23 09 93 – Sequences of Operations HVAC

1. Introduction

   A. The HVAC operational sequences in this guideline are commonly used by Duke University. They are being provided as a preferred design base reference. They are not meant to be used as the only permitted sequences. Exceptions for HVAC systems other than those provided in this guideline may be allowed with Duke FMD approval.

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3. Operational Sequences

   A. AHU Economizer

      a. Initiate economizer mode operation when outdoor air enthalpy reaches **28 Btu/lb.** (adjustable) and disable economizer mode when outdoor air enthalpy increases to **29 Btu/lb.** Enthalpy information shall be gathered via broadcast outdoor temperature, humidity and enthalpy calculation supplied by Duke FMD.

      b. When the unit is in economizer mode the return and outside air damper shall modulate to maintain a mixed air setpoint equal to the supply air set point minus **5°F** (adjustable). Return, exhaust, and outside air dampers shall each have a separate signal from the BAS. The exhaust damper shall track to outdoor air damper and the return shall modulate opposite the outdoor air damper. If the outdoor air damper is fully open and supply air setpoint is not maintained, the chilled water valve shall modulate to maintain the supply temp setpoint.

      c. Outdoor air damper shall maintain a minimum outside cfm air setpoint (adjustable) set by the air balance company. A drop in mixed air temp below the mixed air low limit setpoint of 45°F (adjustable) will override economizer, minimum outdoor air, and CO2 to maintain mixed air temp above low limit setpoint.

   B. AHU Economizer with Demand CO2 Ventilation

a. Initiate economizer mode operation when outdoor air enthalpy reaches **28 Btu/lb** (adjustable) and disable economizer mode when outdoor air enthalpy increases to **29 Btu/lb**. Enthalpy information shall be gathered via broadcast outdoor temp, humidity and enthalpy calculation supplied by Duke FMD.

b. When the unit is in economizer mode the return and outside air damper shall modulate to maintain a mixed air setpoint equal to the supply air setpoint minus **5°F** (adjustable). Return, exhaust and outside air dampers shall each have a separate signal from the BAS. The exhaust damper shall track to outdoor air damper and the return shall modulate opposite the outdoor air damper. If the outdoor air damper is fully open and supply air setpoint is not maintained, the chilled water valve shall air setpoint is not maintained, the chilled water valve shall modulate to maintain the supply temp setpoint.

c. Outdoor air dampers shall maintain a minimum outside cfm air setpoint (adjustable) set by the air balance company. A drop in mixed air temp below the mixed air low limit setpoint of **45°F** (adjustable) will override economizer, minimum outdoor air, and CO2 to maintain mixed air temp above low limit setpoint.

d. System will monitor CO2 via air handler return sensor and/or space CO2 sensor located in a high occupancy area. The system should sample the level every 10 min (adjustable) and trigger a “high CO2 mode” when the level reaches greater the **1100 ppm.** When in high CO2 mode the outside air damper shall modulate to maintain **1000 ppm.** When CO2 level drops to less than **950 ppm** the system will turn off the high CO2 mode. Outside air cfm should be limited to **40%** of the total supply unless there are special considerations. If any sensor reads greater than **1600 ppm,** that sensor should be ignored by the DCV sequence and an alarm should be set. The number of sensors used in the DCV sequence should be minimized to only what is necessary. At no time should be minimized to only what is necessary. At no time should the DCV sequence override the mixed air low temp limit.

C. Summary of OA Damper Control Modes

a. System not in Economizer or High CO2 Mode:

i. OA damper shall control to the minimum OA damper settings and the mixed air low limit loop output.

b. System in Economizer but not in High CO2 Mode:

i. Damper shall control to the minimum of the economizer mixed air loop output, minimum OA damper setting and the mixed air low limit loop output.

c. System in CO2 Mode but not Economizer Mode:

i. OA damper shall control to the maximum of the CO2 loop output and minimum and minimum OA damper setting, with mixed air low limit loop output overriding.

d. System in Economizer and High CO2 Mode:

i. OA damper shall control to the maximum of the economizer mixed air loop output, CO2 loop output, and minimum OA damper setting, with the mixed air low limit loop output overriding.

D. AHU Unoccupied Mode with Morning Warm-up/Cool-down

a. General Guidelines

i. Typical applications serving (including but not limited to): Private offices, open office layouts, classrooms, auditorium, dining, support spaces. These sequences do not apply to Dormitories, Laboratories and critical systems/spaces.
ii. AHU's are typically off in Unoccupied Mode unless specified by Duke FMD.
iii. Minimum OA set point should be set to zero during unoccupied heating/cooling modes.
iv. All general exhaust fans shall be turned on during associated air handler occupied heating/cooling mode and shall be turned off during air handler unoccupied heating/cooling modes.
v. Unoccupied zone heating/cooling set-points shall be 65°F (adj.) for heating mode, and 80°F (adj.) for cooling mode.
vi. Unoccupied zone heating/cooling will be determined by monitoring specific zones as determined by Duke.
vii. AHU supply air reset temperature shall follow Duke FMD guidelines for supply air reset programming temperatures.

b. Sequences with Terminal Units

i. Sequences will be initiated 30 minutes (adj.) prior to building occupancy schedule.
ii. Mode of operation will be determined by evaluating AHU return air temperature.
iii. The AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. Heating of the zones will be performed using the zone VAV reheat valve until AHU return air temperature reaches 68°F (adj.). AHU cooling coil control valve will operate to maintain occupied supply air temperature set-point until AHU return air temperature drops below 76°F (adj.).
iv. Unoccupied Mode Low Temperature Limit: If low temperature limit is activated, the AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. The AHU will operate for a min of 30 minutes (adj.) and modulate appropriate terminal unit reheat control valves until applicable zone sensors are 2°F above Low Limit set-point.
v. Unoccupied Mode High Temperature Limit: If high temperature limit is activated, the AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. The AHU will operate for a min of 30 minutes (adj.) and modulate chilled water coil control valve until applicable zone sensors are 2°F below High Limit set-point.

c. Sequences without Terminal Units

i. Sequences will be initiated 30 minutes (adj.) prior to building occupancy schedule.
ii. Mode of operation will be determined by evaluating AHU return air temperature.
iii. The AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. Heating of the zones will be performed by modulating the AHU preheat coil control valve to maintain normal reset supply air temperature set-point until AHU return air temperature reaches 68°F (adj.). During cool-down mode, AHU cooling coil control valve will modulate to maintain occupied supply air temperature set-point until AHU return air temperature drops below 76°F (adj.).
iv. Unoccupied Mode Low Temperature Limit: If low temperature limit is activated, the AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. The AHU will operate for a minimum of 30 minutes (adj.) and will modulate the AHU preheat control valve to maintain

normal reset supply air temperature set-point until applicable zone sensor is 2°F above Low Limit set-point.

v. Unoccupied Mode High Temperature Limit: If high temperature limit is activated, the AHU will operate with return air damper fully open, and min/max relief and min/max outside air dampers closed. The AHU will operate for a minimum of 30 minutes (adj.) and modulate chilled water coil until applicable zone sensor is 2°F below High Limit set-point.

E. AHU Supply Fan VFD Control

a. On startup, the static pressure set point shall be ramped from 0 to the design set point over a period of 3 minutes to prevent high static trips.

b. The supply fan(s) VFD shall modulate to maintain supply duct static pressure via sensor located approximately 2/3 downstream in ductwork at the static pressure set point determined during air balance.

F. AHU Supply Air Temperature Reset

a. Air handler supply temperature set point should reset from 55°F-65°F (adj.) and should be based on a maximum of several VAV box cooling loopOut values.

b. The VAV boxes sampled for the reset should be selected to best represent all areas of the building. High occupancy spaces such as classrooms, conference rooms, auditoriums, etc. should be factored into the reset to ensure they are cooled properly. The number of VAV boxes used for the maximum cooling loopOut calculation should be kept to the minimum needed to represent all areas of the building. Using too many VAVs in the calculations increases the chance that one VAV box problem will drive down supply temp on the air handler. Final selection of VAV boxes used for reset should be approved by Duke Project team.

c. The supply reset statement should be executed in the program every 5 minutes. If any VAV included in the reset calculation stays at 100% cooling loopOut for greater than 60 minutes (adj.) continuous a virtual alarm should be activated. This alarm point should be on the air handler graphic near the supply temp set point.

G. AHU Low Temperature Limit (Freeze Protection) Sequence

a. If AHU low temperature limit is tripped modulate preheat control valve to maintain mixed or preheat discharge air temperature sensor at set-point of 55°F. Modulate the AHU chilled water and reheat control valve(s) to 20% open (adj.). Low limit shall provide input to BAS for alarming.

b. Provide low temperature safety limit switches that are manual reset only.

H. AHU Dehumidification and Humidification Modes

a. General Guidelines

i. Typical applications serving (including but not limited to): Classrooms, auditoriums, dining, dormitories, laboratories, critical systems/spaces and support spaces. Coordinate with FMD during design phase for specific applications.

ii. If heating hot water supply temperature is below 120F disable dehumidification sequence and send alarm to BAS.

iii. If unit is in Dehumidification mode, disable economizer mode for at least 4 hours.

iv. Provide a BAS chilled water return temperature sensor on all dehumidification AHU's (1" pipe diameter or greater).

b. AHU Dehumidification Mode - Single Zone Units:

i. Dehumidification mode shall be enabled when the return air humidity rises above 60 percent (adj.) and disabled when return air humidity drops below 55 percent (adj.). The supply fan shall remain at low speed during the dehumidification mode. Sequence will open chilled water control valve to full open position and reheat coil control valve will modulate to maintain space air.

c. AHU Dehumidification Mode – Reheat in Unit:

i. Dehumidification mode shall be enabled when the return air humidity rises above 60 percent (adj.) and disabled when return air humidity drops below 55 percent (adj.). Sequence will open chilled water control valve to maintain cooling coil discharge air temperature set-point of 52 Degrees F (adj.) and reheat coil control valve will modulate to maintain unit discharge air temperature set-point.

d. AHU Dehumidification Mode – Reheat at Terminal Unit Level:

i. Dehumidification mode shall be enabled when the return air humidity rises above 60 percent (adj.) and disabled when return air humidity drops below 55 percent (adj.). Sequence will override active discharge air temperature set-point and open chilled water control valve to maintain discharge air temperature set-point of 55 Degrees F (adj.) and terminal unit reheat coil control valves will modulate to maintain individual zone air temperature set-points.

e. <u>AHU Humidification Mode:</u>

i. Humidification mode shall be enabled when either return or zone air humidity set-point (Set-point determined by Engineer). The steam control valve shall modulate to maintain desired set-point. All Provide Humidifiers with a supply air humidity sensor for control and a high limit sensor which either restricts or closes steam control valve when humidity is measure above 85 percent (adj.) in supply ductwork. The humidifier shall be provided with an airflow switch and shall be commanded off when no airflow is sensed by switch or when fan is off.

I. Equipment Lead/Lag Operation

a. This sequence is designed to provide lead/lag switching guidelines for systems with backup/standby equipment such as pumps or fans.

b. Lead/lag equipment should rotate to equalize runtime.

c. Lead/lag systems that run continuously or on a fixed schedule should be rotated weekly on a given day/time during normal working hours.

d. For systems whose runtime will vary from week to week, the equipment should be rotated every 168 hours (adj) based on totalized runtime.

e. When the lead is changed, the new lead equipment should start and run long enough to prove status before shutting down the equipment that was running to minimize drops in pressure or flow.

f. The lag equipment should be staged on based on an alarm on the lead equipment or if the lead piece of equipment exceeds 80% (adjustable based on equipment sizing and efficiency) VFD speed to ensure efficient operation. The lag equipment should be staged back off when the VFD on the lead drops below 50% (adj.).

J. Terminal Unit Master/Slave Configuration

a. The purpose of this guideline is to outline the control strategy for multiple VAV boxes serving the same space. Without linking the controls of the VAVs there is a possibility for some of the VAVs to be heating while others are cooling. This will result in increased energy consumption.

b. Multiple VAVs serving a space when only one has a thermostat:

i. In this case, the VAV with the thermostat would be considered the Master VAV and the ones without a thermostat are the slave TECs. The following points mapped through programming to the slave VAVs:

HEAT.COOL (Heat/Cool Mode)

CTL STPT (Control Set Point)

CTL TEMP (Control Temperature)

Ex. W04T100B:HEAT.COOL=W04T100A:HEAT.COOL

W04T100B:CTL STPT=W04T100A:CTL STPT

W04T100B:CTL TEMP=W04T100A:CTL TEMP

ii. Where W04T100A is the VAV with the thermostat. This would be repeated for other VAVs serving the same space.

iii. Add sequence for multiple VAVs serving same space each having thermostat.

a) HEAT.COOL
b) CTL STPT

iv. Add custom graphic or at minimum note to show multiple VAVs in same space.

K. Alarming and RENO Standards

a. The specified list of alarms and paging is intended to be the minimum for each of the equipment types listed. The project team shall discuss alarming specifics of each project to ensure additional alarms and paging as specified by Duke are set up prior to project turnover.

b. Air Handling Units:

i. Serving critical areas--Alarm and page HVAC group

a) High Static
b) Low Static
c) Freeze stat
d) Fire/smoke alarm
e) Supply fan
f) Return fan

ii. Serving Non-critical areas - Alarm only unless noted otherwise critical areas--Alarm and page HVAC group

a) High Static
b) Low Static
c) Freeze stat
d) Fire/smoke alarm
e) Supply fan
f) Return fan

c. Pumping Systems

i. Alarm pumps on non-critical
ii. Alarm and page HVAC group for pumps and D/P if available on critical
iii. Alarm discharge water temp on hot water convertor systems
iv. Alarm discharge water temp on process loops

d. Exhaust Fans

i. Alarm fan(s) on non-critical
ii. Alarm and page HVAC group for fans and static pressure if available on critical systems

e. Chillers

i. Alarm and page supply temperature and chiller alarm point.