

90.1-2004: An Overview of the Building Envelope Requirements
June 14, 2007

Building Envelope Chapter & Appendices – slide 3

- Chapter 5: Building Envelope
- Appendix A: Rated R-value of Insulation and Assembly U-factor, C-factor, and F-factor Determinations
- Appendix B: Building Envelope Climate Criteria
- Appendix C: Methodology for Building Envelope Trade-off Option in Subsection 5.6
- Appendix D: Climatic Data
- Appendix F: Addenda Description Information
- Appendix G: Performance Rating Method

Chapter 5: Building Envelope (outline) – slide 4

- 5.1: General
- 5.2: Compliance Paths
- 5.3: *(not used in this chapter)*
- 5.4: Mandatory Provisions
- 5.5: Prescriptive Building Envelope Option
- 5.6: Building Envelope Trade-Off Option
- 5.7: Submittals
- 5.8: Product Information and Installation Requirements

Space-Conditioning Categories (§5.1.2) – slide 5

- 5.1.2.1(a) nonresidential conditioned space:
“all occupancies other than residential”
- (b) residential conditioned space:
“spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations”
- (c) semi-heated space:
“heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft² of floor area but is not a conditioned space”

Space-Conditioning Definition – slide 6

- Conditioned space:
“a cooled space, heated space, or indirectly conditioned space defined as follows:
 - cooled space: an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 5 Btu/h·ft² of floor area
 - heated space: an enclosed space within a building that is heated by a heating

system whose output capacity relative to the floor area is greater than or equal to the criteria in Table 3.1”

- Comment:
 - “conditioned” does not mean air-conditioned, it includes heated-only spaces
 - very few spaces qualify as semiheated

Space-Conditioning Categories (§5.1.2) – slide 7

- 5.1.2.2: Assumption of conditioned space:

“Spaces shall be assumed to be conditioned space and shall comply with the requirements for conditioned space at the time of construction, regardless of whether mechanical or electrical equipment is included in the building permit application or installed at that time.”

except “...if approved by the building official”
- - meant to address problem of non-compliance in speculative buildings like warehouses where owners want to pass cost to tenants and it is more expensive to insulate later
 - example exception would be lumber storage

Climate (§5.1.4) continued – slide 8

- 5.1.4.1: United States locations:
 - Use Figure B-1 or Table B-1 in Appendix B to determine the required climate zone (climate zones are specified by county)
- 5.1.4.2: Canada and international locations:
 - For Canada, use Table B-2 in Appendix B,
 - For international, use Table B-3,
 - For locations not listed, use Table B-4
- ***Later examples show the criteria for nonresidential uses in Climate Zone 5: Boston, Pittsburgh, Chicago, Omaha, Denver, Flagstaff, Reno, Vancouver BC.***

Climate Zones and Climatic Data, Normative Appendices B and D – slide 9

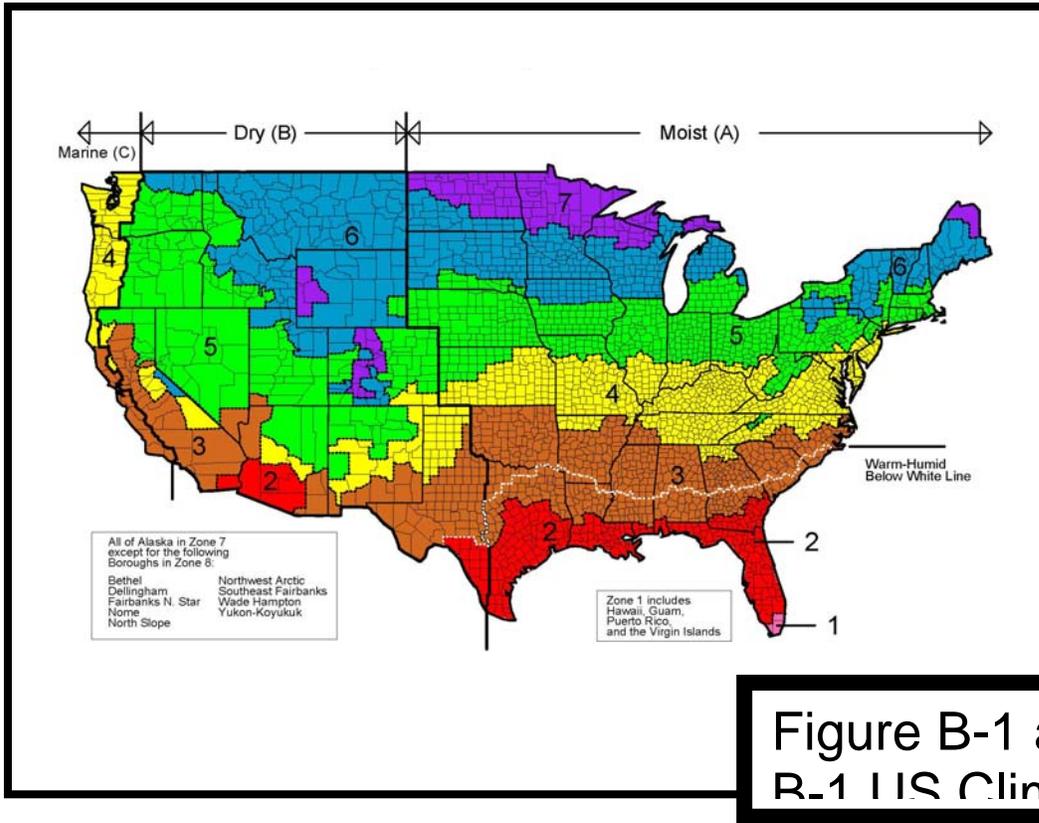


Figure B-1 and Table R-1 IIS Climate Zones

Mandatory Provisions (§5.4) – slide 10

- Insulation (§5.4.1, 5.8.1)
to be discussed with Prescriptive Option
- Fenestration and Doors (§5.4.2, 5.8.2)
to be discussed with Prescriptive Option
- Air Leakage (§5.4.3)
- **Note: Standard 90.1 and LEED require compliance with these mandatory provisions regardless of how energy-efficient the building is or how great the energy savings are.**

Air Leakage (§5.4.3) – slide 11

- Building Envelope Sealing (§5.4.3.1)
- seal, caulk, gasket, weatherstrip all openings
- Fenestration and Doors (§5.4.3.2)
- air leakage < 1.0 cfm/ft² for glazed swinging doors & revolving doors, < 0.4 cfm/ft² for others
- Loading Dock Weatherseals (§5.4.3.3)
- in CZ 4-8 to limit leakage when truck parked

- Vestibules (§5.4.3.4)
 - for entrances in bldgs > 4 stories in CZ 3-8
 - exceptions for small spaces, revolving doors
 (Note: Criteria are more stringent in 90.1-2007.)

Prescriptive Option (§5.5) – slide 12

- Opaque assemblies (§5.5.3)
 - roofs (3 categories)
 - walls, above grade (4 categories)
 - walls, below grade (1 category)
 - floors (3 categories)
 - slab-on-grade floors (2 categories)
 - opaque doors (2 categories)
- Fenestration (§5.5.4)
 - vertical glazing (2 categories)
 - (4 different categories in 90.1-2007)
 - skylights (3 categories)

Opaque Assemblies (§5.5.3) – slide 13

- Two compliance options (§5.5.3)
- R-value of insulation alone:
 - “R-values of insulation for the thermal resistance of the added insulation in framing cavities and continuous insulation only”
 - does not include air films or building materials
 - sometimes only continuous insulation (ci)
- U-factor, C-factor, or F-factor for the entire assembly:
 - “The values ... listed in Normative Appendix A shall be used to determine compliance”

Opaque Assemblies (§5.5.3) – slide 14

**TABLE 5.5-5
Building Envelope Requirements For Climate Zone 5 (A,B,C)**

	Nonresidential		Residential		Semiheated	
	Assembly	Insulation Min.	Assembly	Insulation Min.	Assembly	Insulation Min.
Opaque Elements	Maximum	R-Value	Maximum	R-Value	Maximum	R-Value
<i>Roofs</i>						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.173	R-5.0 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.053	R-19.0
<i>Walls, Above Grade</i>						
Mass	U-0.123	R-7.6 ci	U-0.090	R-11.4 ci	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
Steel Framed	U-0.08	R-13.0 + R-3.8 ci	U-0.064	R-13.0 + R-7.5 ci	U-0.124	R-13.0
Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
<i>Wall, Below Grade</i>						
Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
<i>Floors</i>						
Mass	U-0.087	R-8.3 ci	U-0.074	R-10.4 ci	U-0.322	NR
Steel Joist	U-0.052	R-19.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
<i>Slab-On-Grade Floors</i>						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.840	R-10 for 36 in.	F-0.840	R-10 for 36 in.	F-1.020	R-7.5 for 12 in.
<i>Opaque Doors</i>						
Swinging	U-0.700		U-0.700		U-0.700	
Non-Swinging	U-1.450		U-0.500		U-1.450	

Opaque Roofs (§5.5.3.1) – slide 15

- Roof w/ insulation above deck:
“all insulation installed above (outside of) the roof structure and continuous”

Climate Zone 5
2004: R-15 ci, U-0.063
2007: R-20 ci, U-0.048

- Comments:
 - insulation R-value is a minimum for all locations, not acceptable to “average” R-values for tapered insulation
 - assembly U-factors in Appendix A Table A2.2
 - exception allows reduction for cool roof

Opaque Roofs (§5.5.3.1) – slide 16

- Metal building roof:
“metal, structural, weathering surface, no ventilated cavity, steel framing members”

Climate Zone 5
2004: R-19, U-0.065
2007: addendum under review

- Comments:
 - exception to 5.8.1.2 allows metal building insulation to be compressed between roof skin and structure
 - assembly U-factors in Appendix A Table A2.3
 - exception allows reduction for cool roof

Opaque Roofs (§5.5.3.1) – slide 17

- Attic and all other roofs:
“all other roofs”
- Comments:
 - 5.8.1.8 prohibits installing roof insulation on suspended ceiling with removable ceiling tiles
 - 5.8.1.6 prohibits recessing light fixtures into insulation unless area is < 1%
 - 5.8.1.4 requires baffles around eave vents
 - assembly U-factors in Appendix A in Tables A2.4 for wood joists, A2.5 for steel joists
 - possible reduction for single-rafter roofs

Climate Zone 5

2004: R-30, U-0.034

2007: R-38, U-0.027

Opaque Walls Above Grade (§5.5.3.2) – slide 18

- Wall above grade, mass:
“with a heat capacity exceeding 7 Btu/ft²·°F or a material unit weight of 5 Btu/ft²·°F if < 120 lb/ft³”
- Comments:
 - “ci” (§3.2 definitions) means insulation must be “continuous across all structural members without thermal bridges other than fasteners”
 - if metal or wood studs, then must use U-factor
 - assembly U-factors in Appendix A Table A3.1A
 - heat capacity in A3.1B, A3.1C, option in A3.1D

Climate Zone 5

2004: R-7.6 ci, U-0.123

2007: R-11.4 ci, U-0.090

Opaque Walls Above Grade (§5.5.3.2) – slide 19

- Wall above grade, metal building:
“metal spanning members supported by steel structural”
- Comments:
 - exception to 5.8.1.2 allows metal building insulation to be compressed between wall skin and structure
 - assembly U-factors in Appendix A Table A3.2

Climate Zone 5

2004: R-13, U-0.113

2007: addendum under review

Opaque Walls Above Grade (§5.5.3.2) – slide 20

- Wall above grade, steel-framed:
“typical steel stud walls and curtain wall systems”
- Comments:
 - cavity insulation must also be accompanied by continuous insulation due to thermal bridging
 - assembly U-factors in Appendix A Table A3.3
 - Table A9.2B shows that R-13 insulation only achieves an effective R-6.0 in metal studs
(R-19 in 6” stud only achieves R-7.1)

Climate Zone 5

2004: R-13 + R-3.8 ci,
U-0.084

2007: R-13 + R-7.5 ci,
U-0.064

Opaque Walls Above Grade (§5.5.3.2) – slide 21

- Wall above grade, wood-framed:
“all other wall types, including wood stud walls”
- Comments:
 - while wood studs perform better thermally than s
 - still beneficial
 - assembly U-factors in Appendix A Table A3.4
 - compressing insulation reduces R-value, Table A9.4C shows that R-19 insulation only has an effective R-13 when forced into 4” studs

Climate Zone 5

2004: R-13, U-0.089

2007: R-13 + R-3.8 ci,
U-0.064

Opaque Walls Above Grade (§5.5.3.3) – slide 22

- Wall below grade:
“that portion of a wall ...that is entirely below the finish grade and in contact with the ground”
- Comments:
 - insulation must be continuous across the wall
 - if metal or wood studs, then must use C-factor
 - assembly C-factors in Appendix A Table A4.2
(C-factor does not include R-values for exterior or interior air films or for soil)

Climate Zone 5

2004: NR, C-1.140

2007: R-7.5 ci, C-0.119

Opaque Floors (§5.5.3.4) – slide 23

- Mass floor:
“with a heat capacity exceeding 7 Btu/ft²·°F or a material unit weight of 5 Btu/ft²·°F if < 120 lb/ft³”
- Comments:
 - waffle-slab floors shall be insulated either on the interior above the slab or on all exposed surfaces of the waffle (A5.2.2.3)
 - similar for concrete beams (A5.2.2.4)
 - assembly U-factors in Appendix A Table A5.2

Climate Zone 5

2004: R-8.3 ci, U-0.087

2007: R-10.4 ci, U-0.074

Opaque Floors (§5.5.3.4) – slide 24

- Steel joist floors:
“steel joist members supported by structural members”
- Comments:
 - 5.8.1.5 requires floor insulation be installed
“in substantial contact with the inside surface”
 - assembly U-factors in Appendix A Table A5.3
 - Table A9.2A shows that R-30 insulation only achieves an effective R-23.7 when installed between metal framing 4 feet on center

Climate Zone 5

2004: R-19, U-0.052

2007: R-30, U-0.038

Opaque Floors (§5.5.3.4) – slide 25

- Wood framed and other floors:
“all other floor types, including wood joist floors”
- Comments:
 - 5.8.1.5 requires floor insulation have
“supports no greater than 24 in. on center”
 - assembly U-factors in Appendix A Table A5.4

Climate Zone 5
2004: R-30, U-0.033
2007: same

Opaque Slab-on-Grade (§5.5.3.5) – slide 26

Slab-on-grade floor:

“a slab floor...in contact with the ground and that is either above grade or is \leq 24 in. below the final elevation of the nearest exterior grade”

- Unheated slab-on-grade floor:
“a slab-on-grade that is not a heated slab-on-grade floor”
- Heated slab-on-grade floor:
“a slab-on-grade with a heating source either within or below it”

Climate Zone 5
2004: NR, F-0.730
2007: same

Climate Zone 5
2004: R-10 for 36 inches
F-0.840
2007: R-15 for 24 inches
F-0.860

Opaque Door (§5.5.3.6) – slide 27

Door:

“all operable opening areas (which are not fenestration) ...including swinging and roll-up doors, fire doors, and access hatches. Doors...more than one-half glass are... fenestration.”

- Swinging:
“all operable opaque panels with hinges on one side and opaque revolving doors”
- Non-swinging:
“roll-up, sliding, and...doors that are not swinging doors”

Climate Zone 5
2004: U-0.700
2007: same

Climate Zone 5
2004: U-1.450
2007: U-0.500

Fenestration (§5.5.4) – slide 28

	Assembly	Assembly Max.	Assembly	Assembly Max.	Assembly	Assembly Max.
	Max. U	SHGC (All	Max. U	SHGC (All	Max. U	SHGC (All
	(Fixed/	Orientations/	(Fixed/	Orientations/	(Fixed/	Orientations/
	Operable)	North-Oriented)	Operable)	North-Oriented)	Operable	North-Oriented)
<i>Vertical Glazing, % of Wall</i>						
0-10.0%	U ^{fixed} -0.37	SHGC ^{all} -0.49	U ^{fixed} -0.37	SHGC ^{all} -0.49	U ^{fixed} -1.22	SHGC ^{all} -NR
	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -1.27	SHGC ^{north} -NR
10.1-20.0%	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -1.22	SHGC ^{all} -NR
	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -1.27	SHGC ^{north} -NR
20.1-30.0%	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -1.22	SHGC ^{all} -NR
	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -1.27	SHGC ^{north} -NR
30.1-40.0%	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -0.37	SHGC ^{all} -0.39	U ^{fixed} -1.22	SHGC ^{all} -NR
	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -0.43	SHGC ^{north} -0.49	U ^{oper} -1.27	SHGC ^{north} -NR
40.1-50.0%	U^{fixed}-0.46	SHGC^{all}-0.25	U^{fixed}-0.46	SHGC^{all}-0.25	U^{fixed}-0.98	SHGC^{all}-NR
<i>Skylight with Curb, Glass, % of Roof</i>						
0-2.0%	U ^{all} -1.17	SHGC ^{all} -0.49	U ^{all} -1.17	SHGC ^{all} -0.49	U ^{all} -1.58	SHGC ^{all} -NR
2.1-5.0%	U ^{all} -1.17	SHGC ^{all} -0.39	U ^{all} -1.17	SHGC ^{all} -0.39	U ^{all} -1.58	SHGC ^{all} -NR
<i>Skylight with Curb, Plastic, % of Roof</i>						
0-2.0%	U ^{all} -1.10	SHGC ^{all} -0.77	U ^{all} -1.10	SHGC ^{all} -0.77	U ^{all} -1.50	SHGC ^{all} -NR
2.1-5.0%	U ^{all} -1.10	SHGC ^{all} -0.62	U ^{all} -1.10	SHGC ^{all} -0.62	U ^{all} -1.50	SHGC ^{all} -NR
<i>Skylight without Curb, All, % of Roof</i>						
0-2.0%	U ^{all} -0.66	SHGC ^{all} -0.49	U ^{all} -0.66	SHGC ^{all} -0.49	U ^{all} -1.56	SHGC ^{all} -NR
2.1-5.0%	U ^{all} -0.66	SHGC ^{all} -0.39	U ^{all} -0.66	SHGC ^{all} -0.39	U ^{all} -1.56	SHGC ^{all} -NR

Fenestration Definition (§3.2) – slide 29

- **Fenestration:**
“all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls”
- **Comments:**
- if it is not insulated roof, wall, or floor, then it is fenestration

Fenestration Ratings (§5.8.2) – slide 30

- **U-factor** (§5.8.2.4)
“U-factors shall be determined in accordance with NFRC 100.
U-factors for skylights shall be determined for a slope of 20 degrees above the horizontal.”
- **Comments:**
- ratings are for overall product including glass, sash, and frame (not center of glass)
- the overall product U-factor w/frame can be twice as high as the center-of-glass U-factor
- higher U-factor for products at a slope

Fenestration Ratings (§5.8.2) – slide 31

- NFRC 100
 - first published in 1991
 - certified by U.S. DOE as EAct-compliant
 - specifies standard rating conditions and sizes for apples-to-apples comparison
 - includes all product types: glazed wall systems (i.e. curtainwalls/storefronts), sloped glazing, skylights, casement, awning, picture, slider, pivoted, swinging doors, sliding doors, etc.
 - ratings are based on simulation, not testing (limited testing is done for validation)
 - further information at www.nfrc.org

Fenestration Ratings (§5.8.2) – slide 32

- Solar Heat Gain Coefficient (§5.8.2.5)
“SHGC for the overall fenestration area shall be determined in accordance with NFRC 200.”
- Exceptions to 5.8.2.5:
 - (a) allowable to use shading coefficient (SC) for the center of the glass multiplied by 0.86 provided that SC is from a spectral data file determined in accordance with NFRC 300

Fenestration Ratings (§5.8.2) – slide 33

- Exceptions to 5.8.2.5 (cont.):
 - (b) allowable to use SHGC for the center of the glass (instead of for the overall product)
- Comments:
 - using the exceptions does not give the full credit that the NFRC-certified SHGC does
 - though the SHGC for the frame is not zero
(ranges from 0.11-0.14 for metal frames and from 0.02 to 0.07 for wood/vinyl/ fiberglass), the SHGC for the frame is almost-always lower than the SHGC for the glass

Fenestration Ratings (§5.8.2) – slide 34

- Visible Light Transmittance (§5.8.2.6)
“Visible light transmittance shall be determined in accordance with NFRC 200.”
- Comments:
 - only necessary if using the EnvStd compliance option in §5.6
 - however, NFRC requires products to be rated for visible light transmittance as well as U-factor and SHGC, so information available

- important for daylighting, can now find products with VT more than twice as high as SHGC

Fenestration Ratings (§5.8.2) – slide 35

- Ratings (§5.8.2.1)
 “U-factor, solar heat gain coefficient (SHGC)... shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council ”
- - ratings done by a qualified, independent party
 (though software is helpful for designers and is used by manufacturers for product design)
 - Appendices A8.1 & A8.2 provide some limited default values for unlabeled products

Fenestration Ratings (§5.8.2) – slide 36

- Labeling (§5.8.2.2-3)
 “All manufactured fenestration products shall have a permanent nameplate, installed by the manufacturer, listing the U-factor, solar heat gain coefficient (SHGC)”
 OR
 “...certification for the installed fenestration listing the U-factor, SHGC”
- NFRC labeling for inspectors:
 - manufactured products, 4” x 4” label at factory
 - site-built products, 8-1/2” x 11” label certificate

Fenestration Labeling (§5.8.2) – slide 37

	World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: Vertical Slider	
	ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient	
0.35	0.32	
ADDITIONAL PERFORMANCE RATINGS		
Visible Transmittance	Air Leakage (U.S./I-P)	
0.51	0.2	
<small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org</small>		

Fenestration Labeling (§5.8.2) – slide 38

<p>NFRC PRODUCT CERTIFICATION PROGRAM</p> <hr/> <p>NFRC Label Certificate for Site-Built Products</p> <p>Project Location</p> <p>Street Address: _____</p> <p>City: _____ State: _____ Zip Code: _____</p> <p>Project Name (Optional): _____ Designer (Optional): _____</p> <hr/> <p>Product Line Information</p> <p>Operator Type (per Table 4-3 of NFRC 100) _____</p> <p>Product Line ID No. _____ Individual Product ID No. _____</p> <p>How many of this individual product _____ Location in building _____</p> <p>Elevation drawing page _____ Fenestration (window & door) schedule page _____</p> <hr/> <p>Frame Material Supplier Company name: _____</p> <p>City: _____ State: _____ Zip Code: _____</p> <p>Street Address: _____</p> <p>Contact: _____ Phone: _____ Fax: _____</p> <hr/> <p>Glazing Material Supplier Company name: _____</p> <p>City: _____ State: _____ Zip Code: _____</p> <p>Street Address: _____</p> <p>Contact: _____ Phone: _____ Fax: _____</p> <hr/> <p>Glazing Contractor/Installer Comp. name: _____</p> <p>City: _____ State: _____ Zip Code: _____</p> <p>Street Address: _____</p> <p>Contact: _____ Phone: _____ Fax: _____</p> <hr/> <p>Certification Authorization</p> <p>Independent Certification & Inspection Agency (IA): _____</p> <p>Date Certification Authorization Issued: _____</p>	 <p>World's Best Window Co. Millennium 2000+ Vinyl Clad Wood Frame Double Glazing - Argon Fill - Low E Product Type: Vertical Slider</p> <table border="1"> <tr> <th colspan="2">ENERGY PERFORMANCE RATINGS</th> </tr> <tr> <td>U-Factor (U.S./I-P)</td> <td>Solar Heat Gain Coefficient</td> </tr> <tr> <td style="text-align: center;">0.35</td> <td style="text-align: center;">0.32</td> </tr> <tr> <th colspan="2">ADDITIONAL PERFORMANCE RATINGS</th> </tr> <tr> <td>Visible Transmittance</td> <td>Air Leakage (U.S./I-P)</td> </tr> <tr> <td style="text-align: center;">0.51</td> <td style="text-align: center;">0.2</td> </tr> </table> <p><small>Manufacturers stipulate that these ratings conform to applicable NFRC procedures for determining what product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product use. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information. www.nfrc.org</small></p>	ENERGY PERFORMANCE RATINGS		U-Factor (U.S./I-P)	Solar Heat Gain Coefficient	0.35	0.32	ADDITIONAL PERFORMANCE RATINGS		Visible Transmittance	Air Leakage (U.S./I-P)	0.51	0.2
ENERGY PERFORMANCE RATINGS													
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient												
0.35	0.32												
ADDITIONAL PERFORMANCE RATINGS													
Visible Transmittance	Air Leakage (U.S./I-P)												
0.51	0.2												

Fenestration General (§5.5.4.1) – slide 39

- Calculation methodology:
“Gross wall areas and gross roof areas shall be calculated separately for each space-conditioning category for the purposes of determining compliance.”
- - for mixed-use buildings, must do separate calculations for nonresidential, residential, and semiheated spaces.
- within these subcategories, an exception allows area-weighted averaging for U-factor, SHGC

Fenestration Area Definition (§3.2) – slide 40

Fenestration area:

“total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area.”

- - must use rough opening, not glass area

Fenestration Area Definition (§3.2) – slide 41

- Vertical glazing:
“all fenestration other than skylights”
- Skylights:
“a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration”
- - clerestories and roof monitors are considered vertical fenestration

Fenestration Area (§5.5.4.2) – slide 42

- Vertical:
“total vertical fenestration area shall be less than 50% of the gross wall area”
- Skylights:
“total skylight area shall be less than 5% of the gross roof area”
- - exception allows up to 75% area for the street-side of street-level retail provided it has projection factor (overhang) > 0.5

Climate Zone 5
2004: 50% max.
2007: 40% max.

Climate Zone 5
2004: 5% max.
2007: same

Fenestration U-Factor (§5.5.4.3) – slide 43

- Vertical, fixed (curtainwall):
2004: all frame materials, < 40%
2007: metal/other
- Vertical, operable:
2004: all frame materials, < 40%
2007: metal/other
- - for 2004, typically achieve with double-glazing with a very-good low-emissivity coating
- for 2007, also need thermal-break in the frame

Climate Zone 5
2004: U-0.57 max.
2007: U-0.45/0.35 max.

Climate Zone 5
2004: U-0.67 max.
2007: U-0.55/0.35 max.

Fenestration SHGC (§5.5.4.4) – slide 44

- Vertical, north-oriented:
2004: varies by area, 30-40%
2007: same for all areas
- Vertical, other-oriented:
2004: varies by area, 30-40%
2007: same for all areas
- - exception allows credit for “each fenestration product shaded by permanent projections that will last as long as the building itself”

Climate Zone 5

2004: SHGC-0.49 max.

2007: SHGC-0.40 max.

Climate Zone 5

2004: SHGC-0.39 max.

2007: SHGC-0.40 max.

Fenestration U-Factor (§5.5.4.3) – slide 45

- Skylight, glass with curb and plastic with curb:
- Skylight, all materials without curb:
- - skylights with curbs can have a surface area that is double the rough opening area
- - skylights without curbs are sloped glazing like curtainwalls but higher heat loss due to slope

Climate Zone 5

2004: U-1.17/1.10 max.

2007: same

Climate Zone 5

2004: U-0.69 max.

2007: same

Fenestration SHGC (§5.5.4.4) – slide 46

- Skylight, glass with curb and plastic with curb:
- Skylight, all materials without curb:
- - glass skylights can achieve the same SHGC as vertical fenestration with same low-e coating
- - plastic skylights must use other technologies
- - for 2010, may require w/auto daylighting control

Climate Zone 5

2004: SHGC-0.39/0.62

2007: same

Climate Zone 5

2004: SHGC-0.39 max.

2007: same

EnvStd Trade-Off Option (§5.6) – slide 47

- More flexibility, but more work
- Trade-offs limited to envelope components - no lighting or HVAC
- Includes daylighting – need good VT
- Methodology and assumptions in Appendix C
- See Users Manual with EnvStd

More Building Envelope Energy Efficiency – slide 48

- ASHRAE/IESNA Standard 90.1-2007:
 - requires increased insulation, better fenestration
 - to be published this summer
- ASHRAE/USGBC/IESNA Standard 189P, *Design for High-Performance Green Buildings Except Low-Rise Residential Buildings*:
 - available for public review through July 9th
 - goal of 30% additional energy savings
 - requires increased insulation, better fenestration
 - addresses fenestration orientation, exterior shading

More Information – slide 51

- Standard 90.1-2004, the Users Manual, and more detailed training opportunities are available from:

www.ashrae.org

- More information on the standard and compliance tools available from:

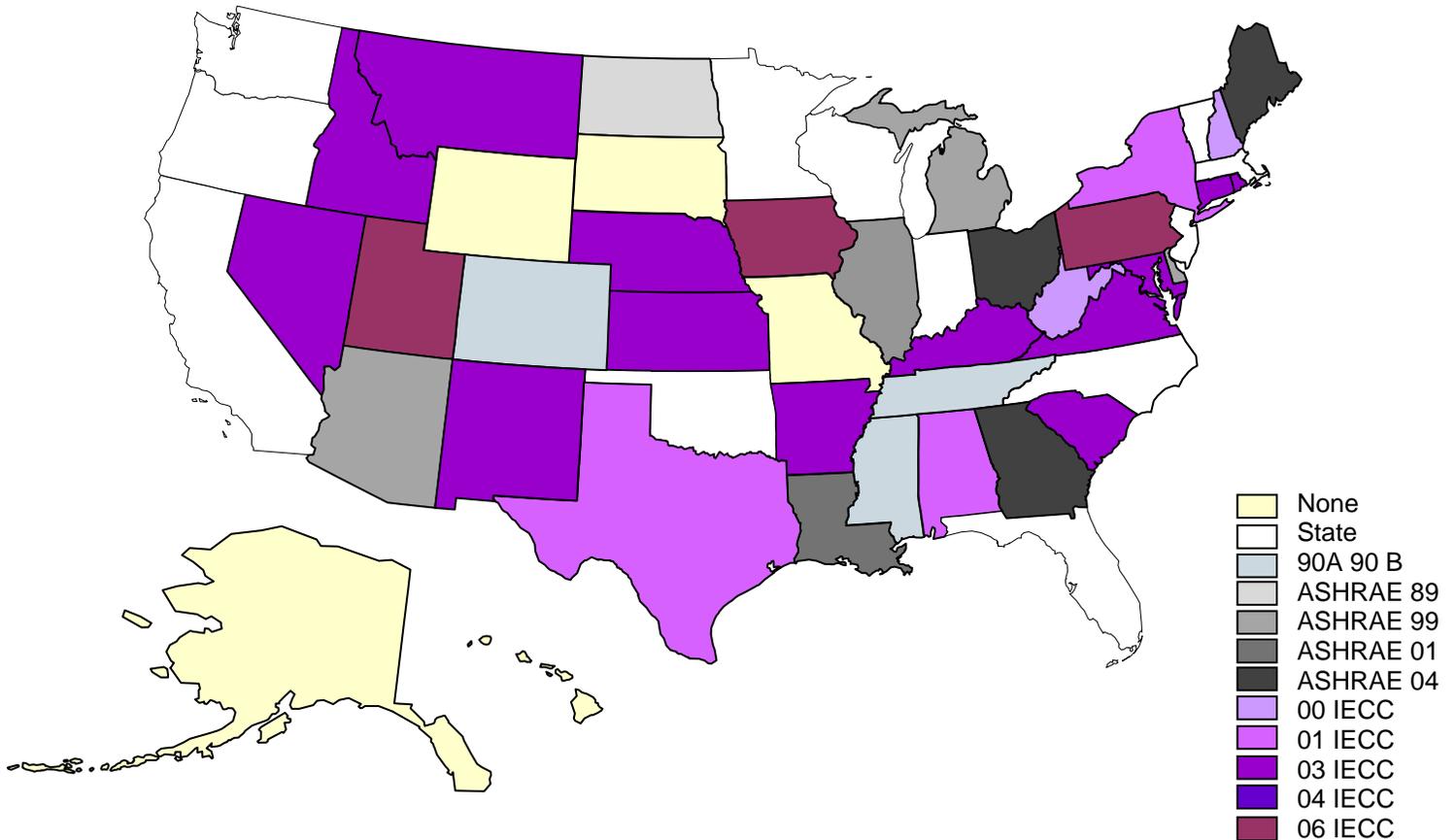
www.energycodes.gov

90.1-2004: An Overview of the Lighting and Power Requirements
April 19, 2007

The Basis for Energy Requirements – slide 2

- Energy Conservation and Production Act, as amended by EPAct, requires States to adopt a commercial energy code
.....This drives state adoption of energy codes
- DOE determines the effective stringency level to meet or exceed
- Many code/standard versions available and currently adopted – varies by state:
 - Some adopt nationally available codes/standards
 - Some develop state-specific codes
 - Some have no code!

Commercial Energy Codes Adoption by State – slide 3



Standard 90.1-2004 Basics – slide 4

- Jointly sponsored by ASHRAE and IESNA
- 2004 is the current version...but many states have older versions of 90.1 in place (2001, 1999, 1989)
- Many State-specific codes and the IECC are based on 90.1. IECC references 90.1 as compliance option
- 2004 version is the commercial building energy code reference in NFPA 5000
- 2004 version lighting power limits are approximately 25% more stringent than previous versions

Building Power Requirements – slide 5

- Voltage Drop:
 - Feeder conductors
 - Run between the service entrance and the branch circuit 2% maximum voltage drop allowed
 - Branch circuit conductors
 - Run from the final circuit breaker to the outlet or load
 - 3% maximum voltage drop allowed

Building Power Requirements – slide 6

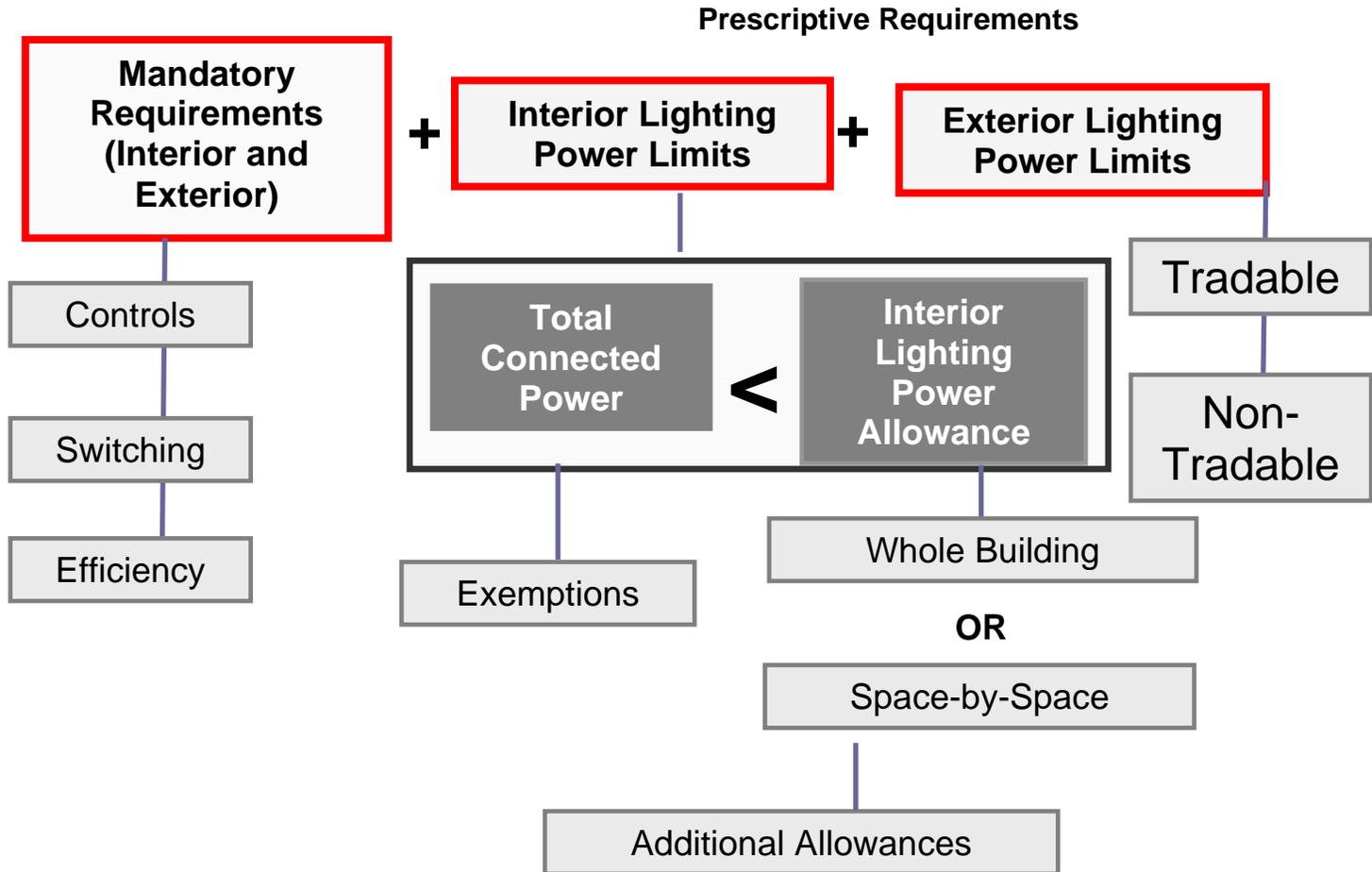
- Document submittals: owner gets information about the building's electrical system
 - Record drawings of actual installation within 30 days
 - Single-line diagram of electrical distribution system
 - Floor plans showing location of distribution equipment and areas served by equipment
 - Manuals
 - Submittal data stating equipment nameplate rating
 - O&M manuals for equipment
 - Qualified service agency
 - Complete narrative and schematic of system as it's normally intended to operate

Standard 90.1 Lighting Scope – slide 7

- New Construction and Additions
 - All commercial type buildings including residential structures of 4 or more stories above grade
 - Interior and exterior lighting
 - Some exceptions to all requirements:
 - Lighting in dwelling units
 - Emergency lighting that is normally off
 - Lighting required by life, health, safety statute

- Historic buildings (whole code exemption)
- Alterations/Renovations
 - Generally treated as new construction
 - Some exemptions apply

Basic Lighting Requirements – slide 8



A Few Words About Alterations/Renovations – slide 9

- The requirements are effectively the same as for new construction or additions:
 - The replacement of lighting systems in building spaces must comply
 - Any new or replacement control devices must comply
- Exception: Replacement of less than 50% of the luminaires in a space need not comply (if no increase in power density)

Mandatory: Individual Space Control – slide 10

- At least one for each room or space enclosed by ceiling-height partitions
 - in spaces $\leq 10,000 \text{ ft}^2$, each control serves 2500 ft^2 maximum and in spaces $> 10,000 \text{ ft}^2$, serves $10,000 \text{ ft}^2$ maximum
- Readily accessible to occupants

- Remote location is allowed to accommodate areas where safety or security is a concern

Intent: Allow occupants to control unneeded lighting

Mandatory: Additional Space Controls – slide 11

- Hotel/motel guest room lighting must be controlled at room entry

Intent: Allow occupant to turn off lights at exit point

- Occupancy sensors are required in:
 - Classrooms (except shop,lab,K-12)
 - Conference/meeting rooms
 - Employee lunch/break rooms

Intent: Capture major occupied hours wasted light

Mandatory: Individual Space Control – slide 12

- Additional control required for:
 - Display/accent lighting
 - Case lighting
 - Task lighting
 - Nonvisual lighting
 - Demonstration lighting

Intent: Provide opportunity to turn off special application lighting

Mandatory: Automatic Shutoff – slide 13

Automatic lighting shutoff control device required in all buildings larger than 5,000 ft²

- Override of automatic shutoff required for not more than 4 hours
- Exceptions to automatic shutoff:
 - Lighting for 24-hour operation
 - Patient care spaces

- Areas with safety or security concerns

Intent: Eliminate after hours lighting waste

Mandatory: Automatic Shutoff – slide 14

- Compliance options:
 1. Control lights on a scheduled basis (automatic time switch)
 - Time-of-day controller
 - Controls $\leq 25,000 \text{ ft}^2$ and not more than one floor
 2. Occupant sensor
 - Turn lights off within 30 minutes of occupant leaving the space
 3. Signal from another control or alarm that indicates the area is unoccupied

NOTE: earlier versions include faulty “occupant intervention” phrase

Application of Automatic Shutoff – slide 15

Intent is to apply to business entities or structures where whole building control is practical

Example applications:

- Strip mall – individual business unit
- Multi-tenant office – whole building with tenant schedule control

Mandatory: Exterior Lighting Control – slide 16

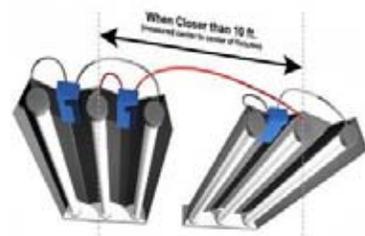
Intent: Eliminate exterior lighting left on during the day

- Photocell (for dawn-to-dusk lighting) **OR**
- Seven-day/seasonal programmable with astronomic correction and 4 hour battery backup
- Exceptions:
 - Covered vehicle entrances
 - Exits from buildings or parking structures (where required for safety, security, or eye adaptation)

Mandatory: Tandem Wiring/Exit Signs – slide 17

- Tandem wiring: eliminate use of single lamp ballast where possible

Intent: Eliminate use of magnetic ballasts driving single lamps



- Exit signs: limited to 5 watts per face maximum

Intent: Control extended use applications where practical

Prescriptive: Interior Lighting Power – slide 18

- Prescriptive Option
 - Whole Building or Space-by-space method
 - Compare actual **Installed Power** (wattage) to **Lighting Power Allowance** (lighting power density LPD) limits
 - Additional power allowances and exemptions available

A few words about the Performance Option “Energy Cost Budget”

- Whole building energy use modeling
- Compare prescriptively compliant base building with proposed building
- Can provide flexibility but requires detailed modeling inputs

Intent: Eliminate waste by promoting thoughtful design and application

Prescriptive: Determine Installed Power – slide 19

- Calculate installed lighting wattage for entire lighted space(s)
- Include all permanent and portable interior lighting designed for general, ambient, or task illumination
 - Exception: for 2 or more mutually exclusive lighting systems only count the system with highest wattage

Prescriptive: Determine Installed Power – slide 20

- Standard incandescent = labeled wattage of the luminaire
- Luminaires with ballasts = wattage of the lamp/ballast combination – not just nominal lamp wattage!
- Line voltage track = actual wattage with minimum 30 W per foot
- Low voltage track = transformer wattage
- All others as specified on equipment

Prescriptive: Wattage Exemptions – slide 21

- Lighting for the following can be excluded:
 - Theatrical, stage, film, and video production
 - Used only during medical and dental procedures
 - Display/accent in exhibits/displays for museums, monuments, and galleries
 - Plant growth or maintenance
 - Integral to equipment or instrumentation installed by manufacturer
 - Integral to both open and glass-enclosed refrigerator and freezer cases
 - Food warming and food prep equipment
 - In retail display windows when the display is enclosed by ceiling-height partitions
 - For use in areas specifically designed for the visually impaired
 - In spaces specifically designated as registered interior historic landmarks
 - Integral part of advertising or directional signage
 - Exit signs
 - Sale or lighting educational demonstration systems
 - For television broadcasting of sporting activities
 - Casino gaming areas
 - (90.1-2007 will add task lights that are occupancy sensor controlled)

Prescriptive: Lighting Power Allowance – slide 22

- Choose appropriate Lighting Power Density (LPD)
 - Whole Building Path
 - Easier
 - Less flexibility
 - Space-by-Space Path
 - More math
 - Often higher potential total allowance
- Multiply LPD by square footage
 - Whole building LPD times total building area
 - Space-by-space LPD times space area(s) and sum values

Space LPDs – slide 23

90.1-2004 Space type LPD sample

90.1-2004 Space Type (LPD) Allowance - Partial List		
Building Type	Space Type description	Watts/sqft
Common Space Type	Corridor/Transition	0.5
Common Space Type	Classroom/Lecture/Training	1.4
Common Space Type	Electrical/Mechanical	1.4
Common Space Type	Dining Area	0.9
Common Space Type	Food Preparation	1.2
Common Space Type	Lounge/Recreation	1.2
Common Space Type	Stairs - Inactive	0.4
Common Space Type	Stairway	0.6
Common Space Type	Restrooms	0.9
Common Space Type	Lobby	1.3
Common Space Type	Atrium - first three floors	0.6
Common Space Type	Atrium - each additional floor	0.2
Common Space Type	Office - enclosed	1.1
Common Space Type	Office - open plan	1.1
Common Space Type	Conference Meeting/Multipurpose	1.3
Common Space Type	Inactive storage	0.3
Common Space Type	Active storage	0.8
Auditorium	Lobby	1.0
Convention Center	Exhibit space	1.3
Court House	Courtroom	1.9
Exercise Center	Dressing/Locker/Fitting Room	0.6
Hospital/Healthcare	Exam/Treatment	1.5
Hospital/Healthcare	Emergency	2.7
Hospital/Healthcare	Recovery	0.8
Library	Stacks	1.7
Library	Reading Area	1.2
Manufacturing Facility	General Low Bay	1.2
Manufacturing Facility	General High Bay	1.7
Museum	General exhibition	1.0
Parking Garage	Parking Area - Pedestrian	0.2
Performing Arts Theatre	Audience/Seating Area	2.6
Police/Fire Station	Fire Station Engine room	0.7
Post Office	Sorting Area	1.2
Transportation	Airport - Concourse	0.6
Transportation	Terminal - Ticket counter	1.5

Whole Building LPDs – slide 24

90.1-2004 whole building LPD values as shown

90.1-2004 Whole Building (LPD) Allowance	
Building Type	Watts per Square Foot
RETAIL	1.5
OFFICE	1
POST OFFICE	1.1
DINING: BAR LOUNGE/LEISURE	1.3
CONVENTION CENTER	1.2
MUSEUM	1.1
PARKING GARAGE	0.3
COURTHOUSE	1.2
POLICE STATIONS	1
HEALTHCARE/CLINIC	1
HOSPITAL	1.2
MANUFACTURING	1.3
PERFORMING ARTS THEATER	1.6
SCHOOL/UNIVERSITY	1.2
SCHOOL/UNIVERSITY	1.2
SCHOOL/UNIVERSITY	1.2
TOWN HALL	1.1
PENITENTIARY	1
TRANSPORTATION	1
WORKSHOP	1.4
FIRE STATIONS	1
LIBRARY	1.3
HOTEL	1
MOTEL	1
MOTION PICTURE THEATRE	1.2
DINING: CAFETERIA/FAST FOOD	1.4
DORMITORY	1
MULTI-FAMILY	0.7
EXCERCISE CENTER	1
SPORTS ARENA	1.1
DINING: FAMILY	1.6
GYMNASIUM	1.1
AUTOMOTIVE FACILITY	0.9
RELIGIOUS BUILDINGS	1.3
WAREHOUSE	0.8

How Were the Space Type LPDs Developed? – slide 25

- Developed within the ANSI/ASHRAE/IESNA 90.1 Lighting subcommittee with IESNA committee support
- Similar general process for 90.1-1999, 2001, 2004
- Apply:
 - Current lighting product performance data
 - Current lamp/ballast efficacy and light loss factors
 - Latest IES recommended light levels
 - Professional consensus of quality lighted environments
- Combine these elements into building space models to calculate lighting power densities

...and Whole Building LPDs? – slide 26

- Develop detailed space-by-space data for commercial buildings
 - Source: DODGE Construction data plans sets - best available current, multiple commercial building data
 - Perform space type area takeoffs for detailed square footage by space type for “typical” buildings
 - Current set at 246 buildings for 31 building types
- Assign applicable space type model LPD for each space
- Calculate whole building LPD

Process Detail Available at IESNA – slide 27

- Interactive version of the process is available at IESNA at:

<http://12.109.133.232/cgi-bin/lpd/lpdhome.pl>

Prescriptive: Additional Lighting Power – slide 28

- Additional power allowed for design flexibility and specific needs
- These are use-it-or-lose-it allowances
- They must be used only for specific designed use and not for general illumination
- Should be separately switched from other general lighting

Prescriptive: Additional Lighting Power – slide 29

- Decorative luminaires in addition to the general lighting at 1.0 W/ft²
- Use of specific luminaires designed to eliminate computer screen glare at 0.35 W/ft²
- **Retail Display Lighting:**
 - **Additional 1.6 W/ft² of specific display, or**
 - **Additional 3.9 W/ft² of specific display for valuable merchandise, such as jewelry, fine apparel and accessories, china and silver, art, and similar items, where detailed display and examination of merchandise are important**

Exterior Lighting Power – slide 30

- Building grounds lighting luminaires over 100 watts must have lamp efficacy of at least 60 lumen/Watt
- Exterior Building Lighting Power must meet prescribed wattage limits. Exterior applications divided into 2 categories:

Tradable: allowed wattage may be traded among these applications

Non-Tradable: allowed wattage **cannot** be traded between surfaces or with other exterior lighting

Exterior Lighting Power – slide 31

- The total exterior lighting power allowance is the sum of the individual lighting power densities [LPD]....
- ...plus an additional unrestricted allowance of 5% of that sum. Trade-offs are allowed only among “Tradable Surfaces” applications.
- Some exemptions apply

Exterior LPDs: 90.1-2004 – slide 32

Applications	Lighting Power Densities
Tradable Surfaces (Lighting Power Densities for open parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas may be traded)	
Uncovered Parking Areas	
Parking lots and drives	0.15 W/ft ²
Building Grounds	
Walkways less than 10 feet wide	1.0 W/linear foot
Walkways 10 feet wide or greater, Plaza areas and Special feature areas	0.2 W/ft ²
Stairways	1.0 W/ft ²

Exterior LPDs: 90.1-2004 – slide 33

Applications	Lighting Power Densities
More Tradable Surfaces...	
Building Entrances and Exits	
Main entries	30 W/linear foot of door width
Other doors	20 W/linear foot of door width
Canopies and Overhangs	
Canopies (free standing & attached) and overhangs	1.25 W/ft ²
Outdoor Sales	
Open areas (including vehicle sales lots)	0.5 W/ft ²
Street frontage for vehicle sales lots in addition to “open area” allowance	20 W/linear foot

Exterior LPDs: 90.1-2004 – slide 34

Applications	Lighting Power Densities
Non-Tradable Surfaces (Lighting Power Density calculations for the following applications can only be used for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the Tradable Surfaces section of this table.)	
Building facades	0.2 W/ft ² for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Automated teller machines & night depositories	270 W per location plus 90 watts per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities	1.25 W/ft ² of uncovered area (covered areas are included in the Canopies and Overhangs section of Tradable Surfaces)

Exterior LPDs: 90.1-2004 – slide 35

Applications	Lighting Power Densities
Non-Tradable Surfaces	
Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft ² of uncovered area (covered areas are included in the Canopies and Overhangs section of Tradable Surfaces)
Drive-up windows at fast food restaurants	400 W per drive through
Parking near 24-hour retail entrances	800 W per main entry

Exterior Lighting Power Exemptions – slide 36

- The following are exempt when equipped with separate control:
 - Specialized signal, directional, and marker lighting associated with transportation;
 - Lighting that is integral to advertising signage or directional signage;
 - Lighting that is integral to equipment or instrumentation and is installed by its manufacturer;
 - Lighting for theatrical purposes, including performance, stage, film, and video production;
 - Lighting for athletic playing areas;
 - Temporary lighting;
 - Lighting for industrial production, material handling, transportation sites, and associated storage areas;
 - Theme elements in theme/amusement parks;
 - Lighting used to highlight features of public monuments and registered historic landmark structures or buildings.

More Information – slide 37

- Standard 90.1-2004, the Users Manual, and more detailed training opportunities are available from:

www.ashrae.org

www.iesna.org

- More information on the standard and compliance tools available from:

www.energycodes.gov

**90.1-2004: An Overview of the Mechanical and
Service Water Heating Requirements
May 24, 2007**

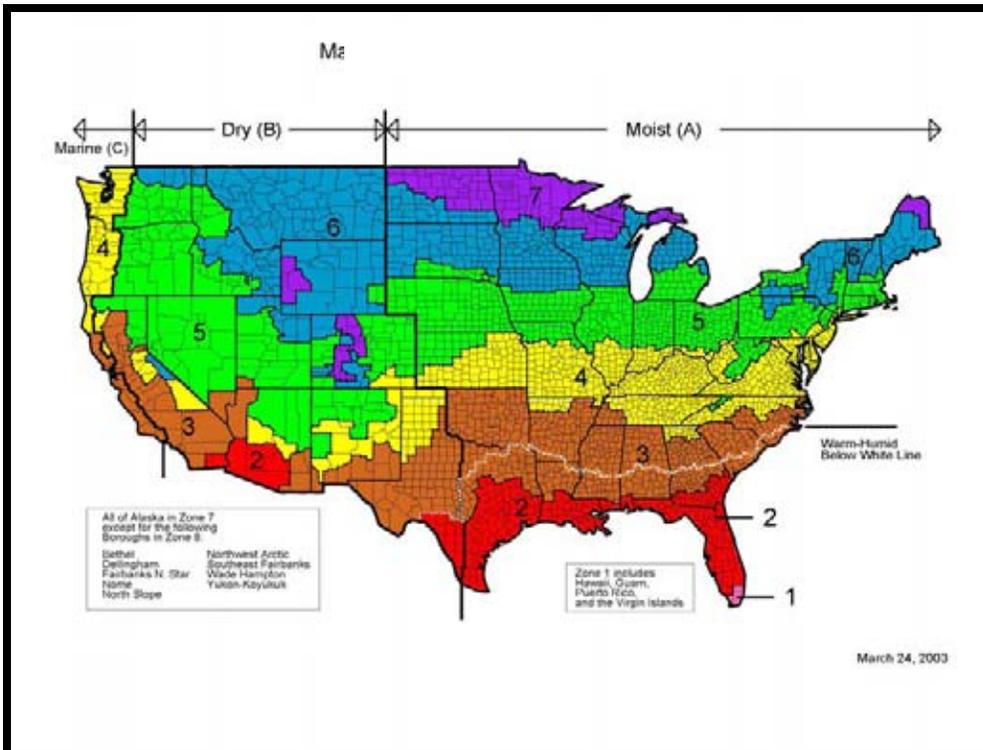
Resources – slide 4

- ASHRAE (<http://www.ashrae.org>)
 - Standard and User's Manual (bookstore)
 - Interactive compliance forms
 - SSPC 90.1 meeting schedule
 - List services
 - Public review drafts
 - Continuous maintenance proposal forms
 - Addenda
 - Errata and interpretations

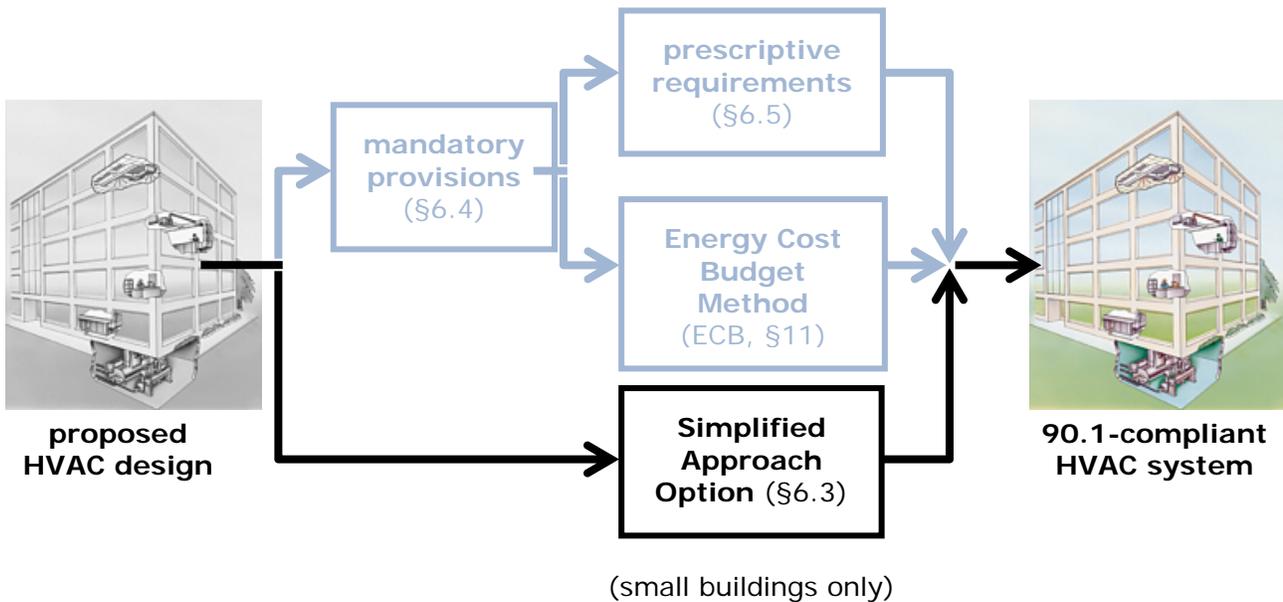
Resources Continued – slide 5

- DOE's Building Energy Codes Program (<http://www.energycodes.gov>)
 - COMcheck (compliance software)
 - Training
 - Information about State Energy Codes
 - Resource Center
 - Code Notes
 - Other valuable resources

Climate Criteria – Normative Appendices B and D – slide 6



Compliance Paths: HVAC – slide 7



Simplified Approach (§6.3) – slide 8

- Minimal effort
- Equally stringent requirements
- Fits on two pages
- Limited to ...
 - Buildings with 1 or 2 stories
 - Buildings less than 25,000 gsf
 - Single-zone systems (unitary or split)
 - Air-cooled or evaporatively cooled

Simplified Approach (§6.3) continued – slide 9

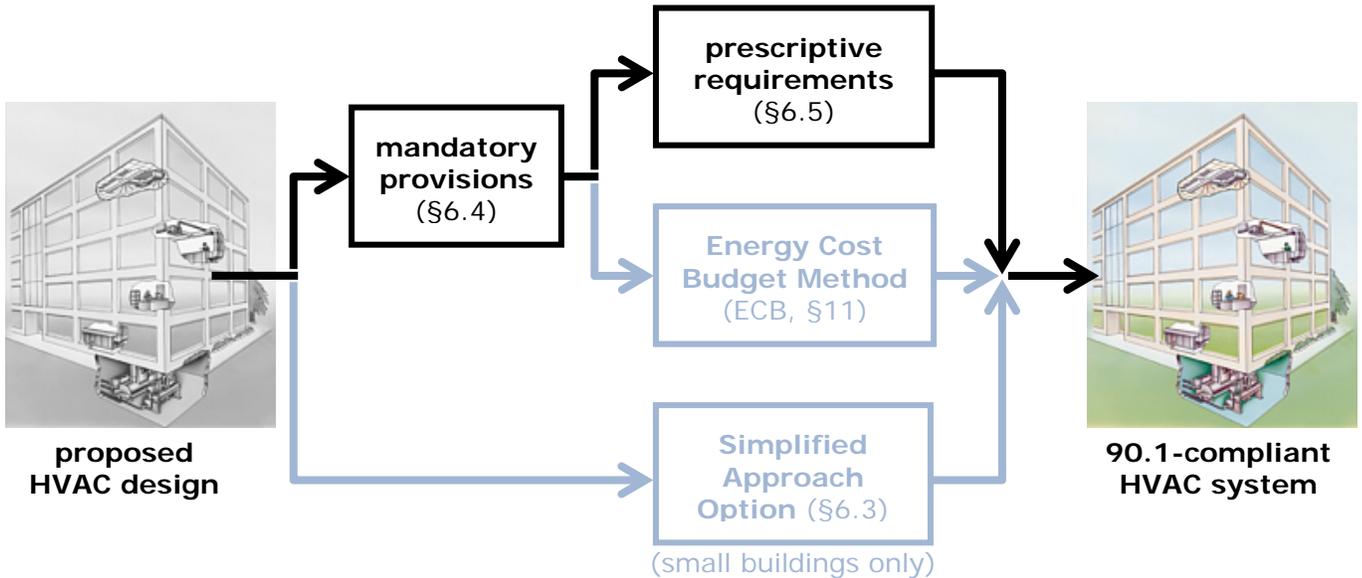
- Economizer as necessary
- Heat: Heat pump, fuel-fired furnace, electric resistance, or baseboard system with boiler
- Min outdoor air: $\leq 3,000$ cfm AND $< 70\%$ of SA, unless energy recovery is used
- Manual-changeover or dual-setpoint thermostat
- Controls for heat pumps with auxiliary heat
- No reheat for humidity control

Simplified Approach (§6.3) concluded – slide 10

- Timeclock and night setback controls (except hotel/motel guest rooms)
- Insulation for piping and ductwork

- Balancing of ducted systems
- Interlocked thermostats for separate heating and cooling equipment
- Exhaust > 300 cfm: Gravity or motorized dampers unless operated continuously
- System > 10,000 cfm: Optimum start

Mandatory Provisions – slide 11



Mandatory Provisions (§6.4) – slide 12

- Equipment efficiencies (§6.4.1)
 - Load calculations (§6.4.2)
 - Controls (§6.4.3)
 - Construction and insulation (§6.4.4)
 - Completion requirements (§6.4.5)
- Drawings, manuals, balancing, and commissioning**

Equipment Efficiencies (§6.4.1) – slide 13

- Air conditioners and condensing units
- Heat pumps
- Chillers
- PTACs
- Furnaces
- Boilers
- Heat-rejection equipment

Equipment Efficiencies – Examples – slide 14

Equipment type	Minimum efficiency
Self-contained, water-cooled w/electric resistance heat (20–100 tons)	11.0 EER 10.3 IPLV
Water-source heat pump (1.5–5.25 tons)	12.0 EER (cooling) 4.2 COP (heating)
Centrifugal chiller, water-cooled (≥ 300 tons)	6.10 COP 0.576 kW/ton 6.40 IPLV 0.549 IPLV (at ARI rating conditions)

§6.4.1.1: “... Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements ...”

Load Calculations (§6.4.2) – slide 15

- Must calculate heating and cooling system design loads
- Must base calculations on generally accepted engineering standards and handbooks

Controls (§6.4.3) – slide 16

- Zone Thermostatic Controls (§6.4.3.1)
- Off-Hour Controls (§6.4.3.2)
- Ventilation System Controls (§6.4.3.3)
- Heat Pump Auxiliary Heat Control (§6.4.3.4)
- Humidifier Preheat (§6.4.3.5)
- Humidification and Dehumidification (§6.4.3.6)
- Freeze Protection and Snow/Ice Melting Systems (§6.4.3.7)
- Ventilation Controls for High-Occupancy Areas (§6.4.3.8)

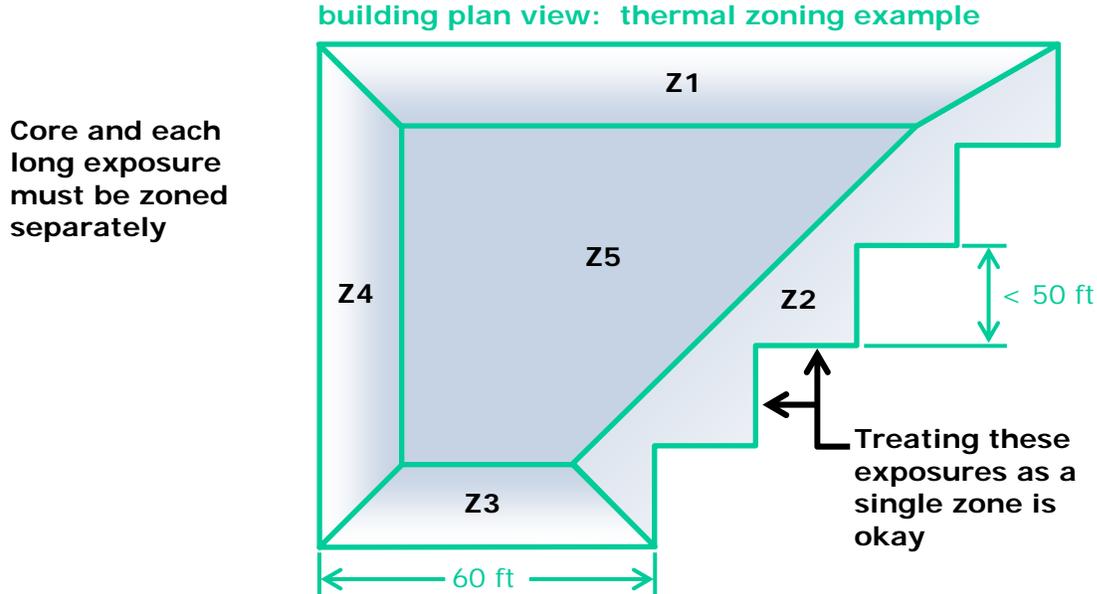
Zone Thermostatic Controls (§6.4.3.1) – slide 17

Required for each zone

Perimeter can be treated differently

- Capable of 5°F dead band or larger
- Dual setpoint or dead band
(can be software for DDC)**
- The standard defines equipment capability not operation

Zone Thermostatic Controls (§6.4.3.1) – slide 18



Zone Thermostatic Controls (§6.4.3.1) – slide 19

- Automatic Shutdown (§6.4.3.2.1)
- Setback Controls (§6.4.3.2.2)
- Optimum Start (§6.4.3.2.3)
- Zone Isolation (§6.4.3.2.4)
- Exceptions to 6.4.3.2
 - Hotel/Motel Guest Rooms
 - Systems that operate continuously
 - Systems with cooling capacity <15,000 Btuh with manual on/off controls

Automatic Shutdown (§6.4.3.2.1) – slide 20

- Automatic 7-day/week time clock with 10-hour battery backup
 - Exception: 2-day/week thermostat for residential applications
- Occupancy sensor
- Manually operated timer (maximum duration: 2 hours)
- Security system interlock

Setback Controls (§6.4.3.2.2) – slide 21

- Climate zones 2-8:
Lower heating setpoint to 55°F or less
- Climate zones 1b, 2b, 3b (hot/dry):
Automatically restart, temporarily operate
 - Raise cooling setpoint to 90°F or higher

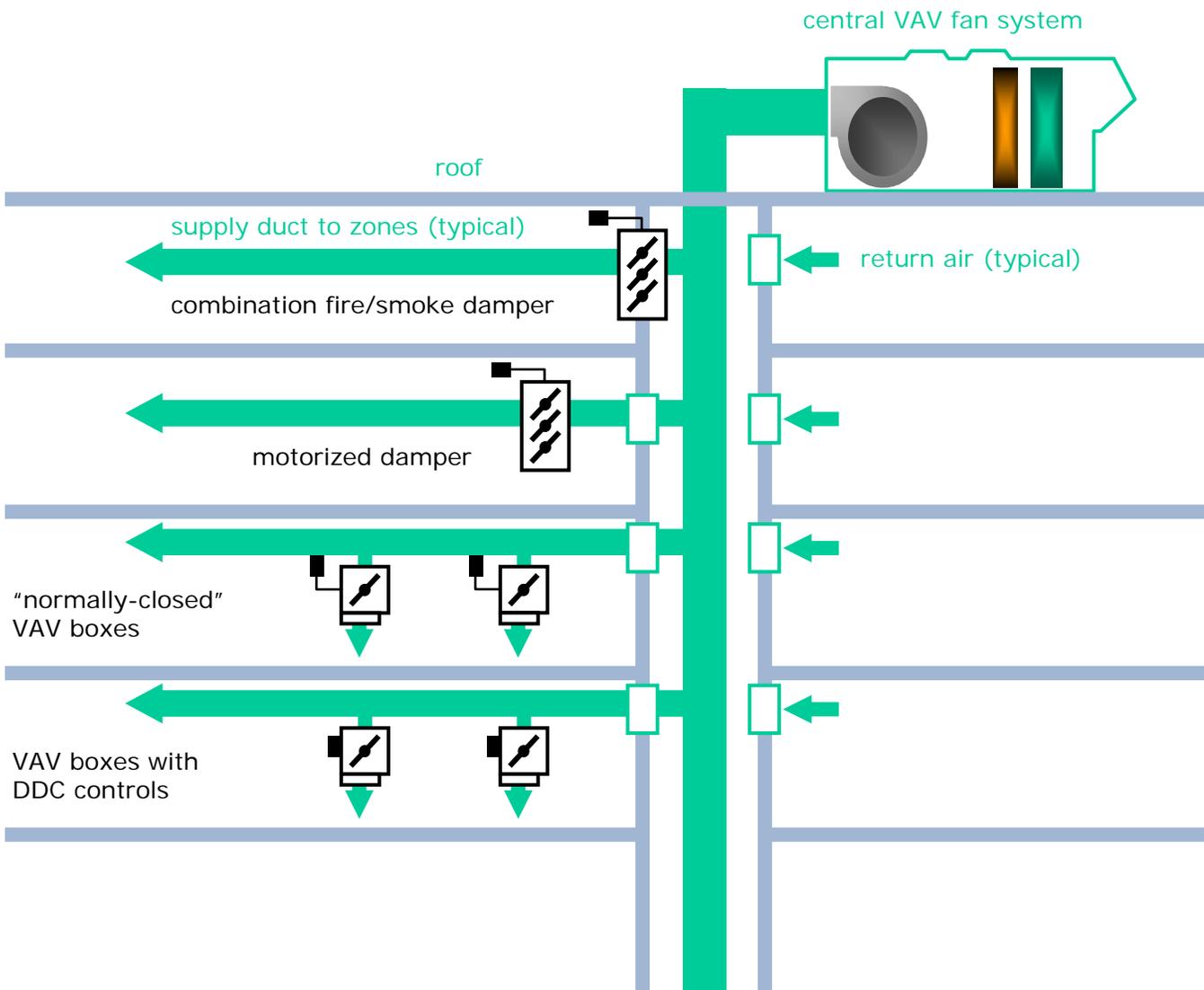
Or

- Prevent high space humidity levels

Other Off-Hour Controls – slide 22

- Optimum start (§6.4.3.2.3)
 - If system supply-air capacity > 10,000 cfm
- Zone isolation (§6.4.3.2.4)
 - Each floor
 - $\leq 25,000$ ft² maximum zone size on one floor
 - Isolation devices to shut off outdoor and exhaust airflow
 - Central systems capable of stable operation
 - Capable of separate time schedules for each isolation zone

Zone Isolation – Example – slide 23



Ventilation System Controls (§6.4.3.3) – slide 24

Provide motorized dampers:

- In stair and elevator shafts
- On gravity hoods, vents, and ventilators

Exceptions:

- Buildings < 3 stories high
- Any building in climate zones 1,2,3 (hot climates)
- Ventilation systems serving unconditioned spaces

Ventilation System Controls (§6.4.3.3) continued – slide 25

Provide shutoff-damper control for outdoor-air supply and exhaust systems

- Automatically shut when systems or spaces are not in use
- Automatically shut during building warm-up, cool-down, and setback

Exceptions for gravity (non-motorized) dampers:

- Buildings < 3 stories high
- Any building in climate zones 1,2,3
- Outdoor-air intake or exhaust < 300 cfm

Ventilation System Controls (§6.4.3.3) concluded – slide 26

Maximum leakage at 1.0 in. wg, cfm/ft ² of damper area		
Climate zone	Motorized	Non-motorized
1, 2, 6, 7, 8	4 cfm/ft²	Not allowed
All others	10 cfm/ft²	20 cfm/ft²*

* Dampers < 24 inches in either dimension may have leakage of 40 cfm/ft²

Applies to OSA, EA and RA (economizer) dampers

Heat Pumps: Auxiliary Heat (§6.4.3.4) – slide 27

For heat pumps with internal electric heaters, controls must lock out electric heat when load can be met by heat pump alone

Exception:

Heat pumps regulated by NAECA if HSPF rating meets Table 6.8.1B and includes electric resistance heating

Humidification Controls (§6.4.3.5 & 6) – slide 28

- Humidifier preheat (§6.4.3.5)
Shut off humidifier preheat when humidification is not required
- Humidification and dehumidification (§6.4.3.6)
Prevent simultaneous operation

Exception:

Spaces that require specific humidity levels (computer rooms, museums, hospitals) if approved by authority having jurisdiction

Ventilation: High Occupancy (§6.4.3.8) – slide 29

If outdoor air > 3,000 cfm and design occupancy > 100 people/1000 ft²:

Automatically reduce outdoor air intake below design requirements when spaces are partially occupied

Exception:

Systems with exhaust-air energy recovery complying with Section 6.5.6.1

Construction & Insulation (§6.4.4) – slide 30

Insulation must be suited to environment

- Duct, plenum insulation
 - Climate zone
 - Location
- Piping insulation
 - Heating, domestic hot water, or cooling
 - Temperature
 - Pipe size

Duct Insulation Example – slide 31

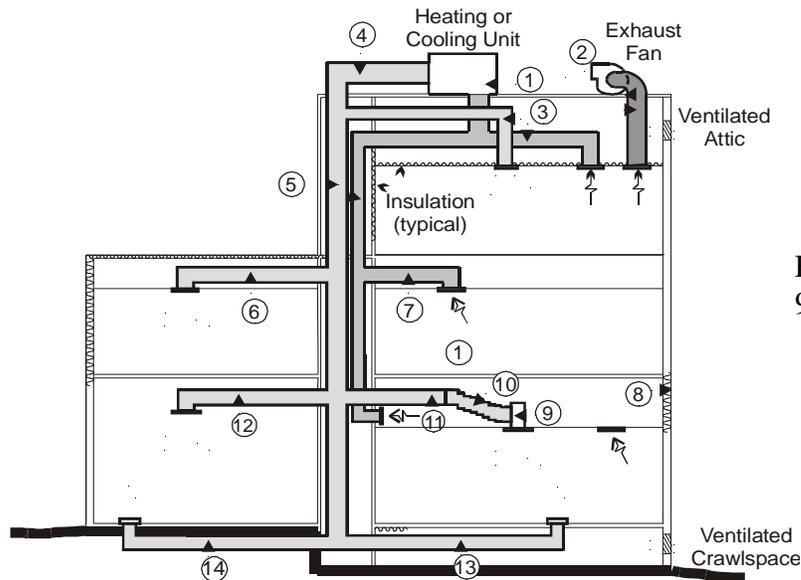


Figure 6-G from
90.1 User's

KEY

- | | |
|---|-----------------------------------|
| 1. Insulation of unit casing | 8. Exterior wall of return plenum |
| 2. Exhaust | 9. Supply outlet in plenum |
| 3. Supply and return in vented attic | 10. Supply runout in plenum |
| 4. Supply on exterior of building | 11. Supply in plenum |
| 5. Supply and return in shaft | 12. Supply in conditioned space |
| 6. Supply in unvented attic | 13. Supply in vented crawlspace |
| 7. Return in indirectly conditioned ceiling space | 14. Buried supply |

Construction & Insulation (§6.4.4) – slide 32

Minimum sealing levels for ducts by location, service and pressure class
Must leak-test 25% of the ductwork with design static pressure > 3 in. wg

Completion Requirements (§6.4.5 & 6.7) – slide 33

Documentation within 90 days of system acceptance:

- Drawings of actual installation
- Submittal data
- Operation and maintenance manuals
- Service agency information
- Control sequences and schematics

Completion Requirements Continued – slide 34

System balancing (§6.7.2.3)

- Written report conditioned spaces > 5000 ft²
- For airside system fan power > 1 hp and hydronic pumps >10 hp:
 1. Minimize throttling losses
 2. Trim impeller or adjust design speed

Completion Requirements Concluded – slide 35

Commissioning (§6.7.2.4 & Appendix E)

- Control elements calibrated, adjusted, and in working order
- Designer must provide detailed instructions (per Appendix E) for projects > 50,000 ft²

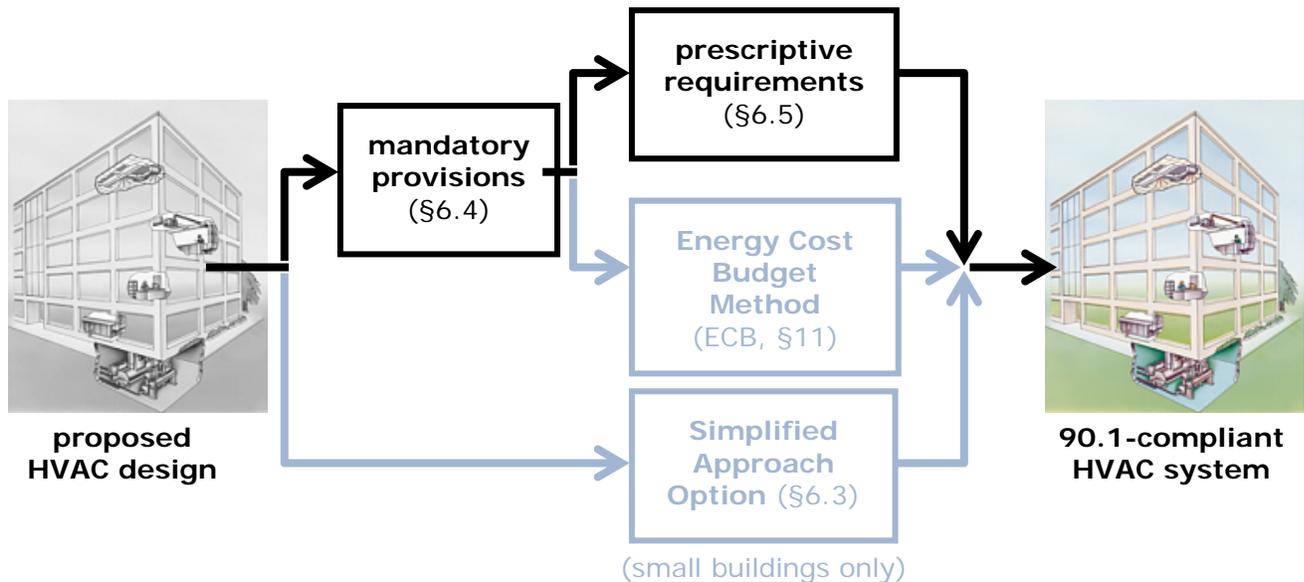
Exceptions:

Warehouses, semi-heated spaces

Mandatory Provisions Recap – slide 36

- Must be met whether using prescriptive or performance (ECB method) path
- Mandates include:
 - Equipment efficiency
 - Controls
 - Construction and insulation
 - Completion requirements (drawings, manuals)
 - Balancing and commissioning

Prescriptive Requirements – slide 37



Prescriptive Requirements (§6.5) – slide 38

- Economizers (§6.5.1)
- Simultaneous heating and cooling (§6.5.2)
- Air system design and control (§6.5.3)
- Hydronic system design and control (§6.5.4)

- Heat rejection equipment (§6.5.5)
- Energy recovery (§6.5.6)
- Exhaust hoods (§6.5.7)
- Radiant heating (§6.5.8)
- Hot gas bypass limitation (§6.5.9)

Economizers (§6.5.1) – slide 39

- Climate and system size determine need for an economizer
- May be either airside or waterside
- Numerous exceptions (see next slide)
- Control must be integrated with mechanical cooling
- Operation must not increase heating energy consumption

Economizers (§6.5.1) – slide 40

- Exceptions:
 - Cooling capacity - Table 6.5.1 (next slide)
 - Systems with gas phase air cleaning per Standard 62
 - Where >25% of the air must be humidified >35°Fdp
 - Systems with condenser heat recovery per 6.5.6.2
 - Residential systems <5X limits in Table 6.5.1
 - Systems with a balance point ≤60°F
 - Systems expected to operate < 20hrs/wk
 - Systems serving zones with refrigerated casework
 - Where cooling efficiency exceeds Table 6.3.2

Economizers (Table 6.5.1) – slide 41

Climate zone	Cooling capacity for which an economizer is required
1a, 1b, 2a, 3a, 4a (Miami, St. Louis, Charlotte)	Economizer unnecessary
2b, 5a, 6a, 7, 8 (Yuma, Chicago, Edmonton)	≥ 135,000 Btu/h
3b, 3c, 4b, 4c, 5b, 5c, 6b (Denver, Lubbock, Vancouver)	≥ 65,000 Btu/h

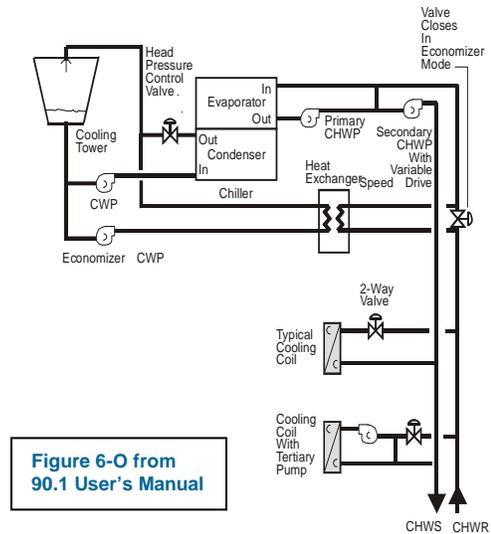
Air Economizers (§6.5.1.1) – slide 42

- Prohibited control types (Table 6.5.1.1.3A)
 - **Fixed enthalpy** in climate zones 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8

- **Differential dry bulb** in climate zones 1a, 2a, 3a, 4a
- High-limit shutoff control settings (Table 6.5.1.1.3B)
- Damper leakage ratings OA and RA (see 6.4.3.3.4)
- Able to relieve excess outdoor air without recirculation of exhaust

Water Economizers (§6.5.1.2) – slide 43

- Capacity: 100% of system cooling load at 50°F DB/45°F WB (**45°F DB/40°F WB for dehumidification**)
- Maximum pressure drop < 15 ft (or bypassed) when not in use
- Must be integrated (some exceptions)



Simultaneous Heating–Cooling (§6.5.2) – slide 44

Zone controls

- No reheating
- No recooling
- No mixing of simultaneously supplying mechanically (or economizer) cooled and mechanically heated air
- No simultaneous heating and cooling of the same zone
- Multiple exceptions (see next slide)

Zone-Control Exceptions (§6.5.2.1) – slide 45

Zone airflow does not exceed whichever is largest:

- Code required ventilation
- 0.4 cfm/ft²
- 30% of supply air
- 300 cfm
- Where it would reduce overall system energy due to ventilation requirements of a critical zone

Zone-Control Exceptions (§6.5.2.1) Concluded – slide 46

- Zones with special pressurization requirements
- Zones with code-required minimum circulation rates
- Site-recovered or site-solar energy provides $\geq 75\%$ of reheat energy

Hydronic System Controls (§6.5.2.2) – slide 47

- Three-pipe: Not allowed
- Two-pipe changeover: Controls must prevent changeover unless ...
 - Controlled by OA with dead band $\geq 15^\circ\text{F}$
 - System operates in each mode for a minimum of 4 hours
 - Difference between reset cooling and heating temperatures is $\leq 30^\circ\text{F}$

WLHP Systems (§6.5.2.2.3) – slide 48

- Loop temperature dead band $\geq 20^\circ\text{F}$
(Exception: Optimized loop control)
- For climate zones 3-8:
 - Closed-circuit fluid cooler shall have either:
 - Bypass all but minimum flow (for freeze protection), or
 - Low leakage automatic air dampers on tower
 - Isolate open towers from heat-pump loop using bypass or shutting down tower pump where provided with HX

Dehumidification (§6.5.2.3) – slide 49

Prohibited:

- Reheating, mixing or simultaneous heating and cooling for humidity control

Exceptions:

- Reducing supply airflow to $\leq 50\%$, or minimum ventilation rate
- Systems < 6.67 tons that can unload at least 50%
- Systems smaller than 3.3 tons
- Systems with specific humidity requirements (museums, surgical suites)
- 75% of reheat/recool energy is site-recovered or site-solar
- Desiccant system with heat recovery (see standard)

Humidification (§6.5.2.4) – slide 50

Water side economizer required if:

- An economizer is required by 6.5.1
- System has hydronic cooling, and
- Humidification system is designed to maintain inside humidity at $>35^\circ\text{F}$ dew-point temperature

Air System Design & Control (§6.5.3) – slide 51

Fan system power limitation:

- Applies to systems > 5 hp
- Limits based on nameplate hp of fans operating at design (excludes relief fan and parallel fan powered boxes)
- Conditional credits available
 - Pressure drop due to filtration or heat-recovery coils > 1 in. wg
 - Low-temperature supply air (return–supply air $\Delta T > 20^{\circ}\text{F}$)

Fan Power Limitation (Table 6.5.3.1) – slide 52

Supply air volume	Allowable nameplate motor power	
	Constant volume	Variable volume
< 20,000 cfm	1.2 hp /1,000 cfm	1.7 hp /1,000 cfm
\geq 20,000 cfm	1.1 hp /1,000 cfm	1.5 hp /1,000 cfm

VAV Fan Control (§6.5.3.2) – slide 53

Motors \geq 15 hp require one of the following:

- **Variable-speed drive**
- **Vaneaxial fan with variable-pitch blades**
- **Design wattage \leq 30% at 50% air volume**

For systems without DDC zone controls

- **Locate pressure sensor so that control setpoint is $\leq 1/3 SP_{\text{design}}$**

For systems with DDC zone controls

- **Provide pressure reset by zone demand**
- **Sensor placement is not important**

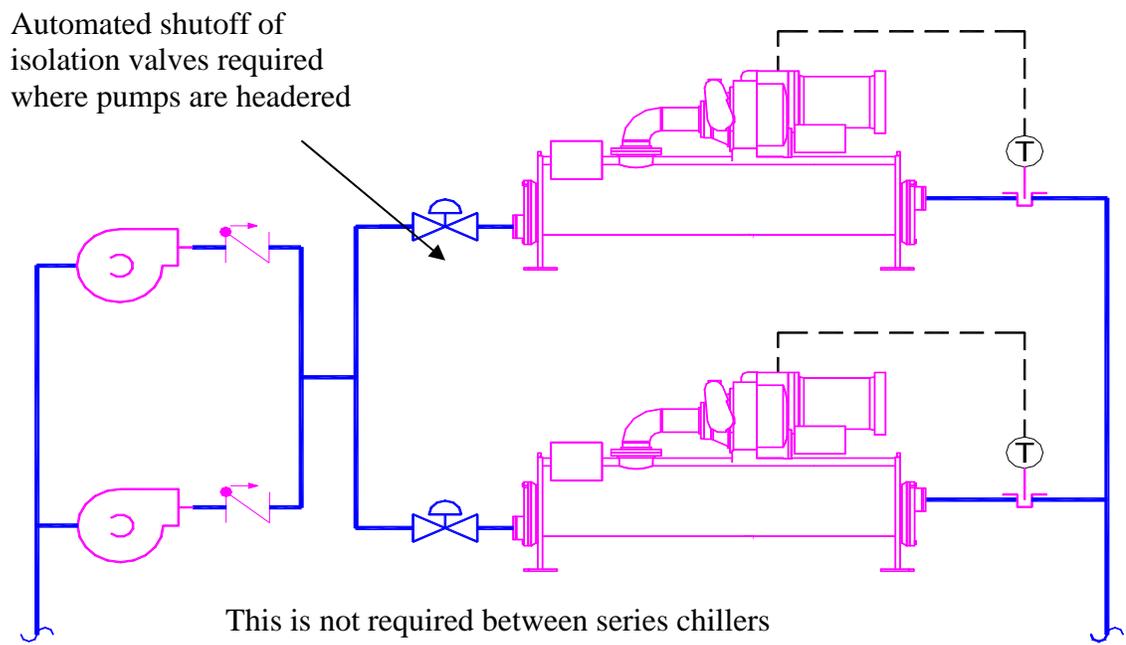
Hydronic System Design & Control (§6.5.4) – slide 54

- Systems with total pump system hp > 10 shall meet all of the following
 - Hydronic variable flow design (§6.5.4.1)
 - Pump isolation (§6.5.4.2)
 - Chilled and hot water reset (§6.5.4.3)
 - WLHP variable flow (§6.5.4.4)

Hydronic Variable Flow (§6.5.4.1) – slide 55

- Must be able to reduce flow $\leq 50\%$
- Limit demand of individual variable-flow pumps to 30% of design wattage at 50% flow (e.g., use VSD) where:
 - Pump head > 100 ft
 - Motor > 50 hp
- Exceptions:
 - System that have ≤ 3 control valves
 - Minimum flow required for equipment with < 75 hp of pumping

Pump Isolation (§6.5.4.2) – slide 56

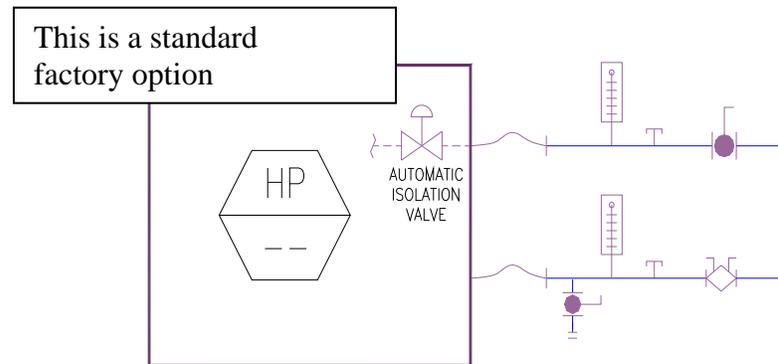


CHW and HW Water Reset (§6.5.4.3) – slide 57

- Required where capacity $> 300,000$ Btu/h unless:
 - Improper operation results
 - System is variable flow per §6.5.4.1

WLHP Isolation (§6.5.4.4) – slide 58

Two-position shutoff valves are required for each heat pump



Heat-Rejection Equipment (§6.5.5) – slide 59

Fan speed control

- Motors ≥ 7.5 hp must be able to operate at $2/3$ of full speed or less
- Exceptions:
 - Condenser fans serving multiple circuits or flooded condensers
 - Installations in climate zones 1 and 2
 - Up to $1/3$ of the fans on a multiple-fan application (if lead fans meet speed control requirement)

Airside Energy Recovery (§6.5.6.1) – slide 60

- Required if:
 - Supply air capacity $\geq 5,000$ cfm
 - Minimum outdoor air $\geq 70\%$
- Recovery system effectiveness $\geq 50\%$
- Exceptions (9)
 - Labs, toxic exhaust, etc.
 - Largest exhaust $< 75\%$ outdoor airflow
 - ...

Waterside Energy Recovery (§6.5.6.1) – slide 61

- Must recover condenser heat for service water heating (SWH) if:
 - Facility operates “24/7” and
 - Heat rejection $> 6,000,000$ Btu/h and
 - SWH load $> 1,000,000$ Btu/h
- Where required, meet the smaller of:
 - Recover 60% of rejected condenser heat or

- Preheat water to 85°F

Exhaust Hoods (§6.5.7) – slide 62

- Kitchen hoods > 5,000 cfm:
Provide makeup air $\geq 50\%$ of exhaust air volume
- Fume hoods if total capacity > 15,000 cfm:
 - Capability to reduce exhaust and makeup-air volumes to $\leq 50\%$ or
 - Direct makeup-air supply $\geq 75\%$ of exhaust rate at specified conditions or
 - Heat recovery to precondition makeup air

Radiant Heating (§6.5.8) – slide 63

- Required for unenclosed spaces
- Exception:
Loading docks with air curtains

Hot Gas Bypass Limitation (§6.5.9) – slide 64

Rated capacity of system	Maximum HGBP capacity, % of total capacity
$\leq 240,000$ Btu/h	50%
$> 240,000$ Btu/h	25%

- Applied in systems with stepped or continuous unloading
- Limitation also pertains to chillers
- Exception: Packaged unitary systems $\leq 90,000$ Btu/h (7.5 tons)

Service Water Heating – slide 65

- Mandatory provisions:
 - Equipment efficiency
 - Piping insulation
 - SWH system controls (temperature, pump operation)
 - Pool heaters and covers
- Prescriptive requirements:
 - Space and water heating
 - Service water heating

More Information – slide 66

- Standard 90.1-2004, the Users Manual, and more detailed training opportunities are available from:

www.ashrae.org

- More information on the standard and compliance tools available from:

www.energycodes.gov