

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

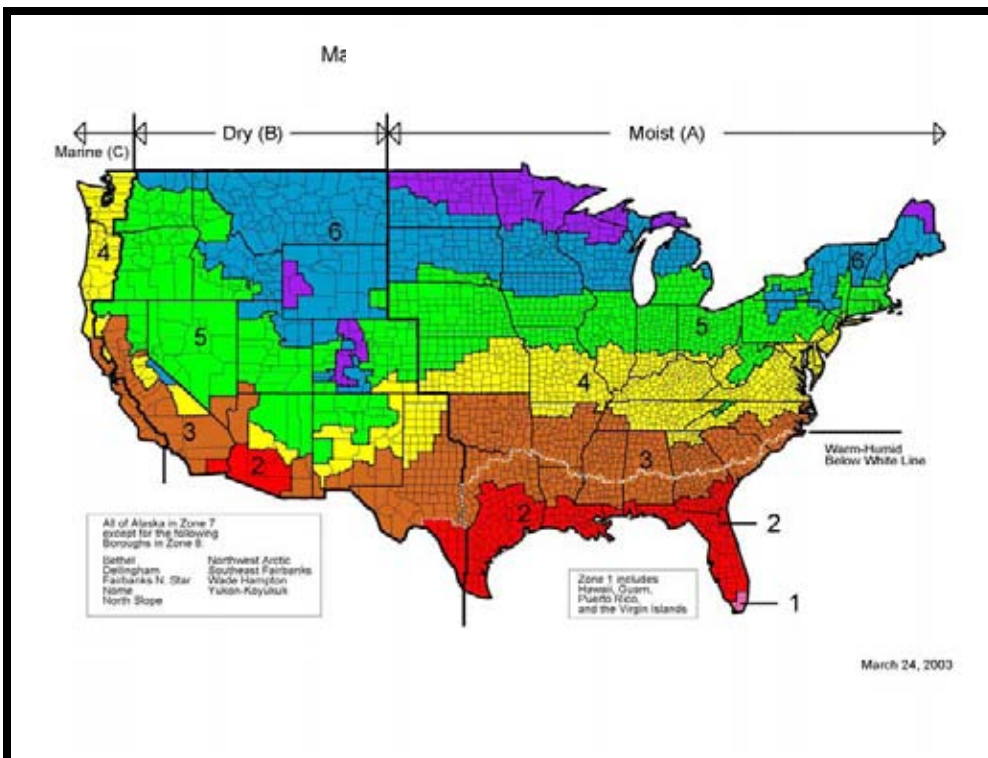
**Resources – slide 4**

- 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

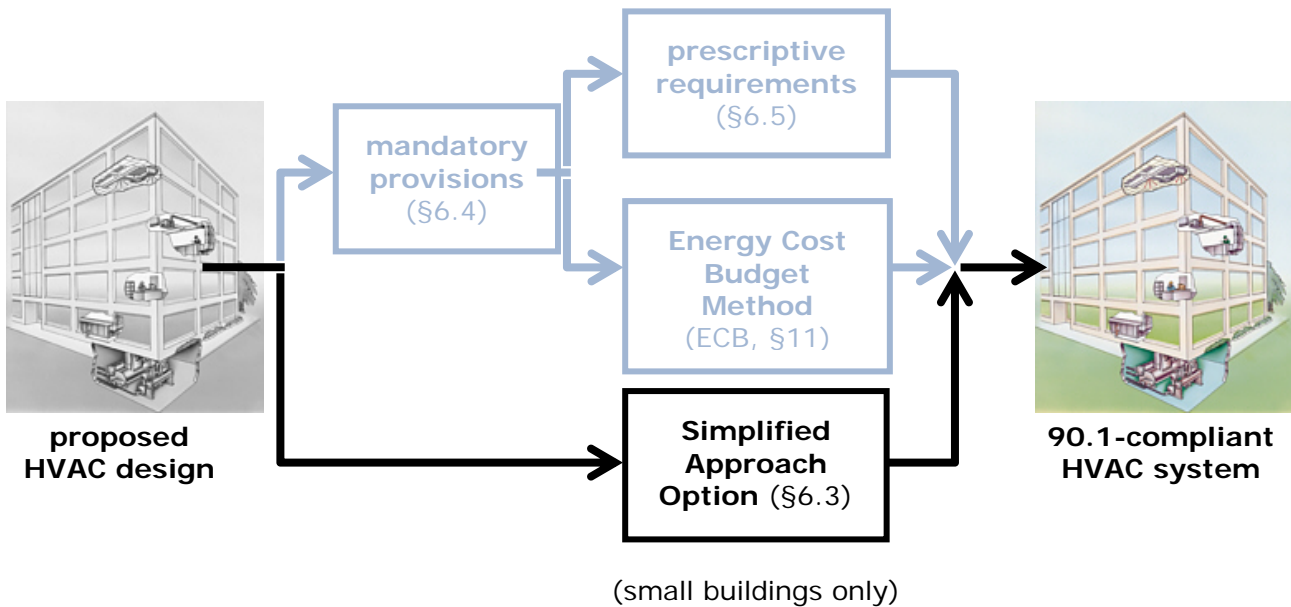
**Resources Continued – slide 5**

- 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

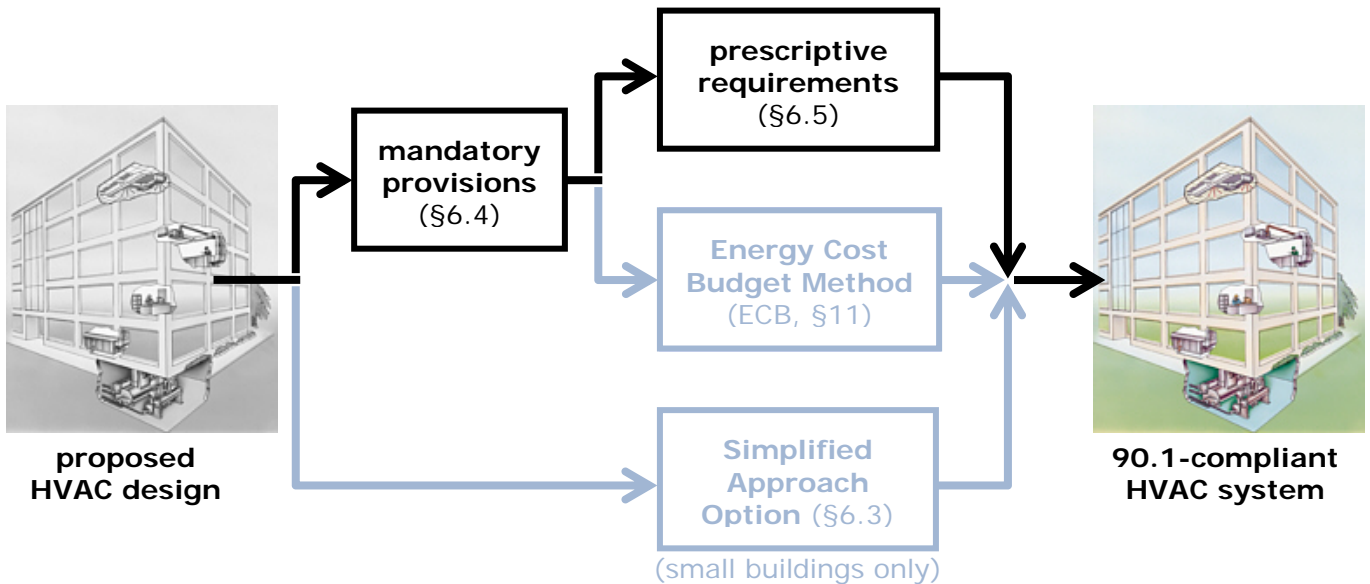
- Economizer as necessary
- Heat: Heat pump, fuel-fired furnace, electric resistance, or baseboard system with boiler
- Min outdoor air:  $\leq 3,000$  cfm AND  $< 70\%$  of SA, unless energy recovery is used
- Manual-changeover or dual-setpoint thermostat
- Controls for heat pumps with auxiliary heat
- 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 ( $\geq 300$ 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)

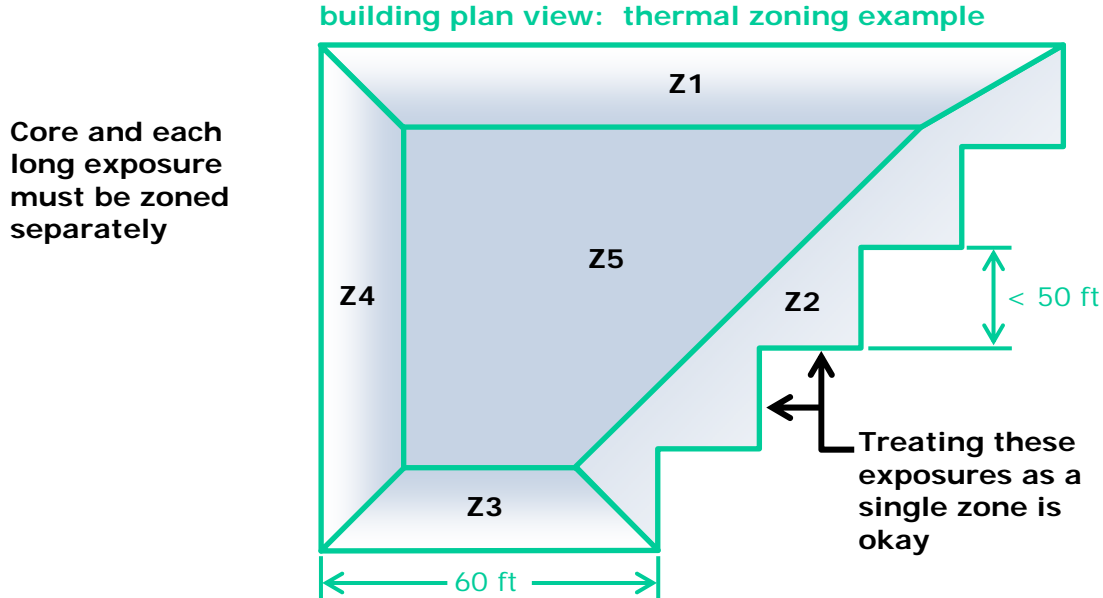
## Zone Thermostatic Controls (§6.4.3.1) – slide 17

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

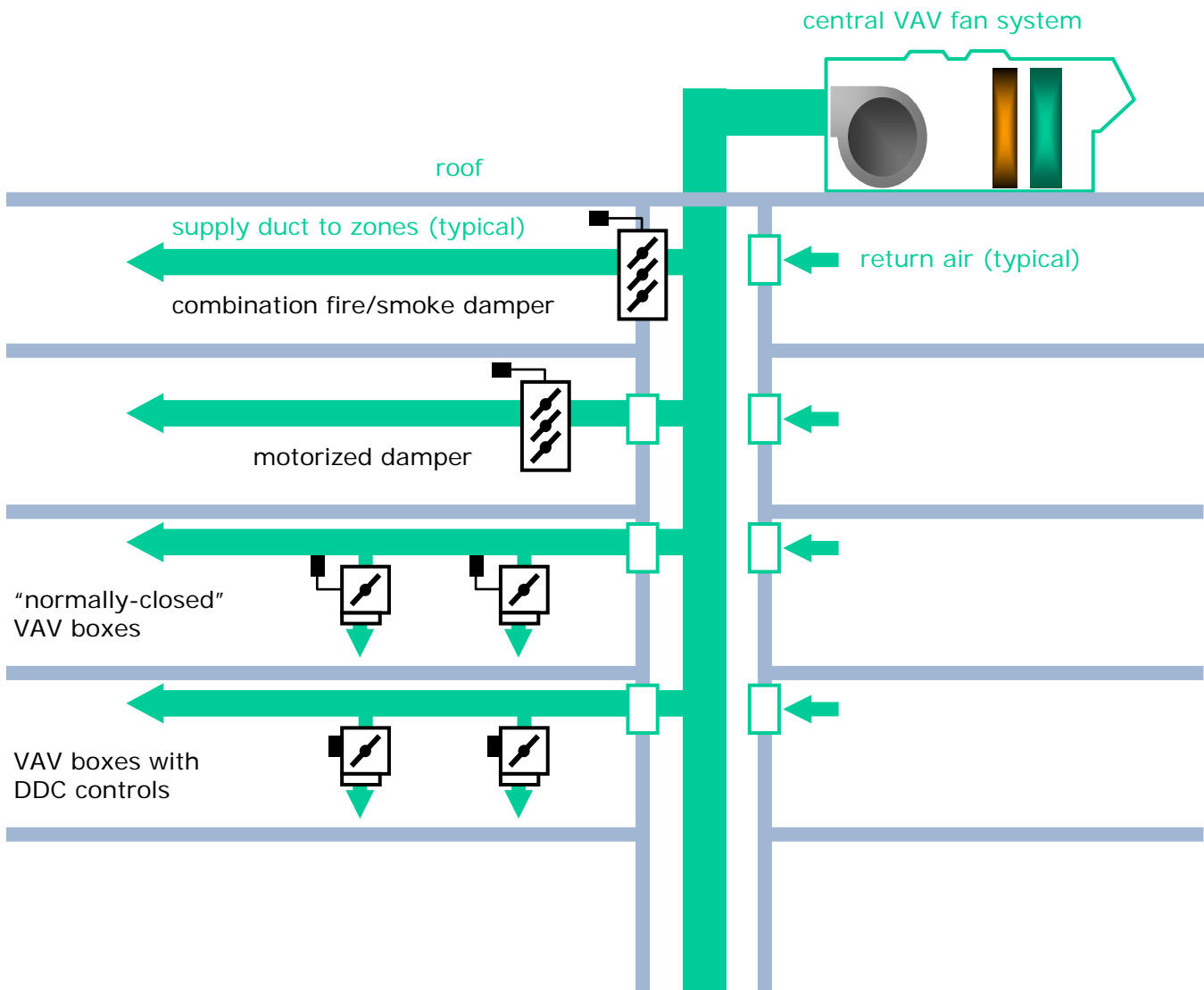
Or

- 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
  - $\leq 25,000$  ft<sup>2</sup> 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

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

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\* Dampers < 24 inches in either dimension may have leakage of 40 cfm/ft<sup>2</sup>

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 ft<sup>2</sup>:

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

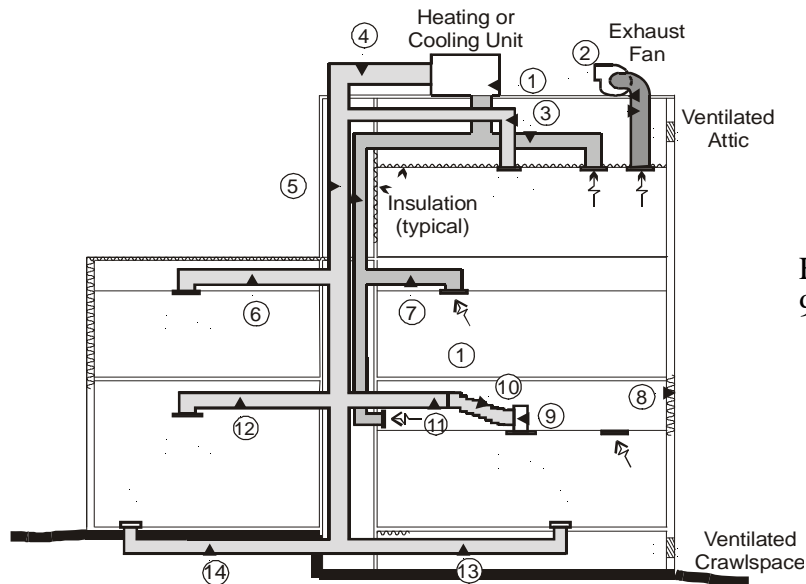


Figure 6-G from  
90.1 User's

### 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 ft<sup>2</sup>
- 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 ft<sup>2</sup>

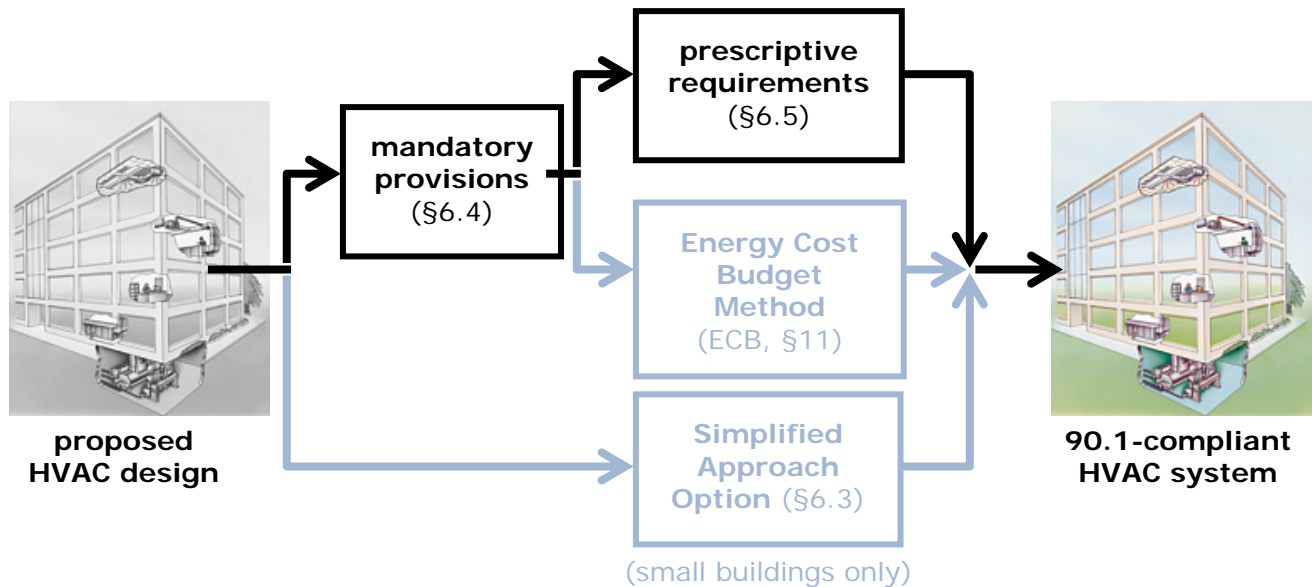
Exceptions:

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
<b>1a, 1b, 2a, 3a, 4a</b> (Miami, St. Louis, Charlotte)	<b>Economizer unnecessary</b>
<b>2b, 5a, 6a, 7, 8</b> (Yuma, Chicago, Edmonton)	<b>≥ 135,000 Btu/h</b>
<b>3b, 3c, 4b, 4c, 5b, 5c, 6b</b> (Denver, Lubbock, Vancouver)	<b>≥ 65,000 Btu/h</b>

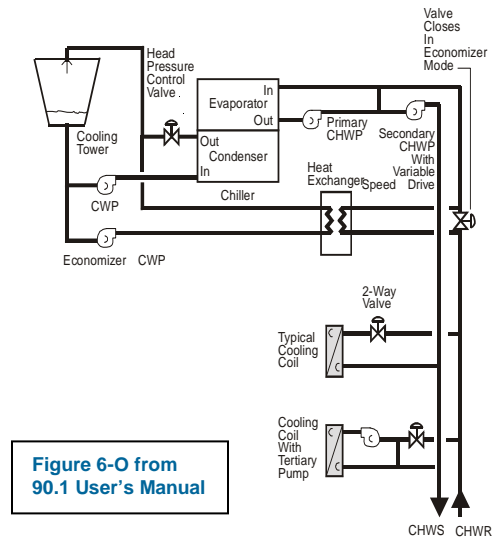
**Air Economizers (§6.5.1.1) – slide 42**

- 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/ft<sup>2</sup>
- 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	<b>1.2 hp</b> /1,000 cfm	<b>1.7 hp</b> /1,000 cfm
$\geq$ 20,000 cfm	<b>1.1 hp</b> /1,000 cfm	<b>1.5 hp</b> /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**

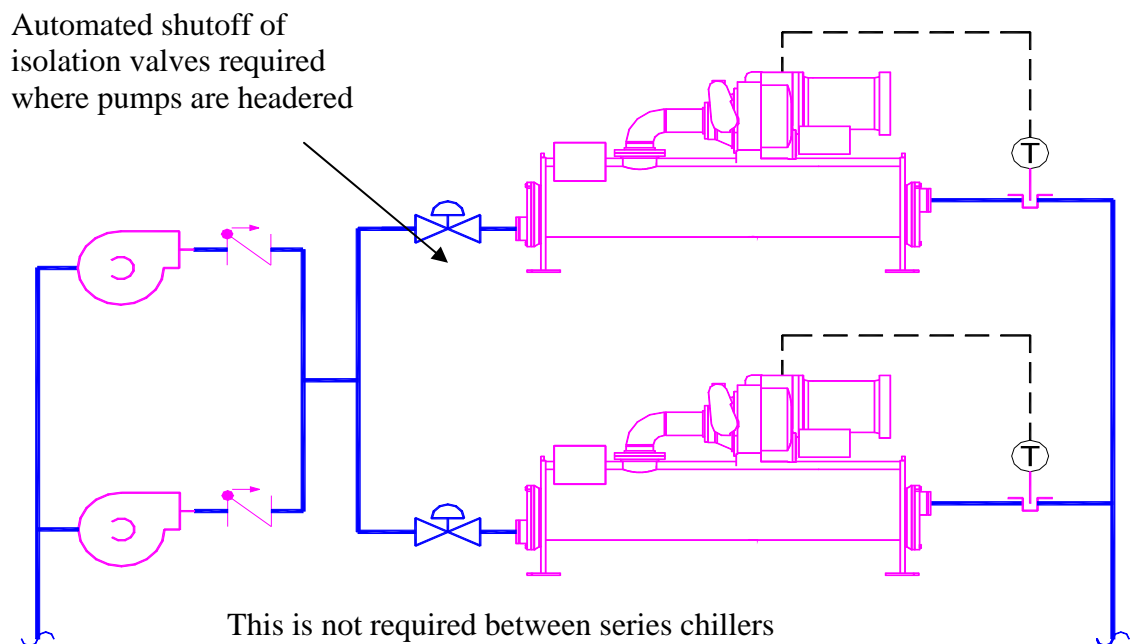
## Hydronic System Design & Control (§6.5.4) – slide 54

- 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  $\leq 3$  control valves
  - Minimum flow required for equipment with  $< 75$  hp of pumping

### Pump Isolation (§6.5.4.2) – slide 56

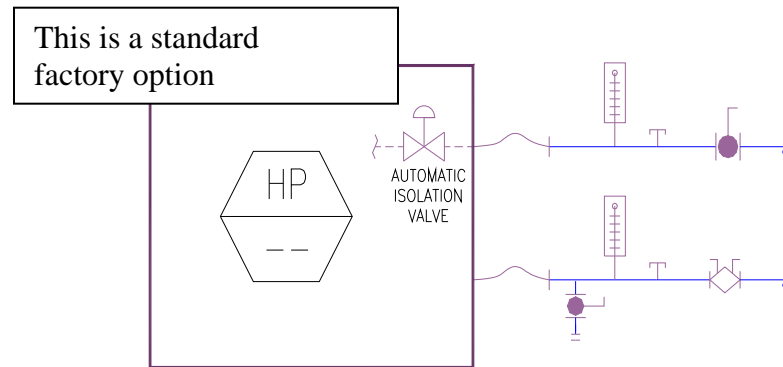


### CHW and HW Water Reset (§6.5.4.3) – slide 57

- 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  $\geq 7.5$  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](http://www.ashrae.org)

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

[www.energycodes.gov](http://www.energycodes.gov)