



U.S. Department of Energy
Energy Efficiency and Renewable Energy



Building Energy Codes

ANSI/ASHRAE/IESNA Standard 90.1-1999

U.S. Department of Energy
Building Energy Codes Program



Why is Standard 90.1-1999 important?

- It replaces ANSI/ASHRAE/IESNA Standard 90.1-1989 and the codified version of Standard 90.1-1989 (the gray book).
- It is the reference standard for Chapter 7 of the 2001 IECC.
- It is also the commercial energy reference in NFPA's family of codes.



How is it different?

- Written in mandatory, enforceable language
- Contains true prescriptive path for envelope
- Mechanical and envelope sections heavily dependent on economic analysis
- Lighting section heavily dependent on lighting quality considerations
- Does pay considerable more attention to existing buildings



How is it different?

- Does not include lighting tradeoff software (LTGSTD)
- Does include a simplified mechanical systems approach for “simple” buildings
- Does include separate envelope requirements for non-residential, residential, and semi-heated spaces
- Is accompanied by ASHRAE Guideline 18 (More stringent than 90.1) – *in process*
- Extends scope and coverage (alterations and additions)
- Includes international units
- Expands climate locations
- Is reorganized for ease of use



How is it the same?

- Still contains separate envelope, HVAC, SWH, and lighting provisions
- Still includes envelope tradeoff software (ENVSTD – new version)
- Still contains an energy cost budget tradeoff method



How have requirements changed?

- Mechanical requirements generally more stringent (with exception of economizers)
- Envelope requirements a mixed bag – some more stringent, some less, depending on economics
- Lighting requirements generally more stringent with exception of some building types and space types



How can I find out more about the differences?

- Excruciatingly detailed comparisons of Standards 90.1-1989 and 90.1-1999 may be found at http://www.energycodes.gov/implement/determinations_com.stm
- PNNL is also working on comparisons of the 90.1-1999 Standard and Chapter 8 of the 2001 IECC



How can I get a copy?

- Standard 90.1-1999 and the Standard 90.1-1999 Users Manual are available from ASHRAE



404-636-8400



www.ashrae.org



Section Organization

90.1-1989

- 4 – Compliance
- 5 – Electric power
- 6 – Lighting
- 7 – Auxiliary systems and equipment
- 8 – Building Envelope
- 9 – HVAC Systems
- 10 – HVAC Equipment
- 11 – SWH
- 12 – Energy management
- 13 – Energy Cost Budget Method

90.1-1999

- 4 – Administration and enforcement
- 5 – Building envelope
- 6 – HVAC
- 7 – SWH
- 8 – Power
- 9 – Lighting
- 10 – Other equipment
- 11 – Energy Cost Budget Method



Standard 90.1-1999

- Section 1 – Purpose
- Section 2 - Scope
- Section 3 - Definitions, Abbreviations, and Acronyms
- Section 4 - Administration and Enforcement
- Section 5 - Building Envelope
- Section 6 - Heating, Ventilating, and Air-Conditioning
- Section 7 - Service Water Heating
- Section 8 - Power



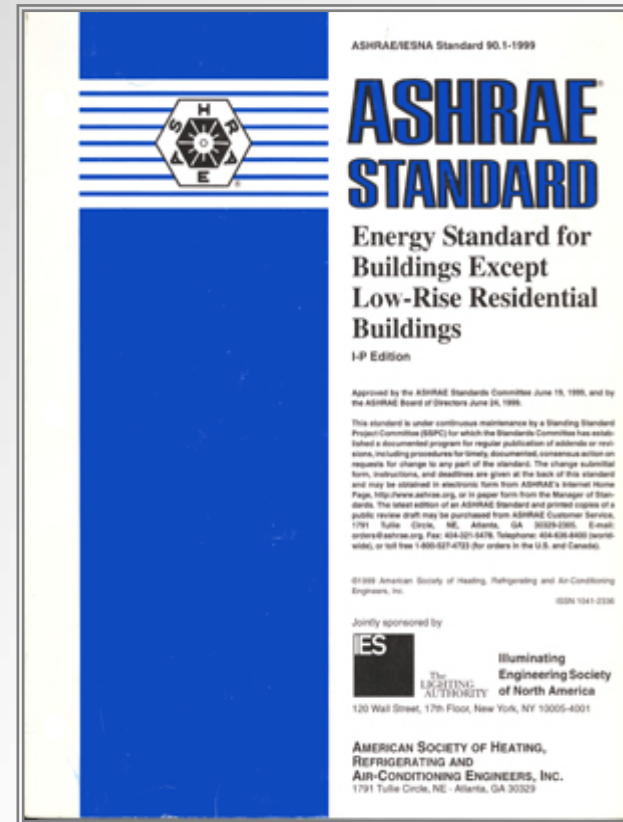
Standard 90.1-1999

- Section 9 - Lighting
- Section 10 - Other Equipment
- Section 11 - Energy Cost Budget Method
- Section 12 - Normative References
- Appendices A-D - Mostly envelope related
- Appendix E - Informative References



Section 1 - Purpose

The purpose of this standard is to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings





Section 2 - Scope

- New buildings and their systems
- New *portions* of buildings and their systems (additions)
- New systems and equipment in *existing* buildings (alterations)





Section 2 – Scope *(cont'd)*

- Envelope
 - if heated by a heating system with an output capacity $\geq 3.4 \text{ btu/h-ft}^2$ or
 - if cooled by a cooling system with a sensible output $\geq 5 \text{ btu/h-ft}^2$
- Virtually all mechanical and lighting systems are covered



Scope Exceptions

- Too little heating or cooling
- Single-family, multifamily of three stories or less, manufactured or modular homes
- Buildings that don't use electricity or fossil fuel
- Equipment and portions of building systems that use energy primarily for industrial, manufacturing, or commercial purposes



Section 3 - Definitions, Abbreviations, and Acronyms

- 10.5 pages of definitions
- 1 page of abbreviations and acronyms
- Defined terms are italicized in text of standard



Section 4 – Administration and Enforcement

- Specifies what applies to new buildings, existing buildings, additions to existing buildings, alterations to existing buildings
- Specifies exemptions for envelope, HVAC, SWH, power, lighting, and other equipment alterations
- Discusses changes in space conditioning



Section 4 – Administration and Enforcement

- Addresses compliance documentation
- Addresses labeling of materials and equipment
 - Fenestration, doors, insulation, mechanical equipment, and packaged terminal air conditioners
- Addresses alternative materials and methods of construction
- Addresses inspections



Building System

Compliance Options

Envelope

Lighting

Mechanical

HVAC

SWH

Mandatory Provisions
(required for all compliance options)

Prescriptive Option

Trade Off Option

Energy Cost Budget

Energy Code Compliance



Envelope Compliance

Building System

Compliance Options

Energy Code Compliance

Envelope

Lighting

Mechanical

HVAC

SWH

Mandatory Provisions
(required for all compliance options)

Prescriptive Option

Trade Off Option

Energy Cost Budget



Section 5 – Building Envelope

- General (*Section 5.1*)
 - Scope
 - Compliance
 - Climate
 - Space-Conditioning Categories and Basis
- Mandatory Provisions (*Section 5.2*)
 - Insulation
 - Fenestration and Doors
 - Air Leakage



Section 5 – Building Envelope *(cont'd)*

- Prescriptive Building Envelope Option *(Section 5.3)*
 - Opaque Areas
 - Fenestration
- Building Envelope Trade-Off Options *(Section 5.4)*



Scope

- Envelope components that enclose
 - Conditioned space
 - Semi-heated space
 - Has a heating system with a capacity $> 3.4 \text{ Btu/h.ft}^2$ (10 W/m^2) of floor area but is not conditioned space
- Requirements apply to three types of spaces
 - Nonresidential
 - Residential
 - Semi-heated

Section 5.1.1



Climate

- Bins based on CDD50 and HDD65
 - Locations listed in Appendix D
 - If location not listed, select one with “closest” climatic conditions



Space-Conditioning Categories and Basis

- Each space to be included in a category
 - Nonresidential conditioned space
 - Residential conditioned space
 - Both nonresidential and residential semiheated space
- Spaces in climates > 1800 HDD65 assumed to be conditioned space unless
 - Space will only be semiheated or unconditioned and
 - Approved as such by the building official



Mandatory Provisions

- Insulation (*Section 5.2.1*)
 - Installation 5.2.1.1 and 5.2.1.2
 - Recessed equipment 5.2.1.3
 - Location of roof insulation and insulation protection 5.2.1.4 and 5.2.1.5

Required in all compliance paths



Mandatory Provisions Insulation Installation

- Per manufacturer's instructions
- Achieve rated R-value
- No open-blown or poured loose-fill insulation when ceiling slope is $> 3/12$
- If eave vents installed
 - Provide baffling of air vents to deflect incoming air above the surface of the insulation
- Exception
 - Metal buildings – if roof and wall insulation is compressed between roof or wall skin and the structure

Section 5.2.1.1



Mandatory Provisions

Insulation - Substantial Contact

- Install insulation in a permanent manner in substantial contact with inside surface
- Flexible batt insulation in floor cavities
 - To be supported in a permanent manner by supports no more than 24 in. o.c.



Mandatory Provisions Recessed Equipment

- Do not recess equipment to affect insulation thickness
 - Lighting fixtures
 - HVAC equipment (includes wall heaters, ducts, and plenums)
 - Other
- Except when
 - Total combined area affected (include necessary clearances) is $< 1\%$ of opaque area of the assembly, **OR**
 - Entire roof, wall, or floor is covered with insulation to the full depth required, **OR**
 - Effects of reduced insulation are included in area-weighted calculations

Section 5.2.1.3



Mandatory Provisions Roof Insulation

- Roof Insulation
 - Not installed on a suspended ceiling with removable ceiling panels



Section 5.2.1.4



Mandatory Provisions **Insulation Protection**

- Insulation Protection
 - Cover exterior insulation with protective material
 - Sunlight
 - Moisture
 - Landscaping operations
 - Equipment maintenance
 - Wind
 - Access to attics and mechanical rooms without damaging or compressing insulation
 - Insulation materials in ground contact to have a water absorption rate $\leq 0.3\%$ (ASTM C272)

Section 5.2.1.5



Mandatory Provisions Fenestration and Doors

- U-factors
 - NFRC 100 or
 - Assemblies listed in Appendix A
- SHGC
 - NFRC 200 or
 - Assemblies listed in Appendix A
- Visible Light Transmittance
 - NFRC 200 when building envelope trade-off option is used



Section 5.2.2



U-Factor

- Skylights – determine for a slope of 20° above the horizontal
- Labeled and certified by manufacturer
- Exceptions
 - Glazed wall systems in vertical fenestration and skylights – may use U-factors in A.8.1
 - A.8.2 acceptable for other vertical fenestration
 - A.7 acceptable for opaque doors
 - NAGDM 105 acceptable for garage doors



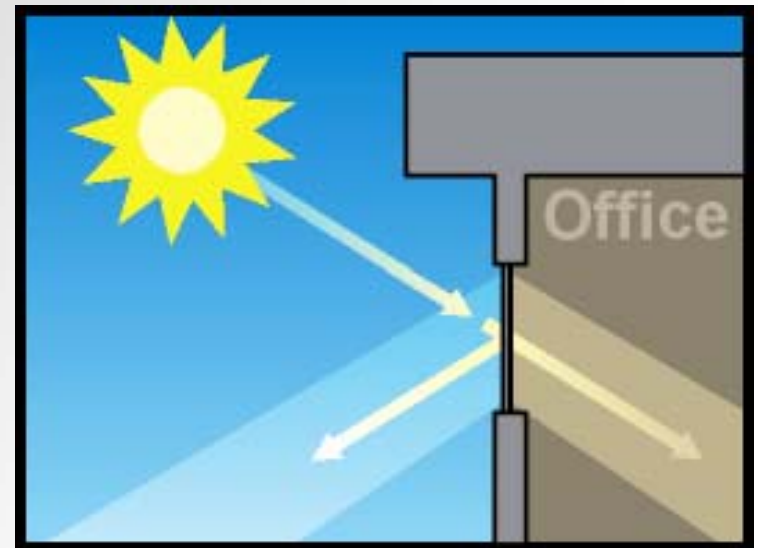
Solar Heat Gain Coefficient (*SHGC*)

- Exceptions
 - $SC \times 0.86$ is acceptable for overall fenestration area (NFRC 300)
 - SHGC of center of glass is acceptable (NFRC 300) for overall fenestration area
 - SHGC from A.8.1 for glazed wall systems in vertical fenestration and skylights
 - SHGC from A.8.2 for other vertical fenestration
- The glazing's effectiveness in rejecting solar heat gain



SHGC (cont'd)

- The glazing's effectiveness in rejecting solar heat gain
- Part of a system for rating window performance
 - used by the National Fenestration Rating Council (NFRC)
- Gradually replacing shading coefficient (SC) in product literature and design standards
 - convert SC to SHGC by multiplying the SC value by 0.86





Visible Light Transmittance

- A measure of the amount of visible light that passes through fenestration
- Affected by:
 - composition of the glass
 - coatings
 - internal shading devices





Mandatory Provisions **Air Leakage**

- Seal, caulk, gasket, or weather-strip
 - Openings and joints in building envelope
 - Fenestration and doors per NFRC 400
 - Loading docks in climates > 3600 HDD
 - Vestibules and doors separating conditioned space from exterior



Section 5.2.3



Mandatory Provisions **Building Envelope Sealing**

- **Joints around fenestration and door frames**
- **Junctions between walls**
 - and foundations
 - at building corners
 - and structural floors or roofs
 - and roof or wall panels
- **Openings for utility services through roofs, walls, and floors**
- **Site-built fenestration and doors**
- **Building assemblies used as ducts or plenums**
- **Joints, seams, and penetrations of vapor retarders**
- **All other openings in the building envelope**

Section 5.2.3.1



Mandatory Provisions Fenestration and Doors

- NFRC 400
- Labeled and certified by manufacturer
- Glazed swinging entrance doors and revolving doors – not to exceed 1.0 cfm/ft²
- All other products – not to exceed 0.4 cfm/ft²
- Exceptions
 - Field-fabricated fenestration and doors
 - Garage doors – NAGDM 105

Section 5.2.3.2



Mandatory Provisions Loading Dock Weatherseals

- > 3600 HDD65
 - Cargo doors and loading dock doors equipped with weatherseals
 - To restrict infiltration when vehicles are parked in the doorway

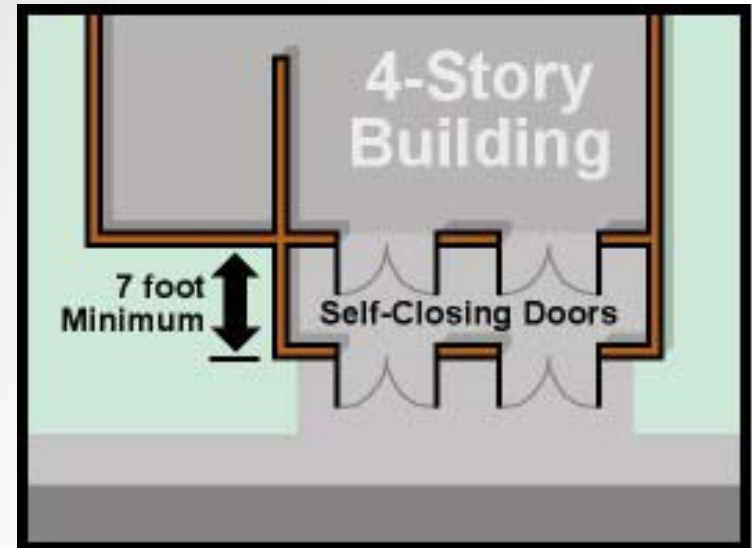


Section 5.2.3.3



Mandatory Provisions **Vestibules**

- All exterior doors in tall buildings in cold climates must have a vestibule with
 - Self-closing doors
 - Interior and exterior doors must not be open at the same time
 - Distance between interior and exterior doors not < 7 ft when in closed position (remember ADA!)

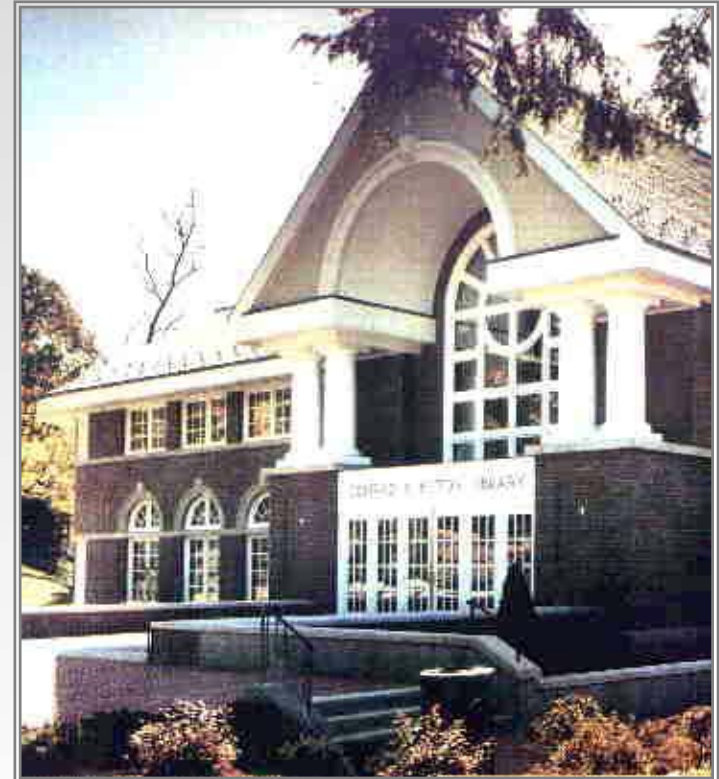


Section 5.2.3.4



Vestibule Exceptions

- Non-entrance doors (mechanical/electrical rooms)
- Vehicle and material handling doors and adjacent personnel doors **OR** revolving doors
- All doors in climates < 1800 HDD65 **OR** in buildings < 4 stories
- All doors that open into spaces < 3000 ft² **OR** into dwelling units





Building Envelope Prescriptive Option

WWR \leq 50% of gross wall area
Skylight-roof ratio \leq 5% of roof area
Each envelope component must separately meet requirements

- 26 criteria sets for different climate types
 - Set = single page that summarizes all prescriptive requirements
 - Insulation levels for roofs, walls floors
 - Fenestration criteria

Section 5.3



Designers

- Specify
 - R-values for walls, floors, and roofs
 - U-factors for opaque doors
 - U-factor and SHGC for fenestration, OR
- Use
 - Pre-calculated assemblies from Appendix A





Envelope Prescriptive Option **Opaque Areas**

- Compliance
 - Meet or exceed minimum R-values in table
 - Only R-value of insulation, not to include air films, etc
- OR
- Meet maximum U-factor, C-factor, or F-factor for the entire assembly
- OR
- Perform area-weighted average U-factor, C-factor, or F-factor
 - Only if there are multiple assemblies within a single class of construction for a single space-conditioning category

Section 5.3.1



Envelope Prescriptive Option **Roof Insulation**

- Meet or exceed minimum R-value in table
- Skylight curbs insulated to level of roofs with insulation entirely above deck or R-5, whichever is less
- Roofs with insulation entirely above deck
 - R-value is for continuous insulation
 - Interruptions for mechanical equipment $\leq 1\%$ of surface of the total roof area

Section 5.3.1.1



Roof Insulation *(cont'd)*

- Metal building roofs
 - First value is for
 - insulation draped over purlins and then compressed when metal spanning members attached or
 - insulation hung between purlins provided there's a min. of 1" thermal break between purlins and metal spanning members
 - Second value is for double-layer installations with insulation installed parallel to the purlins
- Attics and other roofs
 - R-value is for insulation installed both inside and outside the roof or entirely inside the roof cavity



Envelope Prescriptive Option Above-Grade Wall Insulation

- Meet or exceed R-value in appropriate table
- Mass walls
 - heat capacity determined from Table A-6 or A-7
 - R-value is for continuous insulation or when uninterrupted by framing other than metal clips no closer than 24 in. o.c. horizontally and 16 in. o.c. vertically
- Exception – requirement of U-0.151



Above-Grade Wall Insulation *(cont'd)*

- Metal building wall R-value is for insulation compressed between metal wall panels and the steel structure
- Steel-framed wall R-value is for uncompressed insulation installed in the cavity between steel studs
- Wood-framed and other R-value is for uncompressed insulation installed in the cavity between wood studs; also acceptable to be continuous insulation uninterrupted by studs



Envelope Prescriptive Option **Below-Grade Wall Insulation**

- Meet or exceed values in appropriate table in Appendix B
- R-value is for continuous insulation
- If framing is used, compliance is based on maximum assembly C-factor



Envelope Prescriptive Option **Floor Insulation**

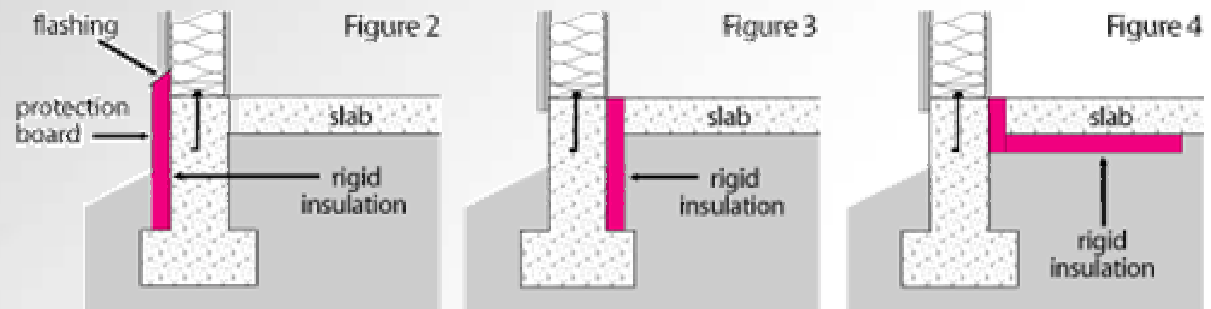
- Meet or exceed values in appropriate table in Appendix B
- Mass floors
 - R-value is for continuous insulation
 - If framing is used, compliance is based on maximum assembly U-factor
- Steel joist floors
 - R-value is for uncompressed insulation or spray-on insulation, but is also acceptable for continuous insulation
- Wood-framed and others
 - R-value is for uncompressed insulation, but is also acceptable for continuous insulation

Section 5.3.1.4



Envelope Prescriptive Option **Slab-on-Grade Floor Insulation**

- Meet or exceed values in appropriate table in Appendix B (includes R-value and depth or width of insulation)
- Be installed around the perimeter to the distance specified
 - Inside foundation wall – extend downward from top of slab a minimum distance specified or to the top of the footing, whichever is less
 - Outside foundation wall – extend from top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum distance specified



Section 5.3.1.5



Envelope Prescriptive Option Opaque Doors

- Meet or exceed maximum U-factors in appropriate table in Appendix B

TABLE B-1
Building Envelope Requirements (HDD65: 0-900, CDD50: 10801+)

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
<i>Roofs</i>						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.048	R-20 ci	U-1.282	NR
Metal Building	U-0.065	R-19.0	U-0.055	R-13.0 + R-13.0	U-1.280	NR
Amc and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.614	NR
<i>Walls, Above Grade</i>						
Mass	U-0.580	NR	U-0.151*	R-5.7 ci*	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-1.180	NR
Steel Framed	U-0.124	R-13.0	U-0.084	R-13.0 + R-3.8 ci	U-0.352	NR
Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.292	NR
<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-0.322	NR	U-0.322	NR	U-0.322	NR
Steel Joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood Framed and Other	U-0.282	NR	U-0.282	NR	U-0.282	NR
<i>Slab-On-Grade Floors</i>						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 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-1.450		U-1.450	

Section 5.3.1.6



Envelope Prescriptive Option **Fenestration**

- Criteria apply to fenestration, including windows, glass doors, glass block, plastic panels, and skylights
- Compliance
 - Meet or exceed maximum U-factors in table
 - Meet or exceed minimum SHGC in table
 - Use NFRC ratings or default values in Appendix A

Section 5.3.2



Envelope Prescriptive Option **Fenestration Area**

- Total vertical fenestration area to be $< 50\%$ of gross wall area
 - Including both fixed and operable vertical fenestration
- Total skylight area to be $< 5\%$ of gross roof area
 - Including glass skylights, plastic skylights with a curb, and all skylights without a curb



Section 5.3.2.1



Envelope Prescriptive Option **Fenestration U-Factor**

- NFRC or meet or exceed maximum U-factors in A-17
- Exception
 - Vertical fenestration complying with Exception (c) to 5.3.2.3 to have a U-factor \leq U-factor specified for 40% of the gross wall area

Section 5.3.2.2



Envelope Prescriptive Option **Fenestration SHGC**

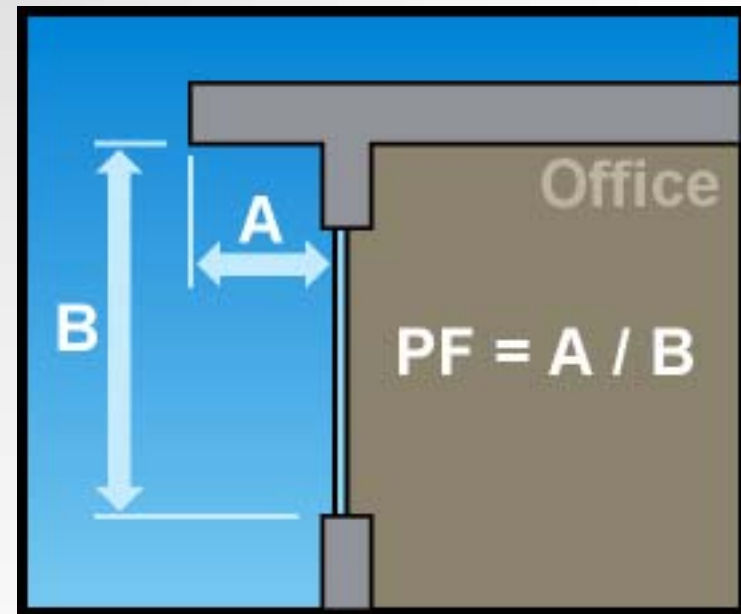
- Vertical fenestration
 - SHGC values < Table 5.3 (Appendix A-18) for appropriate total vertical fenestration area
- Skylights
 - SHGC values < Table 5.3 (Appendix A-18) for appropriate total skylight area
- No SHGC requirements for semiheated spaces or for buildings in climates > 10800 HDD65
- No criteria in the for Visible Light Transmittance in Prescriptive Building Envelope Option, but there are minimum criteria in the Trade-Off Option (5.3.2.4)

Section 5.3.2.3



Overhangs

- Standard credits permanent overhangs by adjustment to SHGC
- Size of overhang is determined by projection factor





Building Envelope Trade-Off Option

- Building complies if
 - It satisfies the provisions of 5.1 and 5.2
 - Envelope performance factor (EPF) of proposed building is \leq EPF of budget building
 - EPF considers only the building envelope components and is calculated using procedures in Normative Appendix C
 - Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems to be the same for both the proposed building and the budget building



Mechanical Compliance

Building System

Compliance Options

Envelope

Lighting

Mechanical

HVAC

SWH

Section 6.1

Mandatory Provisions
(required for all compliance options)

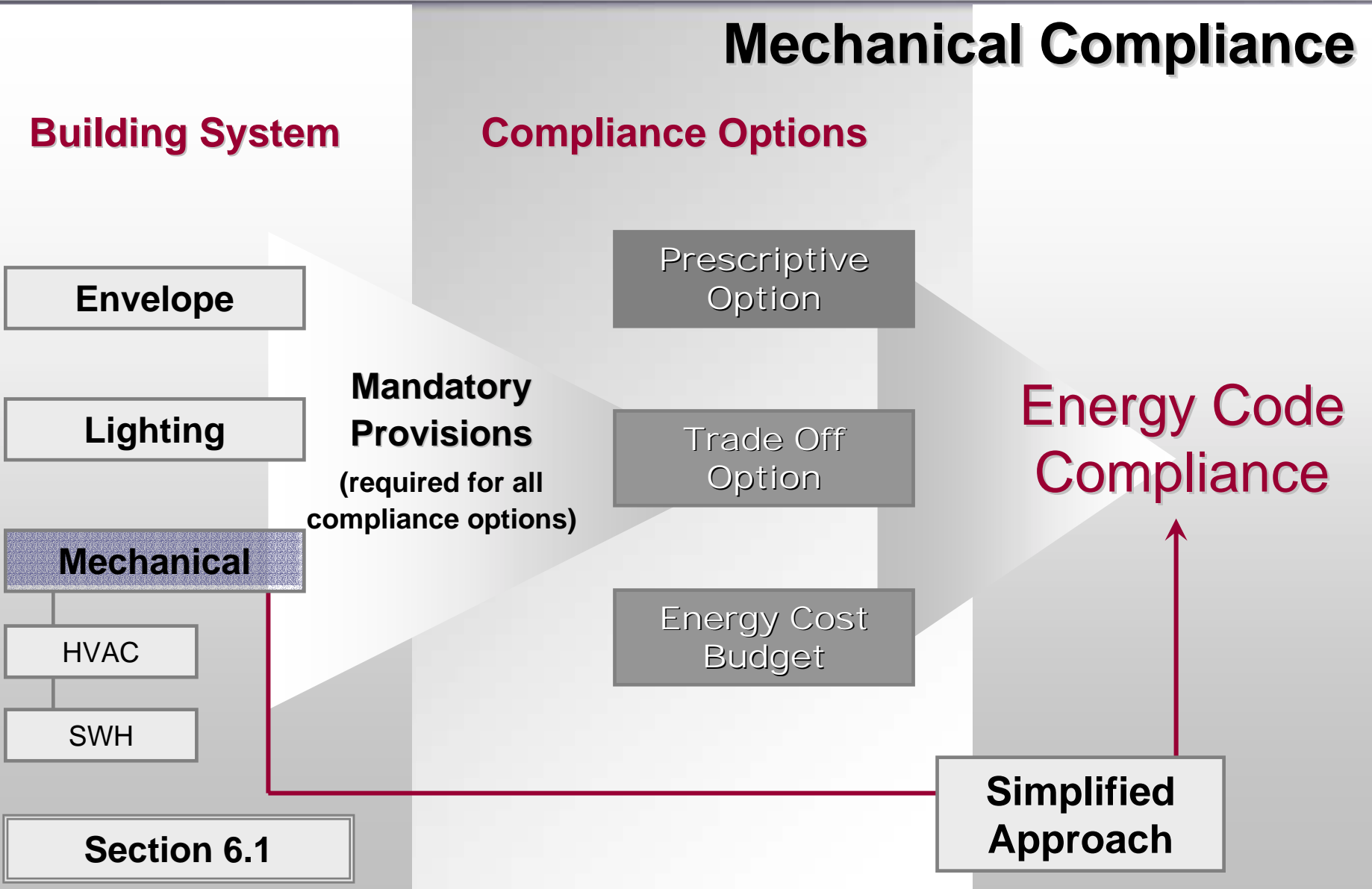
Prescriptive Option

Trade Off Option

Energy Cost Budget

Energy Code Compliance

Simplified Approach





Simplified Approach Option

- Limited to...
 - Buildings with 1 or 2 stories
 - Buildings $< 25,000\text{ft}^2$
 - Single-zone systems
 - Air-cooled or evaporatively cooled only



Simplified Approach *(cont'd)*

- **Economizer Trade-off Option**
 - Limited to:
 - System size
 - Climate (Cooling Degree-Days)
 - Minimum Cooling Efficiency (EER)



Section 6.1.3



Simplified *(cont'd)*

- Manual changeover or dual set-point thermostat
- Heat pump supplementary control
- No reheat or simultaneous heating and cooling for humidity control
- Time clocks (except hotel/motel...)
- Pipe and ductwork insulated
- Ducted system to be air balanced to within 10% of design air flow rates
- Interlocked thermostats to prevent simultaneous heating and cooling
- Exhausts (design capacity > 300 cfm unless continuous operation)
- Optimum start controls (design supply air capacity $> 10,000$ cfm)



HVAC Mandatory Provisions

- Mechanical Equipment Efficiency (*Section 6.2.1*)
- Load Calculations (*Section 6.2.2*)
- Controls (*Section 6.2.3*)
- HVAC System Construction and Insulation (*Section 6.2.4*)
- Completion Requirements (*Section 6.2.5*)
Required in both Prescriptive and ECB compliance paths



Equipment Covered

- Package air conditioners
- Heat pumps
- Chillers
- Furnaces
- Boilers
- Heat rejection equipment
- Packaged terminal room air conditioners



Equipment Covered for the First Time in 90.1

- Ground-source heat pumps
- Single- and double-effect absorption chillers
- Heat rejection equipment
- New categories for
 - Hot water and steam boilers
 - Replacement PTACs and PTHPs



HVAC Mandatory Provisions **Mechanical Equipment Efficiency**

- Tables 6.2.1A – 6.2.1G
- Combination systems to meet all requirements for appropriate space heating or cooling category
- Gas-fired and oil-fired forced air furnaces with input ratings $\geq 225,000$ Btu/h to have intermittent ignition or interrupted device and have either power venting or a flue damper
- All furnaces with input ratings $\geq 225,000$ Btu/h, including electric furnaces, not located in conditioned space, to have jacket losses $\leq 0.75\%$ of the input rating

Section 6.2.1



HVAC Mandatory Provisions **Load Calculations**

- Determined in accordance with generally accepted engineering standards and handbooks acceptable to the adopting authority



Section 6.2.2



HVAC Mandatory Provisions **Controls**

- Thermostatic controls (*Section 6.2.3.1*)
 - Required for each zone
 - Dead Band controls
 - Set Point Overlap Restrictions
- Off-Hour controls (*Section 6.2.3.2*)
 - Automatic Shutdown
 - Setback Controls
 - Optimum Start Controls
 - Shutoff Damper Controls
 - Zone Isolation

Section 6.2.3



HVAC Mandatory Provisions **Controls** *(cont'd)*

- Gravity Vent Controls (*Section 6.2.3.3*)
 - Stair and Shaft Vent dampers
 - Gravity Hoods, Vents, and Ventilator Dampers
- Heat Pump Auxiliary Heat Control
(*Section 6.2.3.4*)
- Enclosed Parking Garage Ventilation controls
(*Section 6.2.3.5*)



HVAC Mandatory Provisions **Controls** *(cont'd)*

- Humidifier Preheat Controls (*Section 6.2.3.6*)
- Humidification and Dehumidification Controls (*Section 6.2.3.7*)
- Freeze Protection and Ice Melting Systems Controls (*Section 6.2.3.8*)
- Ventilation Controls for High-Occupancy Areas (*Section 6.2.3.9*)
- Exceptions



HVAC Mandatory Provisions/Controls **Dead Band**

- Thermostats must have a 5°F dead band
- Exceptions
 - Thermostats that require manual changeover between heating and cooling modes
 - Special occupancy or applications where wide temperature ranges aren't acceptable (e.g., retirement homes) and approved by adopting authority



HVAC Mandatory Provisions/Controls **Set Point Overlap Restriction**

- If limit switches, mechanical stops, or software programming for DDC systems are used, means will be provided to prevent the heating set point from exceeding the cooling set point minus any applicable proportional band



HVAC Mandatory Provisions/Controls **Off-Hour Controls**

- Systems with heating/cooling capacity > 65,000 Btu/h and fan > $\frac{3}{4}$ hp
 - Shall have the following off-hour controls
 - automatic shutdown
 - setback controls
 - optimum start controls
 - shutoff damper controls
 - zone isolation
- Exceptions, HVAC systems
 - serving hotel/motel guestrooms
 - intended to operate continuously

Section 6.2.3.2



HVAC Mandatory Provisions/Controls **Automatic Shutdown**

- Controls to operate on different time schedules for seven different day-types per week and retain programming and time setting during loss of power for at least 10 hrs
- Each control to have
 - Occupant sensor, **OR**
 - Manually-operated timer with maximum two hour duration, **OR**
 - Interlock to security system



HVAC Mandatory Provisions/Controls **Setback Controls**

- Applies when heating systems are located where heating design temperature is $\leq 40^{\circ}\text{F}$ and cooling systems located where cooling design temperature $< 100^{\circ}\text{F}$
- Heating set point adjustable down to $\leq 55^{\circ}\text{F}$
- Cooling set point adjustable up to $\geq 90^{\circ}\text{F}$ or to prevent high space humidity levels
- Exception
 - Radiant floor and ceiling heating systems



HVAC Mandatory Provisions/Controls **Optimum Start Controls**

- Individual heating and cooling air distribution systems with
 - Total design supply air capacity $> 10,000$ cfm
 - Served by one or more supply fans
- Control algorithm to at least be a function of
 - Difference between space temperature and occupied setpoint and amount of time prior to scheduled occupancy



HVAC Mandatory Provisions/Controls **Shutoff Damper Controls**

- Motorized dampers for outdoor air supply and exhaust systems
- Ventilation outside air dampers to be capable of automatically shutting off during
 - Preoccupancy building warm up, cool down, and setback
(Except when ventilation reduces energy costs or when ventilation must be supplied to meet code requirements)
- Supply and exhaust dampers to have maximum leakage rate of 3 cfm/ft² at 1.0 in. w.g. when tested in accordance with AMCA Standard 500

Section 6.2.3.2.4



HVAC Mandatory Provisions/Controls **Shutoff Damper Controls - Exceptions**

- Gravity dampers okay in buildings
 - < 3 stories in height
 - Of any height in climates < 2700 HDD65
- Systems with design outside air intake or exhaust capacity ≤ 300 cfm
 - if equipped with motor-operated dampers that open and close when unit is energized and de-energized, respectively



HVAC Mandatory Provisions/Controls **Zone Isolation**

- Each isolation area
 - Maximum 25,000 ft² zone on one floor
 - Ability to shut off airflow to isolation area
 - Automatic shutdown device
 - Central systems capable of stable operation for smallest isolation area



HVAC Mandatory Provisions/Controls **Stair and Shaft Vents**

- Motorized dampers
 - Can be automatically closed during normal building operation
 - Interlocked to open as required by fire and smoke detection systems



HVAC Mandatory Provisions/Controls

Gravity Hoods, Vents, and Ventilators

- Motorized dampers to automatically shut when spaces served are not in use
- Exceptions
 - Gravity dampers okay in buildings
 - < 3 stories in height
 - Of any height in climates < 2700 HDD65



HVAC Mandatory Provisions/Controls

Heat Pump Auxiliary Heat Control

- Controls to prevent supplementary heat when heat pump can handle the load
 - Exception
 - Heat pumps
 - With minimum efficiency regulated by NAECA
 - With HSPF rating meeting Table 6.2.1B
- (Includes all usage of internal electric resistance heating)

Section 6.2.3.4



HVAC Mandatory Provisions/Controls **Enclosed Parking Garage Ventilation**

- Garage ventilation fan systems with total design capacity $> 30,000$ cfm to have at least one
 - Automatic control capable of staging fans or modulating fan volume as required to maintain CO levels below ASHRAE Standard 62 (only applies to garages used predominantly by gasoline-powered vehicles)
 - Automatic control complying with 6.2.3.2.1 that's capable of shutting off fans or reducing fan volume during periods when garage is not in use

Section 6.2.3.5



HVAC Mandatory Provisions/Controls **Humidifier Preheat**

- Automatic valve to shut off preheat when humidification isn't required

Section 6.2.3.6



HVAC Mandatory Provisions/Controls

Humidification and Dehumidification

- Provide means to prevent simultaneous operation of humidification and dehumidification equipment
 - Limit switches, mechanical stops, or software programming (DDC systems)
- Exceptions
 - Zones served by desiccant systems, used with direct evaporative cooling in series
 - Systems serving zones where specific humidity levels are required and approved by jurisdiction
 - Computer rooms, museums, and hospitals

Section 6.2.3.7



HVAC Mandatory Provisions/Controls

Freeze Protection and Snow/Ice

- Automatic controls for
 - freeze protection systems
 - outside air temperatures $> 40^{\circ}\text{F}$ or when conditions of protected fluid will prevent freezing
 - Snow- and ice-melting systems
 - pavement temperature $> 50^{\circ}\text{F}$ and no precipitation is falling and outdoor temperature $> 40^{\circ}\text{F}$

Section 6.2.3.8



HVAC System Construction and Insulation HVAC Mandatory Provisions

- Insulation installed in accordance with industry accepted standards
- Insulation protection
- Duct and plenum insulation
- Duct Sealing
- Duct Leakage Testing
- Piping Insulation



HVAC Mandatory Provisions **General**

- Insulation installed in accordance with industry accepted standards
- Insulation
 - Protected from damage due to sunlight, moisture, equipment maintenance, and wind
 - Exposed to weather to be suitable for outdoor service
 - Covering chilled water piping, refrigerant suction piping, or cooling ducts located outside the conditioned space to include a vapor retardant located outside the insulation, all penetrations and joints of which to be sealed

Section 6.2.4.1



HVAC Mandatory Provisions/HVAC Insulation **Duct and Plenum Insulation**

- All supply and return ducts and plenums to be insulated per Tables 6.2.4.2A and 6.2.4.2B
- Exceptions
 - Factory-installed plenums, casings, or ductwork furnished as part of HVAC equipment
 - Ducts located in heated, semi-heated, or cooled spaces
 - For runouts < 10 ft in length to air terminals or air outlets, the R-value need not exceed R-3.5
 - Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas > 5 ft² need not exceed R-2; those ≤ 5 ft² need not be insulated

Section 6.2.4.2



HVAC Mandatory Provisions/HVAC Insulation **Duct Sealing**

- Table 6.2.4.3A
- Requirements of 6.2.4.4
- Standard industry practice

TABLE 6.2.4.3A
Minimum Duct Seal Level*

Duct Location	Duct Type			
	Supply		Exhaust	Return
	≤2 in. w.c.†	>2 in. w.c.†		
Outdoors	A	A	C	A
Unconditioned Spaces	B	A	C	B
Conditioned Spaces**	C	B	B	C

* See Table 6.2.4.3B definition of Seal Level.

† Duct design static pressure classification.

** Includes indirectly conditioned spaces such as return air plenums.

Section 6.2.4.3



HVAC Mandatory Provisions/HVAC Insulation **Duct Leakage Tests**

- Designed > 3 in. w.c.
 - Leak tested
 - Representative sections \geq 25% of the total installed duct area shall be tested
 - Ratings > 3 in. w.c. to be identified on drawings
 - Maximum permitted duct leakage
 - $L_{\max} = C_L P^{0.65}$

Where L_{\max} = maximum permitted leakage in cfm/100 ft² duct surface area



Section 6.2.4.4



HVAC Mandatory Provisions/HVAC Insulation **Piping Insulation**

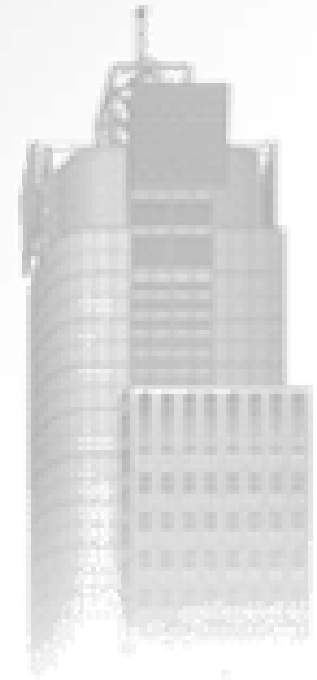
- Table 6.2.4.5
- Exceptions
 - Factory-installed
 - Piping conveying fluids
 - design operating temperature range between 60°F-105°F, inclusive
 - that haven't been heated or cooled through the use of nonrenewable energy or where heat gain or heat loss will not increase energy usage
 - Hot water piping between shut off valve and coil, not > 4 ft in length, when located in conditioned spaces
 - Pipe unions in heating systems (steam, steam condensate, and hot water)

Section 6.2.4.5



HVAC Mandatory Provisions Completion Requirements

- Record drawings
- Operating and maintenance manuals
- System balancing
- System commissioning



Section 6.2.5



HVAC Mandatory Provisions/Completion Req **Drawings**

- Record drawings of actual installation to building owner within 90 days of system acceptance and include, as a minimum
 - Location and performance data on each piece of equipment
 - General configuration of duct and pipe distribution system including sizes
 - Terminal air or water design flow rates



HVAC Mandatory Provisions/Completion Req **Manuals**

- Operating and maintenance manuals to building owner within 90 days of system acceptance and include, as a minimum



HVAC Mandatory Provisions/Completion Req **System Balancing**

- Measured and adjusted within 10% of design rates
- Exception
 - Variable speed, variable volume flow distribution systems need not be balanced upstream of a pressure independent device
- Written report for conditioned spaces > 5000 ft²



HVAC Mandatory Provisions/Completion Req **Air System Balancing**

- Minimize throttling losses
- For fans with system power > 1 hp
 - Adjust fan speed to meet design flow conditions (except variable flow distribution systems need not be balanced upstream of the controlling device)



HVAC Mandatory Provisions/Completion Req **Hydronic System Balancing**

- Proportionately balanced to minimize throttling losses
- Pump impeller trimmed or pump speed adjusted to meet design flow conditions
- Each system to have either the ability to measure differential pressure increase across the pump or have test ports at each side of the pump
- Exceptions
 - Pumps with pump motors ≤ 10 hp
 - When throttling results in $< 5\%$ of the nameplate hp draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed

Section 6.2.5.3.3



HVAC Mandatory Provisions/Completion Req **System Commissioning**

- Control elements are calibrated, adjusted, and in proper working condition
- > 50,000 ft² conditioned area
 - Except warehouses and semiheated spaces
 - Requires commissioning plan



HVAC Prescriptive Path

- Economizers (*Section 6.3.1*)
- Simultaneous Heating and Cooling Limitation (*Section 6.3.2*)
- Air System Design and Control (*Section 6.3.3*)
- Hydronic System Design and Control (*Section 6.3.4*)
- Heat Rejection Equipment (*Section 6.3.5*)
- Energy Recovery (*Section 6.3.6*)
- Exhaust Hoods (*Section 6.3.7*)
- Radiant Heating Systems (*Section 6.3.8*)
- Hot Gas Bypass Limitation (*Section 6.3.9*)



HVAC Prescriptive Path **Economizers**

- Climate and size dependent (Table 6.3.1)
- There are LOTS of exceptions
- Can use air economizers
 - 100% of design supply air
 - Sequenced with mechanical cooling equipment
 - High limit shutoff
 - Dampers
- Can use water economizers
 - 100% of expected system cooling load
 - Maximum pressure drop

Section 6.3.1



HVAC Prescriptive Path/Air Economizers **Design Capacity**

- System capable of modulating outside air and return air dampers to provide up to 100% of the design supply air quantity as outside air for cooling



HVAC Prescriptive Path/Air Economizers **Control Signal**

- Dampers capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature
- Exception
 - Systems controlled from space temperature (such as single-zone systems)



HVAC Prescriptive Path/Air Economizers **High Limit Shutoff**

- Automatically reduce outside air intake to 6.1.2 of ASHRAE Standard 62 when outside air intake will no longer reduce cooling energy usage
- Control types for specific climates from Table 6.3.1.1.3A
- Settings from Table 6.3.1.1.3B



HVAC Prescriptive Path/Air Economizers **Dampers**

- Return air and outside air dampers to have maximum leakage rate of 20 cfm



HVAC Prescriptive Path/Air Economizers **Relief of Excess Outside Air**

- Means to relieve excess outdoor air during economizer operation to prevent overpressurizing the building
- Outlet located to avoid recirculation into the building



HVAC Prescriptive Path/Water Economizers **Design Capacity**

- System capable of cooling supply air by indirect evaporation and providing up to 100% of expected system cooling load at outside air temperatures of 50°F dry bulb/45°F wet bulb and below
- Exception
 - If the building dehumidification requirements cannot be met at the above condition, you can also meet this requirement if your design can meet 100% of expected cooling load at 45°F dry bulb/40°F wet bulb

Section 6.3.1.2.1



HVAC Prescriptive Path/Water Economizers **Maximum Pressure Drop**

- Precooling coils and water-to-water heat exchangers to have either
 - Water-side pressure drop of < 15 ft of water **OR**
 - Create a secondary loop so the coil or heat exchanger pressure drop isn't seen by the circulating pumps when the system is in normal cooling mode



HVAC Prescriptive Path/Water Economizers **Integrated Economizer Control**

- Economizers must be integrated with mechanical cooling systems and be capable of providing partial cooling even when additional mechanical cooling is required
- Some exceptions to this



HVAC Prescriptive Path/Water Economizers

Economizer Heating System Impact

- Designed so economizer operation doesn't increase the building heating energy use during normal operation
- Exception
 - Where heating is allowed by 6.3.2



HVAC Prescriptive Path Simultaneous Heating and Cooling Limitation

- Zone controls capable of operating in sequence the supply of heating and cooling energy to the zone to prevent reheating, recooling, mixing or simultaneously supplying air previously heated or cooled
- Hydronic system controls to prevent reheating or recooling of fluids



Simultaneous Heating and Cooling Limitation (cont'd)

HVAC Prescriptive Path

- Dehumidification controls for humidistats to prevent reheating, mixing, etc
- Humidification controls



HVAC Prescriptive Path **Zone Controls**

- Capable of operating in sequence the supply of heating and cooling energy to the zone
- Controls prevent
 - Reheating
 - Recooling
 - Mixing or simultaneously supplying air previously heated or cooled
 - Other simultaneous operation of heating and cooling systems to the same zone

Section 6.3.2.1



HVAC Prescriptive Path **Zone Controls - Exceptions**

- Zones for which volume of air that is reheated, recooled, or mixed is no greater than the larger of the following
 - Volume of outside air to meet 6.1.3 of ASHRAE 62 for the zone
 - 0.4 cfm/ft² of zone conditioned floor area with several conditions
 - 300 cfm for zones whose peak flow rate totals no more than 10% of the total fan system flow rate
 - Any higher rate that can be demonstrated to jurisdiction to reduce overall system annual energy usage...
- Zones where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that the variable air volume systems are impractical



HVAC Prescriptive Path Hydronic System Controls

- Limit heating and cooling of fluids previously heated or cooled mechanically per 6.3.2.2.1 and 6.3.2.2.3



HVAC Prescriptive Path **Three-Pipe System**

- No common return system for both hot and chilled water



HVAC Prescriptive Path Two-Pipe Changeover System

- Common distribution system acceptable if
 - Deadband from one mode to another is $\geq 15^{\circ}\text{F}$ outside air temperature
 - Controls to allow operation of ≥ 4 hours before changing over
 - Reset controls so heating and cooling supply temperatures at changeover point no more than 30°F apart



HVAC Prescriptive Path Hydronic (Water Loop) Heat Pump Systems

- Controls to provide heat pump water supply temperature deadband of at least 20°F between initiation of heat rejection and heat addition by central devices
- Cooling tower bypass or cooling tower isolation dampers
- A two-position valve at each hydronic heat pump for hydronic systems having a total pump system power > 10 hp
- Exception
 - If system loop temperature optimization controller is used, deadband < 20°F is allowed

Section 6.3.2.2.3



HVAC Prescriptive Path **Dehumidification**

- Humidistatic controls to prevent
 - Reheating
 - Mixing of hot and cold air streams
 - Heating and cooling of same air stream

Section 6.3.2.3



Dehumidification Exceptions

- Systems capable of reducing supply air flow to 50%, or to minimum ventilation
- Systems under 6.67 tons that can unload at least 50%
- Systems smaller than 3.3 tons
- Process applications
- 75% of reheat or recool energy is recovered or solar



HVAC Prescriptive Path **Humidification**

- Systems with hydronic cooling and humidification systems designed to maintain inside humidity at $> 35^{\circ}\text{F}$ dewpoint temperature shall use a water economizer if required by 6.3.1

Section 6.3.2.4



HVAC Prescriptive Path Air System Design and Control

- HVAC systems with total fan system power > 5 hp to meet 6.3.3.1 through 6.3.3.3
 - Fan Power Limitation
 - VAV Fan Control
 - Part Load Fan Power Limitation
 - Static Pressure Sensor location
 - Set Point Reset



HVAC Prescriptive Path **Fan Power Limitation**

- Table 6.3.3.1
- Allowable fan system power may be adjusted if
 - Air systems require air treatment or filtering systems with pressure drops > 1 in. w.c. when filters are clean, or heat recovery coils or devices, or direct evaporative humidifiers/coolers, or other devices to serve process loads in the airstream
- If
 - design room temperature – supply air temp at cooling design condition = $> 20^{\circ}\text{F}$, allowable fan system power may be adjusted

Section 6.3.3.1



HVAC Prescriptive Path

Part-Load Fan Power Limitation

- Individual VAV fans with motors ≥ 30 hp
 - Have other controls and devices to result in fan motor demand $\leq 30\%$ of design wattage at 50% of design air volume when static pressure set point = $1/3$ of total design static pressure, based on manufacturer's certified fan data



HVAC Prescriptive Path

Static Pressure Sensor Location

- Placed so controller set point is $\leq 1/3$ the total design fan static pressure
 - Except for digital control systems with zone reset capabilities where it may be at the fan discharge
- If this results in the sensor being located downstream of major duct splits, install multiple sensors in each major branch



HVAC Prescriptive Path **Set Point Reset**

- For systems with direct digital control of individual zone boxes reporting to the central control panel
 - Static pressure set point reset based on zone requiring the most pressure



Hydronic System Design HVAC Prescriptive Path and Control

- HVAC hydronic systems with total pump system power > 10 hp shall meet 6.3.4.1 – 6.3.4.3
 - Hydronic Variable Flow Systems
 - Pump Isolation
 - Chilled and Hot Water Temperature Reset



HVAC Prescriptive Path **Hydronic Variable Flow**

- HVAC pumping systems to include control valves
 - Designed to modulate or step open and close as a function of load
 - Designed for variable fluid flow
 - Capable of reducing flow rates to $\leq 50\%$ of design flow rate
- Individual pumps serving variable flow systems with a pump head > 100 ft and motor > 50 hp
 - Have controls and/or devices resulting in pump motor demand $\leq 30\%$ of design wattage at 50% of design water flow

Section 6.3.4.1



HVAC Prescriptive Path Hydronic Variable Flow - Exceptions

- Systems where
 - Minimum flow is $<$ minimum flow required by equipment manufacturer for proper operation of equipment served by the system
 - Total pump system power ≤ 75 hp
- Systems that include ≤ 3 control valves



HVAC Prescriptive Path **Pump Isolation**

- If chilled water plant has more than one chiller or boiler plant has more than one boiler
 - Provide for flow reduction when chiller or boiler is shut down

Section 6.3.4.2



HVAC Prescriptive Path

Chilled and Hot Water Temperature Reset Controls

- Affects systems with design capacity $> 300,000$ Btu/h
 - To include controls to automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature
- Exceptions
 - Would result in improper operation
 - Hydronic systems with variable flow



HVAC Prescriptive Path Heat Rejection Equipment

- Applies to heat rejection equipment used in comfort cooling systems such as
 - Air-cooled condensers
 - Open cooling towers
 - Closed-circuit cooling towers
 - Evaporative condensers
- Exceptions
 - Heat rejection devices included as an integral part of equipment listed in Tables 6.2.1A-6.2.1D

Section 6.3.5



HVAC Prescriptive Path **Fan Speed Control**

- Each fan powered by a motor ≥ 7.5 hp
 - Have capability to operate fan at $\leq 2/3$ full speed
 - Have controls to automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device
- Exceptions
 - Condenser fans serving multiple refrigerant circuits or flooded condensers
 - Installations located in climates > 7500 CDD50
 - 1/3 of the fans on a multiple fan application speed controlled

Section 6.3.5.2



HVAC Prescriptive Path Exhaust Air Energy Recovery

- Incorporate exhaust air energy recovery in systems with
 - $\geq 70\%$ outside air and ≥ 5000 cfm total
 - 50% energy recovery effectiveness



Exhaust Air Energy Recovery HVAC Prescriptive Path Exceptions

- Lab systems meeting 6.3.7.2
- Systems serving uncooled spaces that are heated to $< 60^{\circ}\text{F}$
- Systems exhausting toxic, flammable, paint or corrosive fumes or dust
- Commercial kitchen hoods classified as Type 1 by NFPA 96
- Where $> 60\%$ of outdoor heating energy is provided from site-recovered or site solar energy
- Heating systems in climates < 3600 HDD65
- Cooling systems in climates with a 2.5% cooling design wet-bulb temperature $< 65^{\circ}\text{F}$
- Where largest exhaust source is $< 75\%$ of the design outdoor airflow
- Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil



Heat Recovery for Service Water Heating

HVAC Prescriptive Path

- Condenser recovery required if
 - 24 hrs per day and
 - Heat rejection $> 6,000,000$ Btu/h and
 - SWH load $> 1,000,000$ Btu/h

Section 6.3.6.2



HVAC Prescriptive Path **Kitchen Hoods (Exhaust)**

- Hoods $>$ 5000 cfm to be provided with makeup air sized for at least 50% of exhaust air volume that is a) unheated or heated to more than 60°F and b) uncooled or cooled without the use of mechanical cooling
- Exceptions
 - Where hoods are used to exhaust ventilation air that would otherwise exfiltrate or be exhausted by other fan systems
 - Certified grease extractor hoods that require a face velocity no greater than 60 fpm

Section 6.3.7.1



HVAC Prescriptive Path **Fume Hoods (Exhaust)**

- Hood systems with a total exhaust rate $> 15,000$ cfm to have ONE of the following features
 - Operation to $< 50\%$ design flow OR
 - Direct make up at least 75% of exhaust rate at specified conditions OR
 - Heat recovery for make-up air



HVAC Prescriptive Path Radiant Heating Systems

- Required for unenclosed spaces except loading docks with air curtains
- “Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard”

Section 6.3.8



HVAC Prescriptive Path **Hot Gas Bypass Limitation**

- Not used (including other evaporator pressure control systems) unless system is designed with multiple steps of unloading or continuous capacity modulation
- Exception
 - Unitary packaged systems with cooling capacities \leq 90,000 Btu/h



Section 7 - Service Water Heating

- General (*Section 7.1*)
- Mandatory Provisions (*Section 7.2*)
 - Sizing of systems
 - Equipment efficiency
 - Service hot water piping insulation
 - System controls
 - Pools
 - Heat traps
 - Space heating and water heating
 - Service water heating equipment
- Prescriptive Path (*Section 7.3*)





SWH Mandatory Provisions **Sizing of Systems**

- In accordance with manufacturer's published sizing guidelines

Section 7.2.1



SWH Mandatory Provisions **Equipment Efficiency**

- Table 7.2.2
- Equipment not listed in Table 7.2.2 has no minimum performance requirements
- Exception
 - Water heaters and hot water supply boilers > 140 gal storage capacity don't have to meet standby loss requirements when
 - Tank surface is thermally insulated to R-12.5, and
 - A standing pilot light isn't installed, and
 - Gas- or oil-fired water heaters have a flue damper or fan-assisted combustion

Section 7.2.2



SWH Mandatory Provisions Service Hot Water Piping Insulation

- Table 6.2.4.5, Section 6
- Circulating water heater
 - Recirculating system piping, including supply and return piping
- Nonrecirculating storage system
 - First 8 ft of outlet piping
 - Inlet pipe between storage tank and heat trap
- Externally-heated pipes (heat trace or impedance heating)



SWH Mandatory Provisions **System Controls**

- Temperature Controls
- Temperature Maintenance Controls
- Outlet Temperature Controls
- Circulating Pump Controls

Section 7.2.4



SWH Mandatory Provisions **Temperature Controls**

- To allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use
- Exception
 - If manufacturer's installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion

Section 7.2.4.1



SWH Mandatory Provisions **Temperature Maintenance Controls**

- Automatic time switches or other controls
 - Set to switch off usage temperature maintenance system during extended periods when hot water is not required

Section 7.2.4.2



SWH Mandatory Provisions Outlet Temperature Controls

- Automatic time switches or other controls
 - To limit maximum temperature of water delivered from lavatory faucets in public facility restrooms to 110°F

Section 7.2.4.3



SWH Mandatory Provisions **Circulating Pump Controls**

- To limit operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle



SWH Mandatory Provisions **Pools**

- Pool heaters to have readily accessible on-off switch
- Pool heaters fired by natural gas to NOT have continuously burning pilot lights
- Vapor retardant pool covers required (unless recovered or solar heat)
- Time switches required



Section 7.2.5





SWH Mandatory Provisions **Heat Traps**

- Noncirculating systems to have heat traps on both the inlet and outlet piping as close as practical to storage tank (if no integral heat traps)
 - Either a device specifically designed for this purpose or
 - Arrangement of tubing that forms a loop of 360° or piping that form the point of connection to the water heater includes a length of piping directed downward before connection to the vertical piping of the supply water or hot water distribution system, as applicable

Section 7.2.6



SWH Prescriptive Path

Space Heating and Water Heating

- Gas- or oil-fired space heating boiler system (complying with Section 6) is allowed to provide total space heating and water heating when ONE of the following conditions is met
 - Single boiler or component that is heating the service water has a standby loss in Btu/h not exceeding
 - $(13.3 \times pmd + 400) / n$; where pmd is probable maximum demand in gal/h and n is the fraction of the year when outdoor daily mean temperature is $> 64.9^{\circ}\text{F}$
 - Jurisdiction agrees use of a single heat source will consume less energy than separate units
 - Energy input of the combined boiler and water heater system is $< 150,000$ Btu/h
- Instructions for determining standby loss are included in this Section

Section 7.3.1



SWH/Prescriptive Path Service Water Heating Equipment

- Equipment used to provide the additional function of space heating as part of a combination (integrated) system shall satisfy all requirements for service water heating equipment



Section 8 - Power

- Voltage drop
- Completion requirements



Voltage Drop

- Two types of conductors
 - Feeder conductors
 - Run between the service entrance equipment and the branch circuit distribution equipment
 - 2% maximum voltage drop allowed
 - Branch circuit conductors
 - Run from the final circuit breaker to the outlet or load
 - 3% maximum voltage drop allowed

Section 8.2.1



Completion Requirements

- 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

Section 8.2.2



Lighting Compliance

Building System

Compliance Options

Envelope

Lighting

Mechanical

HVAC

SWH

Section 9

Mandatory Provisions
(required for all compliance options)

Prescriptive Option

Trade Off Option

Energy Cost Budget

Energy Code Compliance



Section 9 - Lighting

- General Application (*Section 9.1*)
- Mandatory Provisions (*Section 9.2*)
 - Lighting controls
 - Tandem wiring
 - Exit signs
 - Installed interior lighting power
 - Luminaire wattage
 - Exterior building grounds lighting
- Prescriptive Path (*Section 9.3*)
 - Interior Lighting Power Allowance
 - Building Area Method
 - Space-by-Space Method
 - Exterior Lighting Power Allowance





Lighting General Application

- Interior spaces of buildings
- Exterior building features
- Exterior grounds lighting powered through building
- Exceptions
 - Emergency lighting
 - Lighting required by life safety statute
 - Lighting within living units of buildings
 - Decorative gas lighting



Lighting Changes Between 90.1-1989 and 90.1-1999

- More efficient lighting
 - Less power allowed
- No lighting control credits
 - Lighting power allowance now based only on connected lighting power
- No control points for spaces
- No separate lighting controls for daylighted spaces



Lighting Changes Between 90.1-1989 and 90.1-1999 *(cont'd)*

- Automatic shutoff controls required
- Most exterior power requirements replaced with minimum efficacy requirements
 - Parking garages included in interior lighting
- Interior power requirements updated
 - More stringent requirements
 - Area factors no longer need to be calculated
 - Building area allowances no longer depend on size
- Additional power allowances for certain specialty lighting



Lighting Scope

- New construction
- Existing nonresidential and high-rise residential
 - If $\geq 50\%$ of existing luminaires are replaced
 - If renovation increases lighting power
- Control devices can't control
 - $> 2500 \text{ ft}^2$ in spaces $< 10,000 \text{ ft}^2$
 - $> 10,000 \text{ ft}^2$ in spaces $> 10,000 \text{ ft}^2$
- Control must be readily accessible and located so occupants can see the controlled lighting



Lighting Mandatory Provisions **Lighting Control**

- Automatic lighting shutoff
 - Applies to buildings $> 5000 \text{ ft}^2$
 - Time-scheduling devices
 - Accommodate separate schedules for each floor or each space $> 25,000 \text{ ft}^2$
 - Occupant-sensing devices
 - All general lighting controlled by one or more occupant sensors
 - Must turn off lights in each controlled space within 30 minutes of last occupant detection

Section 9.2.1



Lighting Mandatory Provisions **Space Control**

- At least one for each room or space enclosed by ceiling-height partitions
- Readily accessible to occupants
 - Except for safety or security
- In spaces $\leq 10,000 \text{ ft}^2$, each control can serve a maximum of 2500 ft^2
- In spaces $> 10,000 \text{ ft}^2$, each control can serve a maximum of $10,000 \text{ ft}^2$

Section 9.2.1.2



Lighting Mandatory Provisions **Exterior Lighting Control**

- Photocells or astronomical time switch 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)
- Exceptions – lighting for
 - Covered vehicle entrances
 - Exits from buildings or parking structures
(where required for safety, security, or eye adaptation)

Section 9.2.1.3



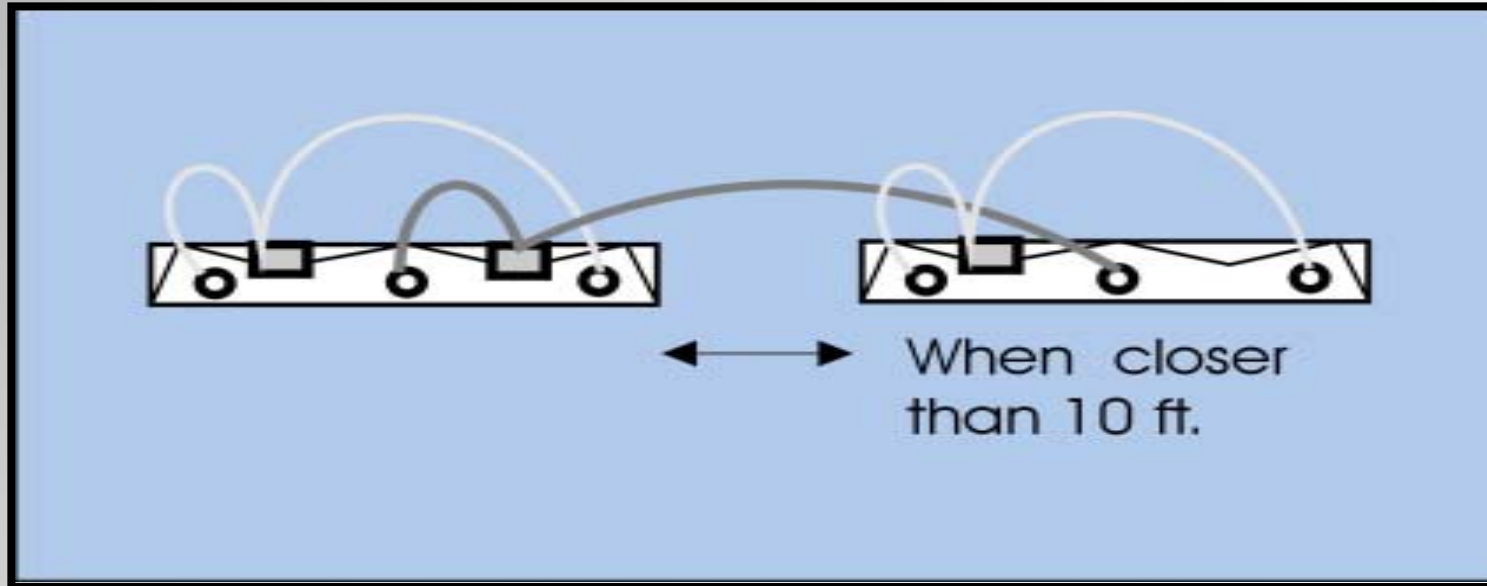
Lighting Mandatory Provisions **Additional Control**

- Many special lighting applications must be controlled separately
 - Display/accent lighting
 - Case lighting
 - Hotel/motel guest room lighting
 - Task lighting
 - Nonvisual lighting
 - Demonstration lighting

Section 9.2.1.4



Lighting Mandatory Provisions **Tandem Wiring**



Section 9.2.2



Lighting Mandatory Provisions **Tandem Wiring Exceptions**

- Separated surface or pendant luminaires
- Recessed luminaires more than 10 ft apart
- Other luminaires
 - With three-lamp ballasts
 - On emergency lighting circuits
 - With no available pair
 - With one lamp, high frequency, electronic ballast



Lighting Mandatory Provisions **Exit Signs**

- Exit signs operating at > 20 W must have a source efficacy ≥ 35 lumens/W
- LED lamps okay
- CF lamps with electronic ballasts usually okay
- Majority of incandescent lamps not okay



Section 9.2.3



Efficacy

- The ratio of light output to watts input
 - lumens per watt
- The higher the efficacy, the more efficient the light source
 - 40 watt incandescent = 480 lumens
 - 40 watt fluorescent = 2640 lumens



Lighting Mandatory Provisions Installed Interior **Lighting Power**

- Includes all permanent and portable interior lighting intended for general, ambient, or task illumination
- Includes lamp, power used by ballast, the control (when applicable), current regulators, and any other power draws associated with the lighting system
- Exception
 - If 2 or more independently operating lighting systems in a space can be controlled to prevent simultaneous operation, can base IILP on lighting system with highest wattage

Section 9.2.4



Lighting Mandatory Provisions **Luminaire Wattage**

- Standard incandescent = max. labeled wattage of the luminaire
- Luminaires with ballasts = wattage of the lamp/ballast combination
- Line voltage track = min. 30 W per foot
- Low voltage track = transformer wattage
- All others as specified



Lighting Power Development Concept

- Create building space models to calculate power densities with:
 - Current product performance data
 - Updated efficacy and loss factors
 - New building construction data
 - IES-recommended light levels
 - Professional lighting design consensus



Lighting Mandatory Provisions **Exterior Building Grounds Lighting**

- Luminaires that operate at $> 100 \text{ W}$ = efficacy $> 60 \text{ lumens/W}$
- Exceptions
 - Traffic signals
 - Lighting within outdoor signs
 - Lighting used to illuminate public monuments or registered historic landmarks
 - If an occupancy sensor or motion sensor controls the lighting application



Lighting Prescriptive Path **Interior Lighting Power**

- Lots of exemptions
- Calculation methods
 - Building area
 - Space-by-space
 - Trade-offs of interior lighting power allowance among portions of the building for which a different calculation method has been used is not permitted



Lighting Power Allowance Exemptions

- Theatrical, stage, film, and video production
- Medical and dental procedures
- Exhibit 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
- Retail display windows, provided the display is enclosed by ceiling-height partitions
- Interior spaces specifically designated as registered interior historic landmarks
- Integral part of advertising or directional signage
- Exit signs
- Sale or lighting educational demonstration systems
- Athletic playing areas with permanent facilities for TV broadcasting
- Casino gaming areas
- For use in areas specifically designed for the visually impaired



Lighting Prescriptive Path **Building Area Method**

- Used for projects involving
 - An entire building
 - A single, independent, and separate occupancy in a multi-occupancy building
- Gross lighted area is multiplied by allowance from Table 9.3.1.1
- Limitations
 - Insensitive to specific space functions and room configurations
 - Generally is more restrictive
 - Does not apply to all building types - but “selection of a reasonably equivalent type” is permitted

Section 9.3.1.1



Lighting Prescriptive Path **Gross Lighted Area**

- Sum of total lighted area of a building
 - Measured from the exterior faces of the exterior walls or from the centerline of walls separating buildings
- Used in the building area method of determining interior lighting power allowance



Lighting Prescriptive Path **Building Area Allowances**

- Table 9.3.1.1



Lighting Prescriptive Path **Space-by-Space Method**

- Identify different building types in your project
- Divide gross lighted area of the building into each of the space types
- Calculate lighting power allowance by multiplying area of space type by lighting power density for that specific space type
- Sum all the allowances
- Advantages
 - More flexible
 - Applicable to all building types
 - Accounts for room geometry (e.g., lighting needs of enclosed office vs. open office)

Section 9.3.1.2



Lighting Prescriptive Path Additional Interior Lighting Power

- An increase in the ILPA is allowed for specific space functions when using the space-by-space method
 - Decorative – 1.0 W/ft² in space used
 - Fluorescent designed to eliminate glare - .35 W/ft²
 - Lighting equipment installed in retail spaces specifically to highlight merchandise in specific space used
 - Additional 1.6 W/ft², or
 - Additional 3.9 W/ft² for fine merchandise



Lighting Prescriptive Path Exterior Building Lighting Power

- Sum of all lighting power allowances for applicable exterior applications
- Building Surface Requirements
 - Building entrance with canopy – 3 W/ft²
 - Building entrance – 33 W/linear ft
 - Building exit – 20 W/linear ft
 - Building facades – 0.25 W/ft²
- Exceptions, when equipped with a control device
 - Specialized signal, directional, and market lighting associated with transportation
 - Public monuments
 - Registered historic landmark structures or buildings
 - Lighting integral to advertising signage

Section 9.3.2



Section 10 - Other Equipment

- Changes between 90.1-1989 and 90.1-1999
 - No transformer recommendations and requirements
 - No subdivision of electrical feeders or provisions for check metering
 - *Motor efficiency levels are higher and correspond to EPC Act (only requirement in this section)*
 - Motor efficiency requirement now covers all relevant motors, even if they're part of equipment rated elsewhere in the Standard
 - No exemption for motors running < 1000 hrs/yr



Section 11 - Energy Cost Budget Method

- The ultimate trade-off method allowing you to trade-off across building systems through the use of annual, hourly simulation tools and a baseline building.
- The only real way to deal with unique designs, renewables, high-efficiency equipment, etc.
- The basis of the energy portion of the LEED rating
- Limits allowable energy costs of the design to those of a building meeting the Standard



Section 12 - Normative References

- Normative (read “mandatory”) reference documents
- Includes test methods, rating procedures, and other standards



Assembly U-Factor, C-Factor, and F-Factor Determination

- Includes pre-calculated U-factors, C-factors, and F-factors
 - Above-grade walls
 - Below-grade walls
 - Floors
 - Slab-on-grade floors
 - Opaque doors
 - Fenestration

**Normative
Appendix A**



Building Envelope Criteria

- Actual prescriptive requirements tables for 26 different climate bins
- These are in an appendix because they would have taken up too much space in Chapter 5 and would have broken up the continuity of the text of the Standard

**Normative
Appendix B**



Methodology for Building Envelope Trade-Off Option in Subsection 5.4

- The gory details of how the envelope trade-off option is implemented
- For those familiar with the “old” ENVSTD trade-off, this new trade-off allows trade-offs between roof and wall elements. The “metric” of trade-off is ultimately an energy dollar trade-off.

**Normative
Appendix C**



Climate Data

- Climatic data for a number of US, Canadian, and international locations
- HDD65 and CDD50 for use in envelope calculations
- Heating and cooling design temperatures and the old “number of hours between 8 am and 4 pm with T_{db} between 55 and 69” for HVAC calculations

**Normative
Appendix D**



Informative References

- Other useful references that are not mandatory
- In general, these are not consensus documents so ASHRAE procedures do not allow them to be mandatory references

**Informative
Appendix E**