Energy Codes *IN ACTION*

Increasing Role of Controls in Commercial Energy Codes

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Learning Objectives

Participants will be able to

- Explain the fundamental control requirements for lighting and HVAC systems contained in energy efficiency codes, along with the underlying intent.
- Critically identify the more impactful control requirements for a building project.
- Assess compliance documentation to verify that controls have been installed correctly.
- Perform plan review and inspection of control requirements.
- Judge what happens when the controls are not implemented correctly.

The Challenge

To many in the building code world these requirements are a complex mystery, and it is not uncommon to see these controls not functioning as intended. In order to achieve the intended savings,

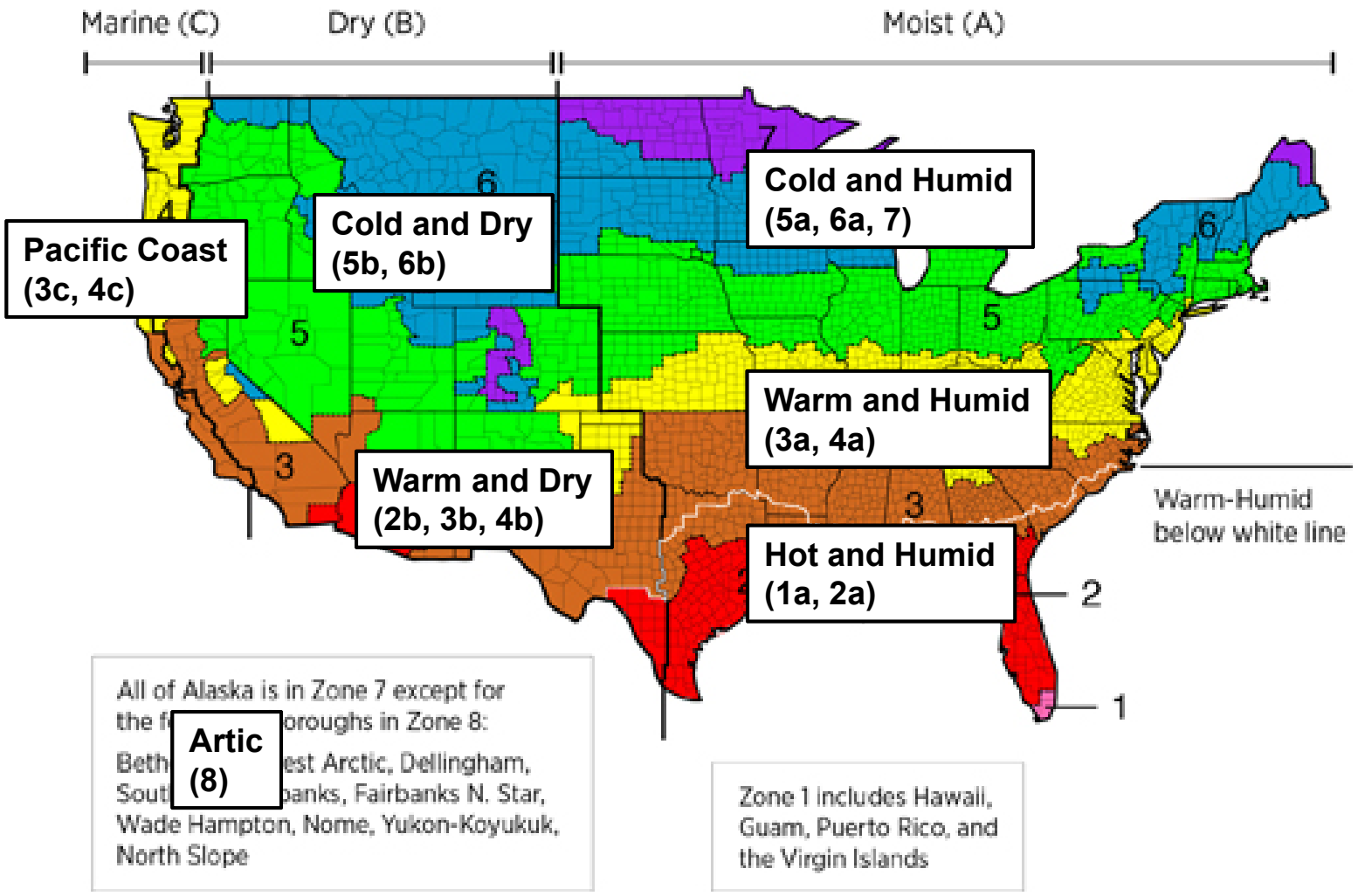
- Building designers need to understand how to specify control requirements,
- **Code officials need to understand how to verify those requirements,**
- Building operators need to know how to keep them running correctly, and building owners and
- Occupants need to understand how these controls will impact the user experience.

Presentation Outline

- Background
  - History
  - Fundamentals
  - Components
- Control Requirements in Current Standards
  - HVAC
  - Lighting
  - Other
- Acceptance Testing
- Emerging Control Requirements
  - Plug loads
  - Institutional Tuning
- Wrap-up and Panel Discussion

Progress in Energy Codes

DOE/ASHRAE Thermal Climate Zones



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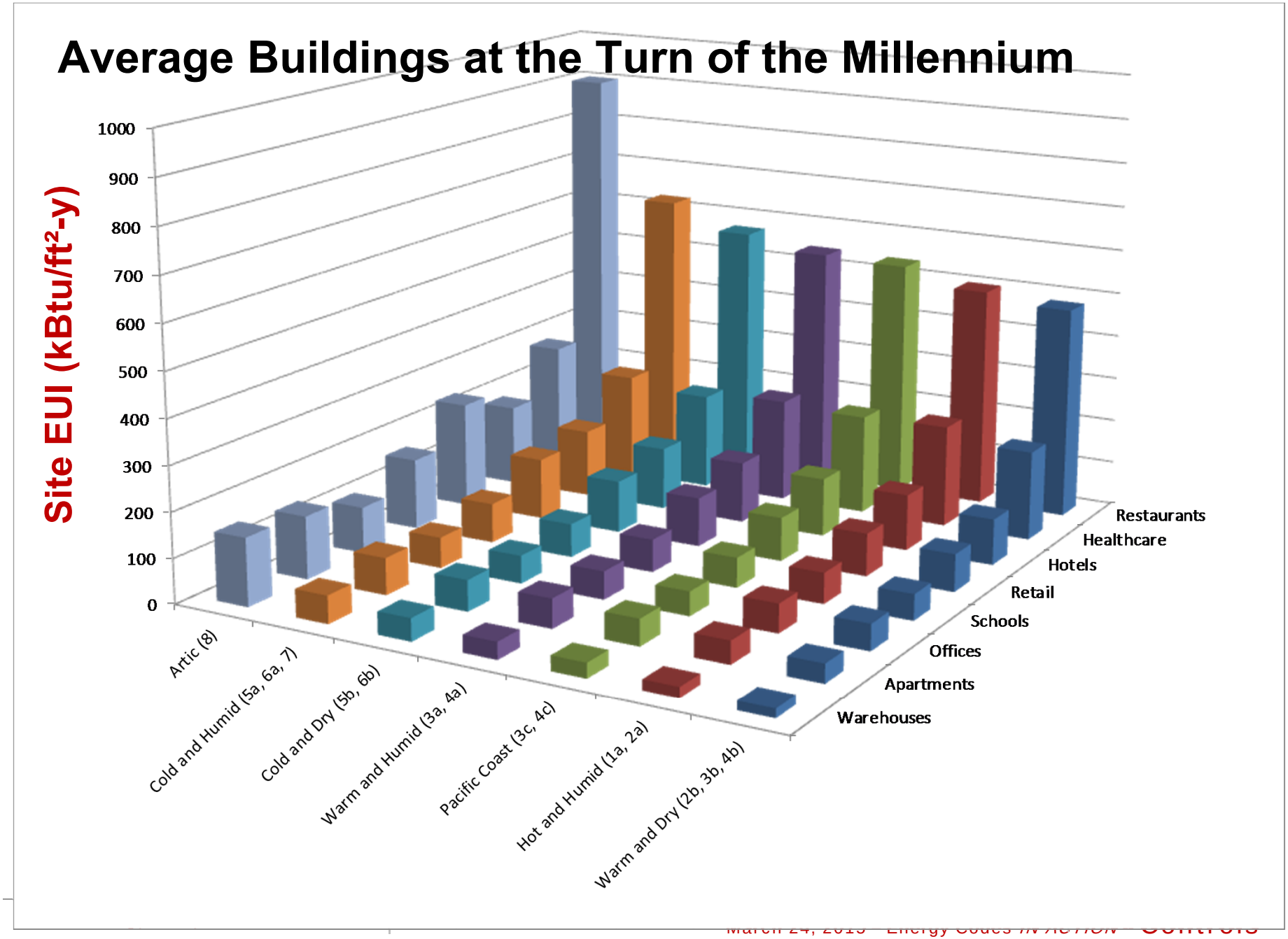

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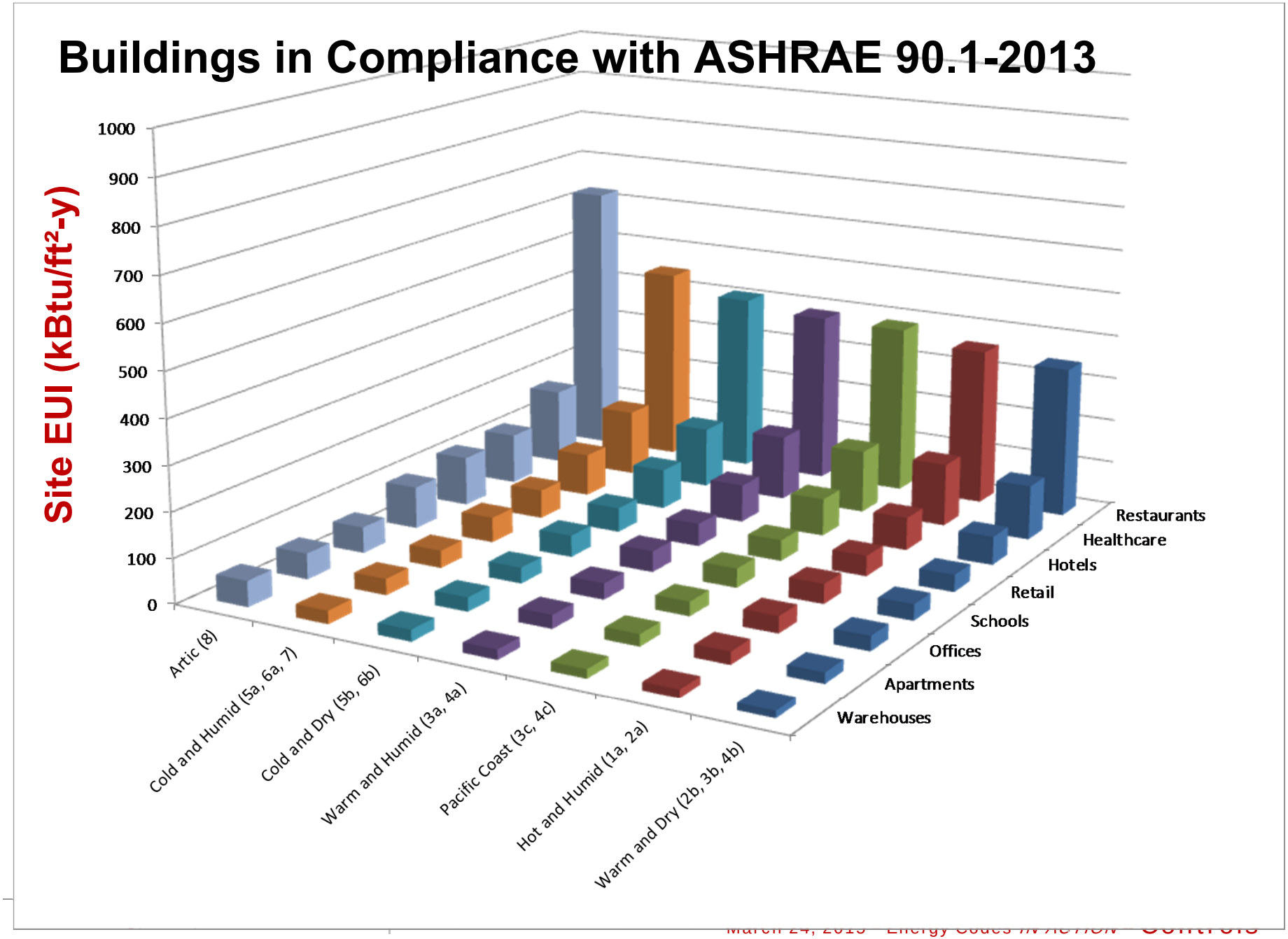
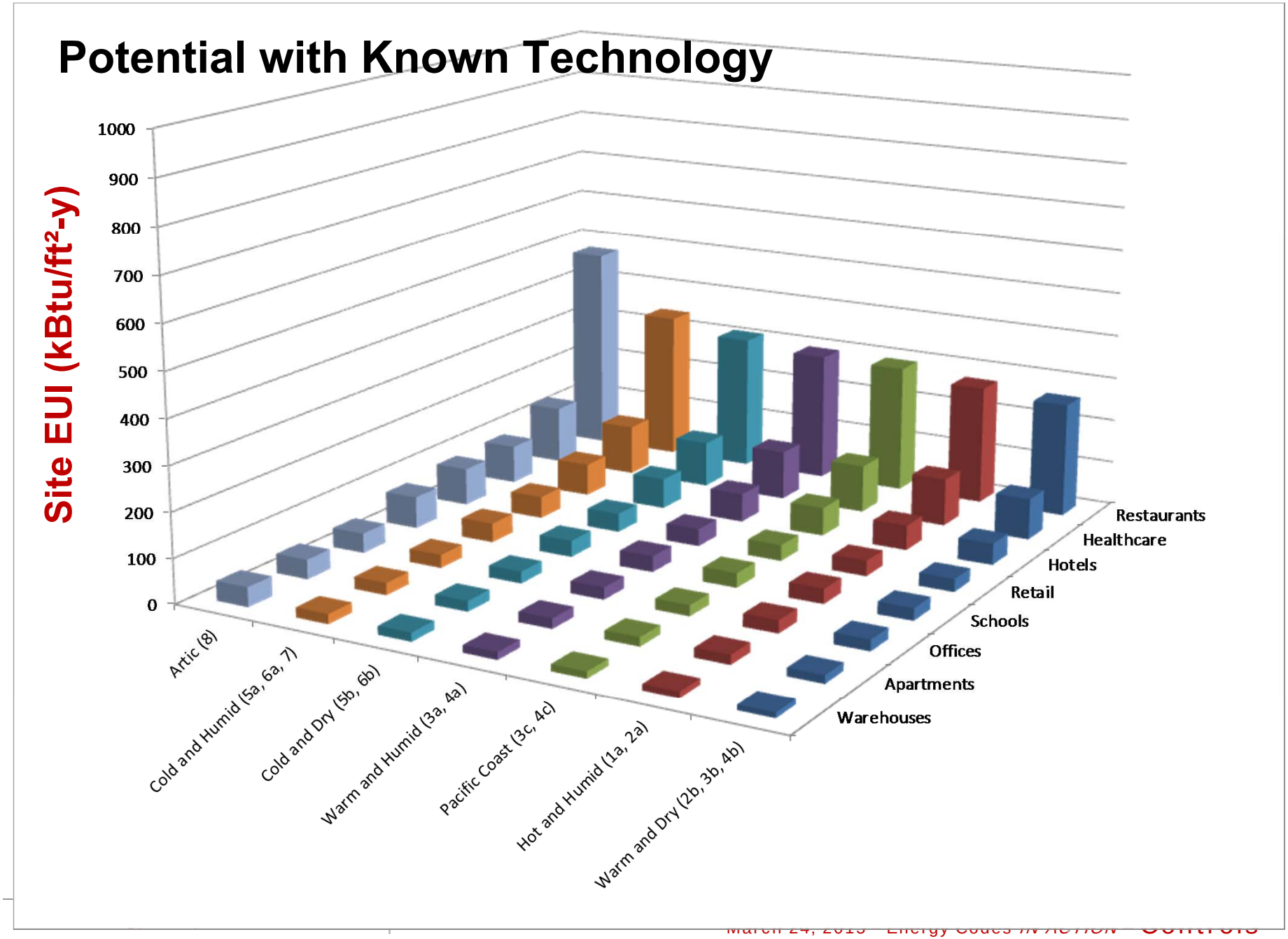


Progress in Energy Codes



Controls are a big part of these savings . . .

Of the 134 addenda to ASHRAE Standard 90.1 between 2004 and 2013, 52 included new or modified control requirements.

Control Fundamentals

Control Functions

- Thermal Comfort
- Indoor Air Quality/Occupant Health
- Lighting
- Fire/Life Safety
- Environmental Control for Equipment, Products and Processes
- **Energy Conservation**

Terms

- **Controlled Variable**

  the property that is to be controlled (e.g. temperature, humidity, pressure, lighting level, CO_2 concentration, etc.)
- **Sensor**

  the device that senses the condition or value of the controlled variable.
- **Control Point**

  the current condition or value of the controlled variable.
- **Setpoint**

  the desired condition or value of the controlled variable.
- **Controlled Device**

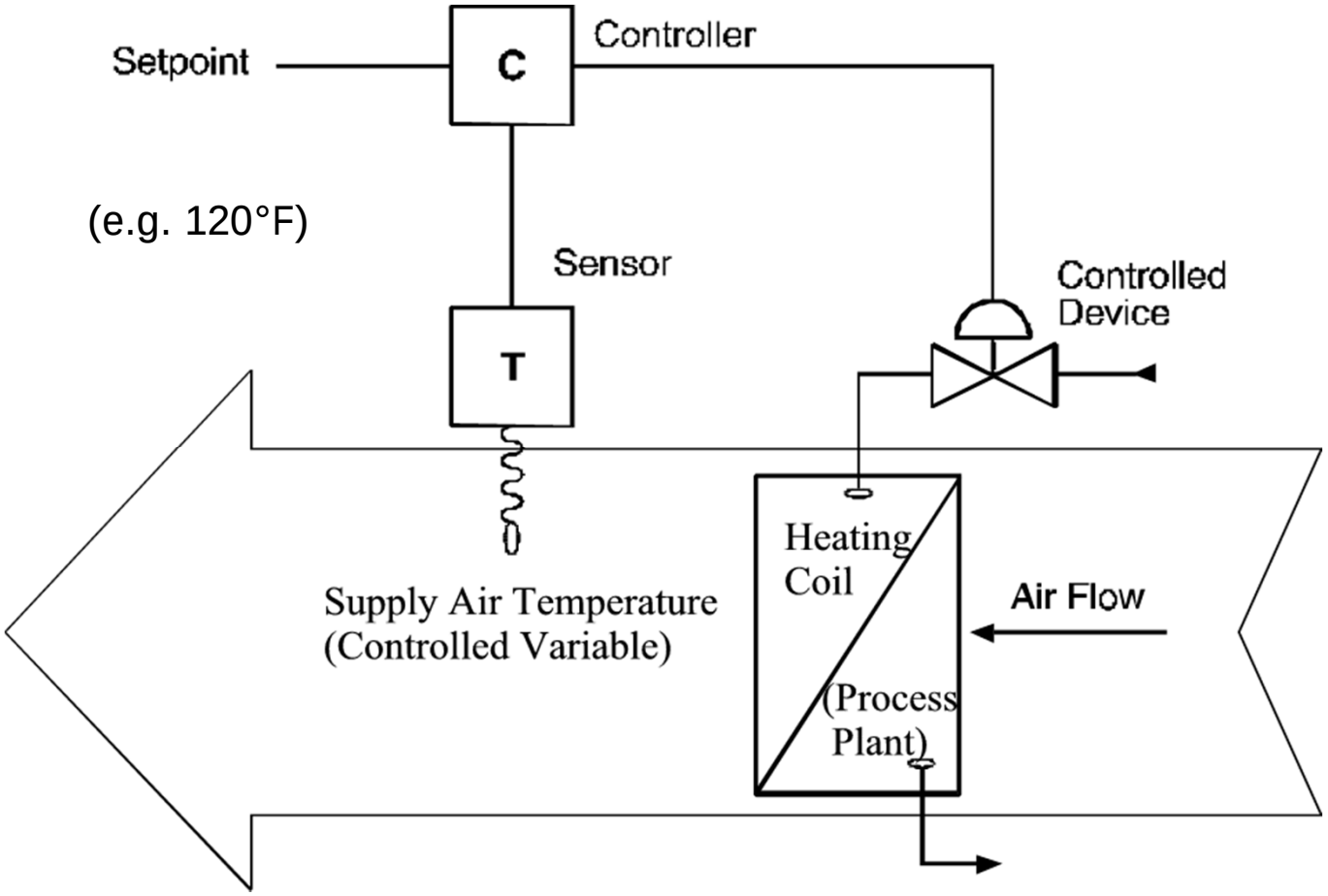
  the device that is used to vary the output of the process plant (e.g. valve, damper)
- **Actuator**

  A motor, solenoid or other device that adjusts the controlled device.
- **Process Plant**

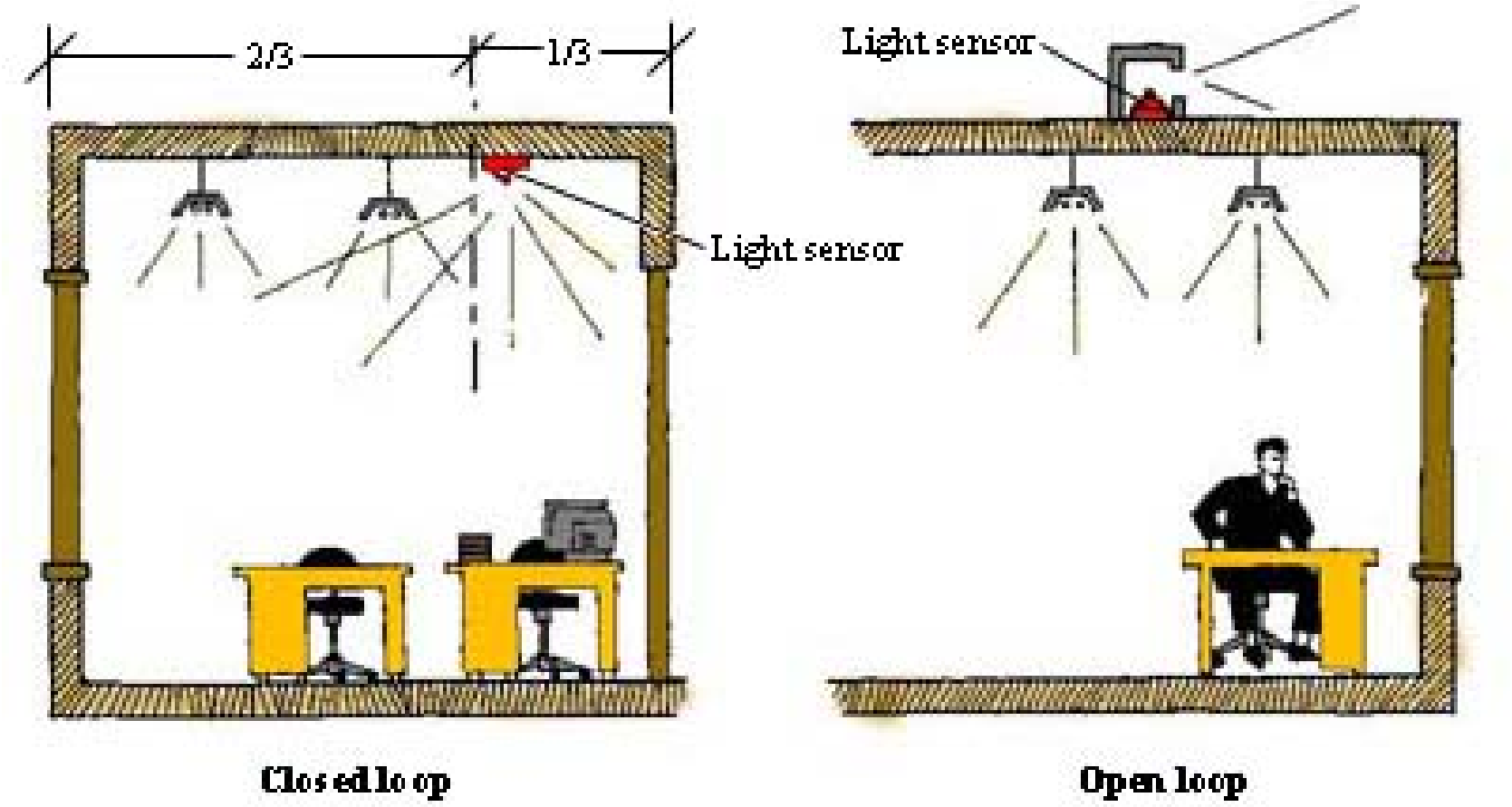
  the equipment used to change the value of the controlled variable (e.g. coil)
- **Controller**

  the device that compares the input from the sensor with the setpoint, determines a response for corrective action, and then sends this signal to the controlled device

Control Loop Example: Heating Coil



Open vs. Closed Controls



http://www.smgov.net/Departments/OSE/vd

Proportional Control

On-Off

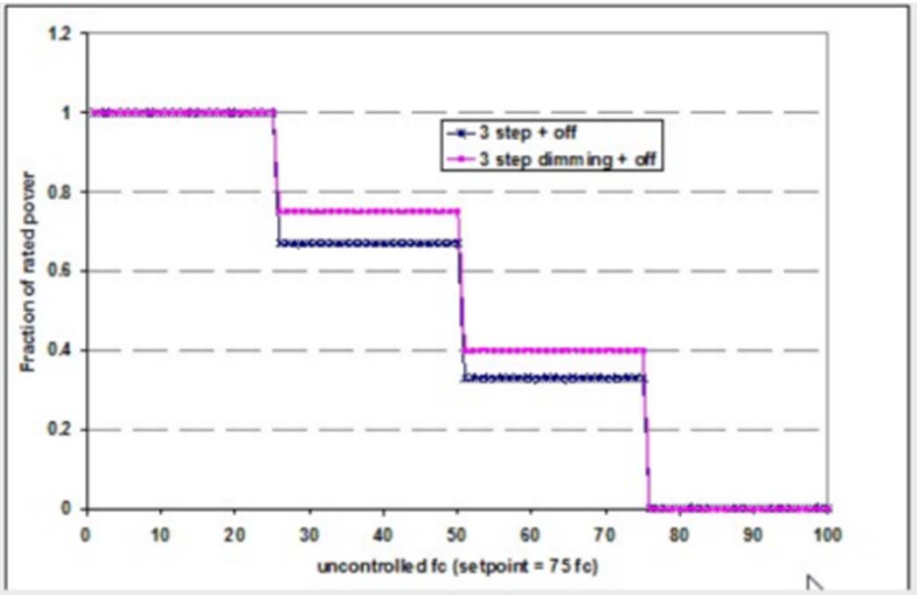


Figure 6.4.4-1: *"Example Stepped Daylighting Control"*

Continuous Dimming (Proportional)

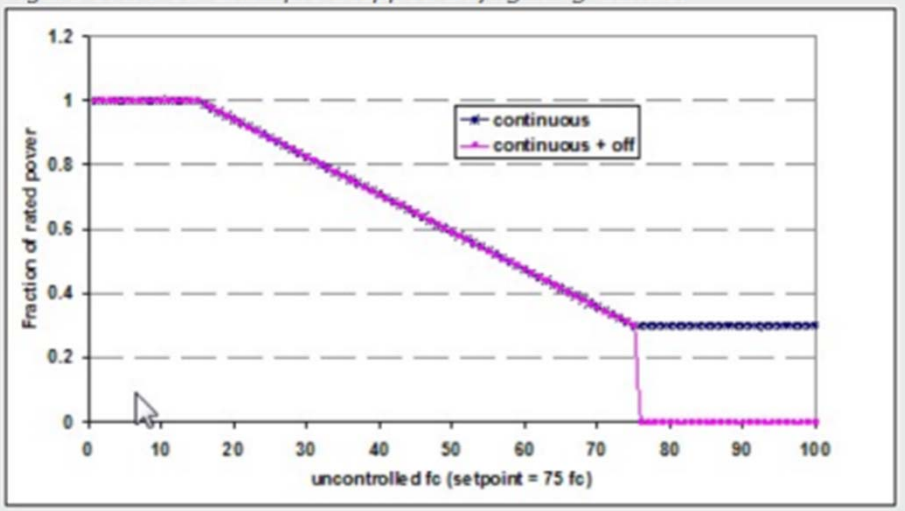


Figure 6.4.4-2: *"Example Dimming Daylight Control"*

HVAC Temperature and Scheduling Controls

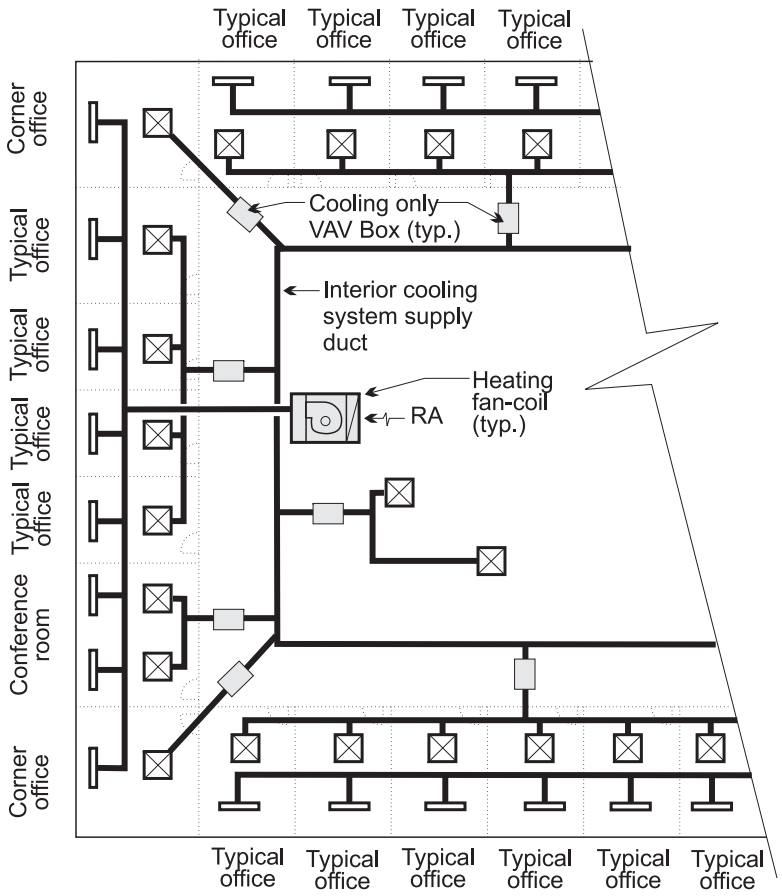
Zone Controls – Thermostats (6.4.3.1.1)

The supply of heating and cooling energy to each zone shall be individually controlled by thermostatic controls responding to temperature within the zone. For the purposes of this section, a dwelling unit shall be permitted to be considered a single zone.

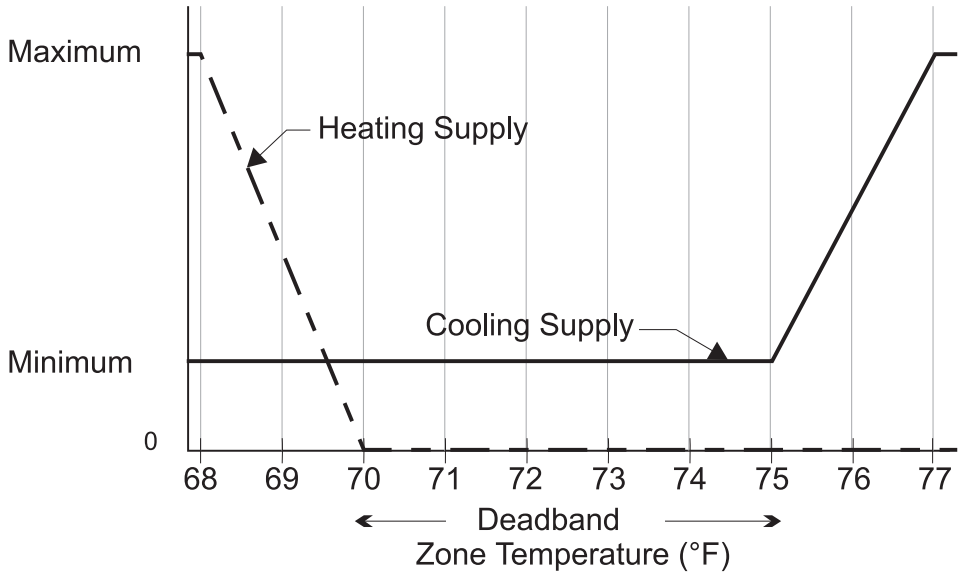
Exceptions: Independent perimeter systems that are designed to offset only building envelope loads shall be permitted to serve one or more zones also served by an interior system, provided that

1. the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for 50 contiguous feet or more and
2. the perimeter system heating and cooling supply is controlled by a thermostatic control(s) located within the zones(s) served by the system.

Independent Perimeter Systems Exception



Zone Controls – Dead Band (6.4.3.1.2)

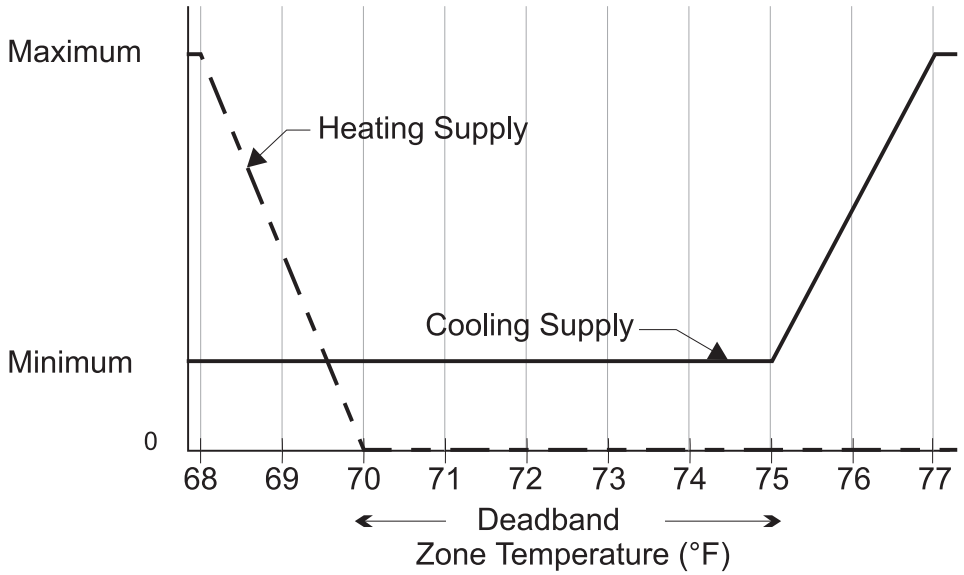


Where used to control both heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 5°F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

Exceptions:

1. Thermostats that require manual changeover between heating and cooling modes
2. Special occupancy or special applications where wide temperature ranges are not acceptable (such as retirement homes, process applications, museums, some areas of hospitals) and are approved by the authority having jurisdiction.

Setpoint Overlap Restriction (6.4.3.2)



Where heating and cooling to a zone are controlled by separate zone thermostatic controls located within the zone, means (such as limit switches; mechanical stops; or, for DDC systems, software programming) shall be provided to prevent the heating setpoint from exceeding the cooling setpoint minus any applicable proportional band.

Off-Hour Controls – *Automatic Shutdown (6.4.3.3.1)*

HVAC systems shall be equipped with at least one of the following:

a. Controls that can start and stop the system under different time schedules for seven different day types per week, are capable of retaining programming and time setting during loss of power for a period of at least ten hours, and include an accessible manual override, or equivalent function, that allows temporary operation of the system for up to two hours

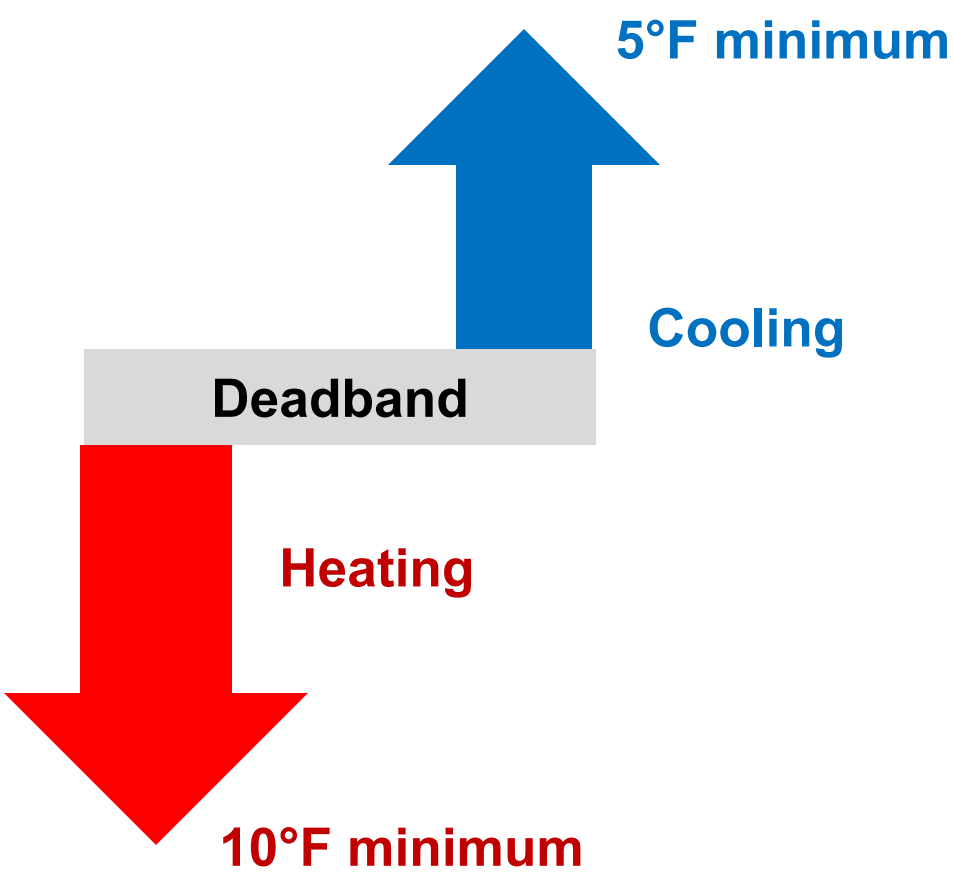
b. An occupant sensor that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes

c. A manually operated timer capable of being adjusted to operate the system for up to two hours

d. An interlock to a security system that shuts the system off when the security system is activated

Exception: Residential occupancies may use controls that can start and stop the system under two different time schedules per week.

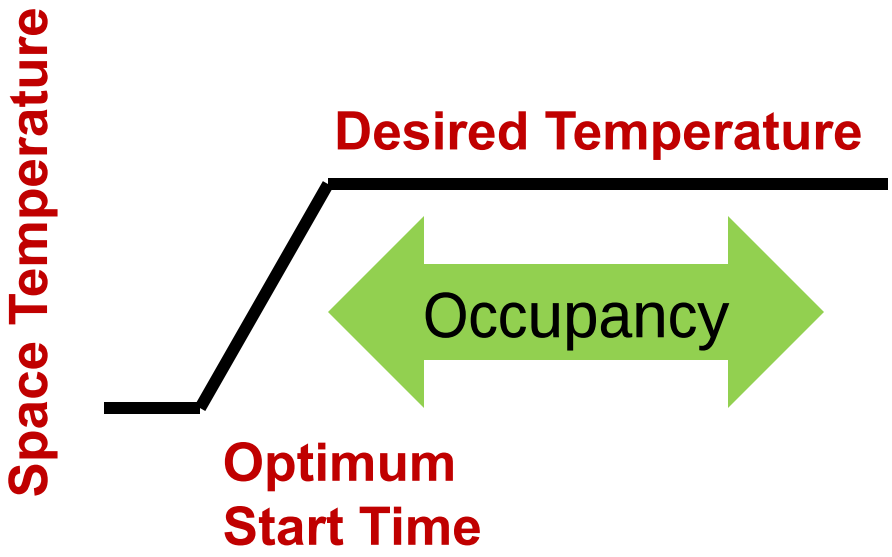
Off-Hour Controls – Setback Controls (6.4.3.3.2)



Heating systems shall be equipped with controls configured to automatically restart and temporarily operate the system as required to maintain zone temperatures above an adjustable heating setpoint at least 10°F below the occupied heating setpoint. Cooling systems shall be equipped with controls configured to automatically restart and temporarily operate the mechanical cooling system as required to maintain zone temperatures below an adjustable cooling setpoint at least 5°F above the occupied cooling setpoint or to prevent high space humidity levels.

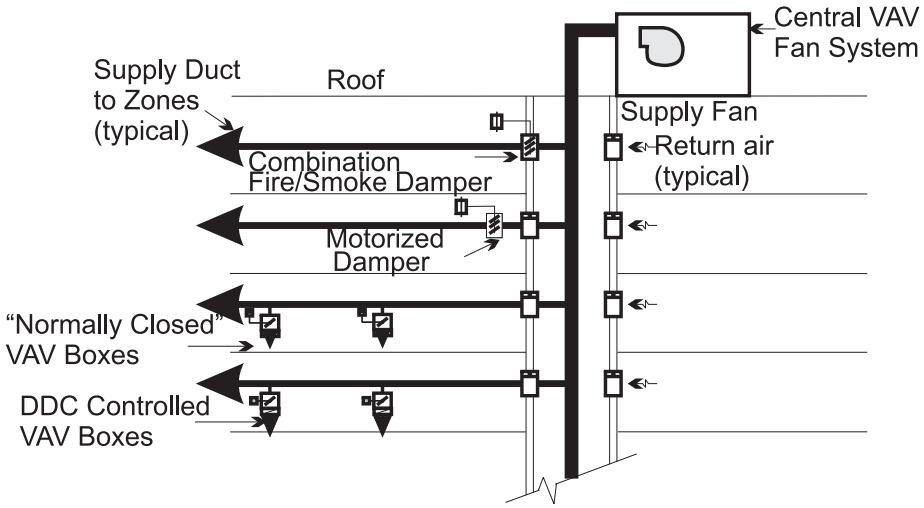
Exception: Radiant heating systems configured with a setback heating setpoint at least 4°F below the occupied heating setpointa

Off-Hour Controls – Optimum Start Controls (6.4.3.3.3)



Individual heating and cooling systems with setback controls and DDC shall have optimum start controls. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied setpoint, the outdoor temperature, and the amount of time prior to scheduled occupancy. Mass radiant floor slab systems shall incorporate floor temperature into the optimum start algorithm.

Off-Hour Controls – Zone Isolation (6.4.3.3.4)



HVAC systems serving zones that are intended to operate or be occupied non-simultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 25,000 ft² of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outdoor air to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of Section 6.4.3.3.1. For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions: Isolation devices and controls are not required for

1. exhaust air and outdoor air connections to isolation zones when the fan system to which they connect is 5000 cfm and smaller;
2. exhaust airflow from a single isolation zone of less than 10% of the design airflow of the exhaust system to which it connects; or
3. zones intended to operate continuously or intended to be inoperative only when all other zones are inoperative.

HVAC Ventilation Controls

Ventilation System – Stair and Shaft Vents (6.4.3.4.1)

Stair and elevator shaft vents shall be equipped with motorized dampers that are capable of being automatically closed during normal building operation and are interlocked to open as required by fire and smoke detection systems.

Ventilation System – Shutoff Damper Controls (6.4.3.4.2)

All outdoor air intake and exhaust systems shall be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use. Ventilation outdoor air and exhaust/relief dampers shall 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.

Exceptions:

1. Back draft gravity (nonmotorized) dampers are acceptable for exhaust and relief in buildings less than three stories in height and for ventilation air intakes and exhaust and relief dampers in buildings of any height located in Climate Zones 1, 2, and 3. Back draft dampers for ventilation air intakes must be protected from direct exposure to wind.
2. Back draft gravity (nonmotorized) dampers are acceptable in systems with a design outdoor air intake or exhaust capacity of 300 cfm or less.
3. Dampers are not required in ventilation or exhaust systems serving unconditioned spaces.
4. Dampers are not required in exhaust systems serving Type 1 kitchen exhaust hoods.

Ventilation System – Ventilation Fan Controls (6.4.3.4.4)

Fans with motors greater than 0.75 hp shall have automatic controls complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required.

Exception: HVAC systems intended to operate continuously.

Ventilation System – Enclosed Parking Garage Ventilation

(6.4.3.4.5)

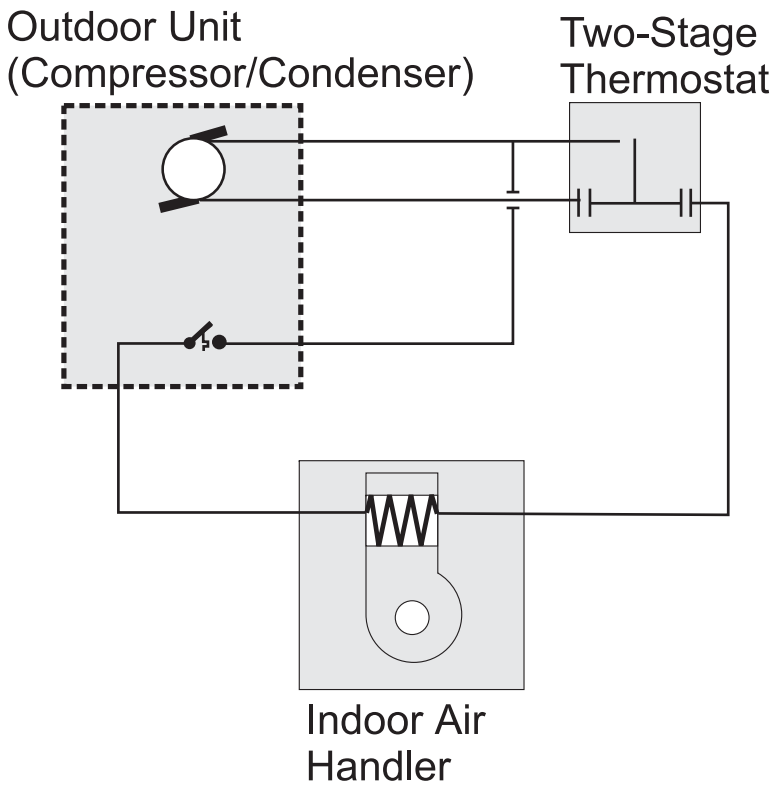
Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity, provided acceptable contaminant levels are maintained.

Exceptions:

1. Garages less than 30,000 ft² with ventilation systems that do not utilize mechanical cooling or mechanical heating
2. Garages that have a garage area to ventilation system motor nameplate hp ratio that exceeds 1500 ft²/hp and do not utilize mechanical cooling or mechanical heating.
3. Where not permitted by the authority having jurisdiction.

Miscellaneous HVAC Controls

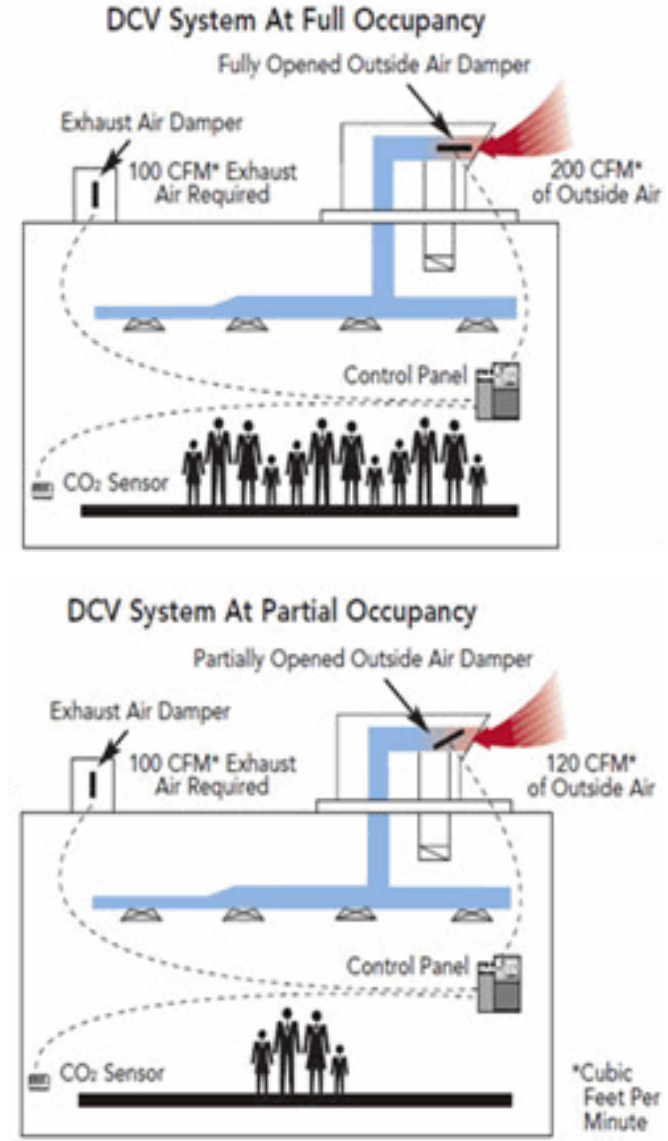
Heat Pump Auxiliary Heat Control (6.4.3.5)



Heat pumps equipped with internal electric resistance heaters shall have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles.

Exception: Heat pumps whose minimum efficiency is regulated by NAECA and whose ratings meet the requirements shown in Table 6.8.1-2 and include all usage of internal electric resistance heating.

Ventilation Controls for High-Occupancy Areas (6.4.3.8)



Demand control ventilation (DCV) is required for spaces larger than 500 ft² and with a design occupancy for ventilation of greater than ≥25 people per 1000 ft² of floor area and served by systems with one or more of the following:

a. Air-side economizer

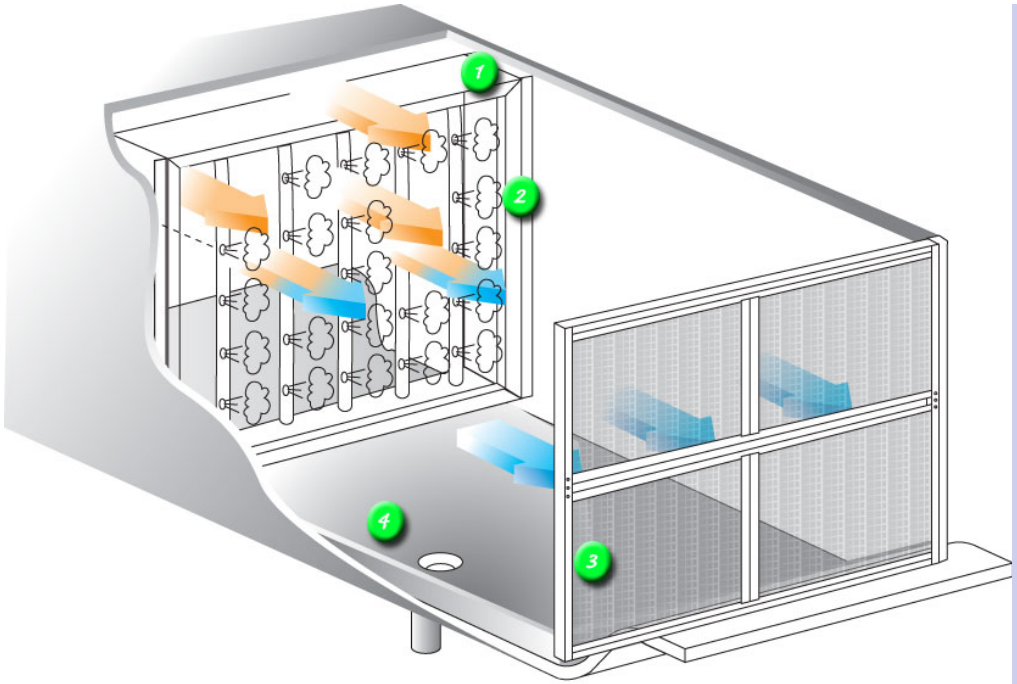
b. Automatic modulating control of outdoor air damper

c. Design outdoor airflow greater than 3000 cfm.

Exceptions:

1. Systems with the exhaust air energy recovery complying with Section 6.5.6.1
2. Multiple-zone systems without DDC of individual zones communicating with a central control panel
3. Systems with a design outdoor airflow less than 750 cfm
4. Spaces where >75% of the space design outdoor airflow is required for makeup air that is exhausted from the space or transfer air that is required for makeup air that is exhausted from other space(s)
5. Spaces with one of the following occupancy categories as defined in ASHRAE Standard 62.1: correctional cells, daycare sickrooms, science labs, barbers, beauty and nail salons, and bowling alley seating.

Humidification and Dehumidification (6.4.3.6)



Humidity control shall prevent the use of fossil fuel or electricity to produce RH above 30% in the warmest zone served by the humidification system and to reduce RH below 60% in the coldest zone served by the dehumidification system. Where a zone is served by a system or systems with both humidification and dehumidification capability, means (such as limit switches, mechanical stops, or, for DDC systems, software programming) shall be provided capable of preventing simultaneous operation of humidification and dehumidification equipment.

Exceptions:

1. Zones served by desiccant systems, used with direct evaporative cooling in series
2. Systems serving zones where specific humidity levels are required, such as museums and hospitals, and approved by the authority having jurisdiction or required by accreditation standards and humidity controls are configured to maintain a deadband of at least 10% RH where no active humidification or dehumidification takes place
3. Systems serving zones where humidity levels are required to be maintained with precision of not more than ±5% RH to comply with applicable codes or accreditation standards or as approved by the authority having jurisdiction

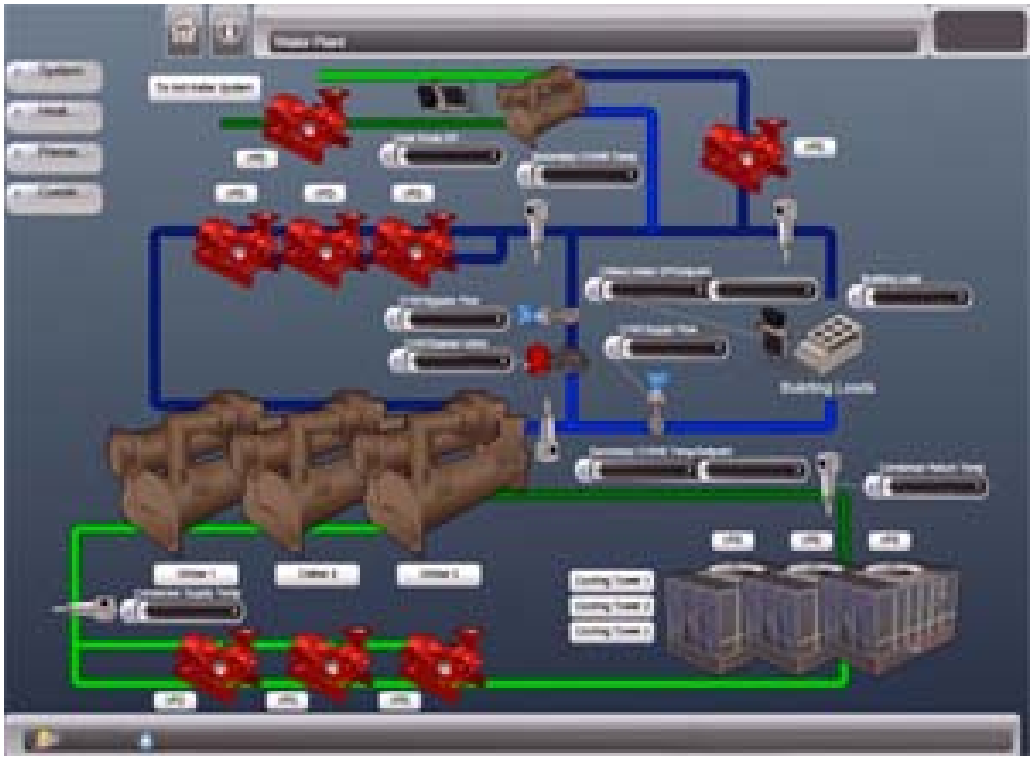
Heating in Vestibules (6.4.3.9)

Heating for vestibules, in accordance with Section 5.4.3.4, and air curtains shall include automatic controls configured to shut off the heating system when outdoor air temperatures are above 45°F. Vestibule heating systems shall also be controlled by a thermostat in the vestibule with a setpoint limited to a maximum of 60°F.

Exception: Vestibules with no heating system or that are tempered with transfer air that would otherwise be exhausted.

HVAC Direct Digital Controls

DDC Requirements – DDC Applications (6.4.3.10.1)



DDC shall be provided in the applications and qualifications listed in Table 6.4.3.10.1.

Exception: DDC is not required for systems using the simplified approach to compliance in accordance with Section 6.3.

DDC Requirements – DDC Applications and Qualifications

(Table 6.4.3.10.1)

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
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
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
Alternation or Addition	
Zone terminal unit such as VAV box	Where existing air-handling system(s) and fan-coil(s) served by the same chilled- or hot-water plant have DDC
Air-handling system or fan coil	Where existing zones served by the same air- handling, chilled-water, or hot-water system have DDC
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
New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

DDC Requirements – DDC Controls (6.4.3.10.2)

Required Functions

- Monitoring
- Communication between systems
- Identifying “trouble zones”
- Allowing easy operator override

Where DDC is required by Section 6.4.3.10.1, the DDC system shall be capable of all of the following, as required, to provide the control logic required in Section 6.5:

a. Monitoring zone and system demand for fan pressure, pump pressure, heating, and cooling

b. Transferring zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers

c. Automatically detecting those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator

d. Readily allowing operator removal of zone(s) from the reset algorithm

DDC Requirements – DDC Display (6.4.3.10.3)

Where DDC is required by Section 6.4.3.10.1 for new buildings, the DDC system shall be capable of trending and graphically displaying input and output points.

Economizers (6.5.1)

Economizers

Air Economizer

OR

Water Economizer

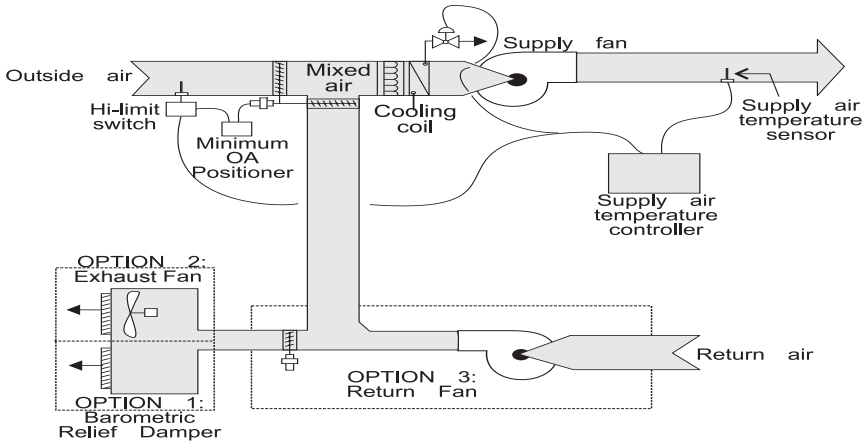
OR

Exception (there are lots of them)

1. Individual fan-cooling units with a supply capacity less than the minimum listed in Table 6.5.1-1 for comfort cooling applications and Table 6.5.1-2 for computer room applications.
2. Systems that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.
3. In hospitals and ambulatory surgery centers, where more than 75% of the air designed to be supplied by the system is to spaces that are required to be humidified above 35°F dew-point temperature to comply with applicable codes or accreditation standards; in all other buildings, where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F dew-point temperature to satisfy process needs. This exception does not apply to computer rooms.
4. Systems that include a condenser heat recovery system with a minimum capacity as defined in Section 6.5.6.2.2.
5. Systems that serve residential spaces where the system capacity is less than five times the requirement listed in Table 6.5.1-1.
6. Systems that serve spaces whose sensible cooling load at design conditions, excluding transmission and infiltration loads, is less than or equal to transmission and infiltration losses at an outdoor temperature of 60°F.
7. Systems expected to operate less than 20 hours per week.
8. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems.
9. For comfort cooling where the cooling efficiency meets or exceeds the efficiency improvement requirements in Table 6.5.1-3.
10. Systems primarily serving computer rooms where
    a. the total design cooling load of all computer rooms in the building is less than 3,000,000 Btu/ h and the building in which they are located is not served by a centralized chilled water plant;
    b. the room total design cooling load is less plant; c. the local water authority does not allow cooling towers; or
    c. less than 600,000 Btu/h of computer-room cooling equipment capacity is being added to an existing building
11. Dedicated systems for computer rooms where a minimum of 75% of the design load serves
    a. those spaces classified as an essential facility,
    b. those spaces having a design of Tier IV as defined by ANSI/TIA-942,
    c. those spaces classified under NFPA 70 Article 708—Critical Operations Power Systems (COPS), or
    d. those spaces where core clearing and settlement services are performed such that their failure to settle pending financial transactions could present systemic risk as described in “The Interagency Paper on Sound Practices to Strengthen the Resilience of the U.S. Financial System, April 7, 2003”

Air Economizers (6.5.1.1)

- Control
- Shut off for warm/humid conditions
- Damper characteristics
- Air relief



6.5.1.1.1 Design Capacity. Air economizer systems shall be capable of modulating outdoor air and return air dampers to provide up to 100% of the design supply air quantity as outdoor air for cooling.

6.5.1.1.2 Control Signal. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed-air temperature.

Exception: The use of mixed-air temperature limit control shall be permitted for systems controlled from space temperature (such as single-zone systems).

6.5.1.1.3 High-Limit Shutoff. All air economizers shall be capable of automatically reducing outdoor air intake to the design minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage. High-limit shutoff control types and associated setpoints for specific climate zones shall be chosen from Table 6.5.1.1.3.

6.5.1.1.4 Dampers. Return, exhaust/relief, and outdoor air dampers shall meet the requirements of Section 6.4.3.4.3.

6.5.1.1.5 Relief of Excess Outdoor Air. Systems shall provide a means to relieve excess outdoor air during air economizer operation to prevent overpressurizing the building. The relief air outlet shall be located so as to avoid recirculation into the building.

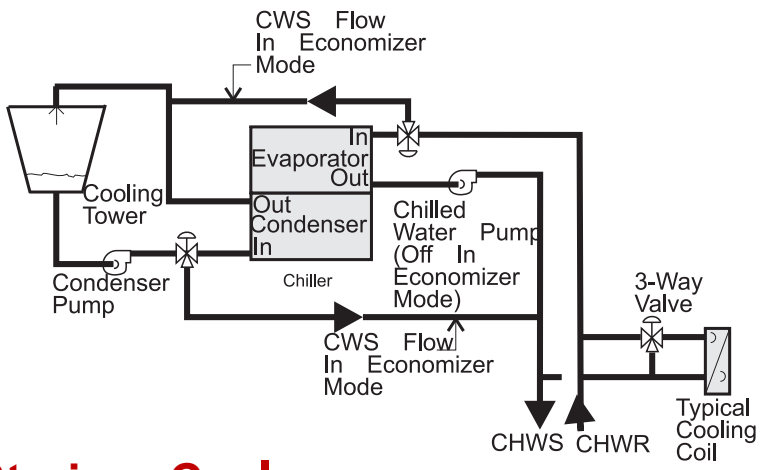
6.5.1.1.6 Sensor Accuracy. Outdoor air, return air, mixed air, and supply air sensors shall be calibrated within the following accuracies:

a. Dry-bulb and wet-bulb temperatures shall be accurate to ±2°F over the range of 40°F to 80°F.

b. Enthalpy and the value of a differential enthalpy sensor shall be accurate to ±3 Btu/lb over the range of 20 to 36 Btu/lb.

c. Relative humidity shall be accurate to ±5% over the range of 20% to 80% RH.

Water Economizers (6.5.1.2)



Strainer Cycle

Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100% of the expected system cooling load at outdoor air temperatures of 50°F dry bulb/45°F wet bulb and below.

Exceptions:

1. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb and wet-bulb listed in Table 6.5.1.2.1 is met with evaporative water economizers

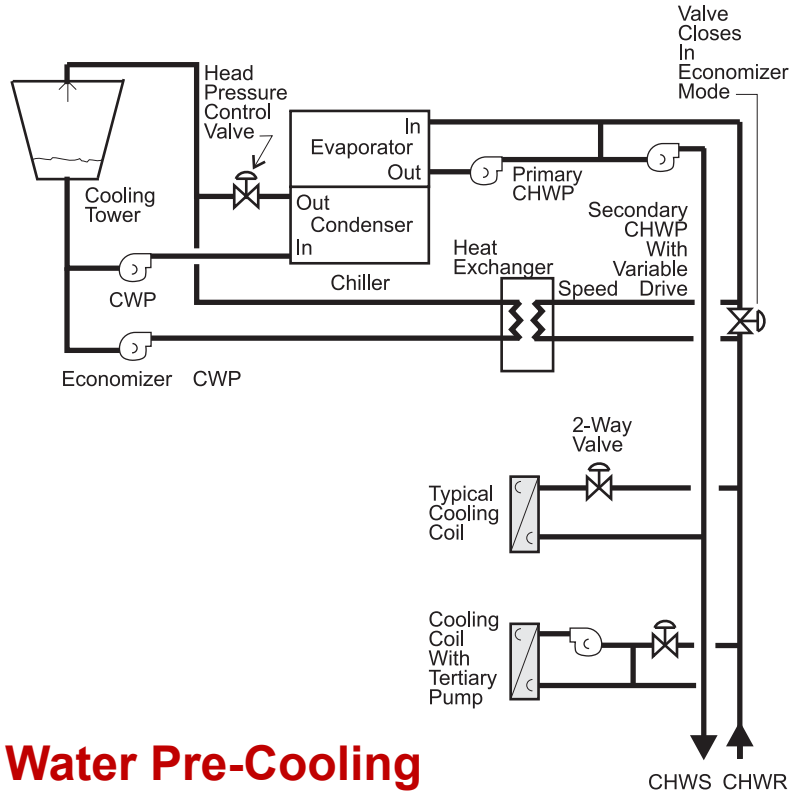
2. Systems primarily serving computer rooms in which 100% of the expected system cooling load at the dry-bulb temperatures listed in Table 6.5.1.2.1 is met with dry cooler water economizers

3. Systems where dehumidification requirements cannot be met using outdoor air temperatures of 50°F dry-bulb/45°F wet-bulb and where 100% of the expected system cooling load at 45°F dry-bulb/40°F wet-bulb is met with evaporative water economizers

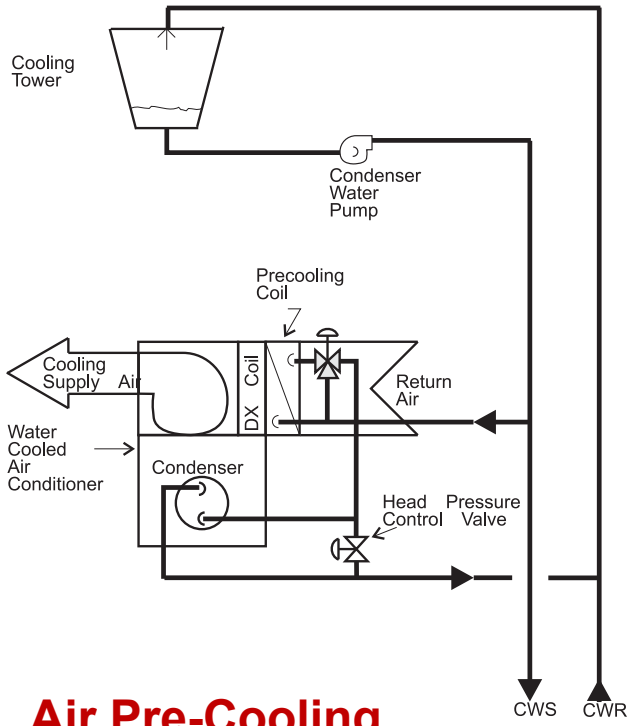
6.5.1.2.2 Maximum Pressure Drop

Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 15 ft of water, or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

Water Economizers (6.5.1.2)

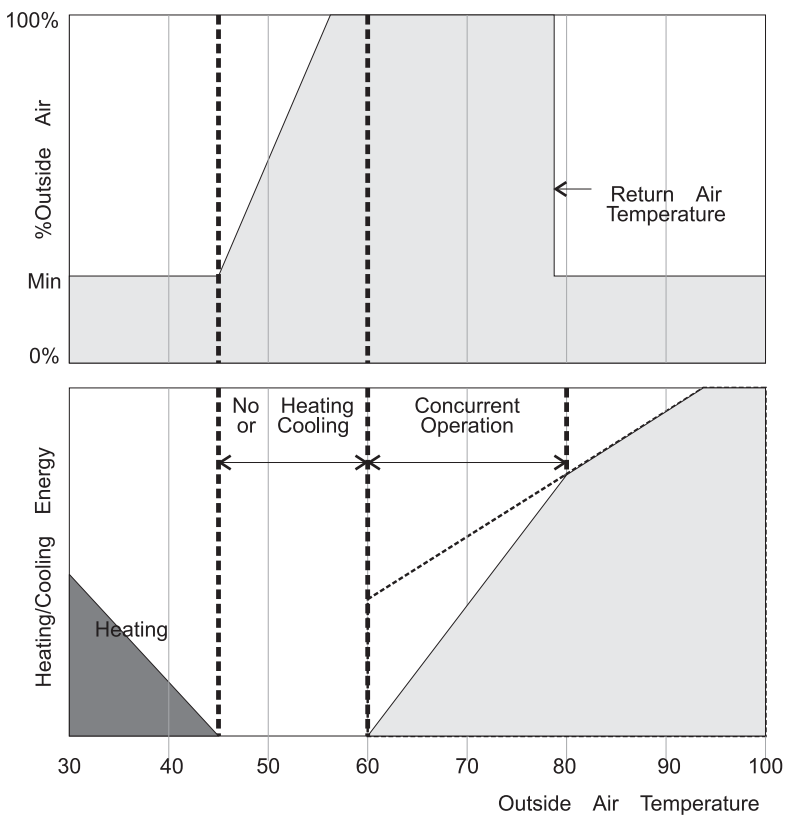


Water Pre-Cooling



Air Pre-Cooling

Integrated Economizer Control (6.5.1.3)



Integrated Economizer

Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load. (Controls shall not false load the mechanical cooling systems by limiting or disabling the economizer or by any other means, such as hot gas bypass, except at the lowest stage of mechanical cooling.

Units that include an air economizer shall comply with the following:

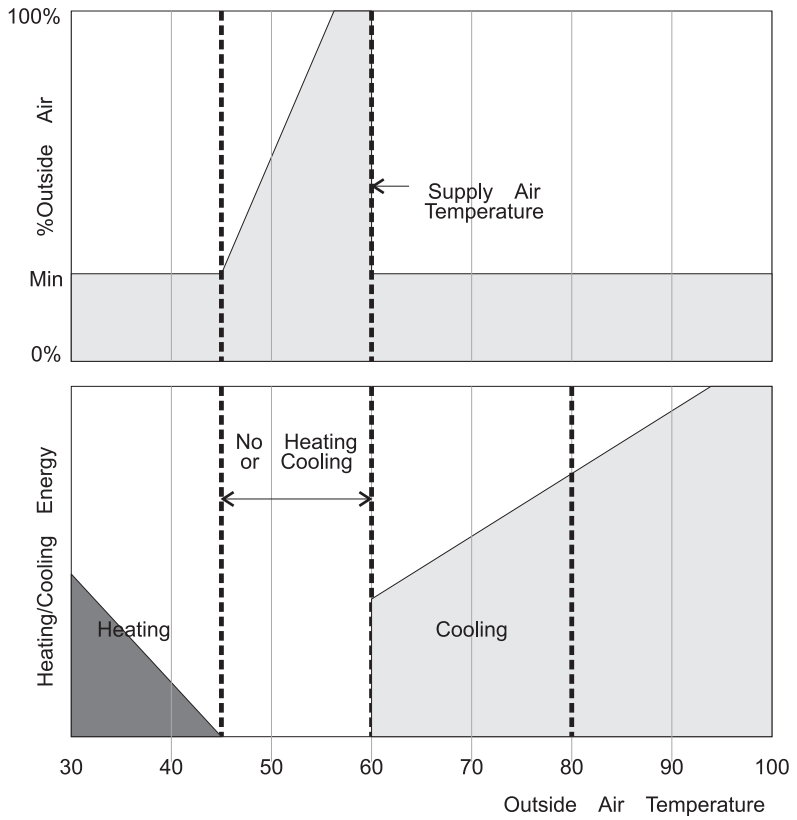
a. Unit controls shall have the mechanical cooling capacity control interlocked with the air economizer controls such that the outdoor air damper is at the 100% open position when mechanical cooling is on, and the outdoor air damper does not begin to close to prevent coil freezing due to minimum compressor run time until the leaving air temperature is less than 45°F.6.5.2)

b. DX units that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of two stages of mechanical cooling capacity per the following effective dates:

≥75,000 Btu/h Rated Capacity—Effective 1/1/2014

≥65,000 Btu/h Rated Capacity—Effective 1/1/2016

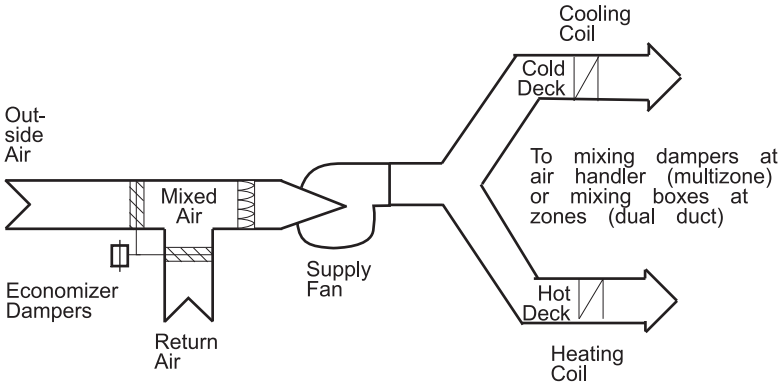
Integrated Economizer Control (6.5.1.3)



Non-Integrated Economizer (allowed only by Exception)

Simultaneous Heating and Cooling (6.5.2)

Zone Controls (6.5.2.1)



Zone thermostatic controls shall prevent

a. reheating;

b. recooling;

c. mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previ-ously cooled, either by mechanical cooling or by economizer systems; and

d. other simultaneous operation of heating and cooling systems to the same zone.

Exceptions:

See standard for detail.

Some sort of variable air volume system is generally required, provided:

≤ 0.4 cfm/ft²,
30% of peak air flow, or
300 cfm

Hydronic System Controls (6.5.2.2)

- Three-Pipe System (prohibited)
- Two-Pipe Changeover
  - Deadband
  - 4 Hour Minimum
  - Reset Controls

The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 6.5.2.2.1 through 6.5.2.2.3.

6.5.2.2.1 Three-Pipe System

Hydronic systems that use a common return system for both hot water and chilled water shall not be used.

6.5.2.2.2 Two-Pipe Changeover System

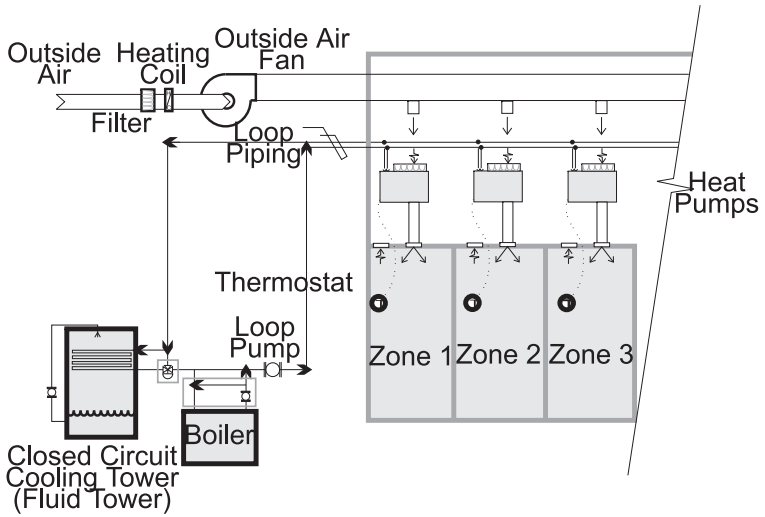
Systems that use a common distribution system to supply both heated and chilled water are acceptable provided all of the following are met:

a. The system is designed to allow a dead band between changeover from one mode to the other of at least 15°F outdoor air temperature.

b. The system is designed to operate and is provided with controls that will allow operation in one mode for at least four hours before changing over to the other mode.

c. Reset controls are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

Hydronic System Controls (6.5.2.2)



6.5.2.2.3 Hydronic (Water Loop) Heat Pump Systems

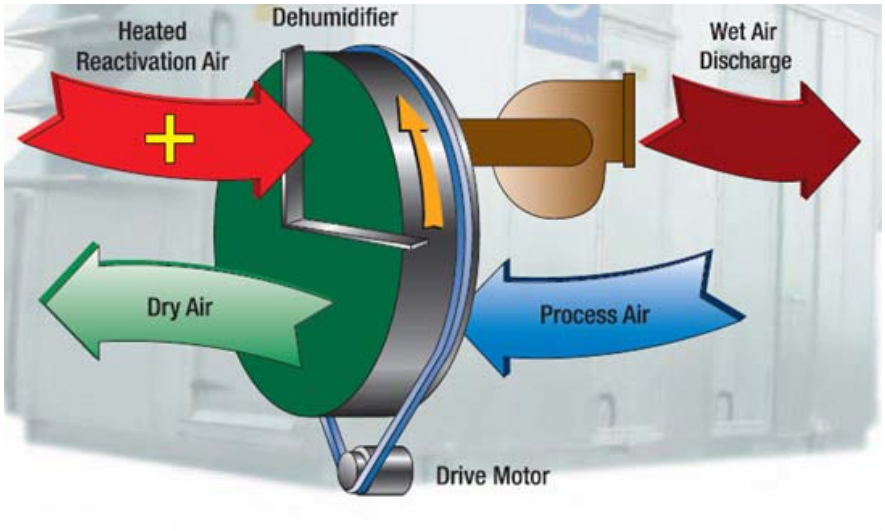
Hydronic heat pumps connected to a common heatpump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall have the following:

a. Controls that are capable of providing a heat-pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).

b. For Climate Zones 3 through 8, if a closed-circuit tower (fluid cooler) is used, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open-circuit tower is used directly in the heat-pump loop, an automatic valve shall be installed to bypass all heat-pump water flow around the tower. If an open-circuit tower is used in conjunction with a separate heat exchanger to isolate the tower from the heat-pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

Exception: Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20°F shall be allowed.

Dehumidification (6.5.2.3)



Where humidity controls are provided, such controls shall prevent reheating, mixing of hot and cold airstreams, or other means of simultaneous heating and cooling of the same airstream.

Exceptions:

1. The system is configured to reduce supply air volume to 50% or less of the design airflow rate or the minimum outdoor air ventilation rate specified in ASHRAE Standard 62.1 or other applicable federal, state, or local code or recognized standard, whichever is larger, before simultaneous heating and cooling takes place.

2. The individual fan cooling unit has a design cooling capacity of 65,000 Btu/h or less and is capable of unloading to 50% capacity before simultaneous heating and cooling takes place.

3. The individual mechanical cooling unit has a design cooling capacity of 40,000 Btu/h or less. An individual mechanical cooling unit is a single system composed of a fan or fans and a cooling coil capable of providing mechanical cooling.

4. Systems serving spaces where specific humidity levels are required to satisfy process needs, such as vivariums, museums, surgical suites, pharmacies, and buildings with refrigerating systems, such as supermarkets, refrigerated warehouses, and ice arenas, and the building includes siterecovered or site solar energy source that provide energy equal to at least 75% of the annual energy for reheating or for providing warm air in mixing systems. This exception does not apply to computer rooms.

5. At least 90% of the annual energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including condenser heat) or site-solar energy source.

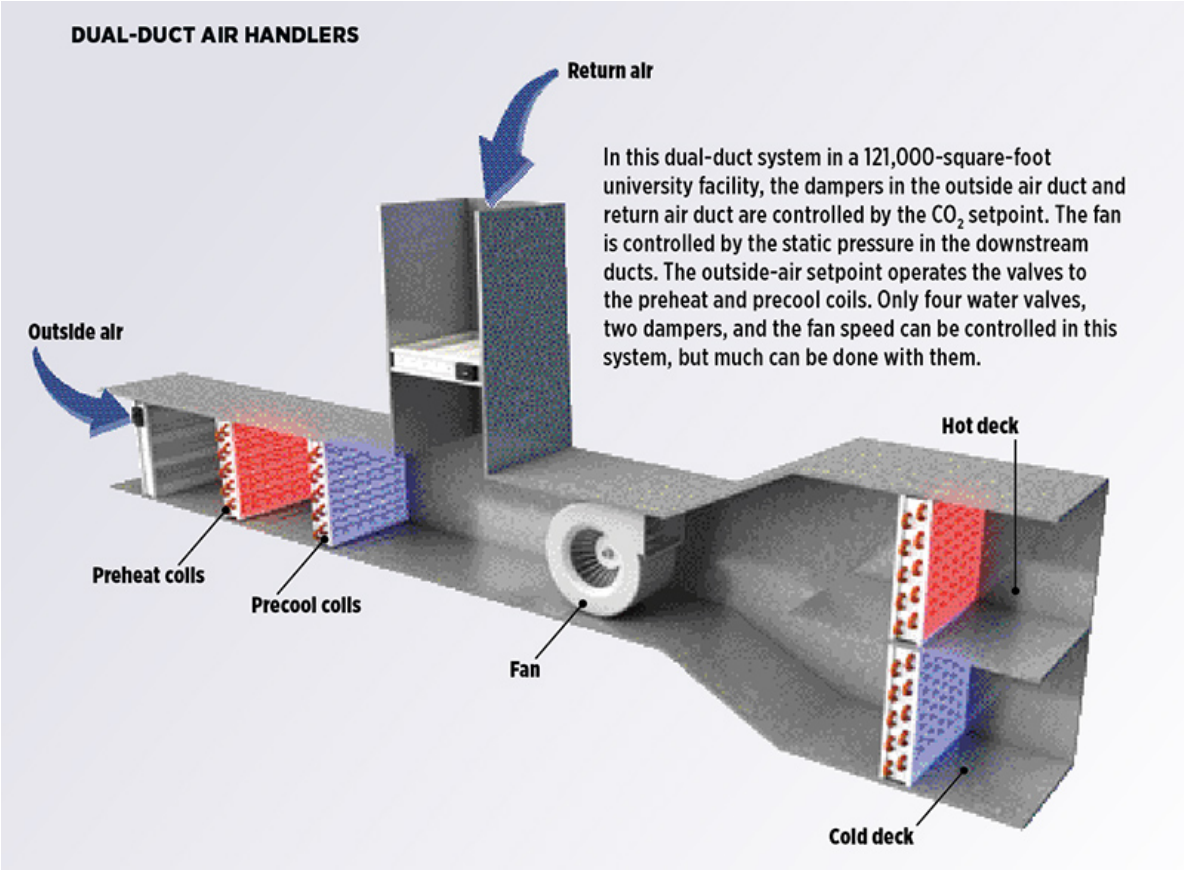
6. Systems where the heat added to the airstream is the result of the use of a desiccant system and 75% of the heat added by the desiccant system is removed by a heat exchanger, either before or after the desiccant system with energy recovery.

Humidification (6.5.2.4)

- 6.5.2.4.1 Systems with hydronic cooling and humidification systems designed to maintain inside humidity at a dewpoint temperature greater than 35°F shall use a water economizer if an economizer is required by Section 6.5.1.
- 6.5.2.4.2 Humidifiers with preheating jackets mounted in the airstream shall be provided with an automatic valve to shut off preheat when humidification is not required.
- 6.5.2.4.3 Humidification system dispersion tube hot surfaces in the airstreams of ducts or air-handling units shall be insulated with a product with an insulating value of at least R-0.5.
- **Exception**: Systems where mechanical cooling, including economizer operation, does not occur simultaneously with humidification

Preheat Coils (6.5.2.5)

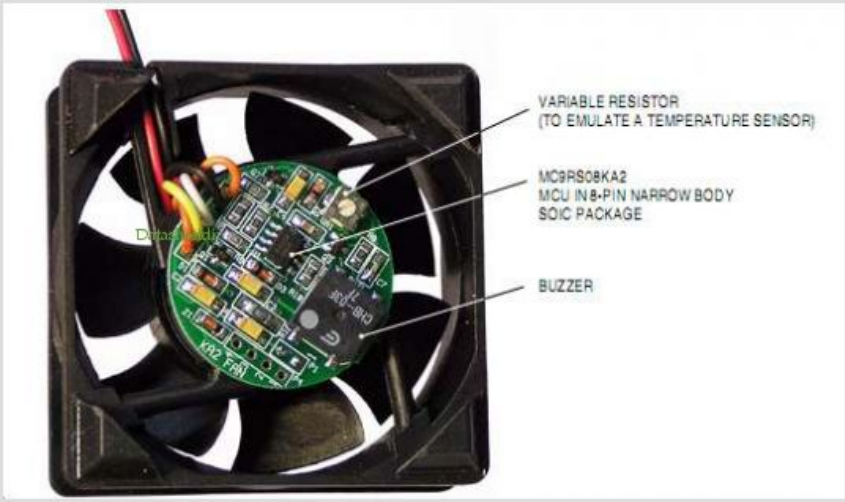
Each HVAC system having a total fan system motor nameplate hp exceeding 5 hp shall meet the provisions of Sections 6.5.3.1 through 6.5.3.5.



Air System Design and Control (6.5.3)

Fan Control (6.5.3.2)

Cooling System Type	Size Threshold
DX cooling	**≥110,000 Btu/h**
	≥75,000 Btu/h (1/1/2014)
	≥65,000 Btu/h (1/1/2016)
Chilled-water and evaporative cooling	**≥5 hp**
	≥1/4 hp



6.5.3.2.1 Fan Airflow Control

Each cooling system listed in Table 6.5.3.2.1 shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

a. DX and chilled-water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have a minimum of two stages of fan control. Low or minimum speed shall not exceed 66% of full speed. At low or minimum speed, the fan system shall draw no more than 40% of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

b. All other units, including DX cooling units and chilledwater units that control the space temperature by modulating the airflow to the space, shall have modulating fan control. Minimum speed shall not exceed 50% of full speed. At minimum speed, the fan system shall draw no more than 30% of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

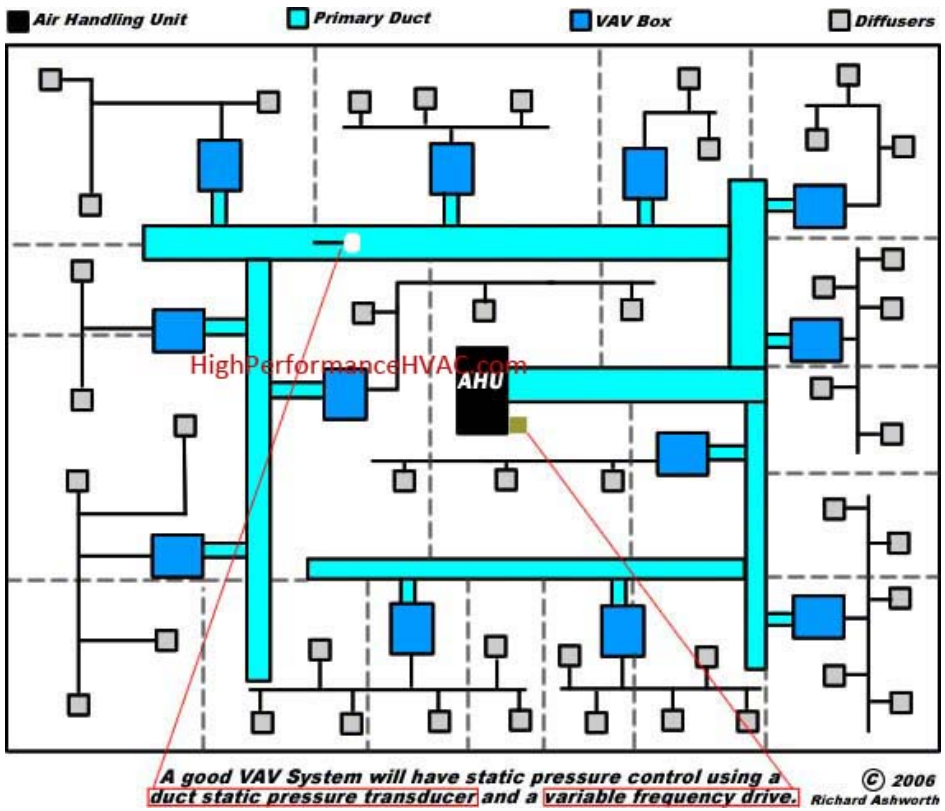
c. Units that include an air-side economizer to meet the requirements of Section 6.5.1 shall have a minimum of two speeds of fan control during economizer operation.

Exceptions:

1. Modulating fan control is not required for chilled-water and evaporative cooling units with <1 hp fan motors if the units are not used to provide ventilation air and the indoor fan cycles with the load.

2. If the volume of outdoor air required to meet the ventilation requirements of Standard 62.1 at low speed exceeds the air that would be delivered at the speed defined in Section 6.5.3.2.1(a) or 6.5.3.2.1(b) then the minimum speed shall be selected to provide the required ventilation air.

Fan Control (6.5.3.2)



6.5.3.2.2 VAV Static Pressure Sensor Location

Static pressure sensors used to control VAV fans shall be located such that the controller setpoint is no greater than 1.2 in. wc If this results in the sensor being located downstream of major duct splits, sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

Exception: Systems complying with Section 6.5.3.2.3 6.5.3.2.3 VAV Setpoint Reset. For systems with DDC of individual zones reporting to the central control panel, static pressure setpoint shall be reset based on the zone requiring the most pressure; i.e., the setpoint is reset lower until one zone damper is nearly wide open. Controls shall provide the following:

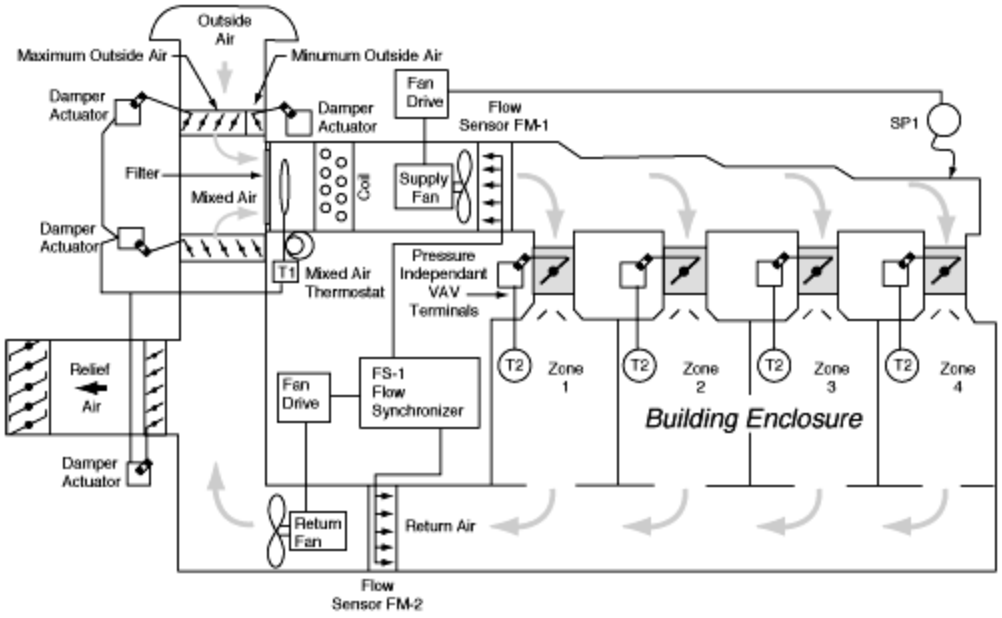
a. Monitor zone damper positions or other indicator of need for static pressure

b. Automatically detect those zones that may be excessively driving the reset logic and generate an alarm to the system operator

c. Readily allow operator removal of zone(s) from the reset algorithm

Multiple-Zone VAV System Ventilation Optimization Control (6.5.3.3)

Fig. 1 VAV SYSTEM WITH SEVEN INTERACTING CONTROL LOOPS.



Multiple-zone VAV systems with DDC of individual zone boxes reporting to a central control panel shall include means to automatically reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency as defined by ASHRAE Standard 62.1, Appendix A.

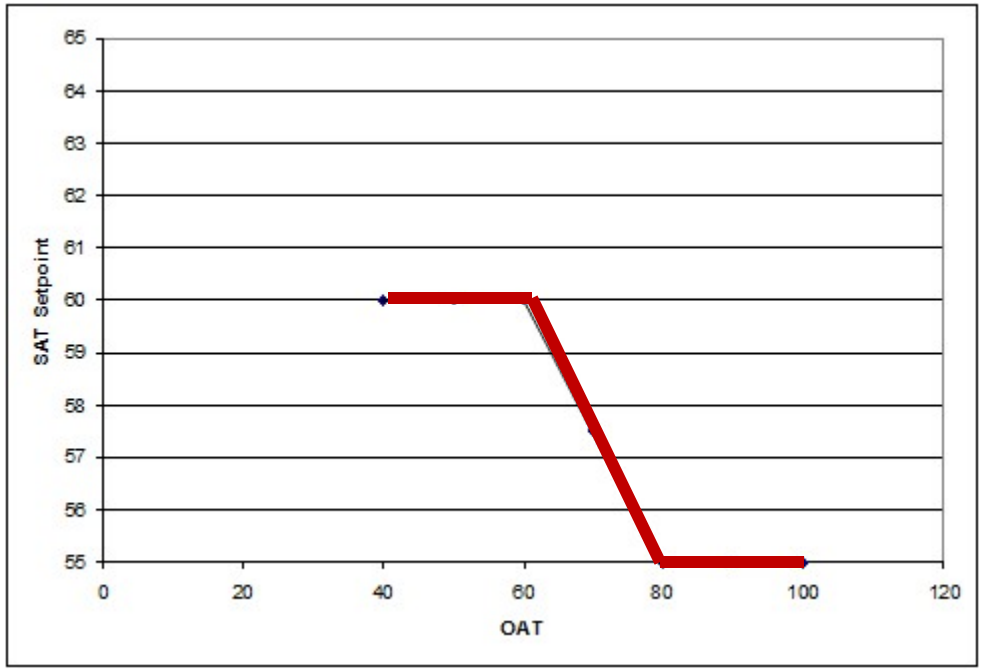
Exceptions:

1. VAV systems with zonal transfer fans that recirculate air from other zones without directly mixing it with outdoor air, dual-duct dual-fan VAV systems, and VAV systems with fan-powered terminal units

2. Systems required to have the exhaust air energy recovery complying with Section 6.5.6.1

3. Systems where total design exhaust airflow is more than 70% of total design outdoor air intake flow requirements

Supply Air Temperature Reset Controls (6.5.3.4)



Multiple zone HVAC systems must include controls that automatically reset the supply air temperature in response to representative building loads, or to outdoor air temperature. The controls shall reset the supply air temperature at least 25% of the difference between the design supply air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity are allowed. Zones that are expected to experience relatively constant loads, such as electronic equipment rooms, shall be designed for the fully reset supply temperature.

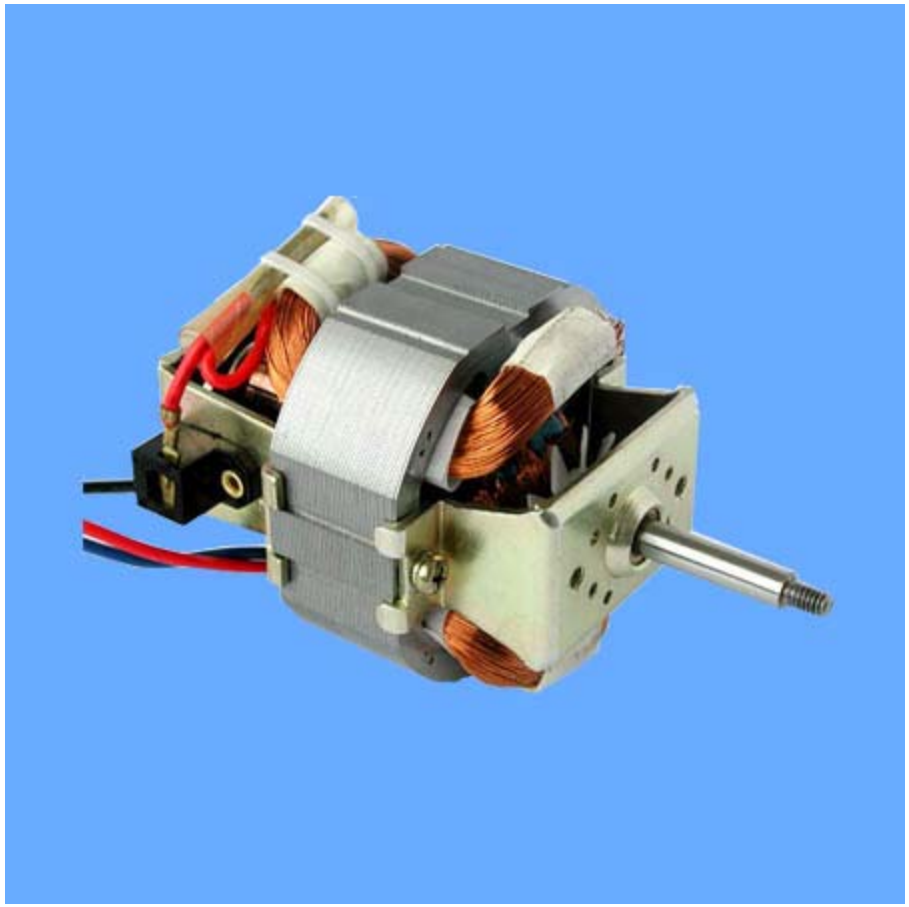
Exceptions:

1. Climate Zones 1a, 2a, and 3a

2. Systems that prevent reheating, recooling, or mixing of heated and cooled supply ai.

3. Systems in which at least 75% of the energy for reheating (on an annual basis) is from site recovered or site solar energy sources

Fractional Horsepower Fan Motors (6.5.3.5)



Motors for fans that are 1/12 hp or greater and less than 1 hp shall be electronically-commutated motors or shall have a minimum motor efficiency of 70% when rated in accordance with DOE 10 CFR 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Beltdriven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

Exceptions:

1. Motors in the airstream within fan-coils and terminal units that operate only when providing heating to the space served

2. Motors installed in space conditioning equipment certified under Section 6.4.1

3. Motors covered by Table 10.8-4 or 10.8-5

Hydronic System Design and Control (6.5.4)

Boiler Turndown (6.5.4.1)

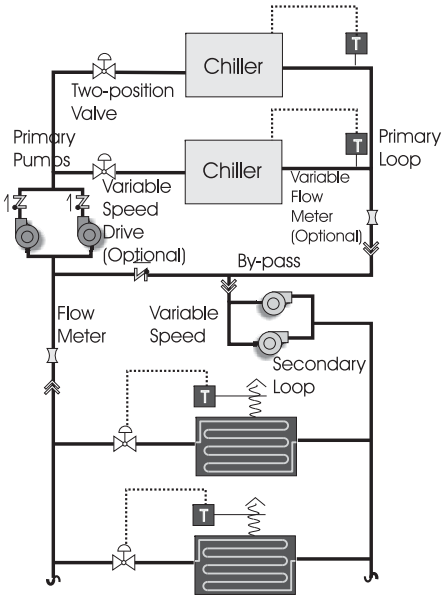
≥1,000,000 and ≤5,000,000 Btu/h	**3 to 1**
>5,000,000 and ≤10,000,000 Btu/h	4 to 1
>10,000,000 Btu/h	5 to 1

Boiler systems with design input of at least 1,000,000 Btu/h shall comply with the turndown ratio specified in Table 6.5.4.1.

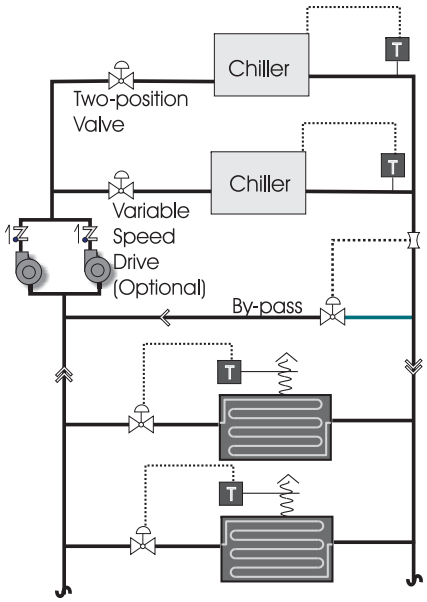
The system turndown requirement shall be met through the use of multiple single-input boilers, one or more modulating boilers, or a combination of single-input and modulating boilers.

All boilers shall meet the minimum efficiency requirements in Table 6.8.1-6

Hydronic Variable Flow Systems (6.5.4.2)



Primary/ Secondary



Primary Only

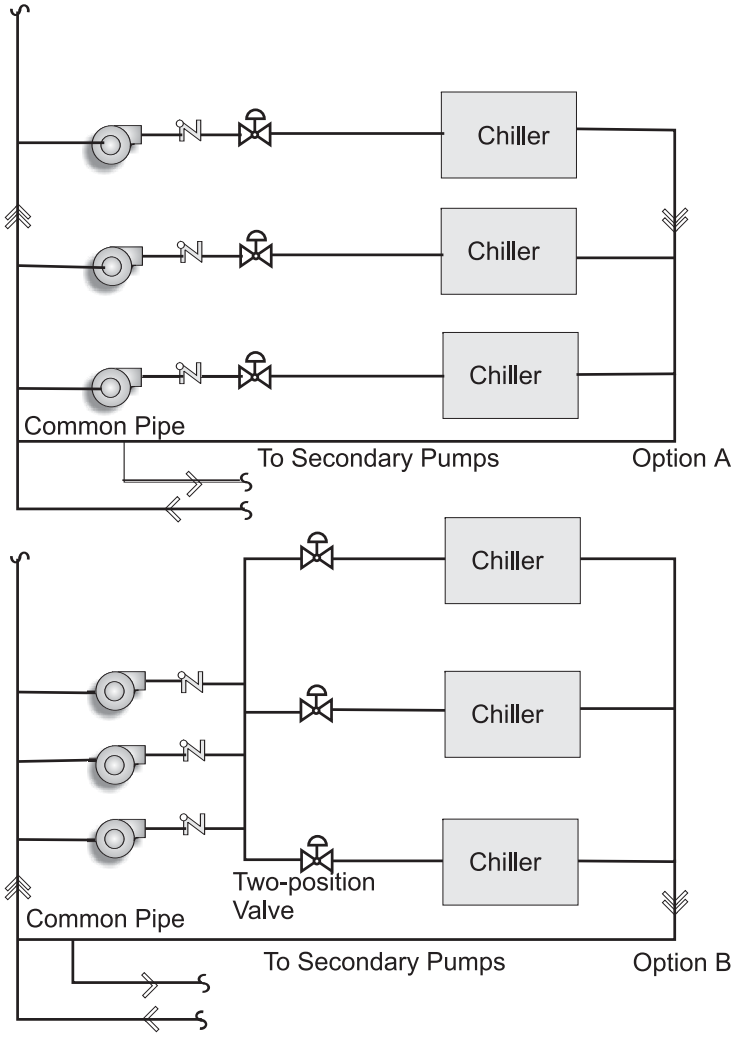
HVAC pumping systems having a total pump system power exceeding 10 hp that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual chilled-water pumps serving variable-flow systems having motors exceeding 5 hpshall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure. The differential pressure setpoint shall be no more than 110% of that required to achieve design flow through the heat exchanger. Where differential pressure control is used to comply with this section and DDC systems are used, the setpoint shall be reset downward based on valve positions until one valve is nearly wide open.

Exceptions:

1. Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 75 hp or less

2. Systems that include no more than three control Valves

Chiller and Boiler Isolation (6.5.4.3)



6.5.4.3.1 When a chilled-water plant includes more than one chiller, provisions shall be made so that all fluid flow through the chiller is automatically shut off when the chiller is shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller. Where constant-speed chilled-water or condenser water pumps are used to serve multiple chillers, the number of pumps shall be no less than the number of chillers and staged on and off with the chillers.

6.5.4.3.2 When a boiler plant includes more than one boiler, provisions shall be made so that the flow through the boiler is automatically shut off when the boiler is shut down. Where constant-speed hot-water pumps are used to serve multiple boilers, the number of pumps shall be no less than the number of boilers and staged on and off with the boilers.

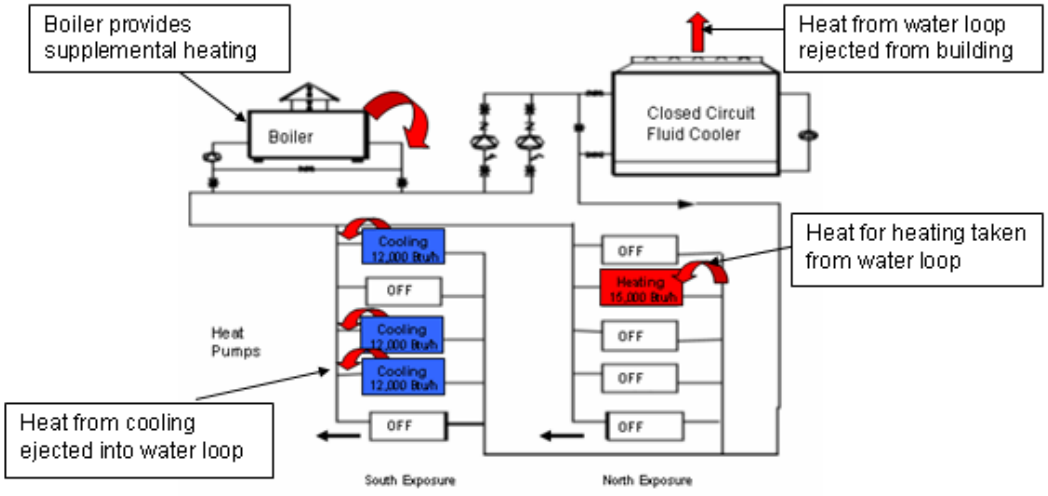
6.5.4.4 Chilled- and Hot-Water Temperature Reset Controls. Chilled- and hot-water systems with a design capacity exceeding 300,000 Btu/h supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems

2. Hydronic systems, such as those required by Section 6.5.4.1, that use variable flow to reduce pumping energy

Hydronic (Water Loop) Heat Pumps and Water-Cooled Unitary Air-Conditioners (6.5.4.5)



6.5.4.5.1 Each hydronic heat pump and water-cooled unitary air-conditioner shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.

Exception: Units employing water economizer 6.5.4.5.2 Hydronic heat pumps and water-cooled unitary air-conditioners having a total pump system power exceeding 5 hp shall have controls and/or devices (such as variable-speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

Heat Rejection Equipment (6.5.5)

Fan Speed Control (6.5.5.2)

6.5.5.2.1 Each fan powered by a motor of 7.5 hp or larger shall have the capability to operate at two-thirds full speed or less and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

Exceptions:

1. Condenser fans serving multiple refrigerant circuits

2. Condenser fans serving flooded condensers

3. Installations located in Climate Zones 1 and 2

6.5.5.2.2 Multicell heat rejection equipment with variable- speed fan drives shall

a. operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components and

b. control all fans to the same fan speed required for the instantaneous cooling duty, as opposed to staged (on/off) operation. Minimum fan speed shall comply with the minimum allowable speed of the fan drive system per the manufacturer's recommendations.

Water Heating Controls

Service Water Heating System Controls (7.4.4)

7.4.4.1 Temperature Controls. Temperature controls shall be provided that allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use.

Exception: When the manufacturers' installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion.

7.4.4.2 Temperature Maintenance Controls. Systems

designed to maintain usage temperatures in hot-water pipes, such as recirculating hot-water systems or heat trace, shall be equipped with automatic time switches or other controls that can be set to switch off the usage temperature maintenance system during extended periods when hot water is not required.

7.4.4.3 Outlet Temperature Controls. Temperature controlling means shall be provided to limit the maximum temperature of water delivered from lavatory faucets in public facility restrooms to 110°F.

7.4.4.4 Circulating Pump Controls. When used to maintain storage tank water temperature, recirculating pumps shall be equipped with controls limiting operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle.

Interior Lighting Controls (9.4.1.1)

Required Control Functions

a. Local Control
b. Restricted to Manual ON
c. Restricted to Partial Automatic ON
d. Bi-Level Lighting Control
e. Automatic Daylight Responsive Controls for Sidelighting (windows)
f. Automatic Daylight Responsive Controls for Toplighting (skylights)
g. Automatic Partial OFF (full OFF complies)
h. Automatic Full OFF
i. Scheduled Shutoff

Interior Lighting Controls (9.4.1.1)

ANSI/ASHRAE/IES Standard 90.1-2013 (I-P Edition)

TABLE 9.6.1 Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method

Informative Note: This table is divided into two sections; this first section covers space types that can be commonly found in multiple building types. The second part of this table covers space types that are typically found in a single building type.

The control functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each space type:
(1) All REQs shall be implemented.
(2) At least one ADD1 (when present) shall be implemented.
(3) At least one ADD2 (when present) shall be implemented.

Common Space Types[1]	LPD, W/ft²	RCR Threshold	Local Control (See Section 9.4.1.1[a]) a	Restricted to Manual ON (See Section 9.4.1.1[b]) b	Restricted to Partial Automatic ON (See Section 9.4.1.1[c]) c	Bilevel Lighting Control (See Section 9.4.1.1[d]) d	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e][6]) e	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f][6]) f	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies]) g	Automatic Full OFF (See Section 9.4.1.1[h]) h	Scheduled Shutoff (See Section 9.4.1.1[i]) i
Atrium											
… that is <20 ft in height	0.03/ft total height	NA	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… that is ≥20 ft and ≤40 ft in height	0.03/ft total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… that is >40 ft in height	0.40 + 0.02/ft total height	NA	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Audience Seating Area											
... in an auditorium	0.63	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a convention center	0.82	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
… in a gymnasium	0.65	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a motion picture theater	1.14	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a penitentiary	0.28	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
... in a performing arts theater	2.43	8	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a religious building	1.53	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
... in a sports arena	0.43	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
… all other audience seating areas	0.43	4	REQ	ADD1	ADD1	—	REQ	REQ	—	ADD2	ADD2
Banking Activity Area	1.01	6	REQ	ADD1	ADD1	REQ	REQ	REQ	—	ADD2	ADD2
Breakroom (See Lounge/Breakroom)											
Classroom/Lecture Hall/Training Room											
… in a penitentiary	1.34	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—
… all other classrooms/lecture halls/ training rooms	1.24	4	REQ	ADD1	ADD1	REQ	REQ	REQ	—	REQ	—

1. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply
2. In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 ft and is not based on the RCR.
3. A "Facility for the Visually Impaired" is a facility that can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and is licensed or will be licensed by local/state authorities for either senior long-term care, adult daycare, senior support and/or people with special visual needs.
4. For accent lighting, see Section 9.6.2(b).
5. Sometimes referred to as a "Picking Area."
6. Automatic daylight responsive controls are mandatory only if the requirements of the specified sections are present.
7. An additional 0.53 w/ft² shall be allowed, provided that the additional lighting is controlled separately from the base allowance of 0.42 W/ft². The additional 0.53 w/ft² allowance shall not be used for any other purpose.

a. Local Control (9.4.1.1a)

Applies to virtually all spaces except those for the visually impaired.

There shall be one or more manual lighting controls in the space that controls all of the lighting in the space. Each control device shall control an area

(1) no larger than 2500 ft² if the space is ≤10,000 ft² and

(2) no larger than 10,000 ft² otherwise.

The device installed to comply with this provision shall be readily accessible and located so that the occupants can see the controlled lighting when using the control device.

Exception: Remote location of this local control device or devices shall be permitted for reasons of safety or security when each remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.

b. Restricted to Manual ON (9.4.1.1b)

None of the lighting shall be automatically turned on.

Exception: Manual ON is not required where manual ON operation of the general lighting would endanger the safety or security of the room or building occupants.

OR

c. Restricted to Partial Automatic ON (9.4.1.1c)

No more than 50% of the lighting power for the general lighting shall be allowed to be automatically turned on, and none of the remaining lighting shall be automatically turned on.

Applies to most spaces except corridors, lobbies, stairways and living and sleeping quarters.

d. Bi-Level Lighting Control

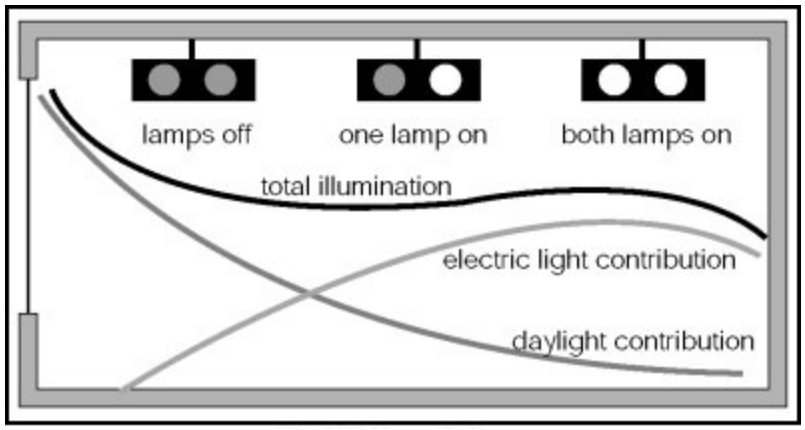
Applies to most spaces except corridors, lobbies, stairways and living and sleeping quarters.

The general lighting in the space shall be controlled so as to provide at least one intermediate step in lighting power or continuous dimming in addition to full ON and full OFF. At least one intermediate step shall be between 30% and 70% (inclusive) of full lighting power.

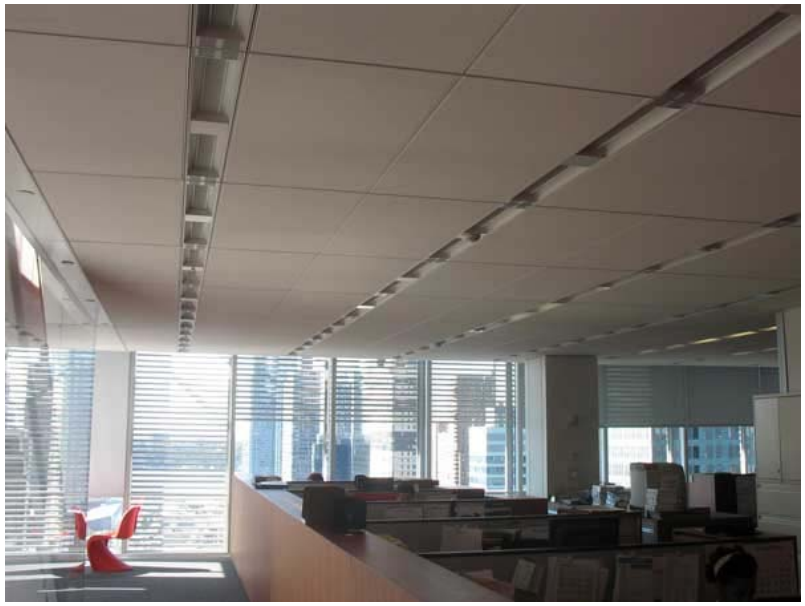
General Lighting Mode

AV Lighting Mode

e. Automatic Daylight Responsive Controls (Sidelighting)



Daylighting controls



In any space where the combined input power of all general lighting completely or partially within the primary sidelighted areas is 150 W or greater, the general lighting in the primary sidelighted areas shall be controlled by photocontrols.

The control system shall have the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. At minimum, general lighting in the secondary sidelighted area shall be controlled independently of the general lighting in the primary sidelighted area.
3. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.

Exceptions: The following areas are exempted from Section 9.4.1.1(e):

1. Primary sidelighted areas where the top of any existing adjacent structure is twice as high above the windows as its distance away from the windows
2. Sidelighted areas where the total glazing area is less than 20 ft2
3. Retail spaces

e. Automatic Daylight Responsive Controls (Sidelighting)

f. Automatic Daylight Responsive Controls for Toplighting

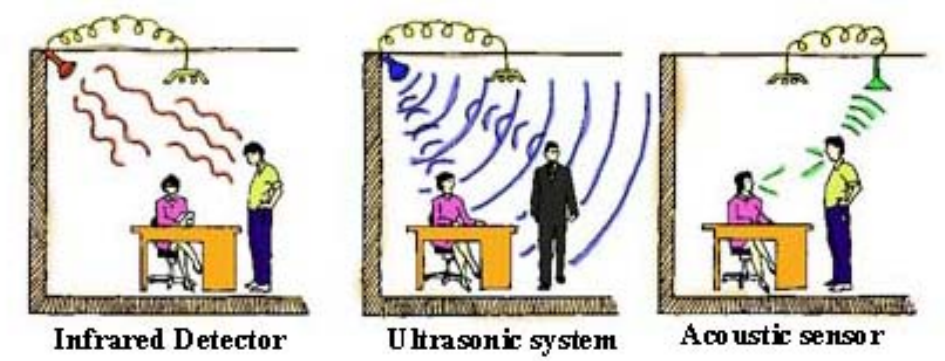
In any space where the combined input power for all general lighting completely or partially within daylight areas under skylights and daylight areas under roof monitors is 150 W or greater, general lighting in the daylight area shall be controlled by photocontrols having the following characteristics:

1. The calibration adjustments shall be readily accessible.
2. The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point that is between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.
3. General lighting in overlapping toplighted and sidelighted daylight areas shall be controlled together with general lighting in the daylight area under skylights or daylight areas under roof monitors.

Exceptions: The following areas are exempted from Section 9.4.1.1(f):

1. Daylight areas under skylights where it is documented that existing adjacent structures or natural objects block direct sunlight for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
2. Daylight areas where the skylight visual transmittance (VT) is less than 0.4
3. In each space within buildings in Climate Zone 8 where the input power of the general lighting within daylight areas is less than 200W

g. Automatic partial OFF (full OFF complies)



Occupancy Sensor Technologies

The general lighting power in the space shall be automatically reduced by at least 50% within 20 minutes of all occupants leaving the space.

Exceptions: This requirement does not have to be complied with in spaces that meet all three of the following requirements:

1. The space has an LPD of no more than 0.80 W/ft2
2. The space is lighted by HID
3. The general lighting power in the space is automatically reduced by at least 30% within 20 minutes of all occupants leaving the space

h. Automatic Full OFF

All lighting shall be automatically shut off within 20 minutes of all occupants leaving the space. A control device meeting this requirement shall control no more than 5000 ft².

Exceptions: The following lighting is not required to be automatically shut off:

1. General lighting and task lighting in shop and laboratory classrooms
2. General lighting and task lighting in spaces where automatic shutoff would endanger the safety or security of room or building occupants
3. Lighting required for 24/7 operation

i. Scheduled Shutoff

Local Override ≤ 2 hours and 5,000 ft²

All lighting in the space not exempted by Exception (1) to Section 9.1.1 shall be automatically shut off during periods when the space is scheduled to be unoccupied using either (1) a time-of-day operated control device that automatically turns the lighting off at specific programmed times or (2) a signal from another automatic control device or alarm/security system. The control device or system shall provide independent control sequences that (1) control the lighting for an area of no more than 25,000 ft2, (2) include no more than one floor, and (3) shall be programmed to account for weekends and holidays. Any manual control installed to provide override of the scheduled shutoff control shall not turn the lighting on for more than two hours per activation during scheduled off periods and shall not control more than 5000 ft2.

Exceptions: The following lighting is not required to be on scheduled shutoff:

1. Lighting in spaces where lighting is required for 24/7 continuous operation
2. Lighting in spaces where patient care is rendered
3. Lighting in spaces where automatic shutoff would endanger the safety or security of the room or building occupants

Lighting Control Credits

Additional Interior Lighting Power Using Nonmandatory Controls (9.6.3)

Additional Interior Lighting Power Allowance = Lighting Power Under Control × Control Factor

An additional lighting power allowance shall be permitted for space types with non-mandatory controls installed as identified in Table 9.6.3 when all mandatory controls are used according to Section 9.4. This allowance is added to the interior lighting power allowance and is calculated as follows:

Additional Interior Lighting Power Allowance = Lighting Power Under Control × Control Factor

where

Lighting Power Under Control = the total input watts of all lamps being controlled using the control method indicated

Control Factor = the value given in Table 9.6.3 for the corresponding space type and control method.

Control Factors (Table 9.6.3)

Additional Control Method	Open Office	Private Office	Conference Room, Meeting Room, Classroom (Lecture/ Training)	Retail Sales Area	Lobby, Atrium, Dining Area, Corridors/ Stairways, Gym/ Pool, Mall Concourse, Parking Garage
Manual, continuous dimming control or programmable multilevel dimming control	0.05	0.05	0.10	0.10	0
Programmable multilevel dimming control using programmable time scheduling	0.05	0.05	0.10	0.10	0.10
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off capabilities	0.25[a]	0	0	0	0
Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off operation, in combination with personal continuous dimming control of downlight illumination by workstation occupant	0.30[a,b]	0	0	0	0
Automatic continuous daylight dimming in secondary sidelighted	10[c]	10[c]	10[c]	10[c]	10[c]

Other Lighting Control Requirements

Parking Garage Lighting Control (9.4.1.2)

Lighting for parking garages shall comply with the following requirements:

a. Parking garage lighting shall have automatic lighting shutoff per Section 9.4.1.1(a) .

b. Lighting power of each luminaire shall be automatically reduced by a minimum of 30% when there is no activity detected within a lighting zone for 20 minutes. Lighting zones for this requirement shall be no larger than 3600 ft².
Exception: Daylight transitions zones and ramps without parking

c. Lighting for covered vehicle entrances and exits from buildings and parking structures shall be separately controlled by a device that automatically reduces the lighting by at least 50% from sunset to sunrise.

d. The power to luminaires within 20 ft of any perimeter wall structure that has a net opening-to-wall ratio of at least 40% and no exterior obstructions within 20 ft, shall be automatically reduced in response to daylight.
Exception: Lighting in daylight transitions zones and ramps without parking

Special Applications (9.4.1.3)

a. The following lighting shall be separately controlled from the general lighting in all spaces:

1. Display or accent lighting
2. Lighting in display cases
3. Nonvisual lighting, such as for plant growth or food warming
4. Lighting equipment that is for sale or used for demonstrations in lighting education

Special Applications (9.4.1.3)

a. Guestrooms

1. All lighting and all switched receptacles in guestrooms and suites in hotels, motels, boarding houses, or similar buildings shall be automatically controlled such that the power to the lighting and switched receptacles in each enclosed space will be turned off within 20 minutes after all occupants leave that space.
Exception: Enclosed spaces where the lighting and switched receptacles are controlled by captive key systems and bathrooms are exempt.

2. 2. Bathrooms shall have a separate control device installed to automatically turn off the bathroom lighting within 30 minutes after all occupants have left the bathroom.
Exception: Night lighting of up to 5W per bathroom is exempt.

b. All supplemental task lighting, including permanently installed undershelf or undercabinet lighting, shall be controlled from either (1) a control device integral to the luminaires or (2) by a wall-mounted control device that is readily accessible and located so that the occupant can see the controlled lighting.

Exterior Lighting Control (9.4.1.4)

Lighting for exterior applications not exempted in Section 9.1 shall meet the following requirements:

a. Lighting shall be controlled by a device that automatically turns off the lighting when sufficient daylight is available.

b. All building façade and landscape lighting shall be automatically shut off between midnight or business closing, whichever is later, and 6 a.m. or business opening, whichever comes first, or between times established by the authority having jurisdiction.

c. Lighting not specified in Section 9.4.1.7(b) and lighting for signage shall be controlled by a device that automatically reduces the connected lighting power by at least 30% for at least one of the following conditions:

   1. From 12 midnight or within one (1) hour of the end of business operations, whichever is later, until 6 a.m. or business opening, whichever is earlier

   2. During any period when no activity has been detected for a time of no longer than 15 minutes

All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least ten hours.

Exceptions:

1. Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security, or eye adaptation

2. Lighting that is integral to signage and installed in the signage by the manufacturer

"Other" Control Requirements

Elevators (10.4.3)

Elevator systems shall comply with the requirements of this section.

10.4.3.1 Lighting

For the luminaires in each elevator cab, not including signals and displays, the sum of the lumens divided by the sum of the watts (as described in Section 9.1.4) shall be no less than 35 lm/W.

10.4.3.2 Ventilation Power Limitation

Cab ventilation fans for elevators without air conditioning shall not consume over 0.33 W/cfm at maximum speed.

10.4.3.3 Standby Mode

When stopped and unoccupied with doors closed for over 15 minutes, cab interior lighting and ventilation shall be de-energized until required for operation.

Escalators and Moving Walks (10.4.4)

Escalators and moving walks shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code when not conveying passengers.

Whole-Building Energy Monitoring (10.4.5)

Measurement devices shall be installed at the building site to monitor the energy use of each new building.

10.4.5.1 Monitoring

Measurement devices shall be installed to monitor the building use of the following types of energy supplied by a utility, energy provider, or plant that is not within the building:

a. Natural gas

b. Fuel oil

c. Propane

d. Steam

e. Chilled water

f. Hot water

10.4.5.2 Recording and Reporting

The energy use of each building on the building site shall be recorded at a minimum of every 60 minutes and reported at least hourly, daily, monthly, and annually. The system shall be capable of maintaining all data collected for a minimum of 36 months and creating user freports showing at least hourly, daily, monthly, and annual energy consumption and demand.

Exceptions to 10.4.5.1 and 10.4.5.2:

1. Buildings or additions less than 25,000 ft2

2. Individual tenant spaces less than 10,000 ft2

3. Dwelling units

4. Residential buildings with less than 10,000 ft2 of common area

5. Fuel used for on-site emergency equipment

Acceptance Testing

What is Acceptance Testing?

- Two components of acceptance testing
  - Construction inspection
    - Is the specified equipment that is required to be installed actually there
  - Equipment testing
    - Does the equipment work as intended
    - Functional “performance” tests
- Does Not replace commissioning
  - Commissioning – broader scope

Is Acceptance Testing Needed?

- PIER Small Commercial HVAC survey http://www.energy.ca.gov/reports/2003-11-17_500-03-082.PDF
- Small commercial buildings < 4 yrs old
  - 64% of economizers failed
    - Cooling energy increased by 37%
  - 38% of supply fans cycling during occupancy
    - Violation of Title 24, §121(c)1
  - 30% unoccupied fan operation
    - Increase of fan and heating energy
  - 8% no outside air
  - 8% simultaneous heating and cooling

Definition of Acceptance Testing Requirements

Acceptance Testing requirements are defined as the application of targeted inspection checks and testing to determine whether specific building systems conform to the criteria set forth in the Standards and to the plans and specifications.

What Systems are Included

- HVAC
  - All packaged HVAC systems
  - All built-up HVAC systems
  - Hydronic systems
- Lighting Controls

Acceptance Tests

- Required self-certification that equipment was tested and works as intended by the Standards
- Liability trail results from cheating on test
- Only one test (air distribution efficiency-leakage) requires 3rd party testing
  - Home Energy Rating Service (HERS)

Acceptance and Compliance Forms

- Found in Appendix A of the Nonresidential Manual
- Compliance forms
  - Filled out by designer
  - MECH-1-C (C for compliance)
- Acceptance Forms
  - Filled out by person conducting test
  - Usually contractor, TAB or commissioning agent
  - MECH-1-A (A for acceptance)

Summary

- Acceptance tests assure that your design intent for energy savings is executed
- Most automatic controls have an associated acceptance test
- The designer identifies which tests get applied to which equipment on the MECH-1-C form
- Construction bids need to account for the costs of conducting and documenting the acceptance tests
- Specifying factory calibrated and factory installed equipment can dramatically reduce testing costs
- Some designs reduce the amount of testing needed
  - ducts run under an insulated roof
  - factory installed economizers

The Future of Controls

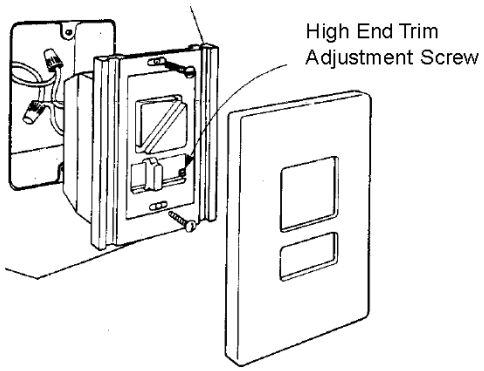
Office of the Future

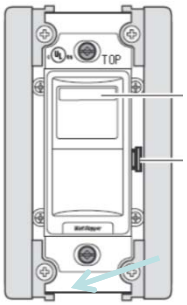
- Task ambient lighting design
- High efficacy general and task lighting
- All luminaires are dimming +off
- Daylighting controls by windows
- Individual controls
- Vacancy controls
- Bi-level occupancy controls in hallways

- Occupancy and daylight sensing integration
- Simple tuning and IP address set-up

Institutional Tuning for Dimming Lighting Systems

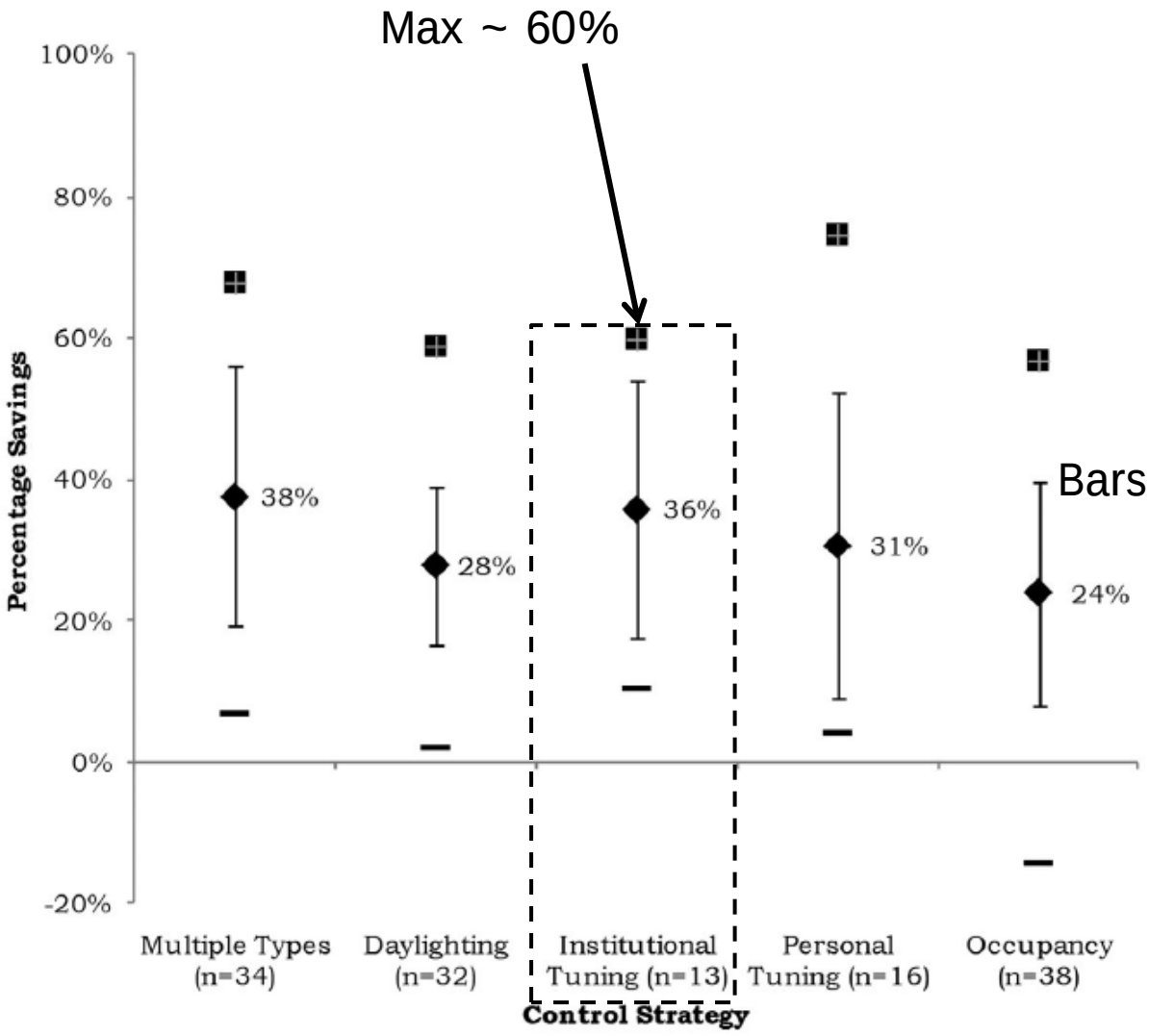
- Integer quantities of luminaires
- Spacing is limited by uniformity and ceiling grid
- Often an excess amount of light provided by the lighting system.
- Designer places on design documents which spaces can be tuned down at least 15% to take control factor credit
- Requires tuning luminaire high end trim or central high end trim on control or at ECMS system.
- Tuning verified by acceptance test.





High end trim

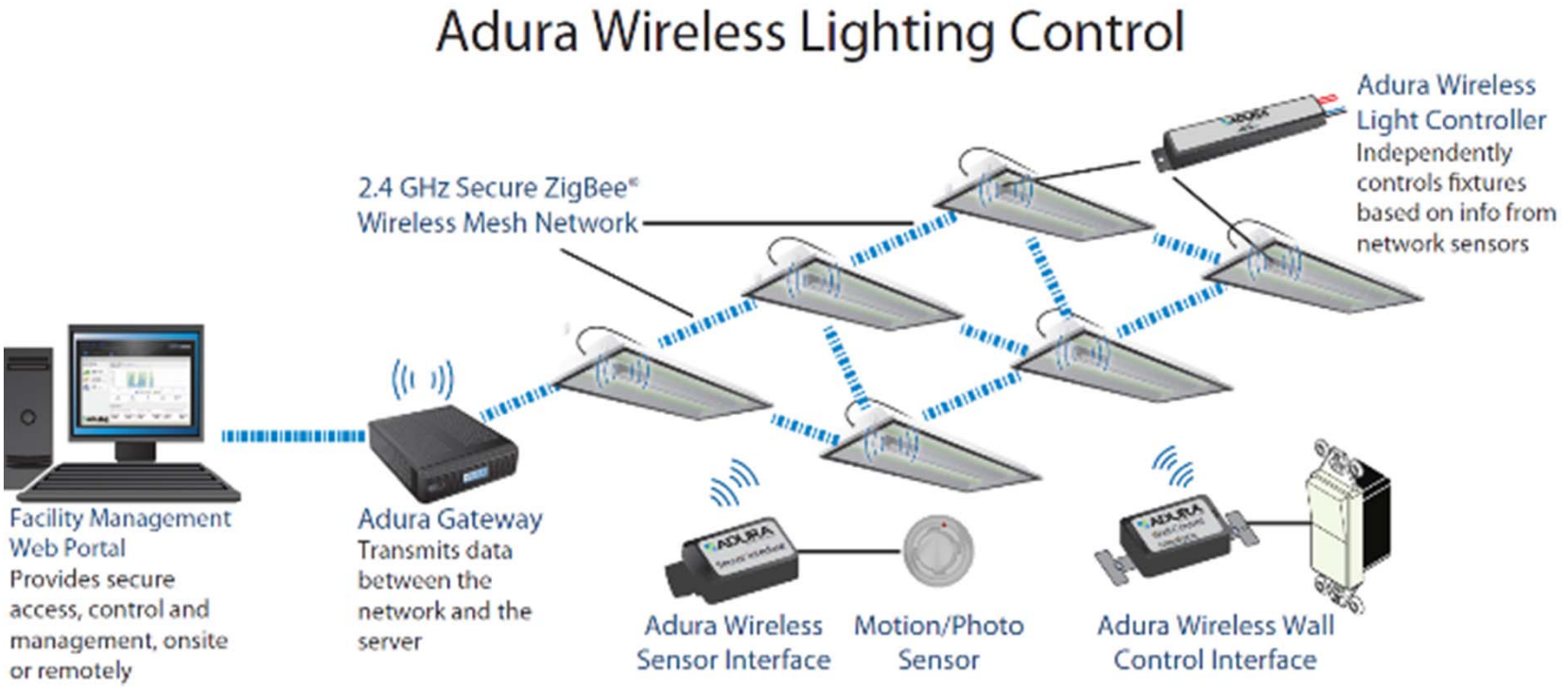
LBNL Estimate of Savings from Control Options



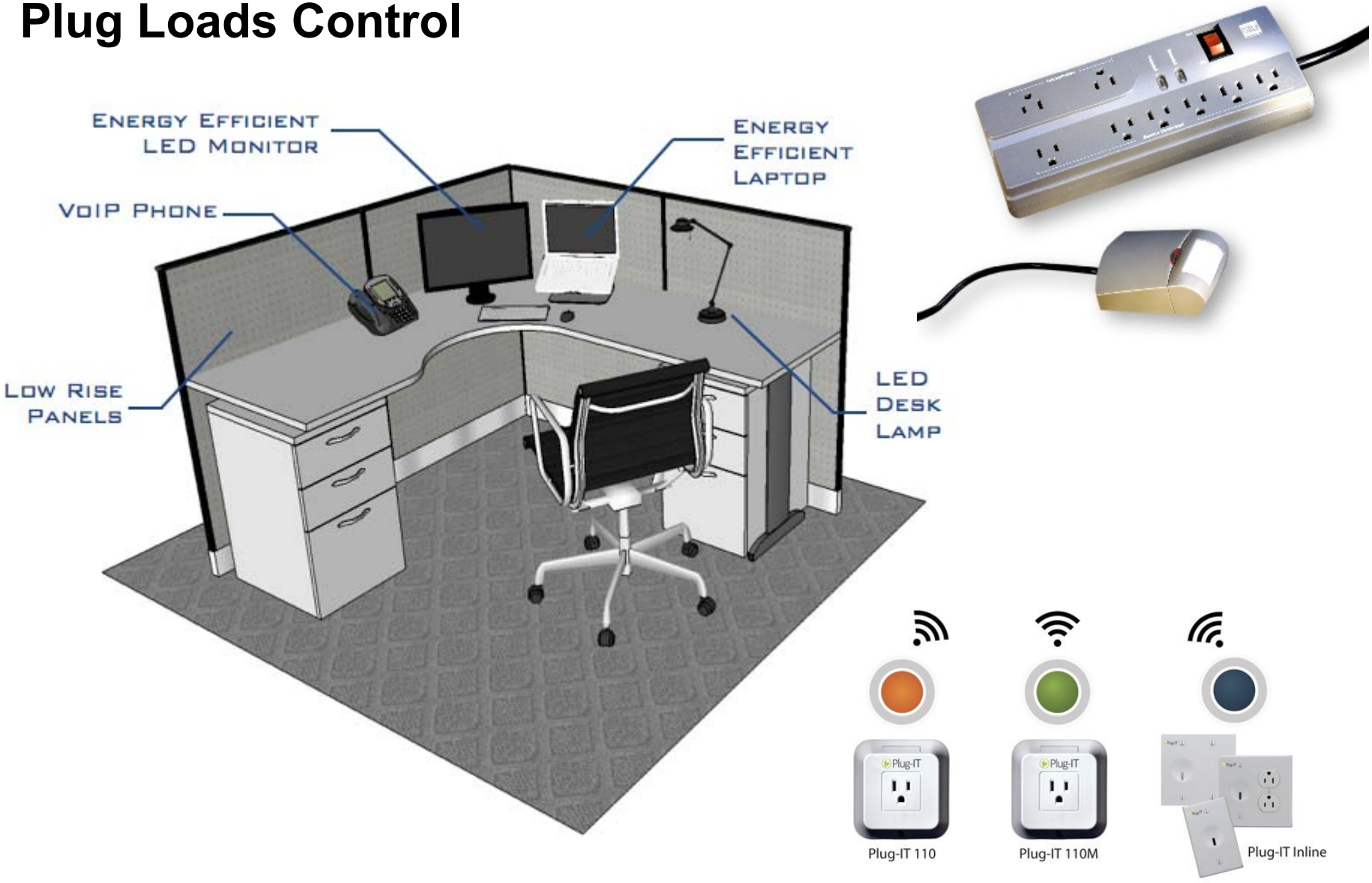
Bars are 1 Std Dev

Williams A., B. Atkinson, K. Garbesi, E. Page, and F. Rubinstein *Lighting Controls in Commercial Buildings* Leukos Vol 8 No 3 January 2012 Pages 161–180.

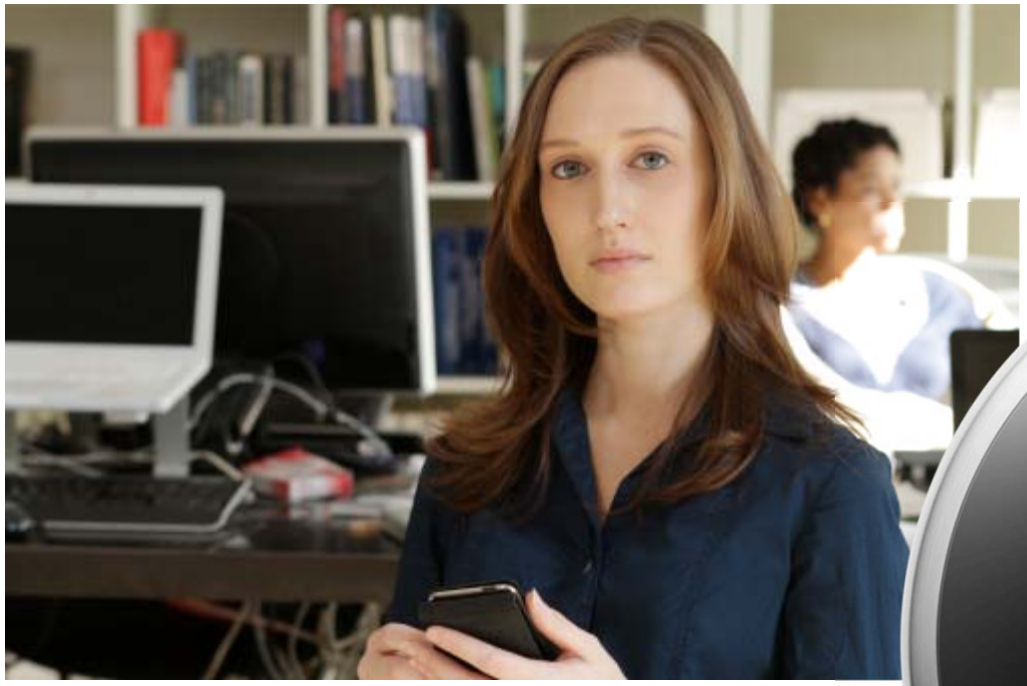
Wireless Controls



Plug Loads Control



Mobile Devices and Buildings that Learn



Wrapup and Panel Discussion