windows

# Exterior Lighting Power Allowances

---

<b>Area Description</b>	<b>Allowance</b>
Exit (with or without canopy)	25 W/lin ft of door opening
Entrance (without canopy)	30 W/lin ft of door opening
Entrance (with canopy):	
High traffic (retail, hotel, airport, theater, etc)	10 W/ft <sup>2</sup> of canopy area
Light traffic (hospital, office, school, etc)	4 W/ft <sup>2</sup> of canopy area
Loading area	0.40 W/ft <sup>2</sup>
Loading door	20 W/lin ft of door opening
Building exterior surfaces/facades	0.25 W/ft <sup>2</sup> of surface area to be illuminated
Storage and non-manufacturing work areas	0.20 W/ft <sup>2</sup>
Other activity areas for casual use, such as picnic grounds, gardens, parks, and other landscaped areas	0.10 W/ft <sup>2</sup>
Private driveways/walkways	0.10 W/ft <sup>2</sup>
Public driveways/walkways	0.15 W/ft <sup>2</sup>
Private parking lots	0.12 W/ft <sup>2</sup>
Public parking lots	0.18 W/ft <sup>2</sup>

## Exterior Lighting

# Establishing Compliance

---

- Calculate exterior lighting power allowance (ELPA)
- Calculate the exterior connected lighting power (CLP)
- Complies if  $ELPA \geq CLP$

## Exterior Lighting Issues

---

- No trade-offs against interior lighting
- Multiple-building campus facilities (all one site) treated as one

Exterior Lighting

# Exterior Lighting Controls

*(Section 401.3.4.6)*

---

- Photocells or automatic timers required
- Seven-day electrically-driven, mechanical clocks with trippers, astronomical dial, and four-hour spring-wound storage
- Seven-day or calendar year, electronic programmable time switches with astronomic correction and battery backup
- Any of the timers above with a photocell (in place of astronomical correction)

# Interior Lighting Power

---

- Interior Lighting Power Approach (*Section 401.3.2*)
  - Code sets limits on Interior Lighting Power Allowance (ILPA)
    - Building space method
    - Specific space method
  - Credits are offered for qualifying automatic lighting controls
    - Programmable timing
    - Occupancy sensing
    - Daylighting
    - Lumen maintenance

Interior Lighting Power  
**What's Covered**

---

- All permanent and portable interior lighting intended for general, ambient, or task illumination

Interior Lighting Power  
**What's Exempt**

---

- Lighting used for theatrical, stage, broadcasting, and similar applications
- Specialized lighting equipment used for medical, dental, and research applications
- Exhibit display lighting for museums, monuments, and galleries
- Lighting used for indoor plant growth (when used between 10:00 p.m. and 6:00 a.m.)

Interior Lighting Power  
**What's Exempt** (*cont'd*)

---

- Emergency lighting that remains off during periods of normal building operation
- Lighting for designated high-risk security areas
- Lighting for use in specifically designed areas for the physically impaired or aged
- Lighting inside dwelling units

Interior Lighting Power  
**Building Space Method**  
*(Section 401.3.2.a)*

---

- Gross lighted area is multiplied by allowance from Table 401.3.2a
- Limitations
  - Insensitive to specific space functions and room configurations
  - Generally is more restrictive
  - Does not apply to all building types

Interior Lighting Power  
**Gross Lighted Area**

---

- Sum of total lighted area of a building measured from the inside surface of the perimeter exterior walls for each floor of the building
- Used in the building space method of determining *interior lighting power allowance* (ILPA)

# Interior Lighting Power Building Space Allowances

- Table 401.3.2a

<b>TABLE 401.3.2a</b> Interior Lighting Power Allowance, W/ft <sup>2</sup>						
Building Space Activity <sup>a, b</sup>	<i>Gross Lighted Area of Total Building</i>					
	0 to 2,000 ft <sup>2</sup>	2,001 to 10,000 ft <sup>2</sup>	10,001 to 25,000 ft <sup>2</sup>	25,001 to 50,000 ft <sup>2</sup>	50,001 to 250,000 ft <sup>2</sup>	> 250,000 ft <sup>2</sup>
Food Service:						
Fast Food/Cafeteria	1.50	1.38	1.34	1.32	1.31	1.30
Leisure Dining/Bar	2.20	1.91	1.71	1.56	1.46	1.40
Offices	1.90	1.81	1.72	1.65	1.57	1.50
Retail <sup>c</sup>	3.30	3.08	2.83	2.50	2.28	2.10
Mall Concourse						
Multi-store Service	1.60	1.58	1.52	1.46	1.43	1.40
Service Establishment	2.70	2.37	2.08	1.92	1.80	1.70
Garages	0.30	0.28	0.24	0.22	0.21	0.20
Schools:						
Preschool/Elementary	1.80	1.80	1.72	1.65	1.57	1.50
Jr.High/High School	1.90	1.90	1.88	1.83	1.76	1.70
Technical/Vocational	2.40	2.33	2.17	2.01	1.84	1.70
Warehouse/Storage	0.80	0.66	0.56	0.48	0.43	0.40

Notes:

<sup>a</sup>If at least 10% of the building area is intended for multiple space activities, such as parking, retail, and storage in an office building, then calculate for each separate building type/space activity.

<sup>b</sup>The values in the categories are building-wide allowances which include the listed activity and directly related facilities such as conference rooms, lobbies, corridors, restrooms, etc.

<sup>c</sup>Includes general, merchandising, and display lighting.

Interior Lighting Power  
**Multi-Use Buildings**  
*(Section 401.3.2)*

---

- Use gross lighted area for the whole building (choose column)
- Look up allowance separately for each use
- Use primary use for whole building if more than 90% of area

Interior Lighting Power  
**Specific Space Method**

---

- $LPB = A \times UPD \times AF$
- Where
  - A = area of specific space
  - UPD = unit power density from Tables 401.3.2b, c and d
  - AF = area factor
  - LPB = lighting power budget
- LPB calculated for each space and summed for the building
- Advantages
  - More flexibility
  - Applicability to all building types
  - Accounts for room geometry

Interior Lighting Power  
**Unlisted Spaces**

---

- A catch-all for all spaces not listed in Tables 401.3.2b, c and d
- General allotment of 0.2 W/ft<sup>2</sup>

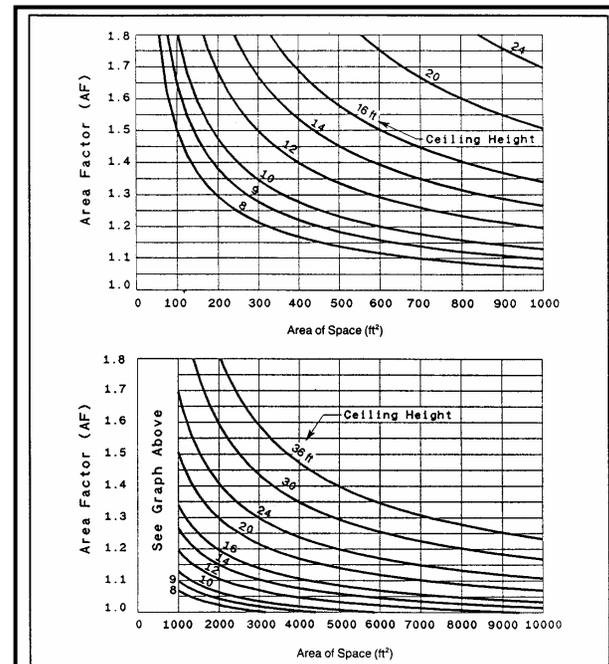
Interior Lighting Power  
**Area Factor**

---

- Accounts for the effect of room geometry
- Value between 1.0 and 1.8
- Certain spaces have fixed values and are so noted in UPD tables

# Interior Lighting Power Area Factor *(cont'd)*

- Figure 401.3.2e



*Figure 401.3.2e Area Factor*

**Area Factor Formula:**

$$\text{Area Factor (AF)} = 0.2 + 0.8 (1/0.9^n)$$

$$\text{where } n = \frac{10.21 (CH - 2.5)}{\sqrt{A_r}} - 1$$

AF = area factor,  
CH = ceiling height (ft),  
A<sub>r</sub> = room area (ft<sup>2</sup>).

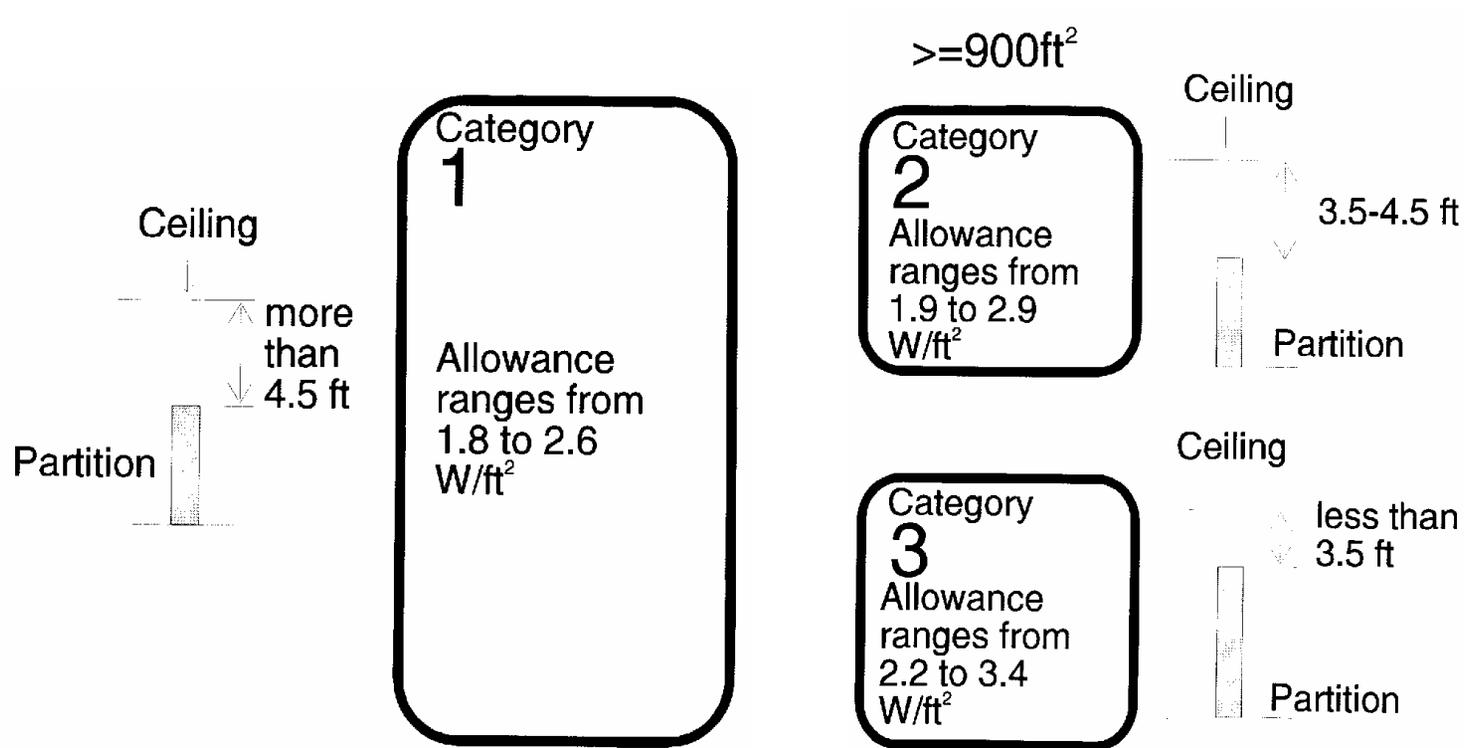
If AF < 1.0 use 1.0; if AF > 1.8 use 1.8.

Interior Lighting Power  
**Organization of UPD Tables**

---

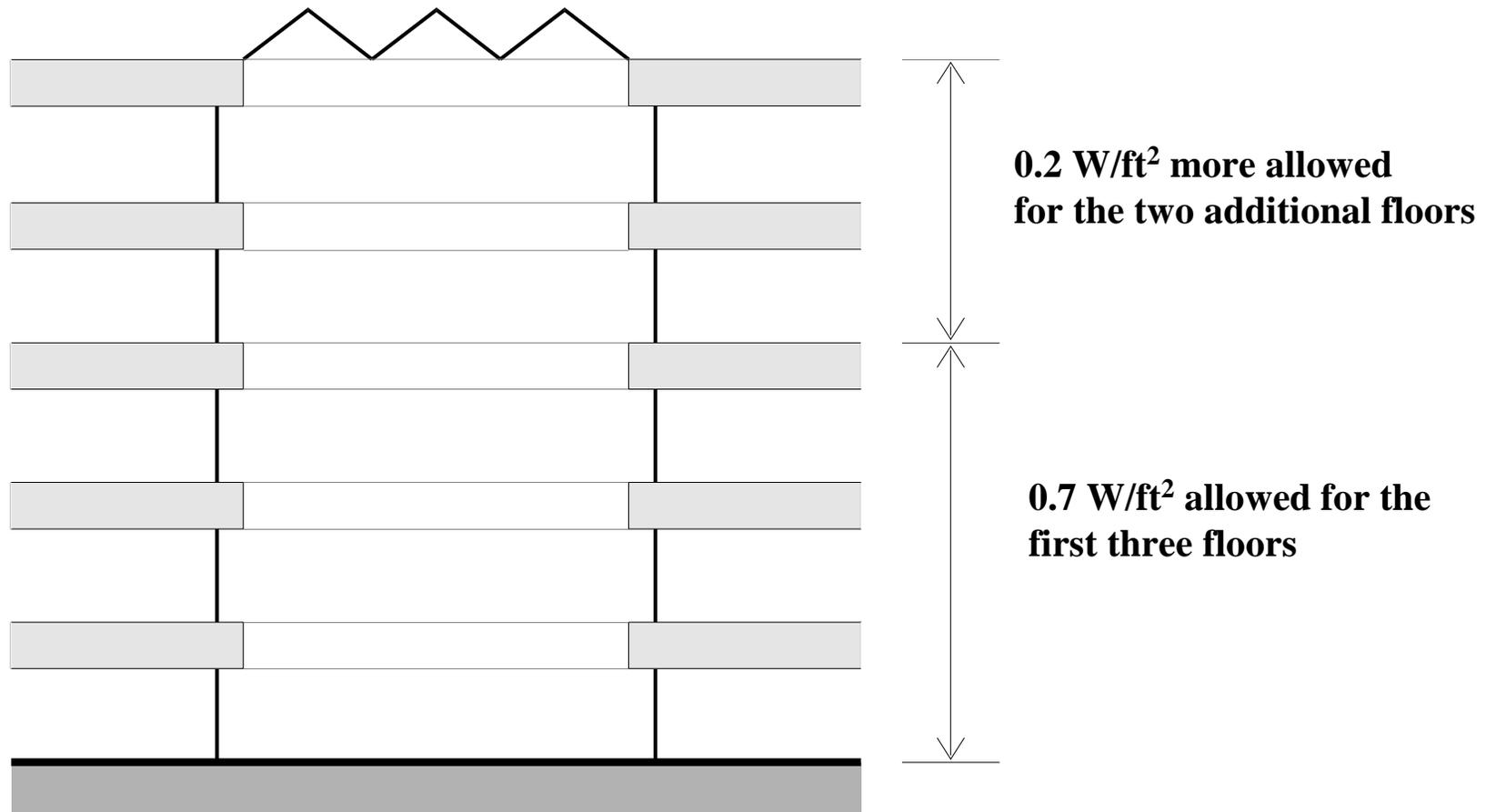
- Table 401.3.2b - Common activities for all building types
- Table 401.3.2c - Specific spaces in specific building types
- Table 401.3.2d - Indoor athletic spaces

# Interior Lighting Power Office Categories



# Interior Lighting Power Atrium Allowance

---



## Interior Lighting Power Special Cases

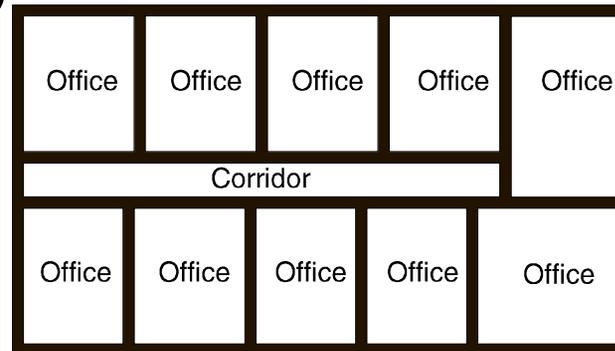
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- Simultaneous activities
  - Use weighted average
- Multi-function rooms and supplementary lighting systems
  - 50% increase in lighting power
  - Supplementary system must be independently controlled
  - Must not represent more than 33% of the ALP

## Interior Lighting Power Example

---

- Question: A project consists of the following:
  - 10 similar private offices ranging from 10ft by 12ft to 10ft by 14ft in size and totaling 1,350 ft<sup>2</sup> (average size 135 ft<sup>2</sup>)
  - 150 ft<sup>2</sup> corridor
  - 9ft ceilings
  - What is the ILPA?



# Connected Lighting Power

---

- Determine power for each luminaire type
  - Default tables, or
  - Manufacturer's literature
- Count luminaires of each type
- Combine data for building level connected lighting power
- Documentation

Connected Lighting Power

# Adjustment Controls for Automatic Lighting Controls (*Section 401.3.3*)

---

- Not required if building already complies
- Credits for:
  - Daylighting sensing
  - Lumen maintenance
  - Programmable timers
  - Occupant sensors
  - Combinations of above

Connected Lighting Power  
**Adjusted Lighted Power**

---

- $ALP = CLP (1 - LPCC)$
- Where
  - ALP = adjusted lighting power
  - CLP = connected lighting power
  - LPCC = lighting power control credit

# Lighting Power Control Credits

- Table 401.3.3

TABLE 401.3.3 Lighting Power Adjustment Factors	
Automatic Control Devices	PAF
(1) <i>Daylight sensing controls (DS)</i> , continuous dimming	0.30
(2) DS, multiple step dimming	0.20
(3) DS, ON/OFF	0.10
(4) DS continuous dimming and <i>programmable</i> timing	0.35
(5) DS multiple-step dimming and <i>programmable</i> timing	0.25
(6) DS ON/OFF and <i>programmable</i> timing	0.15
(7) DS continuous dimming, <i>programmable</i> timing, and <i>lumen maintenance</i>	0.40
(8) DS multiple-step dimming, <i>programmable</i> timing, and <i>lumen maintenance</i>	0.30
(9) DS ON/OFF, <i>programmable</i> timing, and <i>lumen maintenance</i>	0.20
(10) <i>Lumen maintenance control</i>	0.10
(11) <i>Lumen maintenance</i> and <i>programmable</i> timing control	0.15
(12) <i>Programmable</i> timing control	0.15
(13) <i>Occupancy sensor (OS)</i>	0.30
(14) OS and DS, continuous dimming	0.40
(15) OS and DS, multiple-step dimming	0.35
(16) OS and DS, ON/OFF	0.35
(17) OS, DS continuous dimming, and <i>lumen maintenance</i>	0.45
(18) OS, DS multiple-step dimming, and <i>lumen maintenance</i>	0.40
(19) OS, DS ON/OFF, and <i>lumen maintenance</i>	0.35
(20) OS and <i>lumen maintenance</i>	0.35
(21) OS and <i>programmable</i> timing control	0.35

**401.3.4 Lighting Controls**

**401.3.4.1 Type of Lighting Controls** All lighting systems shall have controls.

**Exception:** *Emergency use* or exit lighting.

**401.3.4.2 Number of Manual Controls** Spaces enclosed by walls or ceiling-high partitions shall have a minimum of one *manual* control (on/off switch) for lighting in that space. Additional *manual* controls shall be provided for each *task location* or for each group of *task locations* within an area of 450 ft<sup>2</sup> or less. For spaces with only one lighting fixture or with a single ballast, one *manual* control is required.

**Exceptions:**

- (1) Continuous lighting for security.
- (2) Systems in which *occupancy sensors*, local *programmable* timers, or three-level (including OFF) step controls or preset dimming controls are substituted for *manual* controls at the "exchange rate"

# LTGSTD

---

- Application
  - Calculates interior lighting power allowance (ILPA)
    - Building space method
    - Specific space method
  - Calculates exterior lighting power allowance (ELPA)
  - Verifies the required number of manual controls

# LTGSTD

---

- Must Still Calculate
  - Connected lighting power
    - Interior
    - Exterior
  - Adjusted lighting power

Lighting Controls  
**Interior Lighting Systems**  
*(Section 401.3.4)*

---

- Manual, automatic, or programmable lighting controls required for each lighting system
- Exception for emergency or exit lighting
- Circuit breakers and/or fuses do not qualify as control devices

Lighting Controls  
**Control Accessibility**

---

- Controls shall be readily accessible to personnel using the space
- Exceptions
  - Spaces that must be used as a whole
  - Programmable controls
  - Controls requiring trained operators
  - Lighting required for safety or security

## Lighting Controls

# Minimum Number of Manual Controls

---

- One for each space enclosed by walls or ceiling height partitions
- Additional control for each visual task in the space or group or visual task locations of 450 ft<sup>2</sup> in area, whichever is less
- Minimum of one manual control for each 1,500 ft<sup>2</sup>
- Round up to nearest whole number
- Exceptions
  - Spaces that must be used as a whole
  - 24-hour security lighting

Lighting Controls  
**Task Location**

---

- An area in a space where significant visual functions are performed and where lighting is required above that required for general ambient use

## Lighting Controls

# Spaces that Must be Used as a Whole

---

- Public lobbies of offices, hospitals, and hotels
- Retail and department stores
- Warehouses
- Storerooms
- Corridors

Lighting Controls  
**Exchange Rates for Manual Controls**

---

<b>Type of Control</b>	<b>Equivalent No. of Manual Controls</b>
Manually operated on-off switch	1
Occupancy Sensor	2
Timer (programmable from the controlled space)	2
Three-level, including off, step control or preset dimming	2
Four-level, including off, step control or preset dimming	3
Automatic or continuous dimming	3

## Lighting Controls

# Required Number of Lighting Controls

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- See page 401-40 (Figure 401D) of Code Compliance Manual

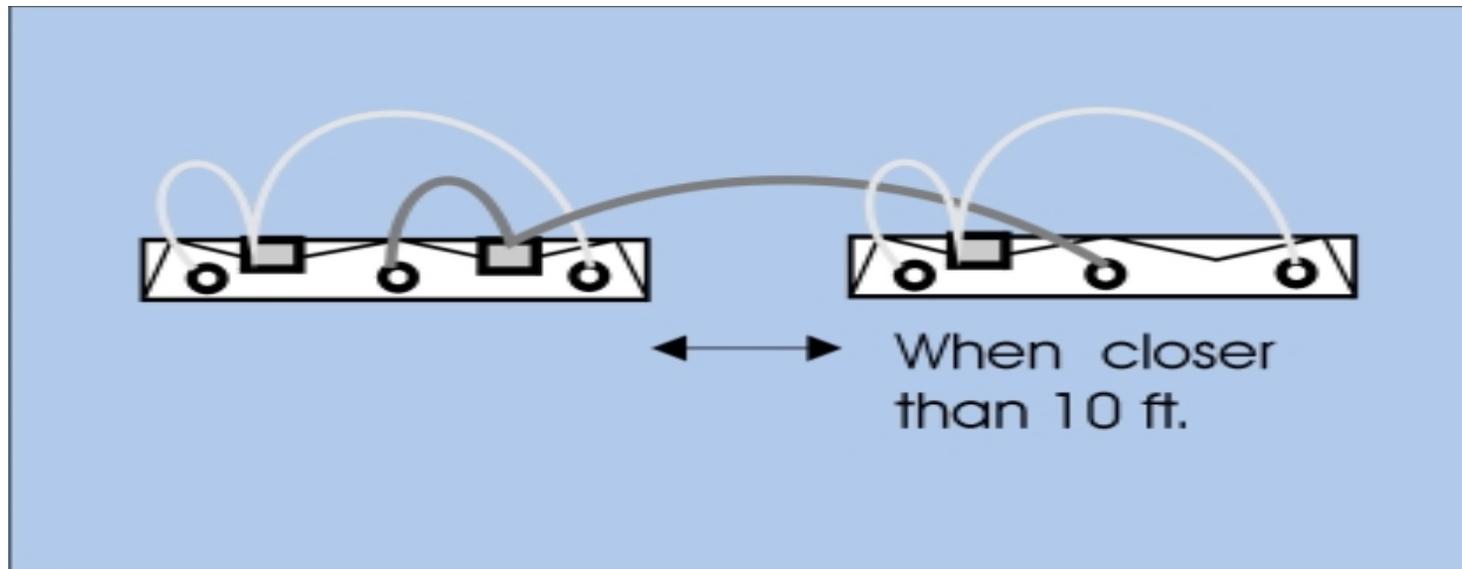
# Lamp Ballasts

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- Power Factor of at Least 90% (Section 401.3.5)
  - Exceptions
    - Dimming ballasts
    - Ballasts for circline fluorescent lamps
    - Compact fluorescent lamp ballasts
    - Ballasts for low-wattage (100 watts) HID lamps
  - Electronic ballasts recommended

# Tandem Wiring

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# Where to Get More Information

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- Other training sessions
- *COMcheck-EZ*<sup>TM</sup>
- List books, articles, electronic sources
  - [www.energycodes.org](http://www.energycodes.org)
  - [www.boca.org](http://www.boca.org)
  - [www.icbo.org](http://www.icbo.org)
  - [www.sbcci.org](http://www.sbcci.org)
  - Hotline: 1-800-270-CODE