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ASHRAE STANDARD 90.1, 2013

**HVAC System Requirements for Reducing Energy
Consumption in Commercial Buildings**

ASHRAE Past President's Luncheon, December 3, 2014

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- 12 yrs as a Mechanical Engineer
- 7 yrs at BCER Engineering
- ASHRAE SSPC 90.1 ECB Subcommittee Member
- Technical Editor of the 90.1, 2013 User's Manual
- ASHRAE High performance Building Design Professional

PRESENTATION TOPICS

- Approx. 40 addenda to 2010 in Chapter 6

Major Changes to be Covered:

- Equipment Efficiency
- Controls
 - Economizer
 - Humidification/dehumidification
 - Simultaneous heating and cooling
 - Fan control
- Fan Power/Efficiency
- Exhaust Air Energy Recovery
- Central Hydronic Plant
- Computer Room Cooling
- Commercial Refrigeration

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EQUIPMENT PERFORMANCE

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EQUIPMENT PERFORMANCE TABLES

(6.8.1)

- 2010 added tables for
 - Heat transfer equipment
 - VRF systems
 - CRAC units
- 2013 added tables for
 - Commercial refrigerators and freezers
 - Commercial refrigeration

TABLE 6.8.1-13 Commercial Refrigeration—Minimum Efficiency Requirements

Equipment Class ^a	Equipment Type			Energy Use Limits as of 1/1/2012, ^{b,c} kWh/day	Test Procedure
	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium temperature	$0.82 \times \text{TDA} + 4.07$	
SVO.RC.M	Semivertical open	Remote condensing	Medium temperature	$0.83 \times \text{TDA} + 3.18$	
HZO.RC.M	Horizontal open	Remote condensing	Medium temperature	$0.35 \times \text{TDA} + 2.88$	
VOP.RC.L	Vertical open	Remote condensing	Low temperature	$2.27 \times \text{TDA} + 6.85$	
HZO.RC.L	Horizontal open	Remote condensing	Low temperature	$0.57 \times \text{TDA} + 6.88$	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium temperature	$0.22 \times \text{TDA} + 1.95$	

EQUIPMENT PERFORMANCE TABLES

(6.8.1)

- Increased efficiency for many Equipment Types
- Improvements focus on annualized efficiency rather than full load efficiency
 - Systems rarely, if ever operate at full load
 - Mechanical efficiencies have reached diminishing return
 - Inexpensive controls enable improved part load efficiency

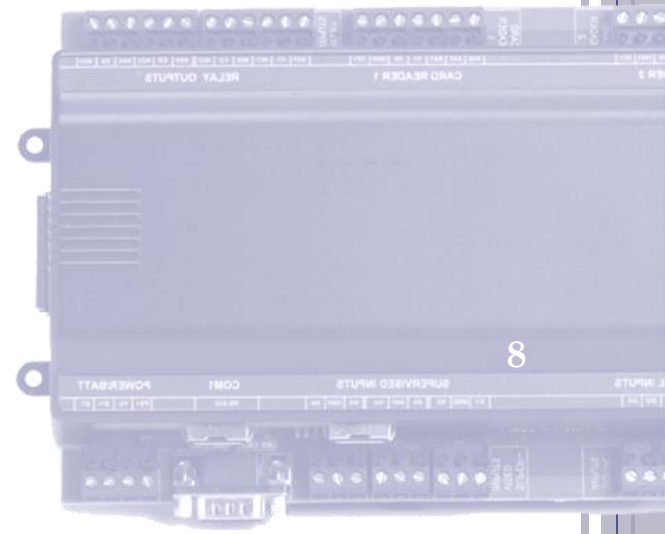
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HVAC CONTROLS

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MANDATORY DIRECT DIGITAL CONTROLS (6.4.3.10)

- DDC Systems are now mandatory in many applications
- Larger new building applications dependent upon:
 - Type and size of equipment
- Also required in many renovations dependent upon:
 - Scope of renovation
 - Type and size of new equipment
 - Existing control system



MANDATORY DIRECT DIGITAL CONTROLS (6.4.3.10)

TABLE 6.4.3.10.1 DDC Applications and Qualifications

Building Status	Application	Qualifications
New building	Air-handling system and all zones served by the system	Individual systems supplying more than three zones and with fan system bhp of 10 hp and larger
New building	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300,000 Btu/h and larger
New building	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300,000 Btu/h and larger
Alteration or addition	Zone terminal unit such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
Alteration or addition	Air-handling system or fan coil	Where existing air-handling system(s) and fan-coil(s) served by the same chilled- or hot-water plant have DDC
Alteration or addition	New air-handling system and all new zones served by the system	Individual systems with fan system bhp of 10 hp and larger and supplying more than three zones and more than 75% of zones are new
Alteration or addition	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
Alteration or addition	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

DDC CAPABILITY (6.4.3.10.2)

- Monitor:
 - Zone demand
 - Duct pressure
 - Hydronic pressure
- Transfer zone information from zone controller to plant controllers
- Automatically identify problem zones
- Allow removal of problem zones from reset logic
- Trend and Display points

WHOLE-BUILDING ENERGY MONITORING (10.4.5)

Measurement devices to monitor and store hourly energy data for the following utility energy types for 36 months:

- Natural gas
- Fuel oil
- Propane
- Steam
- Chilled water
- Heating water

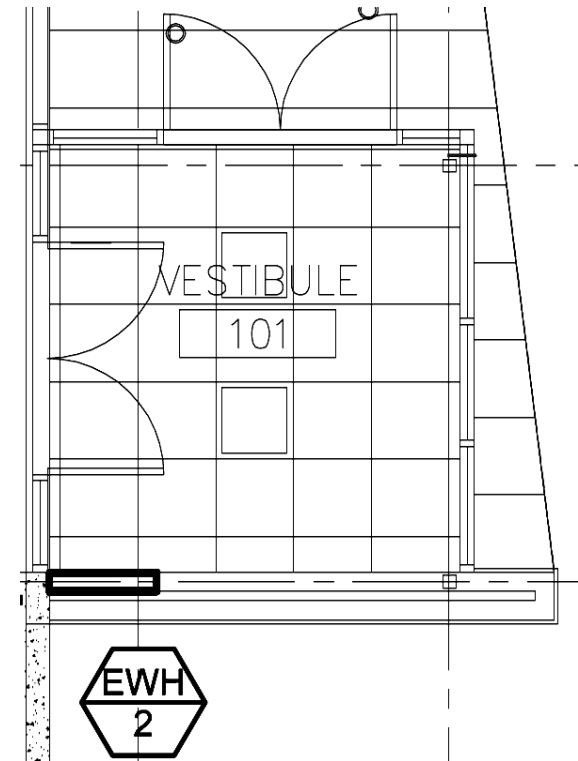
WHOLE-BUILDING ENERGY MONITORING EXCEPTIONS (10.4.5)

Energy monitoring is NOT required for:

- Buildings or additions < 25,000 ft²
- Tenant spaces < 10,000 ft²
- Dwelling units
- Residential buildings with common area < 10,000 ft²
- Fuel for emergency equipment

VESTIBULE HEATING SETPOINT LIMIT (6.4.3.9)

- Vestibules and air curtains must have automatic controls to:
 - Shut off the system when OAT $> 45^{\circ}\text{F}$
 - Maintain vestibule space temp $\leq 60^{\circ}\text{F}$
- Exception for vestibules heated by building relief air.



DEMAND CONTROL VENTILATION (6.4.3.8)

- Occupant Density has been reduced
 - 2010 Threshold ≥ 40 people/1000 ft²
 - 2013 Threshold ≥ 25 people/1000 ft²
- New threshold aligns with green rating systems
- Change will require DCV in many spaces which previously did not require it.
 - Notably, classrooms

demand control ventilation (DCV): a ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.

AIR ECONOMIZER (6.5.1.1.3)

- Acceptable control methods have changed
 - Dry bulb or enthalpy control only

TABLE 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers^b

Control Type	Allowed Only in Climate Zone at Listed Setpoint	Required High-Limit Setpoints (Economizer Off When):	
		Equation	Description
Fixed dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F
	5a, 6a	$T_{OA} > 70^{\circ}\text{F}$	Outdoor air temperature exceeds 70°F
	1a, 2a, 3a, 4a,	$T_{OA} > 65^{\circ}\text{F}$	Outdoor air temperature exceeds 65°F
Differential dry-bulb temperature	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperature	All	$h_{OA} > 28 \text{ Btu/lb}^{\text{a}}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds 28 Btu/lb ^a of dry air ^a or outdoor air temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperature	All	$h_{OA} > h_{RA}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 75°F

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 75°F and 50% RH. As an example, at approximately 6000 ft elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

b. Devices with selectable rather than adjustable setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

AIR ECONOMIZER (6.5.1.1.6)

New Sensor Accuracy Requirements:

- Dry-bulb, $\pm 2^{\circ}\text{F}$ (@ 40°F - 80°F)
- Enthalpy, ± 3 btu/lb (@ 20-36 btu/lb)
- Relative humidity, $\pm 5\%$ (@ 20%-80%)



INTEGRATED ECONOMIZER (6.5.1.3)

Additional requirements added for DX cooling

- Prohibits/limits false loading mech cooling
- Min compressor run time – OA damper may not close until SAT <45°F
- Single zone systems must have at least 2 cooling stages (Capacity dependent)
- Variable air volume systems must have 3 or 4 cooling stages (Capacity dependent)

ECONOMIZER & HUMIDIFICATION (6.5.1.6)

When humidification maintains indoor air wetbulb temp. $>35^{\circ}\text{F}$:

- Airside economizer is prohibited
- Water Economizer must be used

This is not a new requirement:

Moved from 6.5.2.4 in 2010 to a more relevant section in 2013

HUMIDIFICATION AND DEHUMIDIFICATION (6.4.3.6)

- Active humidification limited to $\leq 30\%$ RH in the warmest zone
- Active dehumidification limited to $\geq 60\%$ RH in the coolest zone
- Active humidification and dehumidification may not operate simultaneously



HUMIDIFICATION AND DEHUMIDIFICATION (6.4.3.6)

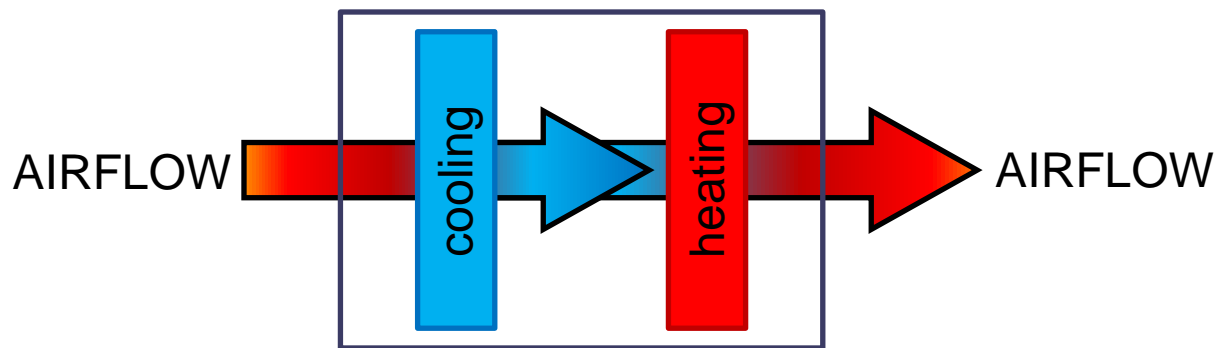
Exceptions:

- Direct evap cooling used with a desiccant
- Museums, hospitals, etc where a 10% humidity deadband is used (as approved by AHJ)
- Critical environment where RH must be maintained within $\pm 5\%$ (as approved by AHJ)

SIMULTANEOUS HEATING AND COOLING (6.5.2)

As in 2010 Zone controls must prevent:

- Reheating
- Recooling
- Mixing of heated and cooled air
- Any form of simultaneously heating and cooling a zone

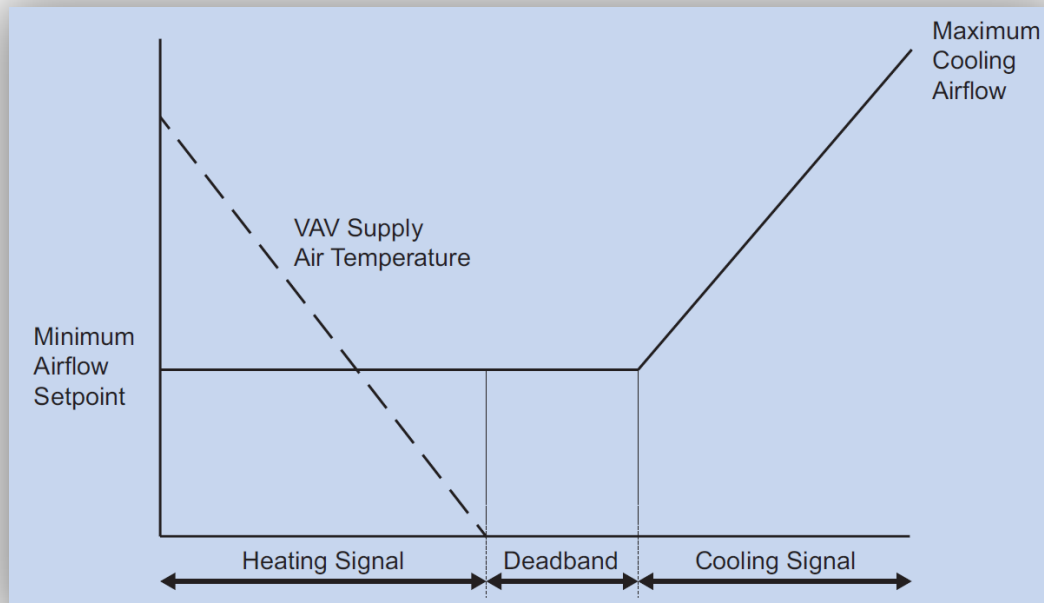


NOT allowed unless.....

SIMULTANEOUS HEATING AND COOLING EXCEPTIONS (6.5.2)

Without DDC reheat/recool no more than the max of:

- 30% of the max SA flow
- Flow require for code ventilation
- Higher SA flow that reduce OA flow
- Higher flow to maintain pressure relationships



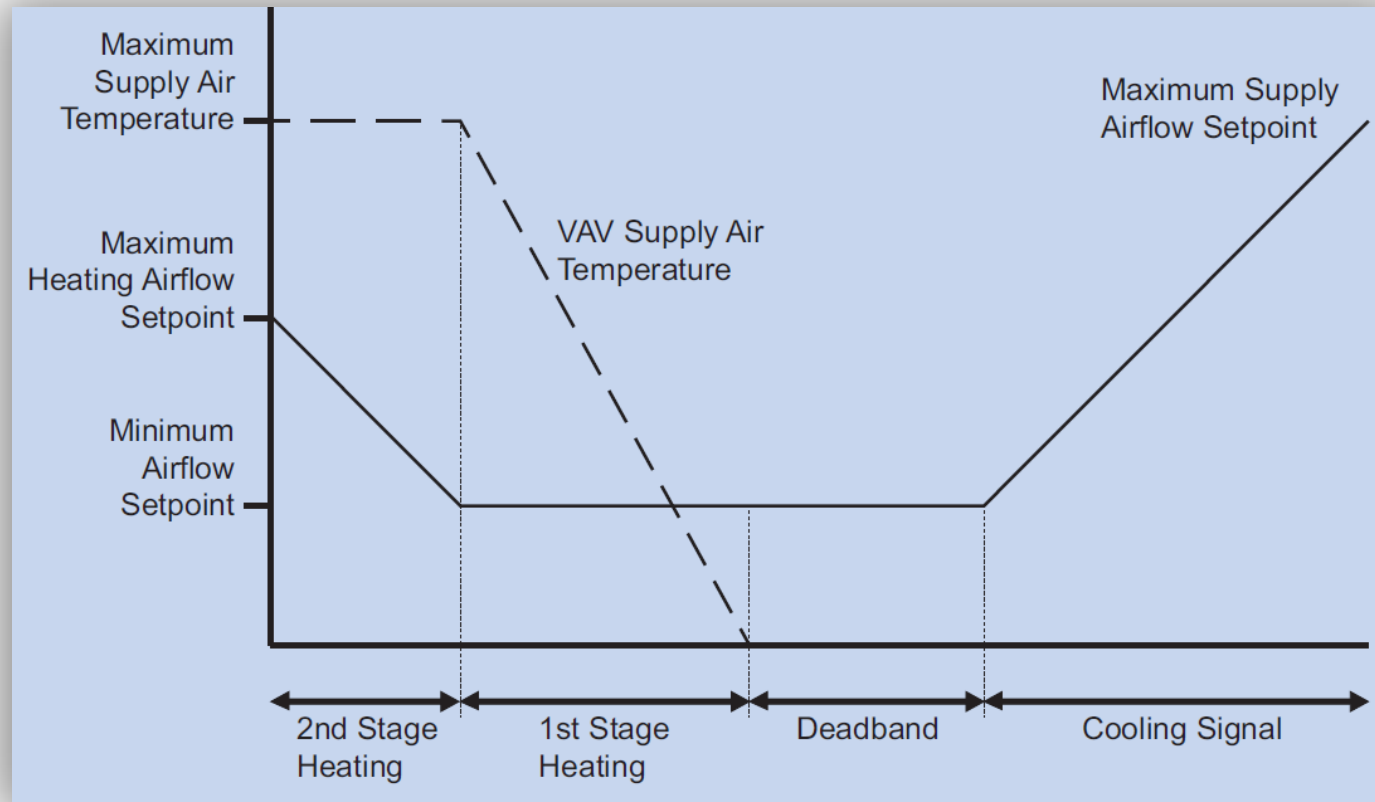
SIMULTANEOUS HEATING AND COOLING EXCEPTIONS (6.5.2)

With DDC reheat/recool allowed provided:

- Deadband flow less than the max of
 - 20% of the max SA flow
 - Flow require for code ventilation
 - Higher SA flow that reduce OA flow
 - Higher flow to maintain pressure relationships
- Reheated/recooled flow $\leq 50\%$ of max SA flow
- 1st heating stage increases SAT only
- 2nd heating stage increases SA flow

SIMULTANEOUS HEATING AND COOLING EXCEPTIONS (6.5.2)

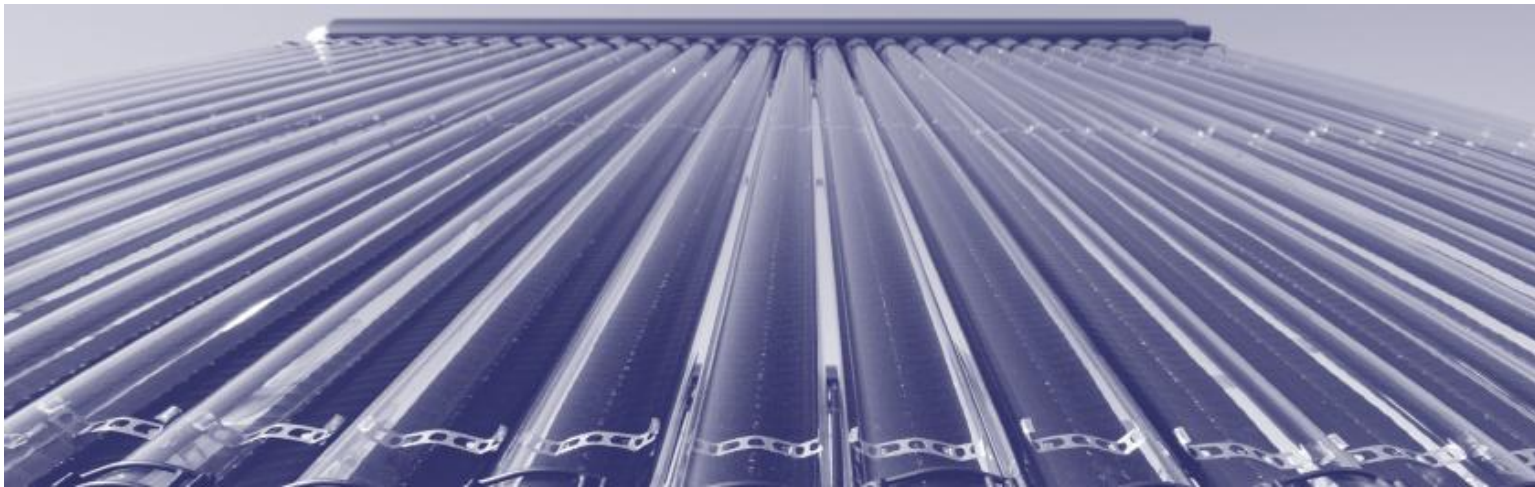
With DDC reheat/recool (continued)



SIMULTANEOUS HEATING AND COOLING EXCEPTIONS (6.5.2)

From 2010, reheat/recool is allowed in:

- VAV Lab Systems
- Where 75% of reheat energy is from site-recovered or renewable energy



FAN CONTROL (6.5.3.2)

- Section was VAV Fan Control in 2010
- Now applies to single zone systems too
 - 2010 Section 6.4.3.10 was rolled into this section
- Specifies variable speed fan operation
- Includes allowable fan power at intermediate flow rates



FAN CONTROL (6.5.3.2)

Cooling load met by adjusting cooling capacity
(typical single zone system)

- Minimum of 2 fan speeds
 - 100% flow @ 100% design fan power
 - $\leq 66\%$ flow @ 40% design fan power
- Must have at least two speeds of operation when using air economizer

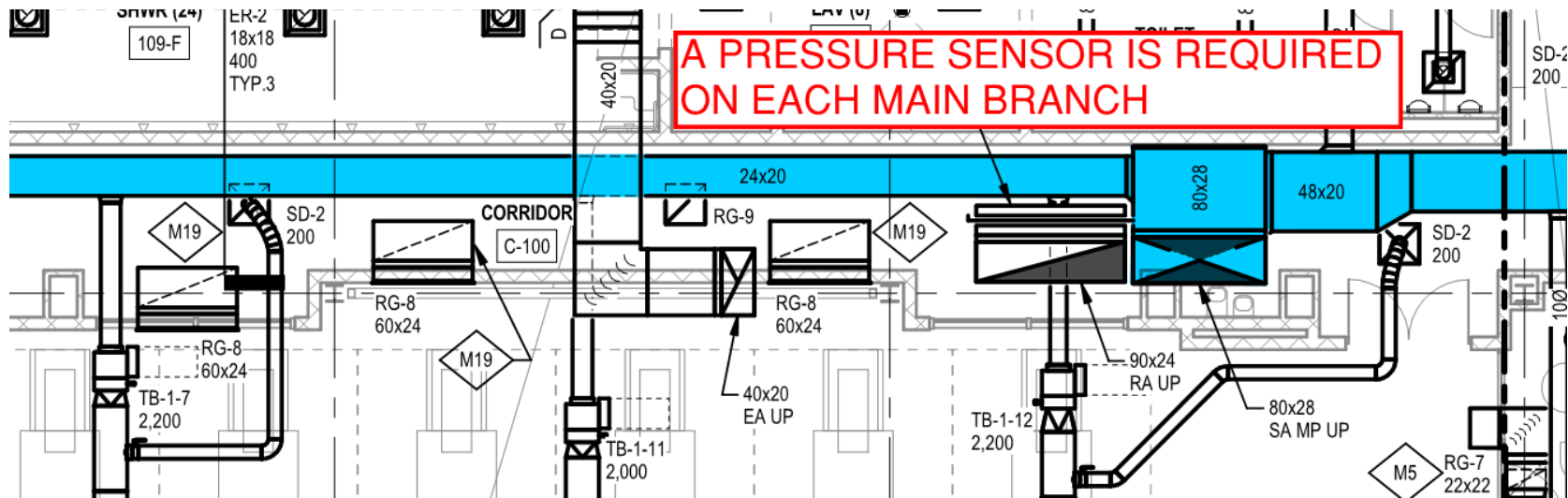
FAN CONTROL (6.5.3.2)

Cooling load met by adjusting air flow
(typical VAV system)

- Modulate fan speed between the following points
 - 100% flow @ 100% design fan power
 - $\leq 50\%$ flow @ 30% design fan power
- Must have at least two speeds of operation when using air economizer (but would likely just modulate)

VAV STATIC PRESSURE SENSOR LOCATION (6.5.3.2.2)

- Locate duct pressure sensor such that the setpoint is not greater than 1.2 in.W.C. (2013)
- May require location downstream of major duct splits (2010)
 - Multiple sensors would be required (both must satisfy setpoint)



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FAN POWER & EFFICIENCY

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FAN POWER (6.5.3.1)

- Fan power allowance equations same as 2010
- Pressure drop adjustments changed
 - Modified sound attenuation credit (added sound level goal)
 - Added deductions for elimination of coils

TABLE 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Sound attenuation section (fans serving spaces with design background noise goals below NC35)	0.15 in. wc
Deductions	
Systems without central cooling device	-0.6 in. wc
Systems without central heating device	-0.3 in. wc
Systems with central electric resistance heat	-0.2 in. wc

FAN EFFICIENCY (6.5.3.1.3)

- In addition to fan power requirements
- Fan must have a Fan Efficiency Grade (FEG) of not less than 67 (per AMCA 205)
- The fan efficiency at design conditions must be within 15 efficiency percent of the max total fan efficiency

- Many exceptions, notably
 - Small fans
 - Fans part of equipment rated as a package

FAN EFFICIENCY GRADE (6.5.3.1.3)

- Fans must have an FEG of 67 (AMCA 205)

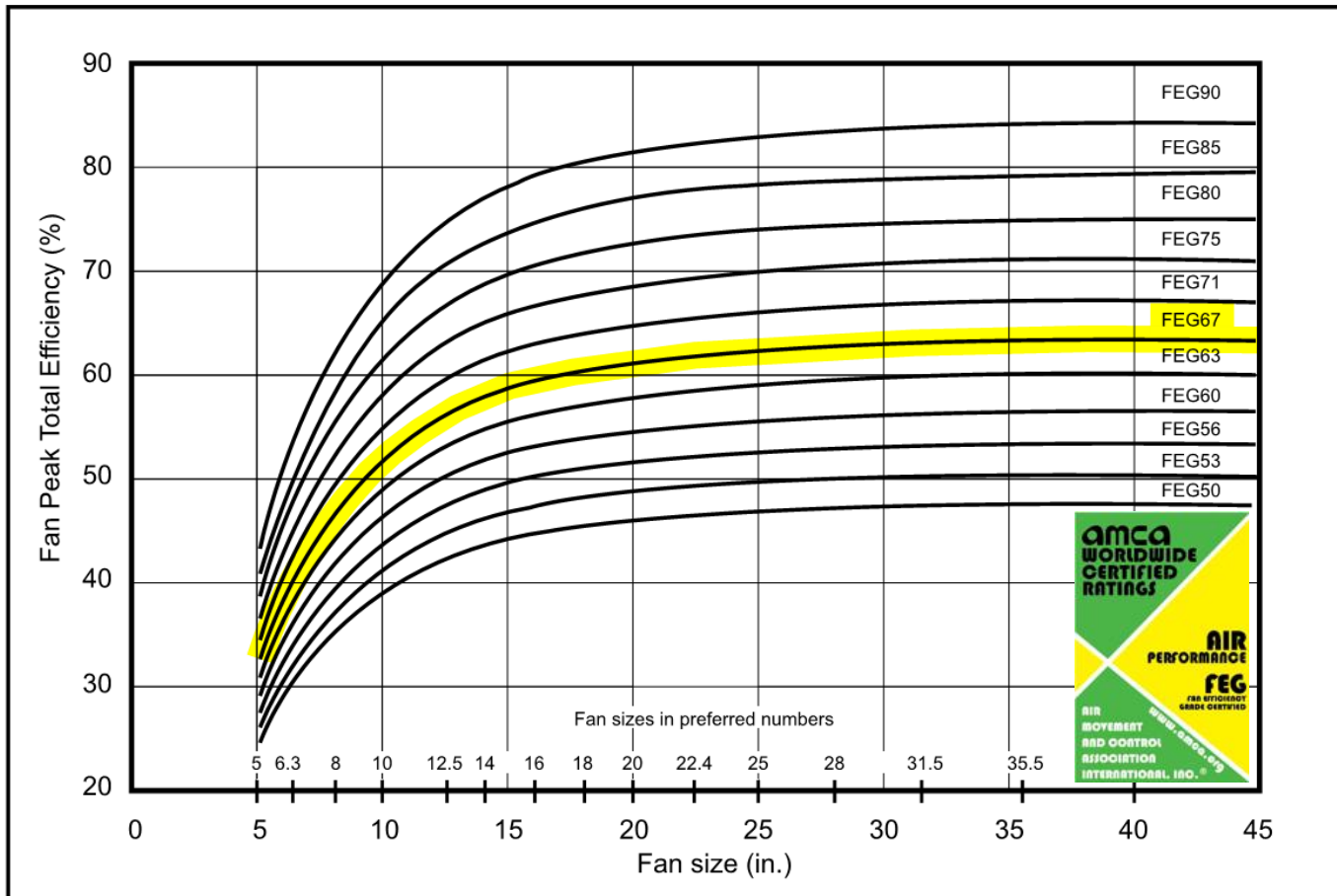
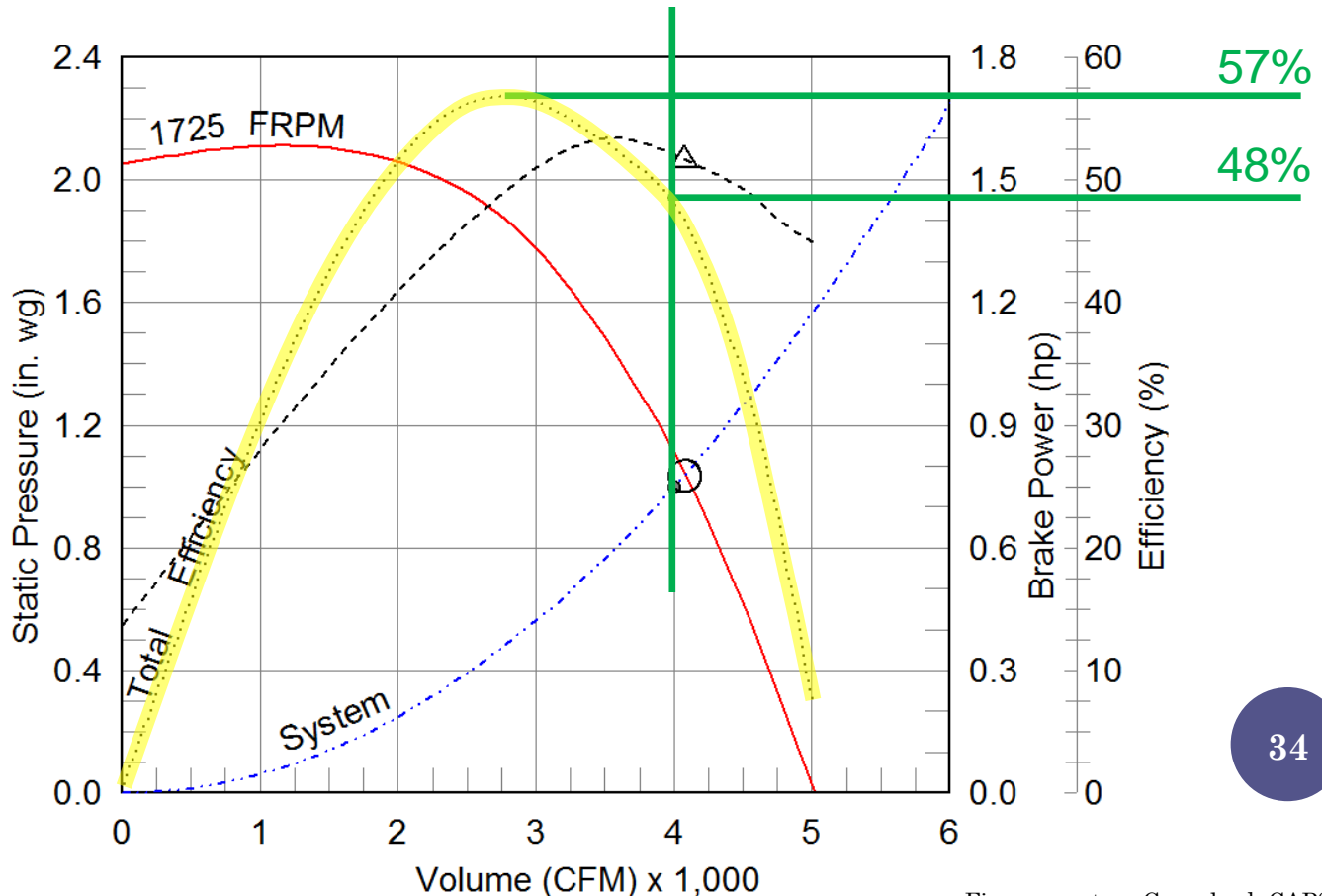


Figure courtesy AMCA 205

FAN EFFICIENCY GRADE (6.5.3.1.3)

- Efficiency at design must be within 15 percentage points of the fan's maximum efficiency

- △ Operating Bhp point
- Operating point at Total SP
- Operating point at External SP
- Fan curve
- - - System curve
- - - Brake horsepower curve
- Static Efficiency curve



$\Delta = 9\%$

This fan selection complies with the total efficiency requirement

FRACTION HP FAN MOTORS (6.5.3.5)

- Motors $\geq 1/12$ HP and < 1 HP must be:
 - Electronically Commutated Motors (DC Brushless)
 - $\geq 70\%$ Efficient (rated in accordance with DOE 10 CFR 431)
- Exceptions:
 - Heating only applications (fan in airstream)
 - Motors in space conditioning equipment rated as a package
 - Motors already covered in Chapter 10 of 90.1

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EXHAUST AIR ENERGY RECOVERY

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EXHAUST AIR ENERGY RECOVERY (6.5.6.1)

- Exhaust air energy recovery based on run time

TABLE 6.5.6.1-1 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Less than 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR

NR—Not required

← Less strict for Denver →

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0

← More strict for Denver →

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CENTRAL HYDRONIC PLANT

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CENTRAL HYDRONIC PLANT REQUIREMENTS (6.5.4)

The following requirements remain from 2010

- Variable flow pumping when either
 - Total pump power > 10HP
 - Single pump power > 5HP
- Supply water temperature reset
 - Reset chilled and heating water setpoints on OAT or demand
 - No reset amount specified

CENTRAL HYDRONIC PLANT REQUIREMENTS (6.5.4)

Boiler and Chiller Isolation (6.5.4.3)

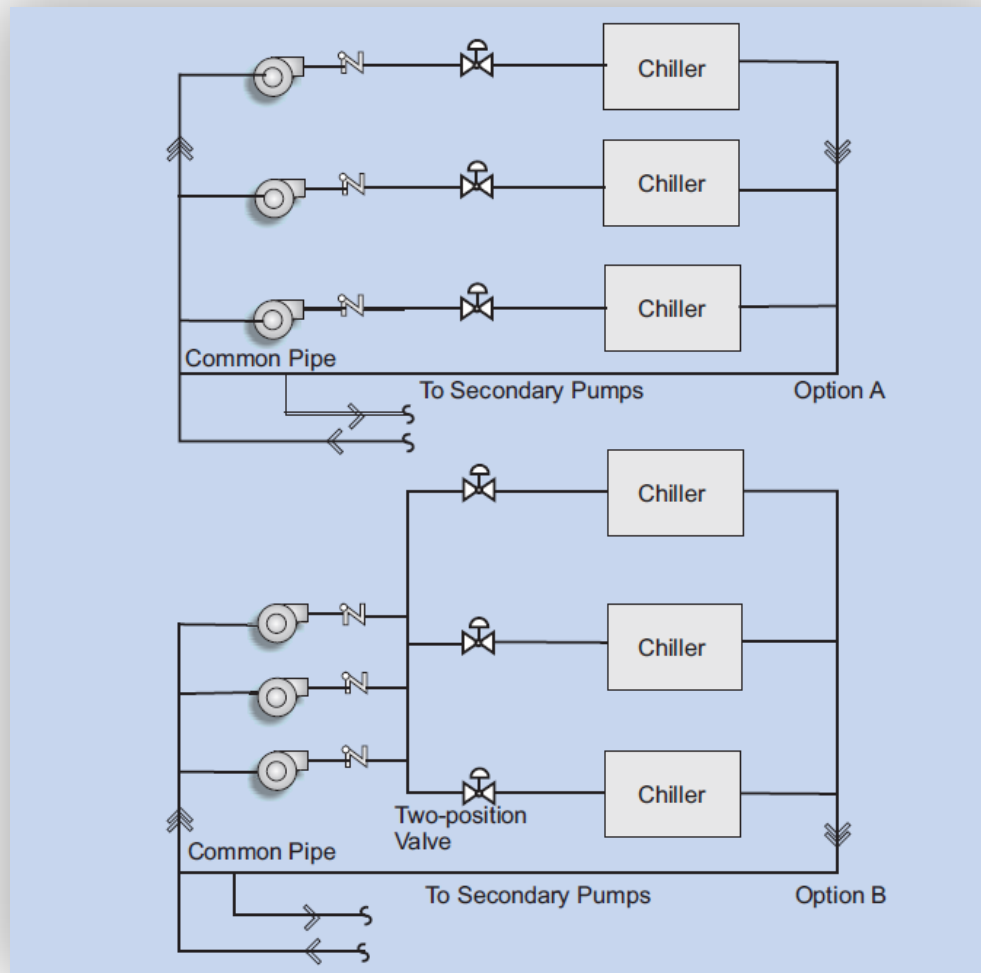
- Water must not flow through boilers or chillers that are staged off
- If primary/secondary pumping is used
 - Pump QTY = Boiler (or chiller) QTY
- Excludes chillers in series

Results

- Reduced pump energy
- Increased ΔT through running equip.

CENTRAL HYDRONIC PLANT REQUIREMENTS (6.5.4)

The following figure applies to both chillers and boilers



BOILER PLANT TURNDOWN (6.5.4.1)

- Boiler plants $\geq 1,000,000$ btu/h must meet minimum turndown ratio
- Plant must modulate from the minimum turn down to the maximum fire
- May use multiple boilers to satisfy the requirement (not all must meet the requirement)

TABLE 6.5.4.1 Boiler Turndown

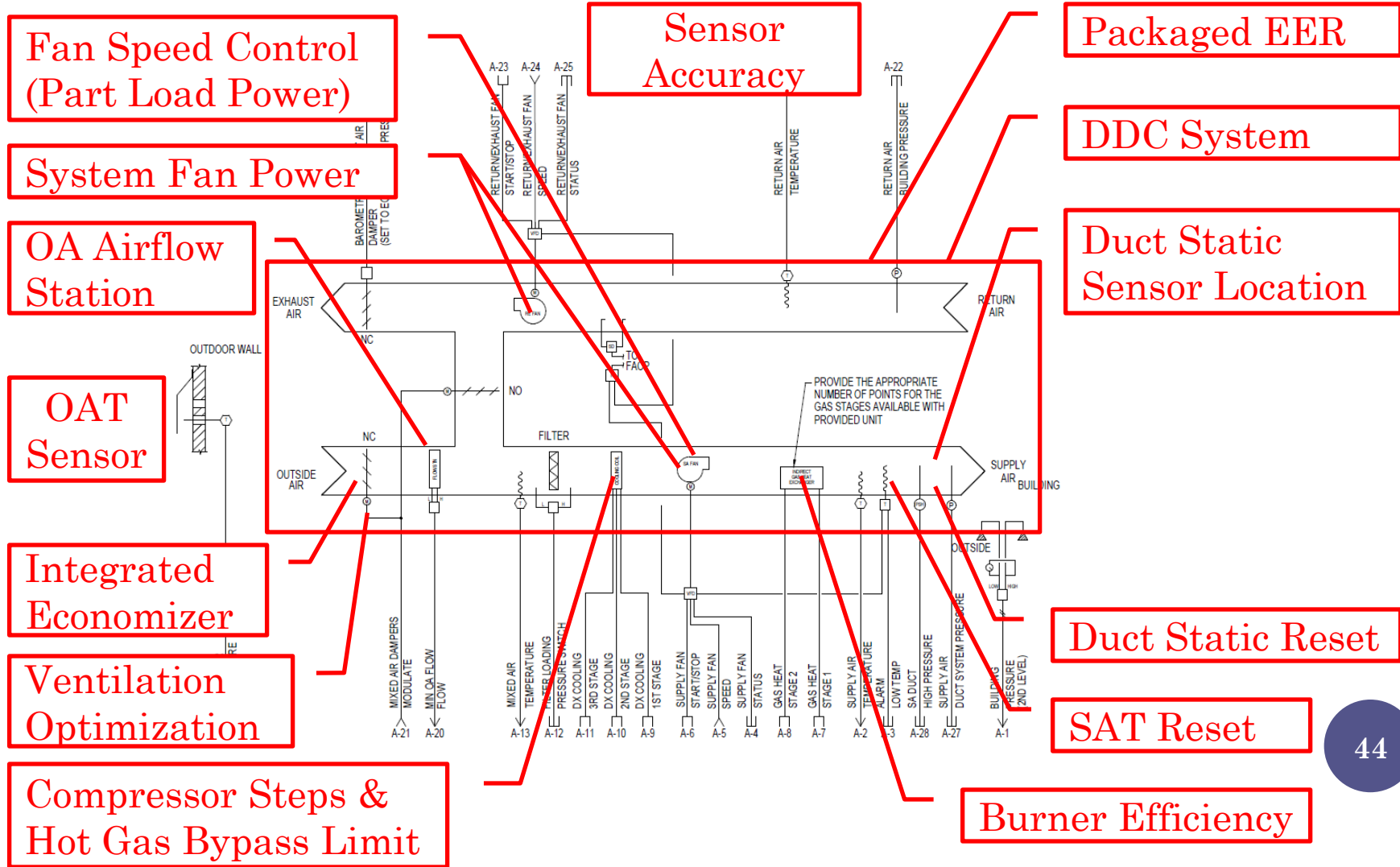
Boiler System Design Input, Btu/h	Minimum Turndown Ratio
$\geq 1,000,000$ and $\leq 5,000,000$	3 to 1
$> 5,000,000$ and $\leq 10,000,000$	4 to 1
$> 10,000,000$	5 to 1

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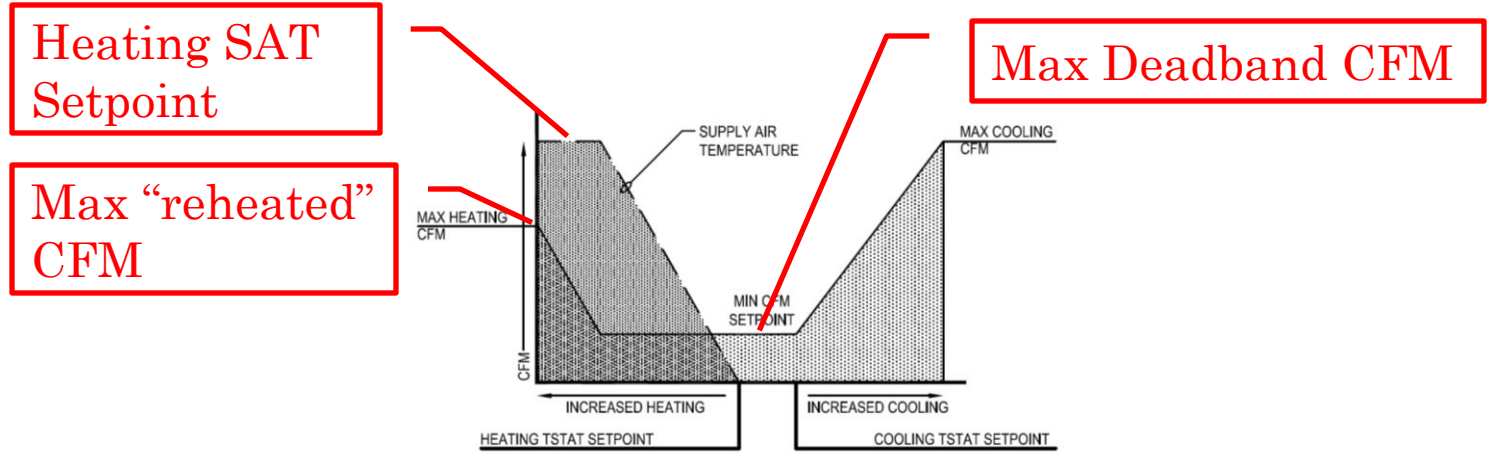
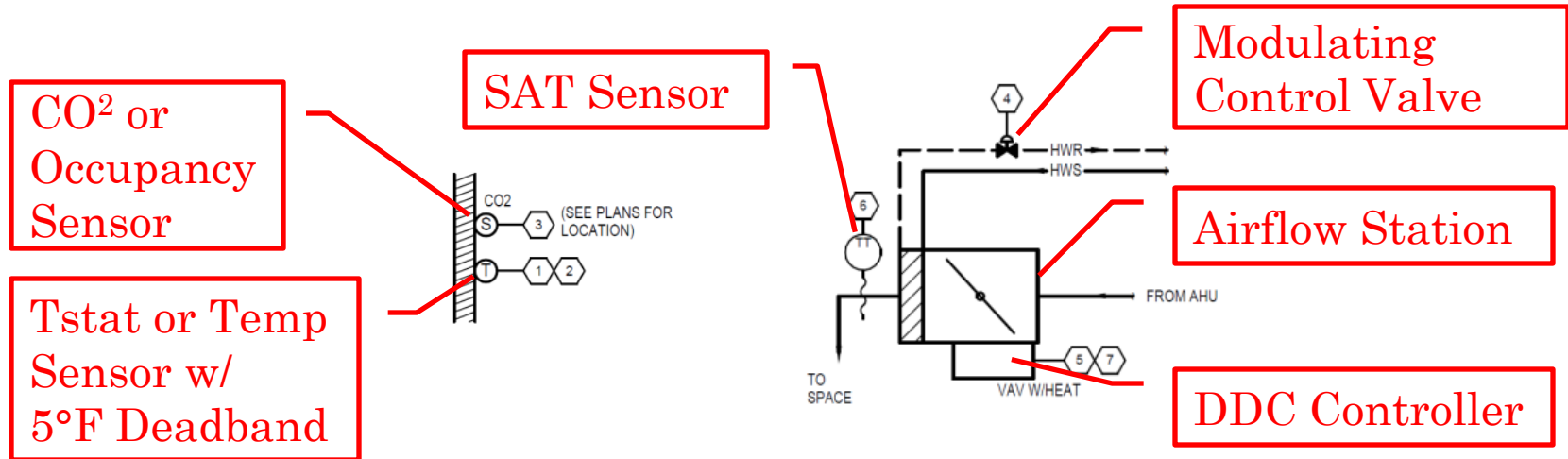
PUT IT ALL TOGETHER

Applying 90.1, 2013 to a Gas/DX VAV System with
Hydronic Reheat

COMPLIANT GAS/DX VAV REHEAT SYSTEM WITH HYDRONIC REHEAT



COMPLIANT GAS/DX VAV REHEAT SYSTEM WITH HYDRONIC REHEAT

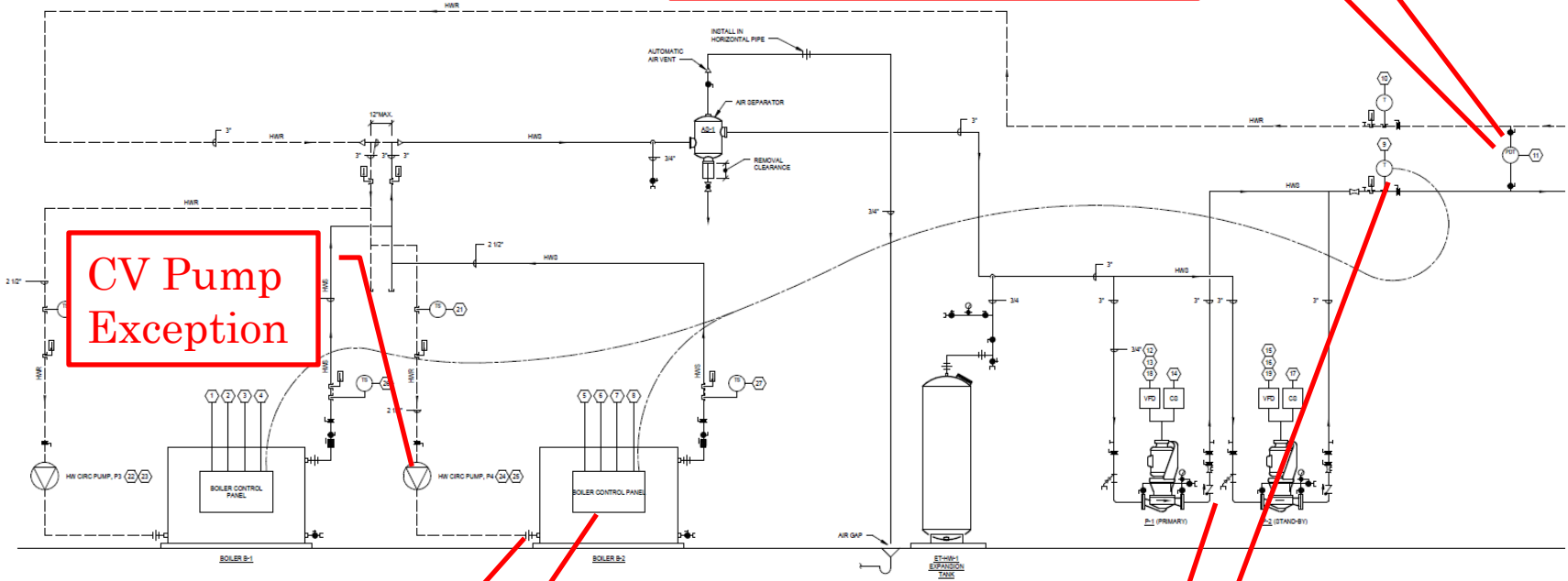


COMPLIANT GAS/DX VAV REHEAT SYSTEM WITH HYDRONIC REHEAT

Measure Building Fuel Usage

Max Pressure Setpoint

Pressure Setpoint Reset



CV Pump Exception

Boiler Isolation

Boiler Plant Turndown

Variable Speed Flow

HWS Temp Reset

BOILER PLANT CONTROL DIAGRAM
NOT TO SCALE

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COMPUTER ROOM COOLING (DATA CENTERS)

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CRAC UNITS

90.1 Scope Changed in 2010

- Included equipment for process cooling
- CRAC Unit requirements are scattered throughout the standard
 - Variable air flow
 - Humidification
 - Dehumidification
 - Efficiencies
 - Economizer



CRAC UNIT ECONOMIZER (6.5.1.2.1)

- Water economizer requirements have changed
 - Table 6.5.1.2.1 provides ambient conditions at which the water economizer must satisfy 100% of the cooling load



TABLE 6.5.1.2.1 Water Economizer Sizing Dry-Bulb and Wet-Bulb Requirements for Computer Rooms

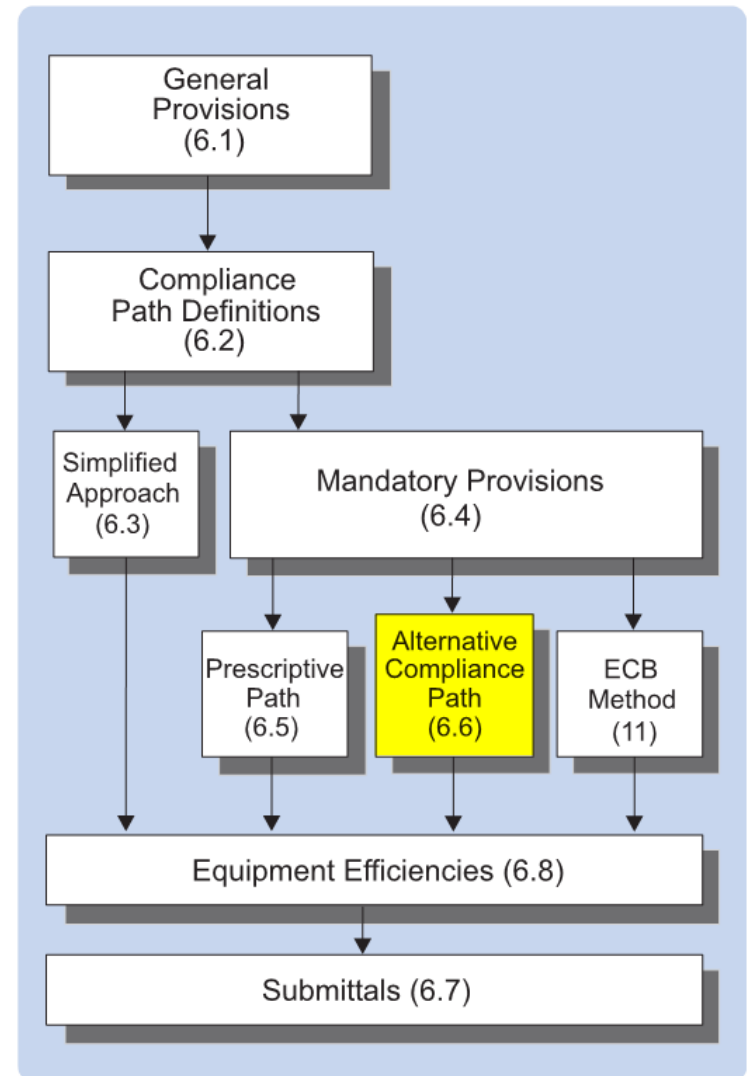
Zone	Evaporative Water Economizer		Dry Cooler Water Economizer
	Dry Bulb, °F	Wet Bulb, °F	Dry Bulb, °F
1 A		NR	NR
1 B		NR	NR
2 A	40.0	35.0	30.0
2 B	35.0	30.0	30.0
3 A	40.0	35.0	25.0
3 B	30.0	25.0	25.0
3 C	30.0	25.0	30.0
4 A	40.0	35.0	25.0
4 B	30.0	25.0	25.0
4 C	30.0	25.0	25.0

SECTION 6.6

Computer Rooms (and Data Centers) may use Section 6.6 as an alternative compliance path using PUE

PUE: Power Usage Effectiveness

Reference: Recommendations for Measuring and Reporting Overall Data Center Efficiency v2 17 May 2011, The Green Grid



SECTION 6.6

$PUE_1 \leq$ Table 6.6.1

or

$PUE_0 \leq$ Table 6.6.1

$$PUE_1 = \frac{\text{Computer Room Energy}}{\text{IT Equipment Energy}}$$

*Hourly Annual Energy Consumption using
Appendix G*

$$PUE_0 = \frac{\text{Computer Room Power}}{\text{IT Equipment Power}}$$

*Peak Power Demand using Outdoor Design
Cooling Conditions at 100% and 50% IT
Equipment Power*

TABLE 6.6.1 Power Usage Effectiveness (PUE)
Maximum

Climate Zone	PUE ^a
1A	1.61
2A	1.49
3A	1.41
4A	1.36
5A	1.36
6A	1.34
1B	1.53
2B	1.45
3B	1.42
4B	1.38
5B	1.33
6B	1.33
3C	1.39
4C	1.38
5C	1.36
7	1.32
8	1.30

a. PUE₀ and PUE₁ shall not include energy for battery charging.

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COMMERCIAL REFRIGERATION

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COMMERCIAL REFRIGERATION (6.4.5 AND 6.5.11)

The 2010 scope change opened the standard up to other equipment including:

- Walk-in Coolers
- Walk-in Freezers
- Commercial Refrigeration

These new requirements cover all aspects of this equipment category



COMMERCIAL REFRIGERATION (6.4.5 AND 6.5.11)

Requirements include:

- Enclosure insulation (including glass)
- Door closer and sealing
- Refrigeration Performance – Table 6.8.1-12 and 6.8.1-13
- Anti-sweat/anti-frost device control
- Motor types (ECM, PSC, 3Phase)
- Design and equipment selection criteria



SUMMARY

Changes covered:

- Equipment Efficiency
- Controls
 - Economizer
 - Humidification/dehumidification
 - Simultaneous heating and cooling
 - Fan control
- Fan Power/Efficiency
- Exhaust Air Energy Recovery
- Central Hydronic Plant
- Computer Room Cooling
- Commercial Refrigeration

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THANK YOU

Questions?

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