HVAC Controls (lite) Upgrades: Requirement Details (10-31-2019)

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REQUIRED CONTROLS/FEATURES

To qualify the upgrade must add or substantially modify 3 or more sequences/system capabilities. Also, all sequences and items listed under the required section are needed in the final system and project unless waived by PSE.

HVAC non-CENTRAL PLANT CONTROL SEQUENCES

1) **Zone Level Scheduling & Limited Time Override** for all air handlers (supply and exhaust) to match occupied hours by zone - DDC or occupancy sensors (OS) allowed. (403.2.4.2.2, *6.4.3.3*)
    a. By zone/Tenant – boxes/FCUs etc. grouped together (*6.4.3.3.4*)
    b. Easy to change to match changing tenants/zones – does not require reprogramming by controls contractor (*6.4.3.3.4*)
    c. 7-days and Holidays (403.2.4.2.2, *6.4.3.3.4)*
    d. Override for zone – with time limit up to 2 hours (403.2.4.2.2, *6.4.3.3.1.c*)
2) **Optimum Start/Stop with Warm-up and Cool-Down** (403.2.4.2.3; *6.4.3.3.3 – specifies how, 6.3 p for simple systems >10,000.)*
    a. Optimum Start
        i. Maximum hours on prior to occupancy (maximum 4 hours)
        ii. OA closed for warm up (403.2.4.3; *6.4.3.4.2)*
        iii. For warm-up use gas pre-heat (if available) and lock out electric re-heat
        iv. For cooldown use OA with mechanical cooling locked out (403.2.4.3 – ventilation purge 1 hour before and precooling)
        v. Only boxes not meeting their occupied room temperature setpoint are on with primary dampers open. All other boxes are off with dampers closed except a minimum number of boxes needed to prevent over pressurization.
    b. Optimum Stop
        i. Gradually adjust room temperature heating setpoints down and room temperature cooling setpoints up, 1-2 hours before the scheduled stop. Make the timing and increments adjustable.
3) **Unoccupied (night) set-back with zone limited time override**
    a. Zone temperature range 80-58 or better (403.2.4.2; *6.4.3.3.2 – 10°F lower for heating, 5°F higher for cooling, 4°F lower for radiant)*
    b. OA closed for heating (403.2.4.3, *6.4.3.4.2)*
    c. VAV fan boxes only come on to heat spaces – AHU stays off for those areas when VAV box can be used to heat
    d. AHU used for cooling – OA no mechanical cooling, minimum number of boxes come on to prevent over pressurization of ducts (403.2.4.3 – ventilation purge 1 hour before and precooling, *6.4.3.4.2*)
    e. Override for zone – with time limit up to 2 hours (403.2.4.2.2, *6.4.3.3.1.c*)
4) **Supply Air Temperature (SAT) Reset** (403.4.5.4; *6.5.3.4, 6.5.3.2.3)*

a. Specific temperature range: 65-55°F or better (403.4.4.4; *6.5.3.4* – at least 25% of the difference between the design SAT and the design room air temperature.)
b. Based on load – heating and cooling signals not OAT (403.4.4.4 or OAT; *6.5.10.2 b,6.5.3.4 or OAT)*
c. Based on at least two zones excluding cooling only or heating only zones and zones with constant load, like equipment rooms. For excluded zones set air/water flow to meet load at the full reset temp (*6.5.3.4)*
d. Method to assure SAT reset and DSP reset do not fight each other. Use Trim-and-response control sequences and be slow reacting, different interval and different controlling variables controlling this and DSP reset.
e. Rogue Zones: Alarm for zones excessively driving reset logic and readily allow operator, at the DDC graphic, to remove a zone from the algorithm (403.7.16.3; *6.4.3.10.2 c & d*)

5) **Duct Static Pressure (DSP) Reset** (403.4.1.2; *6.3.2.3)*
   a. Setpoint determined through TAB to most efficient levels – low all heating, high all in cooling with reasonable diversity. Range 0.4-1.5”WC expected, if higher fully document reason. Based on load – comparison of actual to required flow or VAV box damper position (403.4.1.2; *6.3.2.3).*
   b. Based on at least two zones excluding cooling only zones or zones with constant load, like equipment rooms. For excluded zones set air flow to meet load at the full reset (*6.5.3.4)*
   c. Method to assure SAT reset and DSP reset do not fight each other. Use Trim-and-response control sequences and be slow reacting, different interval and different controlling variables controlling this and SAT reset.
   d. Rogue Zones: Alarm for zones excessively driving reset logic and readily allow operator, at the DDC graphic, to remove a zone from the algorithm (403.4.12, 403.7.16.3; *6.4.3.10.2 c & d*)
6) **Demand Control Ventilation (DCV) in interior spaces** (403.2.6.2; *6.4.3.8)*
   a. Single zone AHUs (atriums, lobbies, gyms, work-out rooms, libraries, stairwells, auditoriums and any room over 500ft with variable occupancy). If an existing unit does not have a fully modulating motorized damper this requirement may be waived if it is less than 5 tons or has a supply fan smaller than 2 hp.
   b. Setpoints shall be by space type per ASHRAE Guideline 36. See bottom on this document for table.
7) **Upgrade to VFD (from inlet vane or from constant volume to variable flow) –** for > 7.5hp (403.2.13)
8) **Zone/Box air and temperature controls**
   a. All boxes
      i. Reduce primary air: at least to 30% primary air or ventilation requirements. See 403.4.5.
      ii. Use efficient box controls and calculation of cfm setpoints as recommended in ASHRAE Guideline 36 and/or EDR Advanced VAV Systems. This may involve

several levels of cfm (heating, cooling, set-back and minimum ventilation) and fan speed modulation. For existing boxes if sensors/equipment needed for the control sequence are not available or being added certain requirement may not apply (example: if DAT or variable speed fan). (*6.5.2.1.2, see bottom of document for links to other references).*

iii. DAT reheat limit of 20°F above room air temperature for HW reheat (*6.5.2.1.1)*
iv. Highly recommend: DAT for each VAV box
v. Fault Detection for the VAV boxes per code (403.7.16.6 & .8). The VAV terminal unit shall be configured to report:
- If the VAV inlet valve has failed by performing the following diagnostic check at a maximum interval of once a month:
  - Command VAV terminal unit primary air inlet valve closed and verify that primary airflow goes to zero.
  - Command VAV thermal unit primary air inlet valve to design airflow and verify that unit is controlling to with 10% of design airflow.
- VAV terminal unit primary air valve failure.

b. **New boxes**
i. ECM motors (403.7.10; *6.5.3.4*)
ii. TAB, cfm requirement determination, box set-up and calibration.
iii. DAT sensor for each box

9) **Air-Side Economizer controls** (403.3.1-3; *6.5.1.1.2*)
a. Lockout based on demand (on return air temperature not on OAT) (403.3.3.3; *6.5.1.1.3*)
b. Integrated for units 5 ≥ tons which do not have fully modulating dampers – mechanical and economizer can run at the same time (403.3.1; *6.5.1.3*)
c. Not based on MAT (403.3.2)
d. Mechanical Cooling Lockout based on 55°F OAT
e. Fault Detection for the economizer per code (403.2.4.7; 403.7.16.8)
i. Air temperature sensors failure/fault.
ii. Not economizing when the unit should be economizing.
iii. Economizing when the unit should not be economizing.
iv. Outdoor air or return air damper not modulating.
v. Excess outdoor air

10) **Room Space temperatures setpoint deadband**, with heating and cooling shut off, at least 5°F including a restriction for setpoint overlap between multiple thermostats serving the same space. It should not be possible for the heating setpoint to exceed the cooling setpoint and reduce the deadband. (403.2.4.1.2, 403.2.4.1.3; *6.4.3.1.2, 6.4.3.2*)

11) **Air side Heat pumps – heating stages** (403.2.4.1.1)
a. Strip heat off at 38°F OAT
b. Heat pump, not strip heat, first stage of heating

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CENTRAL PLANTS CONTROL SEQUENCES

1) **Water Source Heat Pumps** (403.4.2.3; *6.5.2.2.3*)
    a. At least 20°F between loop heating and cooling setpoint (403.4.2.3.1; *6.5.2.2.3 - at least 20°F*)
    b. Maximum heating 80°F, min cooling depends on WSHP
2) **Condenser water temperature (CWT) reset** – down to at least 70°F (*6.5.5.2*)
3) **Chilled water temperature (CHWT) reset** (403.4.2.4 at least 25%; *6.5.4.4*)
    a. Based on load – zone cooling signals/valves not OAT
    b. Range at least 5°F
    c. Based on at least two zones excluding cooling only zones or zones with constant load, like equipment rooms. For excluded zones set air/water to meet load at the full reset temp (*6.5.3.4)*
    d. Rogue Zone: Alarm for zone excessively driving reset logic and readily allowing operator to remove a zone from the algorithm (*6.4.3.10.2 c &d*)
4) **Hot water temperature (HWT) reset** (403.4.2.5 at least 25%; *6.5.4.4*)
    a. Based on load not OAT (*6.5.4.4 – by load or OAT*)
    b. Bottom of reset range must be in the condensing range (below 140°F) if a condensing boiler
    c. Based on at least two zones excluding cooling only zones or zones with constant load, like equipment rooms. For excluded zones set air/water flow to meet load at the full reset temp (*6.5.3.4)*
    d. Rogue Zone: Alarm for zone excessively driving reset logic and readily allowing operator to remove a zone from the algorithm (403.7.15; *6.4.3.10.2 c &d*)
5) **Efficient Boiler staging/modulating:** low fire and fire in parallel if condensing boiler, up to high fire and in series if non-condensing (403.2.5, 403.2.4.8)
6) **Boiler and Chiller Plant lockout on outside air temp (OAT)** – to prevent simultaneous heating and cooling

REQUIRED DDC GUI Features (in text means on GUI graphic not adjustable by any operator)

1) **Central Plant graphic in text (that is not adjustable)**:
    a. HWT reset range and controlling variable
    b. CHWT reset range and controlling variable
    c. CWT reset range and controlling variable
    d. Plant equipment staging criteria and method of determining staging (ex: setpoints, demand)
2) **Floor Plan in text(that is not adjustable):**
    a. Location of Key remote sensors: OAT sensor(s), CO2 sensor(s), duct static pressure sensor and differential pressure sensor
    b. AHU zones showing which floor area they serve

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3) **Zone/ box graphic:**
    a. Which AHU serves box
    b. Supply water temperature(s)
    c. Primary air cfm
    d. Design primary air cfm setpoints in text
    e. Air temperatures: primary air and outside air; if available discharge air temperature (DAT)
    f. CO2 ppm actual and setpoint and/or occupancy sensor status if used for control
4) **Zone/box Table:**
    a. Which AHU serves box
    b. Primary air and hot water temperature
    c. Key points: cfm, damper and valve signal, heating stages, mode, room temperature; DAT if available; CO2 ppm and occupancy sensor status if used for control
    d. Cfm: min and max setpoints; actual
    e. Schedule name
    f. Mode
    g. Ability to easily remove or add each box from reset logic (DAT reset; Duct static reset; water temperature reset for central systems)
    h. VAV terminal unit primary air valve failure (403.16.8.6)
5) **VFDs:** actual speed and speed of VFD when command signal is 0 in text (if does not equal 0)
6) **Digital easy access to**: controls sequences and submittal ; Facility Guide

OTHER REQUIREMENTS For ALL PROJECTS

1) **OAT sensor**
    a. in shaded area
    b. calibrated
2) **Determine AHU existing, required and final outside air minimum** (more accuracy = bigger savings)
    a. Existing: Document existing % min OA damper position; measure existing % min OA cfm – temp calc./rough estimate
    b. Required: Determine required min OA cfm by AHU (see PSE form)
        i. RECOMMENDED: Use sf per occupancy types estimates from owner and apply code ventilation requirements by occupancy type
        ii. OR: Existing design
    c. Final: Measure/determine OA damper % to meet requirement
3) Building Pressure: verify building properly pressurized in all modes of operation (403.3.4)

Required Depending on System Type & Project:

a. VAV boxes or box controls or flow rings replaced: balance/calibration of box flow rates; determine ventilation rates
b. Duct Static Reset: determine efficient minimum and maximum duct static setpoints

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4) **Commissioning** (Section 408; 6.7.2.4)
   Digital easy access to: controls sequences and submittals; Facility Guide
   a. **Functional Performance Tests: provided by PSE** (408.2.3, 408.2.2; 6.7.2.4, 6.7.2.3)
   WSEC 408.2.3: "Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. The testing shall affirm operation during actual or simulated winter and summer design conditions and during full outside air conditions."

   b. **Facility Guide: per outline and specifics provided by PSE** (408.1.3, 103.6.2; 6.7.2.2)
   ASHRAE Guideline 0.2: "a basic building systems description and operating plan with general procedures and confirmed facility operating conditions, set points, schedules, and operating procedures to properly operate the facility." "… including: Operating Plan; Building and Equipment Operating Schedules, Set Points, and Ranges; Systems Operation Control Sequences, Limitations, Emergency Shut-down Actions."

   c. O&M/Staff training: based on Facility Guide (103.6.4)
      i. Intended for the person on staff that will be monitoring and manipulating system
      ii. Meet owner's requirements
      iii. Basic understanding HVAC System
      iv. Minimum final capability of customer **depending on needs**:
         - Schedules: which schedule impacts which systems and how to change
         - Setpoints: what are most efficient and how to change
         - Trends: how to retrieve
         - Sequence of Operation: basic understanding of how they work
         - Facility Guide: where is it located and what is in it

RECOMMENDED OR ADDITIONAL SEQUENCES

REQUIRED if used to meet minimum requirement of 3 sequences added or substantially modified.

1) **Demand Control Ventilation (DCV) in exterior spaces** (403.2.6.4) – hook to controls
   a. Garage – gas detection, on/off or VFD, occupancy detection if not enclosed or less than 8,000 cfm (403.2.6.4; *6.4.3.4.5*)
   b. Loading docks - gas or occupancy detection, on/off (403.2.6.4.1; *6.4.3.4.4*)
2) **VAV setback based on occupancy**
   a. When not occupied – no primary air (403.2.6.3, 403.7.13)
   b. When not occupied space temperature deadband increased by at least 4 degrees (403.7.13)
3) **Demand Control Ventilation (DCV) for Kitchen Hoods**: exhaust fans>2000cfm (403.2.7.1; *6.5.7.1.4*)

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4) **Demand Control Ventilation (DCV) in multi-zones**
    a. Special approach for AHUs that serve multiple zones to assure ventilation (*6.4.3.8*)
    b. Use ASHRAE guidelines (see RP-1547, CO2-Based Demand Control Ventilation for Multiple Zone HVAC Systems) and work with PSE EME
5) **Door Switches (on/off contact)** disable or reset heating and cooling room temperatures, cooling only if OAT> RAT (*6.5.10*)
6) **Valves to isolate pumping loop:** from equipment when not needed
    a. Water Source Heat Pumps (403.4.2.3.3)
        i. valves to isolate compressor from water pump (403.4.2.3.3; *6.5.4.5*)
        ii. isolate Cooling tower from water loop (403.4.2.3.3)
    b. Hydronic Heat pump loop (*6.5.2.2.3)*
        i. Cooling tower water flow isolated when not needed (403.4.2.6)
    c. Boiler or Chiller isolation from loops (403.4.2.6)
7) **Improved outside air (OA) minimum ventilation control:** additional controls to fine tune OA control to respond to variation from different supply air flows (examples: OA measuring station, differential pressure sensors on dampers, supply and return coordination based on TAB, curve based on testing at various fan speeds)
8) **Exterior heater occupancy controls:**
    a. Outside heaters on/off based on occupancy or time switch (*403.2.12*)
    b. Enclosed Loading Docks enable/disable heating based on occupancy (403.2.12)
9) **Vestibules heating controls:** air curtain and shut-off heating when OAT>45°F and max setpoint 60°F
10) **Improved Cooling Tower controls:** add VFD to ramp fan in response to CWT setpoint; use wet bulb as well as dry bulb as control variable. (403.2.13.1.1, 403.4.3.1.1)

REFERENCES:

- WSEC 2015: http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx or http://www.neec.net/energy-codes
- WSEC 2015: section 403.7 – High Efficiency VAV
- ASHRAE 90.1 2013: https://www.ashrae.org/resources--publications/bookstore/standard-90-1
- ASHRAE Guideline 36 Draft PPR #2– High Performance Sequences of Operations for HVAC Systems: http://gpc36.savemyenergy.com/public-files/
- EDR Advanced VAV System Guideline: http://energydesignresources.com/resources/publications/design-guidelines/design-guidelines-advanced-variable-air-volume-(vav)-systems.aspx
- WA State Ventilation requirements: http://publicecodes.cyberregs.com/icod/imc/2012/icod_imc_2012_4_par015.htm

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ASHRAE GPC 36 DRAFT PPR#2 – CO2 setpoints by space type (table on 2 pages).

3. CO_2 Setpoints

Space CO2 setpoints are used for demand controlled ventilation (DCV) and monitoring/alarming as required by LEED and other green building standards.

It is the designer's responsibility to determine CO_2 setpoints. The maximum setpoint varies by ventilation standard. Some guidance is provided below for Standard 62.1 and Title 24. The designer may also decide to set lower, more conservative, setpoints for improved indoor air quality, but at the expense of higher energy use.

Standard 62.1 CO_2 Setpoint Guidance:
The following CO_2 setpoint procedure is from Lawrence T, "Selecting CO_2 Criteria for Outdoor Air Monitoring", ASHRAE Journal December 2008. The author recommends maximum CO_2 is 90% of the steady state concentration:

$$CO_2 setpoint = 0.9\left(C_{OA} + \frac{8400 E_z m}{R_p + {R_a A_z}/{P_z}}\right)$$

Where C_{OA} is the outdoor air CO_2 concentration in ppm, Ez is the zone ventilation effectiveness, m is the metabolic rate of occupants, Rp is the people-based component of the ventilation rate, Ra is the area-based component of the ventilation rate, Az is the zone floor area, and Pz is the number of occupants.

The CO_2 setpoints in the table below are from the Lawrence article. They assume an ambient concentration of 400 ppm, in lieu of using an ambient CO_2 sensor. These sequences are based on not having an ambient sensor. This will be conservative in areas with high ambient CO_2 concentrations; few areas have lower concentrations. The Lawrence article was based on Standard 62.1-2007 but the outdoor air rates on which these are based have not changed in the 2016 Standard.

Setpoints vary by occupancy type, so the easiest way to include this info is by including a column in VAV box and SZ unit schedules and entering the setpoint individually for each zone.

Occupancy Category	CO_2 Setpoint (ppm)	Occupancy Category	CO_2 Setpoint (ppm)
Correctional Facilities		Office Buildings	
Cell	965	Office Space	894
Dayroom	1,636	Reception Areas	1,636
Guard Stations	1,200	Telephone/Data Entry	1,872

ASHRAE Guideline 36: High Performance Sequences of Operation for HVAC Systems
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Occupancy Category	CO_2 Setpoint (ppm)	Occupancy Category	CO_2 Setpoint (ppm)
Booking/Waiting	1,200	Main Entry/Lobbies	1,391
Educational Facilities		Miscellaneous Spaces	
Day Care (Through Age 4)	1,027	Bank Vaults/Safe Deposit	805
Day Care Sickroom	716	Computer (Not Printing)	738
Classrooms (Age 5 – 8)	864	Pharmacy (Preparation Area)	820
Classrooms (Age 9+)	942	Photo Studios	983
Lecture Classroom	1,305	Transportation Waiting	1,305
Lecture Hall (Fixed Seats)	1,305	Public Assembly Spaces	
Art Classroom	837	Auditorium Seating Area	1,872
Science Laboratories	894	Place of Religious Worship	1,872
University/College Lab	894	Courtrooms	1,872
Wood/Metal Shop	1,156	Legislative Chambers	1,872
Computer Lab	965	Libraries	805
Media Center	965	Lobbies	2,628
Music/Theater/Dance	1,620	Museums (Children's)	1,391
Multiuse Assembly	1,778	Museum/Galleries	1,620
Food and Beverage Service		Retail	
Restaurant Dining Rooms	1,418	Sales (Except Below)	1,069
Cafeteria/Fast-Food Dining	1,536	Mall Common Areas	1,620
Bars, Cocktail Lounges	1,536	Barbershop	1,267
General		Beauty and Nail Salons	723
Break Rooms	1,267	Pet Shops (Animal Areas)	709
Coffee Stations	1,185	Supermarket	1,116
Conference/Meeting	1,620	Coin-operated Laundries	1,322
Hotels, Motels, Resorts, Dormitories		Sports and Entertainment	
Bedroom/Living Area	910	Spectator Areas	1,778
Barracks Sleeping Areas	1,116	Disco/Dance Floors	1,440
Laundry Rooms, Central	1,249	Health Clubs/Aerobics Room	1,735
Laundry Within Dwelling	983	Health Clubs/Weight Room	1,232
Lobbies/Prefunction	1,494	Bowling Alley (Seating)	1,232
Multipurpose Assembly	2,250	Gambling Casinos	1,368
		Game Arcades	894
		Stages, Studios	1,391