BUILDING AUTOMATION SYSTEM STANDARDS

SEQUENCE OF OPERATIONS

CONTENTS

INTRODUCTION

Virginia Tech has commissioned CMTA to jointly develop Building Automation System (BAS) standards for future project work. The intention of these standards is to include sequence of operations used in high performing buildings, include best-practices for equipment operation, and to prescribe the minimum functionality for all systems incorporated into the BAS.

Modern BAS systems have a tremendous amount of memory and processing power which is largely unused in most projects. These standards aim to incorporate the latest controls strategies and to allow for integration with third-party systems for data analytics and reporting.

ASHRAE Guideline 36

Although we do not recommend requiring ASHRAE Guideline 36 compliance as this would require preloaded and locked control programs (which would preclude real time energy monitoring); we do recommend the sequences described in ASHRAE Guideline 36. The following sequences are heavily based on Guideline 36 but have been modified to include equipment level energy tracking and sequences that have been proven at Virginia Tech.

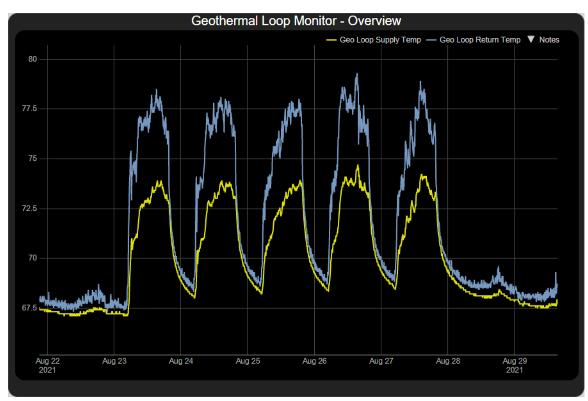
Real-time equipment level energy modeling

Energy modeling is typically accomplished by installing an energy meter at the primary incoming feed, like the utility electrical service, steam meter, or water meter. Sometimes an energy submeter is installed to monitor major system loads like building chilled water consumption; HVAC, lighting and plug loads; or steam condensate metering; however, it is cost prohibitive to install power and btu meters on every fan or coil. That said, the BAS controllers have enough processing power to use the sensors and equipment load ratings to calculate energy demand at a +/- 3% accuracy. This is good enough for a building manager to know where energy is being used in their building and to manage it appropriately.

These sequences include the mathematical algorithms required to calculate and trend energy demand at each piece of equipment.

Trending and Alarming

It is important to specify the minimum level of trending and alarming for the various values in a BAS system. BAS systems vary from being easy to add trending to requiring a manufacturer's technician to program addition trending onsite. Regardless of the manner in which trends are configure, it can be very frustrating to troubleshoot a system and find out that trends haven't been recorded or archived appropriately.



Fault Detection and Diagnostics Readiness

Fault Detection and Diagnostics (FDD) is the process of uncovering issues with building systems before they become a problem for the building occupants. Examples might include:

- Excessive runtime of a motor which is expensive to run and might indicate a capacity problem or a locked point.
- A hunting PID which can wear out an actuator and cause system instabilities
- A leaking hot water valve which overheats a space and causes simultaneous heating and holing
- A stuck outside air damper which either does not bring in enough ventilation, or causes moisture infiltration and high energy bills

FDD can be implemented at the controller level by describing FDD sequences (edge level), or it can be overlaid on a BAS by a 3rd party software solution (cloud based). Although edge level FDD can be a cost-effective method for fault detection, it typically isn't as robust or as flexible as a cloud-based solution. By standardizing on point naming conventions, implementation costs can be reduced for integrating new systems.

3rd Party Building Analytics Readiness

Every year, companies invent new software solutions to integrate and share data with BAS systems. By using standard sequences and point naming conventions, the BAS system can easily be incorporated into external reporting, analytics and operations management software to keep costs low.

Energy Rollups and Dashboarding

Dashboards are an easy way for BAS users to glean a lot of information about their systems from a single graphic. Most BAS systems have a rich set of graphics that can show detailed information about each piece of equipment as a standard offering. In addition, they can offer many dashboard options as an add-on to the basic system. That said, unless they are clearly specified, dashboards are not typically provided as part of the basic BAS package.

CMTA recommends including summary dashboards as a standard requirement.

Sequence of Operations

1 STANDARD SEQUENCE OF OPERATIONS

1.1 GENERAL NOTES AND GUIDANCE

1.1.1 Sequence Options

The sequences listed here are intended to be a basis of design and have many sections regularly found in equipment at Virginia Tech. They are not intended to be used verbatim and will need to be configured for each project as needed.

1.1.2 Setpoints

All setpoints listed are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions. The commissioning authority and owner shall have final approval on all setpoints.

1.1.3 Deadbands

Setpoints shall be programmed with an adjustable deadband appropriate to the controlled system

1.1.4 Hysteresis

Logical trip points shall be programmed with an adjustable hysteresis appropriate to the controlled system

1.1.5 PID Gains

Reasonable PID gains shall be set prior to equipment startup. Final PID gains shall be set by the Building Automation System (BAS) provider during functional testing and commissioning. The commissioning authority and owner shall have final approval on all PID gains.

1.1.6 Trends

Trends shall be enabled on all hard-wired points, setpoints, and calculated variables to record for a minimum of 48 hours. Points specified for historical archival shall be maintained for a minimum of 365 days. The engineer of record, commissioning authority, or other authority may request, with the owner's approval, historical trend archives longer than the minimum period. If a temporary server, or other field device is used, all historical trends shall be migrated to the final archive database.

1.2 STEAM TO HOT WATER CONVERTER

1.2.1 Heat Exchanger System Run Conditions:

The heat exchanger system shall be enabled to run whenever:

- A definable number of hot water coils need heating.

- AND outside air temperature is less than 65°F (adj.).

To prevent short cycling, the heat exchanger shall run for and be off for minimum adjustable times (both user definable).

The heat exchanger system shall also run for freeze protection whenever outside air temperature is less than 38°F (adj.).

Note to Designer: Select one of the following lead/lag or lead/standby sequences and its associated pressure control as appropriate

1.2.2 Hot Water Pump Lead/Standby Operation:

The two hot water pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.
- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Hot Water Pump 1
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.
- Hot Water Pump 2
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.

1.2.2.1 Hot Water Differential Pressure Control:

The controller shall measure hot water differential pressure and modulate the hot water pump VFD and Minimum Flow Bypass Valve in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions. Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

The controller shall modulate hot water pump speeds to maintain a hot water differential pressure of 12 psi (adj.). The VFD's minimum speed shall not drop below 25% (adj.).

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint.

On rising hot water differential pressure, if the lead VFD drops to its minimum speed 25% (adj.), the Minimum Flow Bypass Valve shall modulate to maintain setpoint plus 1 psi (adj.).

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 5 minutes (adj.) the controller will poll the zone valves and determine the # of requests (valves above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the valves, multiplied by the total number of open valves (approximately 10% of your system valves to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 8psi
- $Setpoint_{Max}$ = 18psi
- TotalZones = 50 valves
- $Setpoint_{Span}$ = 18 psi – 8psi = 10psi
- Trim = $Setpoint_{Span}$ * 20% = 2psi
- Respond = Trim/(50 Valves * 10%) = 0.4 psi/request

Alarms shall be provided as follows:

- High Hot Water Differential Pressure: If 25% (adj.) greater than setpoint.
- Low Hot Water Differential Pressure: If 25% (adj.) less than setpoint.

1.2.2.2 Variable Volume Pump Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \left(\frac{\text{VFD\%}_1 + \text{VFD\%}_2}{200\%}\right)^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW\ * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all pump loads
VFD% = The output speed of VFD_1
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.2.3 Hot Water Pump Lead/Lag Operation:

The two hot water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.
- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing hot water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain hot water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Hot Water Pump 1
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.
- Hot Water Pump 2
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.

1.2.3.1 Hot Water Differential Pressure Control:

The hot water differential pressure setpoint shall be programmed as the secondary optimized setpoint and will be enabled after the temperature reset has reached is minimum setpoint. The controller shall measure hot water differential pressure and modulate the secondary hot water pump VFDs and Minimum Flow Bypass Valve in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions. Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy user.

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 5 minutes (adj.) the controller will poll the zone valves and determine the # of requests (valves above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the valves, multiplied by the total number of open valves (approximately 10% of your system valves to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 8psi
- $Setpoint_{Max}$ = 18psi
- TotalZones = 50 valves
- $Setpoint_{Span}$ = 18 psi – 8psi = 10psi
- Trim = $Setpoint_{Span}$ * 20% = 2psi
- Respond = Trim/(50 Valves * 10%) = 0.4 psi/request

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than 50% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising hot water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speed drops back to 25% (adj.), the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.
- If the lead VFD drops to its minimum speed 25% (adj.), the Minimum Flow Bypass Valve shall modulate to maintain setpoint plus 1 psi (adj.).

Alarms shall be provided as follows:

- High Hot Water Differential Pressure: If % (adj.) greater than setpoint.
- Low Hot Water Differential Pressure: If % (adj.) less than setpoint.

1.2.3.2 Lead/Lag Variable Volume Pump Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \left(\frac{\mathrm{VFD\%}_1 + \mathrm{VFD\%}_2}{200\%}\right)^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all pump loads
$\mathrm{VFD\%}_1$ = The output speed of VFD_1
$\mathrm{VFD\%}_2$ = The output speed of VFD_2
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.2.4 Hot Water Supply Temperature Setpoint Reset:

The hot water supply temperature setpoint shall reset using a trim and respond algorithm based on heating requirements.

As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy user. Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 5 minutes (adj.) the controller will poll the zone valves and determine the # of requests (valves above 95% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the valves, multiplied by the total number of open valves (approximately 10% of your system valves to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 150 °F
- $Setpoint_{Max}$ = 180°F
- TotalZones = 500 gpm
- $Setpoint_{Span}$ = 180°F – 150 °F = 30°F
- Trim = $Setpoint_{Span}$ * 20% = 6°F
- Respond = Trim/(500 gpm * 10%) = 0.12 °F/request

Alarms shall be provided as follows:

- High Hot Water Supply Temp: If greater than setpoint by 10°F (adj.).
- Low Hot Water Supply Temp: If less than setpoint by 10°F (adj.).

1.2.5 Heat Exchanger Steam Valves - Hot Water Control:

The controller shall measure the hot water supply temperature and modulate the 1/3 and 2/3 steam valves in sequence to maintain its setpoint as follows:

- Upon an initial call for heat, modulate the lead 1/3 steam valve to maintain its setpoint
- If the lead 1/3 steam valve is 100% open for 5 minutes (adj.) modulate the lag 1/3 steam valve to maintain its setpoint
- If the lead 1/3 steam valve is 100% open for 5 minutes (adj.) open the lead and lag 2/3 steam valves to 50% and close the lead and lag 1/3 steam valves. Modulate the 2/3 steam valves to maintain setpoint.
- If the 2/3 steam valves are 100% open for 5 minutes (adj.) enable the 1/3 steam valves and modulate to maintain setpoint.

The steam valves shall be enabled whenever:

- The heat exchanger is called to run.
- AND hot water supply temperature is below setpoint.

The steam valves shall close whenever the hot water supply temperature rises from 190°F to 200°F (adj.).

1.2.6 Demand Monitoring

The controller shall monitor the steam meter for energy consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the steam meter.

1.2.6.1 Peak Demand History:

The controller shall monitor and record the peak (high and low) demand readings from the steam meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.2.6.2 Usage History:

The controller shall monitor and record BTU meter readings so as to provide an energy consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.2.7 Demand Limiting:

To lower power demand, the hot water system shall automatically relax when a command is received from the power monitoring system as follows:

- Demand Level 1: A command will be sent to the pump VFD's to limit their operation to 95% of capacity.
- Demand Level 2: A command will be sent to the pump VFD's to limit their operation to 90% of capacity.
- Demand Level 3: A command will be sent to the pump VFD's to limit their operation to 80% of capacity.

The pumps shall automatically return to their previous settings when the facility power demand drops below the thresholds.

1.3 CHILLED WATER LOOP PUMPS (VARIABLE VOLUME)

1.3.1 Run Conditions:

The chilled water pumps shall be enabled whenever:

- A definable number of chilled water coils need cooling.
- AND the outside air temperature is greater than 54°F (adj.).

To prevent short cycling, the chilled water pump system shall run for and be off for minimum adjustable times (both user definable).

1.3.2 Chilled Water Pump Lead/Standby Operation:

The two chilled water pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.
- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Chilled Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
- Chilled Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

1.3.2.1 Chilled Water Differential Pressure Control:

The controller shall measure chilled water differential pressure and modulate the chilled water pump VFDs and Minimum Flow Bypass Valve (if present) in sequence to maintain its chilled water differential pressure setpoint. The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

As the facility's chilled water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the chilled water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce pump energy user. Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

If the differential pressure setpoint is at its minimum value and the pumps are running at their minimum speed for 5 minutes (adj.) and the campus loop differential pressure (if present) is greater than the building loop differential pressure setpoint, the secondary pump will turn off and the secondary pumps bypass valve shall open and the two position decoupler valve shall fully close to allow campus water pressure to supply chilled water to the building.

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 5 minutes (adj.) the controller will poll the zone valves and determine the # of requests (valves above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the valves, multiplied by the total number of open valves (approximately 10% of your system valves to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 8psi
- $Setpoint_{Max}$ = 18psi
- TotalZones = 50 valves
- $Setpoint_{Span}$ = 18 psi – 8psi = 10psi
- Trim = $Setpoint_{Span}$ * 20% = 2psi
- Respond = Trim/(50 Valves * 10%) = 0.4 psi/request

On dropping chilled water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 50% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising chilled water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speeds then drops back to 25% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.
- If the lead VFD drops to its minimum speed 25% (adj.), the Minimum Flow Bypass Valve shall modulate to maintain setpoint plus 1 psi (adj.).

Alarms shall be provided as follows:

- High Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) greater than setpoint.
- Low Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) less than setpoint.

1.3.2.2 Lead/Lag Variable Volume Pump Runtime Energy reporting (where specified)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \left(\frac{\text{VFD\%}_1 + \text{VFD\%}_2}{200\%}\right)^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\,min}{60\,min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all pump loads
$VFD\%_1$ = The output speed of VFD_1
$VFD\%_2$ = The output speed of VFD_2
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.3.3 Chilled Water Supply Temperature Setpoint Reset:

If the pumps are running at their minimum speed the chilled water supply temperature setpoint shall reset using a trim and respond algorithm based on cooling requirements.

As the facility's chilled water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a lower value (adj.). Once the chilled water coils are satisfied (valves closing) then the setpoint shall gradually raise over time to reduce cooling energy use. Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

> Every 5 minutes (adj.) the controller will poll the zone valves and determine the # of requests (valves above 95% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the valves, multiplied

by the total number of open valves (approximately 10% of your system valves to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 45°F
- $Setpoint_{Max}$ = 55°F
- TotalZones = 500 gpm
- $Setpoint_{Span}$ = 55°F – 45°F = 10°F
- Trim = $Setpoint_{Span}$ * 20% = 2°F
- Respond = Trim/(500 gpm * 10%) = 0.04°F/request

Alarms shall be provided as follows:

- High Chilled Water Supply Temp: If greater than setpoint by 10°F (adj.).
- Low Chilled Water Supply Temp: If less than setpoint by 10°F (adj.).

1.3.4 Chilled Water Tertiary Bridge Valve

The controller shall measure the chilled water supply temperature and modulate the tertiary loop bypass valve to maintain its supply setpoint. When chilled water supply temperature setpoint has been achieved within its deadband, the bypass valve shall modulate to maintain chilled water differential temperature (chilled water return temperature minus chilled water supply temperature setpoint) at its setpoint, initially set at 16°F (adj.). If at any time, the chilled water temperature exceeds its setpoint deadband, supply temperature setpoint will become the primary variable for control and will equal the Campus Loop Entering Temperature.

Alarms shall be provided as follows:

- High Chilled Water Supply Temp: If greater than setpoint by 5°F (adj.).
- Low Chilled Water Supply Temp: If less than setpoint by 5°F (adj.).
- Low Building dT: If the valve is greater than 25% open and the differential temperature is less than setpoint by 2°F (adj.).
- High Campus Chilled Water Supply: If the Campus Chilled Water Supply Temperature exceeds Building Chilled Water Supply Temperature setpoint plus its deadband.

1.3.5 Central Loop Differential Pressure:

The controller shall monitor the central loop differential pressure.

1.3.6 Demand Monitoring

The controller shall monitor the BTU meter for energy consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the BTU meter.

1.3.6.1 Peak Demand History:

The controller shall monitor and record the peak (high and low) demand readings from the BTU meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.3.6.2 Usage History:

The controller shall monitor and record BTU meter readings so as to provide an energy consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.3.7 Demand Limiting:

To lower power demand, the hot water system shall automatically relax when a command is received from the power monitoring system as follows:

- Demand Level 1: A command will be sent to the pump VFD's to limit their operation to 95% of capacity.
- Demand Level 2: A command will be sent to the pump VFD's to limit their operation to 90% of capacity.
- Demand Level 3: A command will be sent to the pump VFD's to limit their operation to 80% of capacity.

The pumps shall automatically return to their previous settings when the facility power demand drops below the thresholds.

1.4 SINGLE ZONE AIR HANDLING UNIT

1.4.1 Run Conditions - Scheduled:

The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: Scheduled times when the facility is deemed to be fully occupied (>25% capacity), the unit shall maintain
  - A 74°F (adj.) cooling setpoint with a 2°F hysteresis
  - A 70°F (adj.) heating setpoint with a 2°F hysteresis
  - Occupied ventilation rates
- Standby Mode: Scheduled occupied times when the facility is deemed to be lightly occupied by an occupancy sensor (if present) or time of day schedule. During Standby mode the unit shall maintain:
  - A +2°F (adj.) offset from occupied cooling setpoint
  - A -2°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates
- Unoccupied Mode (night setback): The unit shall maintain
  - A +6°F (adj.) offset from occupied cooling setpoint
  - A -6°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates

If at any time, the occupancy sensor (if present) detects people in the space, the zone shall be indexed to Occupied Mode until the detected occupancy plus any delays again detects no occupancy.

If occupancy sensors are not utilized, include an option to allow a standby mode as a scheduled instance.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

1.4.1.1 Demand Limiting - Zone Setpoint Optimization:

To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

1.4.1.2 Zone Setpoint Adjust:

The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor within a BAS operator adjustable range.

1.4.1.3 Zone Optimal Start:

The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period. During the Optimal Start period, ventilation routines will maintain their unoccupied setpoints.

1.4.1.4 Zone Unoccupied Override:

A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

1.4.2 Freeze Protection:

The unit shall shut down and generate an alarm upon receiving a freezestat status.

1.4.3 Smoke Detection:

The unit shall shut down and generate an alarm upon receiving a smoke detector status.

1.4.4 Supply Fan – Constant Volume:

The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.4.4.1 Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage

Amps = The sum of all fan loads
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.4.5 Supply Fan – Variable Volume:

The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

On an initial call for operation the fan will be energized and run at its minimum speed. The controller shall measure the zone temperature and modulate the heating and cooling coil valves to maintain its setpoints. When either valve has been commanded fully open and there is an additional call for heating or cooling, the controller will modulate the fan speed to maintain its setpoint.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.4.5.1 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.4.6 Relief Fan:

The controller shall monitor the building static pressure and enable the relief fan whenever the supply fan runs and building static pressure is above setpoint.

Alarms shall be provided as follows:

- Relief Fan Failure: Commanded on, but the status is off.
- Relief Fan in Hand: Commanded off, but the status is on.
- Relief Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
- Relief Fan VFD Fault.

If the equipment is equipped with a return fan instead of a relief fan, refer to section 1.6.8 VAV AHU – Return Fan for the sequence of operation.

1.4.6.1 Building Static Pressure Control:

The controller shall measure building static pressure and modulate the relief fan VFD speed to maintain a building static pressure setpoint of 0.05in H2O (adj.). The relief fan VFD speed shall not drop below 20% (adj.).

Alarms shall be provided as follows:

- High Building Static Pressure: If the building air static pressure is 25% (adj.) greater than setpoint.
- Low Building Static Pressure: If the building air static pressure is 25% (adj.) less than setpoint.

1.4.6.2 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.4.7 Heat Recovery Wheel - Variable Speed:

The controller shall modulate the heat recovery wheel for energy recovery as follows.

1.4.7.1 Cooling Recovery Mode:

The controller shall measure the zone temperature and modulate the heat wheel speed to maintain a setpoint 2°F (adj.) less than the zone cooling setpoint. The heat wheel shall run for cool recovery whenever:

- Return air temperature is 5°F (adj.) or more below the outside air temperature.
- AND the zone temperature is above cooling setpoint.
- AND the economizer (if present) is off.
- AND the supply fan is on.

1.4.7.2 Heating Recovery Mode:

The controller shall measure the zone temperature and modulate the heat wheel speed to maintain a setpoint 2°F (adj.) greater than the zone heating setpoint. The heat wheel shall run for heat recovery whenever:

- Return air temperature is 5°F (adj.) or more above the outside air temperature.
- AND the zone temperature is below heating setpoint.
- AND the economizer mode (if present) is disabled.
- AND the supply fan is on.

1.4.7.3 Periodic Self-Cleaning:

The heat wheel shall run at 5% speed (adj.) for 10sec (adj.) every 4hr (adj.) the unit runs.

1.4.7.4 Frost Protection:

The heat wheel shall run at 5% speed (adj.) whenever:

- Outside air temperature drops below 15°F (adj.)
- OR the exhaust air temperature drops below 20°F (adj.).

The heat wheel bypass dampers will open whenever the heat wheel is disabled.

Alarms shall be provided as follows:

- Heat Wheel Rotation Failure: Commanded on, but the status is off.
- Heat Wheel in Hand: Commanded off, but the status is on.
- Heat Wheel Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
- Heat Wheel VFD Fault

1.4.7.5 Heat Wheel Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand

- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\,min}{60\,min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all motor loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.4.8 Heating and Cooling - Compressor Stages:

The controller shall measure the zone temperature and cycle the compressor(s) to maintain its setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime. Each compressor shall run subject to its own internal safeties and controls.

The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the fan is on.
- AND the reversing valve is in heat mode.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the fan is on.
- AND the reversing valve is in cool mode.

On mode change, the compressor shall be disabled and remain off until after the reversing valve has changed position.

Alarms shall be provided as follows:

- Compressor Runtime Exceeded: The compressor runtime exceeds a user definable limit (adj.).

1.4.8.1 Compressor energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand

- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\,min}{60\,min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of each compressor
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.4.9 Supplemental Electric Heating Stages:

The controller shall measure the zone temperature and stage the heating to maintain its heating setpoint should the compressors not meet the heating demand. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

- The heating shall be enabled whenever:
- The heat pump is in heating mode.
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

1.4.9.1 Electric heat energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kWStages = \sum_{Stages} kW$$

$$kWh = \sum_{Run}\left(kWStages * \left(\frac{10\,min}{60\,min/hr}\right)\right)$$

Where:

kW = Rated kW of each stage

1.4.10 Preheating Coil Valve:

The controller shall measure the mixed air temperature and preheat coil leaving temperature and modulate the preheating coil valve to maintain the lower of the two sensors at its setpoint, 5°F (adj.) less than the supply air temperature setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. In addition, the preheat coil valve shall modulate to maintain a minimum setpoint of 45°F (ad.).

The preheating shall be enabled whenever:

- Outside air temperature is less than 60°F (adj.).
- AND the supply fan status is on.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The preheating coil valve shall open for freeze protection whenever the freezestat is on.

1.4.10.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\,min}{60\,min/hr} \right) \right)$$

$$kBtu_{Savings} = kBtu_{Base} - kBtu_{Act}$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.4.11 Cooling Coil Valve:

The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% (adj.) control signal in order to extent valve life. The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.
- AND the heating (if present) is not active.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

The controller will monitor the return water temperature (sensed downstream of the cooling coil), and the supply water temperature sensed at the central plant. Upon a call for cooling greater than 25% of the valve capacity, the controller will hold the position of the valve until the differential temperate exceeds 8°F (adj). The controller will resume normal control when the differential temperate is above setpoint.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 5°F (adj.) greater than setpoint.
- Low Supply Air Temperature Alarm: The controller shall alarm if the supply air temperature is less than 45°F (adj.).
- Low Coil dT: If the valve is greater than 25% open and the differential temperature is less than setpoint by 2°F (adj.).

1.4.11.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip Btu – Instantaneous energy demand
- Equip Btu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.4.12 Heating Coil Valve:

The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- OR dehumidification is active
- AND the zone temperature is below heating setpoint.
- AND the supply fan status is on.
- AND the cooling is not active.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The heating coil valve shall open whenever the freezestat (if present) is on.

1.4.12.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days. and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip Btu – Instantaneous energy demand
- Equip Btu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.4.13 Economizer:

The controller shall measure the zone temperature and modulate the economizer dampers in sequence to maintain a setpoint 2°F less than the zone cooling setpoint. The economizer shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the outside air enthalpy is less than 22% (adj.).
- AND the outside air temperature is less than the return air temperature.
- AND the outside air enthalpy is less than the return air enthalpy.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 45°F to 40°F (adj.).
- OR on loss of supply fan status.
- OR freezestat (if present) is on.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

1.4.14 Dehumidification:

The controller shall measure the return or space humidity (if present) and override the cooling sequence to maintain return air humidity at or below 60% rh (adj.).

During dehumidification, the heating shall modulate to maintain a setpoint 1°F (adj.) less than the zone cooling setpoint.

Dehumidification shall be enabled whenever:

- the supply fan status is on.
- AND preheating is disabled.
- AND humidity is greater than the humidity setpoint.

1.4.15 Humidifier Control:

The controller shall measure the return or space humidity (if present) and modulate the humidifier to maintain a setpoint of 30% rh (adj.). The humidifier shall be enabled whenever the supply fan status is on.

The humidifier shall turn off whenever:

- Supply air humidity rises from 90% rh to 95% rh (adj.).
- OR on loss of supply fan status.
- OR if cooling is active.

Alarms shall be provided as follows:

- High Supply Air Humidity: If the supply air humidity is greater than 90% rh (adj.).
- Low Supply Air Humidity: If the supply air humidity is less than 30% rh (adj.).

1.4.16 Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:

When in the occupied mode, the controller shall measure the return air CO2 or space CO2 (if present) levels and modulate the outside air dampers on rising CO2 concentrations, overriding normal damper operation to maintain a CO2 setpoint of 1000 ppm (adj.). The controller shall measure the outside airflow and modulate the dampers between minimum airflow ventilation rates and the maximum airflow ventilation rate.

1.4.17 Minimum Outside Air Ventilation – Airflow Monitoring:

When in the occupied mode, the controller shall measure the outside airflow and modulate the outside air dampers to maintain the proper minimum outside air ventilation, overriding normal damper control. On dropping outside airflow, the controller shall modulate the outside air dampers open to maintain the outside airflow setpoint (adj.).

1.4.18 Filter Status:

The controller shall monitor the filter status.

Alarms shall be provided as follows:

- Filter Change Required: Filter differential pressure exceeds a user definable limit (adj.).

1.4.19 Mixed Air Temperature:

The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- Low Mixed Air Temp: If the mixed air temperature is less than 45°F (adj.).

1.4.20 Return Air Carbon Dioxide (CO2) Concentration Monitoring:

The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

1.4.21 Return Air Humidity:

The controller shall monitor the return air humidity and use as required for economizer control (if present) or humidity control (if present).

Alarms shall be provided as follows:

- High Return Air Humidity: If the return air humidity is greater than 70% (adj.).
- Low Return Air Humidity: If the return air humidity is less than 35% (adj.).

1.4.22 Return Air Temperature:

The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 90°F (adj.).
- Low Return Air Temp: If the return air temperature is less than 45°F (adj.).

1.4.23 Supply Air Temperature:

The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

1.5 Fan Coil Unit, Unit Ventilator, Blower Coils

1.5.1 Run Conditions - Scheduled:

The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: Scheduled times when the facility is deemed to be fully occupied (>25% capacity), the unit shall maintain
    - A 74°F (adj.) cooling setpoint with a 2°F hysteresis
    - A 70°F (adj.) heating setpoint with a 2°F hysteresis
    - Occupied ventilation rates
- Standby Mode: Scheduled occupied times when the facility is deemed to be lightly occupied by an occupancy sensor (if present) or time of day schedule. During Standby mode the unit shall maintain
    - A +2°F (adj.) offset from occupied cooling setpoint
    - A -2°F (adj.) offset from occupied heating setpoint.
    - Unoccupied ventilation rates
- Unoccupied Mode (night setback): The unit shall maintain
    - A +6°F (adj.) offset from occupied cooling setpoint
    - A -6°F (adj.) offset from occupied heating setpoint.
    - Unoccupied ventilation rates

If at any time, the occupancy sensor (if present) detects people in the space, the zone shall be indexed to Occupied Mode until the detected occupancy plus any delays again detects no occupancy.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

1.5.1.1 Demand Limiting - Zone Setpoint Optimization:

To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

1.5.1.2 Zone Setpoint Adjust:

The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

1.5.1.3 Zone Optimal Start:

The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

1.5.1.4 Zone Unoccupied Override:

A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

1.5.2 Supply Fan – Variable Volume:

On an initial call for operation the fan will be energized and run at its minimum speed. The controller shall measure the zone temperature and modulate the heating and cooling coil valves to maintain its setpoints. When either valve has been commanded fully open and there is an additional call for heating or cooling, the controller will modulate the fan speed to maintain its setpoint.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.5.2.1 Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = ECM\%^3 \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$
$$kWh = \sum_{Run} \left(kW \ * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

ECM% = Fan Speed Command Signal (or feedback)
Volts = Equipment supply voltage
Amps = The sum of all fan loads
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.5.3 Cooling Coil Valve:

The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- AND the zone temperature is above cooling setpoint.
- AND the economizer (if present) is disabled or fully open.
- AND the fan is on.
- AND the heating (if present) is not active.

1.5.3.1 The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service. Cooling Coil energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows if zone temp is greater than discharge air temp:

$$kBtu/hr = \frac{ECM\% * CFM * (DAT - ZONT) * 1.08}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

ECM% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan times the VFD fan speed
ZONT = Zone air temperature
DAT = Discharge Air Temperature

1.5.4 Heating Coil Valve:

The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the zone temperature is below heating setpoint.

- AND the fan is on.
- AND the cooling (if present) is not active.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The heating coil valve shall open whenever the freezestat (if present) is on.

1.5.4.1 Heating Coil energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows if zone temp is less than discharge air temp:

$$kBtu/hr = \frac{EC\% * CFM * (ZONT - DAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run}\left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

EC% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan times the VFD fan speed
ZONT = Zone air temperature
DAT = Discharge Air Temperature

1.5.5 Economizer (ASHRAE Cycle II):

The controller shall measure the zone temperature and modulate the mixed air dampers in sequence to maintain the zone cooling setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open during heating and ventilation whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is at least 3°F (adj.) less than the Zone Temperature.
- AND the outside air temperature is less than 75°F (adj.)

The economizer shall close whenever the freezestat (if present) is on.

The outside air dampers shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

The controller shall monitor the discharge air temperature. Should discharge temperature drop below a user definable temperature (adj.), the controller shall enable the heating, close the outside damper and open the return damper.

1.5.6 Discharge Air Temperature:

The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

1.6 VARIABLE AIR VOLUME – AHU

1.6.1 Run Conditions – Requested:

The unit shall run whenever:

- Any zone is occupied.
- OR a definable number of unoccupied zones need heating or cooling.

If unoccupied zones become satisfied, the unit shall be disabled.

1.6.2 Freeze Protection:

The unit shall shut down and generate an alarm upon receiving a freezestat status.

1.6.3 High Static Shutdown:

The unit shall shut down and generate an alarm upon receiving a high static shutdown signal.

1.6.4 Return Air Smoke Detection:

The unit shall shut down and generate an alarm upon receiving a return air smoke detector status.

1.6.5 AHU Optimal Start:

The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoints. The start time shall automatically adjust based on changes in outside air temperature and zone temperatures.

1.6.6 Demand Limiting – Setpoint Adjust:

To lower power consumption, the supply air temperature setpoint shall automatically relax (raised for cooling; lowered for heating) when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be accomplished by one of the following methods:

- The supply air temperature setpoint shall relax by 2°F (adj.) for each demand threshold exceeded.
- The setpoints in the zones supplied by this unit shall be relaxed as specified in the Sequence of Operations for the zones. This shall in turn relax the unit's supply air temperature setpoint by a user definable amount.

All setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

1.6.7 Supply Fan:

The supply fan shall run anytime the unit is commanded to run based on run conditions, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.

- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.6.7.1 Supply Air Duct Static Pressure Control:

The controller shall measure duct static pressure and modulate the supply fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 30% (adj.). The static pressure setpoint shall be reset based on zone cooling requirements.

- The initial duct static pressure setpoint shall be 1.0 in H2O (adj.).
- As airflow demand increases, the setpoint shall incrementally reset up to a maximum of 2.0 in H2O (adj.).
- As airflow demand decreases, the setpoint shall incrementally reset down to a minimum of 0.35 in H2O (adj.).

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 2 minutes (adj.) the controller will poll the zone dampers and determine the # of requests (dampers above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the dampers, multiplied by the total number of open dampers (approximately 10% of your system dampers to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 0.35 in H2O
- $Setpoint_{Max}$ = 2.0 in H2O
- TotalZones = 50 zone dampers
- $Setpoint_{Span}$ = 2.0 in H2O – 0.35 in H2O = 1.65 in H2O
- Trim = $Setpoint_{Span}$ * 20% = 0.33 in H2O
- Respond = Trim/(50 dampers * 10%) = 0.066 psi/request

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan VFD Fault.

1.6.7.2 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand

- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \text{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

Note to the Designer: Modify Return Fan section to be Relief Fan or Exhaust Fan as necessary.

1.6.8 Return Fan:

The return fan shall run whenever the supply fan runs.

Alarms shall be provided as follows:

- Return Fan Failure: Commanded on, but the status is off.
- Return Fan in Hand: Commanded off, but the status is on.
- Return Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
- Return Fan VFD Fault.

1.6.8.1 Return Plenum Static Pressure Control:

The controller shall measure return plenum static pressure and modulate the return fan VFD to maintain a plenum pressure setpoint of 0.2in H2O (adj.).

Alarms shall be provided as follows:

- High Building Static Pressure: If the building air static pressure is 25% (adj.) greater than setpoint.
- Low Building Static Pressure: If the building air static pressure is 25% (adj.) less than setpoint.

1.6.8.2 Building Static Pressure Control:

The controller shall measure building static pressure and modulate the relief damper to maintain a building static pressure setpoint of 0.05in H2O (adj.).

Alarms shall be provided as follows:

- High Building Static Pressure: If the building air static pressure is 25% (adj.) greater than setpoint.
- Low Building Static Pressure: If the building air static pressure is 25% (adj.) less than setpoint.

1.6.8.3 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.6.9 Heat Recovery Wheel – Constant Speed:

The controller shall run the heat recovery wheel for energy recovery as follows.

1.6.9.1 Cooling Recovery Mode:

The controller shall measure the heat wheel discharge air temperature and modulate the heat wheel to maintain a setpoint 2°F (adj.) less than the unit supply air temperature setpoint. The heat wheel shall run for cool recovery whenever:

- The unit return air temperature is 5°F (adj.) or more below the outside air temperature.
- AND the unit is in a cooling mode.
- AND the economizer mode (if present) is disabled.
- AND the supply fan is on.

1.6.9.2 Heating Recovery Mode:

The controller shall measure the heat wheel discharge air temperature and modulate the heat wheel to maintain a setpoint 2°F (adj.) greater than the unit supply air temperature setpoint. The heat wheel shall run for heat recovery whenever:

- The unit return air temperature is 5°F (adj.) or more above the outside air temperature.
- AND the unit is in a heating mode.
- AND the economizer mode (if present) is disabled.
- AND the supply fan is on.

1.6.9.3 Periodic Self-Cleaning:

The heat wheel shall run for 10sec (adj.) every 4hr (adj.) the unit runs.

1.6.9.4 Frost Protection:

The heat wheel shall run for 10sec (adj.) every 600sec (adj.) whenever:

- Outside air temperature drops below 15°F (adj.)
- OR the exhaust air temperature drops below 20°F (adj.).

The heat wheel bypass dampers will open whenever the heat wheel is disabled.

Alarms shall be provided as follows:

- Heat Wheel Rotation Failure: Commanded on, but the status is off.
- Heat Wheel in Hand: Commanded off, but the status is on.
- Heat Wheel Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.6.9.5 Heat Wheel Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all motor loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.6.10 Heat Recovery Coil – Runaround Loop:

The controller shall run the heat recovery loop for energy recovery as follows.

1.6.10.1 Cooling Recovery Mode:

The controller shall measure the heat recovery coil air temperature and modulate the loop pump VFD to maintain a setpoint 2°F (adj.) less than the unit supply air temperature setpoint. The heat recovery loop shall run for cool recovery whenever:

- The unit return air temperature is 5°F (adj.) or more below the outside air temperature.
- AND the unit is in a cooling mode.
- AND the economizer (if present) is off.
- AND the supply fan is on.

1.6.10.2 Heating Recovery Mode:

The controller shall measure the heat recovery coil discharge air temperature and run the loop pump VFD to maintain a setpoint 2°F (adj.) greater than the unit supply air temperature setpoint. The heat wheel shall run for heat recovery whenever:

- The unit return air temperature is 5°F (adj.) or more above the outside air temperature.
- AND the unit is in a heating mode.
- AND the economizer (if present) is off.
- AND the supply fan is on.

1.6.11 Preheating Coil Valve:

The controller shall measure the mixed air temperature and preheat coil leaving temperature and modulate the preheating coil valve to maintain the lower of the two sensors at its setpoint, 5°F (adj.) less than the supply air temperature setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. In addition, the preheat coil valve shall modulate to maintain a minimum setpoint of 45°F (ad.).

The preheating shall be enabled whenever:

- Outside air temperature is less than 60°F (adj.).
- AND the economizer mode (if present) is disabled.
- AND the supply fan status is on.
- AND the heat recovery (if present) is at its full output in the heating mode

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The preheating coil valve shall open for freeze protection whenever the freezestat is on.

1.6.11.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

$$kBtu_{Savings} = kBtu_{Base} - kBtu_{Act}$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.6.12 Supply Air Temperature Setpoint – Optimized:

The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on zone cooling requirements.

If the fan is running at its minimum speed, the supply air temperature setpoint shall be reset based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 55°F (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 53°F (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 72°F (adj.).

Incoming requests shall be weighted in proportion to the size of each coil. For example, a coil rated for 10 gpm shall send 10 requests when the valve is fully open.

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 5 minutes (adj.) the controller will poll the zone dampers and determine the # of requests (dampers above 95% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the dampers, multiplied by the total number of open dampers (approximately 10% of your system dampers to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 55°F
- $Setpoint_{Max}$ = 65°F
- TotalZones = 500 gpm
- $Setpoint_{Span}$ = 65°F – 55°F = 10°F
- Trim = $Setpoint_{Span}$ * 20% = 2°F
- Respond = Trim/(500 gpm * 10%) = 0.04°F/request

1.6.13 Cooling Coil Valve:

The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.
- AND the heating (if present) is not active.
- AND heat recovery (if present) is not active in the heating mode

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

The controller will monitor the return water temperature (sensed downstream of the cooling coil), and the supply water temperature sensed at the central plant. Upon a call for cooling greater than 25% of the valve capacity, the controller will hold the position of the valve until the differential temperate exceeds 8°F (adj). The controller will resume normal control when the differential temperate is above setpoint.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 5°F (adj.) greater than setpoint.
- Low Supply Air Temperature Alarm: The controller shall alarm if the supply air temperature is less than 45°F (adj.).
- Low Coil dT: If the valve is greater than 25% open and the differential temperature is less than setpoint by 2°F (adj.).

1.6.13.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip Btu – Instantaneous energy demand
- Equip Btu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run}\left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.6.14 Economizer:

The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 2°F (adj.) less than the supply air temperature setpoint.

The economizer shall be enabled whenever:

- Outside air temperature is less than 68°F (adj.).
- AND the outside air enthalpy is less than 22Btu/lb (adj.)
- AND the outside air temperature is less than the return air temperature.
- AND the outside air enthalpy is less than the return air enthalpy.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 40°F to 35°F (adj.)
- OR the freezestat (if present) is on.
- OR on loss of supply fan status.

The outside and exhaust air dampers shall close, and the return air damper shall open when the unit is off. If Optimal Start Up is available, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

1.6.15 Minimum Outside Air Ventilation – Airflow Monitoring:

When in the occupied mode, the controller shall measure the outside airflow and modulate the outside air dampers to maintain the proper minimum outside air ventilation, overriding normal damper control. On dropping outside airflow, the controller shall modulate the outside air dampers open to maintain the outside airflow setpoint (adj.).

1.6.16 Dehumidification:

The controller shall measure the return air humidity and override the cooling setpoint to 53°F (adj.) to maintain return air humidity at or below 60% rh (adj.). Dehumidification shall be enabled whenever the supply fan status is on.

1.6.17 Humidifier Control:

The controller shall measure the return air humidity and modulate the humidifier to maintain a setpoint of 50% rh (adj.). The humidifier shall be enabled whenever the supply fan status is on.

The humidifier shall turn off whenever:

- Supply air humidity rises from 90% rh to 95% rh (adj.).
- OR on loss of supply fan status.

Alarms shall be provided as follows:

- High Supply Air Humidity: If the supply air humidity is greater than 90% rh (adj.).
- Low Supply Air Humidity: If the supply air humidity is less than 30% rh (adj.).

1.6.18 Prefilter Differential Pressure Monitor:

The controller shall monitor the differential pressure across the prefilter.

Alarms shall be provided as follows:

- Prefilter Change Required: Prefilter differential pressure exceeds a user definable limit (adj.).

1.6.19 Mixed Air Temperature:

The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 90°F (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 45°F (adj.).

1.6.20 Return Air Carbon Dioxide (CO2) Concentration Monitoring:

The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the unit is running.

1.6.21 Return Air Humidity:
The controller shall monitor the return air humidity and use as required for economizer control (if present) or humidity control (if present).

Alarms shall be provided as follows:

- High Return Air Humidity: If the return air humidity is greater than 70% (adj.).
- Low Return Air Humidity: If the return air humidity is less than 35% (adj.).

1.6.22 Return Air Temperature:
The controller shall monitor the return air temperature and use as required for setpoint control or economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 90°F (adj.).
- Low Return Air Temp: If the return air temperature is less than 45°F (adj.).

1.6.23 Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

1.6.24 Demand Limiting:
To lower power demand, the AHU shall automatically relax when a command is received from the power monitoring system as follows:

- Demand Level 1: A command will be sent to the fan VFD's to limit their operation to 95% of capacity.
- Demand Level 2: A command will be sent to the fan VFD's to limit their operation to 90% of capacity.
- Demand Level 3: A command will be sent to the fan VFD's to limit their operation to 80% of capacity.

The fans shall automatically return to their previous settings when the facility power demand drops below the thresholds.

1.7 100% Outside Air Unit – Supply Air Temp

1.7.1 Run Conditions – Scheduled:

The unit shall run based upon an operator adjustable schedule.

1.7.2 Freeze Protection:

The unit shall shut down and generate an alarm upon receiving a freezestat status.

1.7.3 Smoke Detection:

The unit shall shut down and generate an alarm upon receiving a smoke detector status.

1.7.4 Outside Air Damper:

The outside air damper shall open anytime the unit runs and shall close anytime the unit stops. The supply fan shall start only after the damper status has proven the damper is open. The outside air damper shall close 4sec (adj.) after the supply fan stops.

Alarms shall be provided as follows:

- Outside Air Damper Failure: Commanded open, but the status is closed.
- Outside Air Damper in Hand: Commanded closed, but the status is open.

1.7.5 Supply Fan:

The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.7.5.1 Supply Air Duct Static Pressure Control:

The controller shall measure duct static pressure and modulate the supply fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 30% (adj.). The static pressure setpoint shall be reset based on zone cooling requirements.

- The initial duct static pressure setpoint shall be 1.0in H2O (adj.).
- As airflow demand increases, the setpoint shall incrementally reset up to a maximum of 2.0 in H2O (adj.).
- As airflow demand decreases, the setpoint shall incrementally reset down to a minimum of 0.35 in H2O (adj.).

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 2 minutes (adj.) the controller will poll the zone dampers and determine the # of requests (dampers above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the dampers, multiplied by the total number of open dampers (approximately 10% of your system dampers to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $Setpoint_{Min}$ = 0.35 in H2O
- $Setpoint_{Max}$ = 2.0 in H2O
- TotalZones = 50 zone dampers
- $Setpoint_{Span}$ = 2.0 in H2O – 0.35 in H2O = 1.65 in H2O
- Trim = $Setpoint_{Span}$ * 20% = 0.33 in H2O
- Respond = Trim/(50 dampers * 10%) = 0.066 psi/request

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan VFD Fault.

1.7.5.2 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.7.6 Exhaust Fan:

The exhaust fan shall run whenever the supply fan runs.

Alarms shall be provided as follows:

- Exhaust Fan Failure: Commanded on, but the status is off.
- Exhaust Fan in Hand: Commanded off, but the status is on.
- Exhaust Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
- Exhaust Fan VFD Fault.

1.7.6.1 Building Static Pressure Control:

The controller shall measure building static pressure and modulate the exhaust fan VFD speed to maintain a building static pressure setpoint of 0.05in H2O (adj.). The exhaust fan VFD speed shall not drop below 20% (adj.).

Alarms shall be provided as follows:

- High Building Static Pressure: If the building air static pressure is 25% (adj.) greater than setpoint.
- Low Building Static Pressure: If the building air static pressure is 25% (adj.) less than setpoint.

1.7.6.2 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.7.7 Heat Recovery Wheel – Constant Speed:

The controller shall run the heat recovery wheel for energy recovery as follows.

1.7.7.1 Cooling Recovery Mode:

The controller shall measure the heat wheel discharge air temperature and run the heat wheel to maintain a setpoint 2°F (adj.) less than the unit supply air temperature setpoint. The heat wheel shall run for cool recovery whenever:

- The unit return air temperature is 5°F (adj.) or more below the outside air temperature.
- AND the unit is in a cooling mode.
- AND the economizer (if present) is off.
- AND the supply fan is on.

1.7.7.2 Heating Recovery Mode:

The controller shall measure the heat wheel discharge air temperature and run the heat wheel to maintain a setpoint 2°F (adj.) greater than the unit supply air temperature setpoint. The heat wheel shall run for heat recovery whenever:

- The unit return air temperature is 5°F (adj.) or more above the outside air temperature.
- AND the unit is in a heating mode.
- AND the economizer (if present) is off.
- AND the supply fan is on.

1.7.7.3 Periodic Self-Cleaning:

The heat wheel shall run for 10sec (adj.) every 4hr (adj.) the unit runs.

1.7.7.4 Frost** Protection**:

The heat wheel shall run for 10sec (adj.) every 600sec (adj.) whenever:

- Outside air temperature drops below 15°F (adj.)
- OR the exhaust air temperature drops below 20°F (adj.).

The heat wheel bypass dampers will open whenever the heat wheel is disabled.

Alarms shall be provided as follows:

- Heat Wheel Rotation Failure: Commanded on, but the status is off.
- Heat Wheel in Hand: Commanded off, but the status is on.
- Heat Wheel Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

1.7.7.5 Heat Wheel Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \mathrm{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all motor loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

Note to the Designer: Select one of the following supply temperature control strategies as appropriate and remove the other.

1.7.8 Supply Air Temperature Setpoint – Optimized for Space Conditions:

The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on zone cooling requirements.

The supply air temperature setpoint shall be reset based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 55°F (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 53°F (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 72°F (adj.).

1.7.9 Supply Air Temperature Setpoint – Ventilation Air:

The controller shall monitor the supply air temperature and shall maintain a fixed supply air temperature setpoint of 70°F (adj.).

1.7.10 Preheating Coil Face and Bypass Dampers:

The controller shall measure the mixed air temperature and preheat coil leaving temperature and modulate the preheating coil valve and dampers to maintain the lower of the two sensors at its setpoint, 5°F (adj.) less than the supply air temperature setpoint. In addition, the preheat coil dampers shall modulate to maintain a minimum setpoint of 45°F (ad.). The coil valve and face and bypass dampers shall be sequenced as follows:

- When the unit is off, the face and bypass dampers will be in the full face position and the preheat coil valve shall modulate to maintain setpoint in the airstream with no flow.
- When the unit is running, and the outside air temperature is below 38°F (adj.), the coil valve shall be fully open to the coil and the face and bypass dampers shall modulate to maintain setpoint.

- When the unit is running, and the outside air temperature is above 40°F (adj.), the face and bypass dampers shall be in the full face position and the coil valve shall modulate to maintain setpoint.
- When the unit is running and there is no call for preheating, the coil valve shall be closed and the face and bypass dampers in the full bypass position.

1.7.10.1 Coil energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{VFD\% * CFM * (MAT - PH\ DAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

$$kBtu_{Savings} = kBtu_{Base} - kBtu_{Act}$$

Where:

VFD% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan
MAT = Mixed air temperature
PH DAT = Preheat Coil Discharge Air Temperature

1.7.11 Cooling Coil Valve:

The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.
- AND the heating (if present) is not active.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

The controller will monitor the return water temperature (sensed downstream of the cooling coil), and the supply water temperature sensed at the central plant. Upon a call for cooling greater than 25% of the valve capacity, the controller will hold the position of the valve until the differential temperate exceeds 8°F (adj). The controller will resume normal control when the differential temperate is above setpoint.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 5°F (adj.) greater than setpoint.
- Low Supply Air Temperature Alarm: The controller shall alarm if the supply air temperature is less than 45°F (adj.).
- Low Coil dT: If the valve is greater than 25% open and the differential temperature is less than setpoint by 2°F (adj.).

1.7.11.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Actual Runtime – Run – Actual equipment runtime
- Equip Btu – Instantaneous energy demand
- Equip Btu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\,min}{60\,min/hr} \right) \right)$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.7.12 Heating Coil Valve:

The controller shall measure the supply air temperature and modulate the heating coil valve to maintain its heating setpoint. If the valve provided is a globe valve, upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life. The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the supply air temperature is below heating setpoint.

- AND the fan status is on.
- AND any heat recovery is at full output.

If the heating fluid is not steam, the controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

The heating coil valve shall open to 100% (adj.) whenever the freezestat is on.

1.7.12.1 Coil energy reporting (water-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{Valve\% * GPM * (WST - WRT) * 500}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

$$kBtu_{Savings} = kBtu_{Base} - kBtu_{Act}$$

Where:

Valve% = Valve Actuator Command Signal (or feedback)
GPM = The rated flow of the coil
WST = Water supply temperature (from central plant)
WRT = Water return temperature (from sensor)

1.7.13 Filter Status:

The controller shall monitor the filter status.

Alarms shall be provided as follows:

- Filter Change Required: filter differential pressure exceeds a user definable limit (adj.).

Supply Air Temperature:

The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

1.7.14 Demand Limiting:

To lower power demand, the AHU shall automatically relax when a command is received from the power monitoring system as follows:

- Demand Level 1: A command will be sent to the fan VFD's to limit their operation to 95% of capacity.
- Demand Level 2: A command will be sent to the fan VFD's to limit their operation to 90% of capacity.
- Demand Level 3: A command will be sent to the fan VFD's to limit their operation to 80% of capacity.

The fans shall automatically return to their previous settings when the facility power demand drops below the thresholds.

1.8 VARIABLE AIR VOLUME - TERMINAL UNIT

1.8.1 Run Conditions - Scheduled:

The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: Scheduled times when the facility is deemed to be fully occupied (>25% capacity), the unit shall maintain
  - A 74°F (adj.) cooling setpoint with a 2°F hysteresis
  - A 70°F (adj.) heating setpoint with a 2°F hysteresis
  - Occupied ventilation rates
- Standby Mode: Scheduled occupied times when the facility is deemed to be lightly occupied by an occupancy sensor (if present) or time of day schedule. During Standby mode the unit shall maintain
  - A +2°F (adj.) offset from occupied cooling setpoint
  - A -2°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates
- Unoccupied Mode (night setback): The unit shall maintain
  - A +6°F (adj.) offset from occupied cooling setpoint
  - A -6°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates

If at any time, the occupancy sensor (if present) detects people in the space, the zone shall be indexed to Occupied Mode until the detected occupancy plus any delays again detects no occupancy.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

1.8.1.1 Demand Limiting - Zone Setpoint Optimization:

To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

1.8.1.2 Zone Setpoint Adjust:

The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

1.8.1.3 Zone Optimal Start:

The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

1.8.1.4 Zone Unoccupied Override:

A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

1.8.2 Constant Volume Terminal Unit - Flow Control:

The unit shall maintain constant airflow through one of the following:

Standby:

- The zone damper shall modulate to a constant unoccupied airflow (adj.) distributed into the zone.
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its unoccupied heating setpoint.

Occupied:

- The zone damper shall modulate to maintain a constant occupied airflow (adj.) distributed into the zone.
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its heating setpoint.

Unoccupied:

- The zone damper shall modulate to a constant unoccupied airflow (adj.) distributed into the zone.
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its unoccupied heating setpoint.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the damper is rated for 100 cfm, the controller shall send 100 requests when it is fully open. The operator shall have the ability to suppress requests for any damper that is deemed to be out of service.

1.8.2.1 Cooling energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{EC\% * CFM * (ZONE - SAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

EC% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan times the VFD fan speed
ZONE = Zone temperature
SAT = Supply Air Temperature

1.8.3 Variable Volume Terminal Unit - Flow Control:

The unit shall maintain zone setpoints by controlling the airflow through one of the following:

Standby:

- When zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is less than the cooling setpoint, the zone damper shall control to its minimum unoccupied airflow (adj.).

Occupied:

- When zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is less than the cooling setpoint, the zone damper shall maintain the minimum required zone ventilation (adj.).

Unoccupied:

- When the zone is unoccupied the zone damper shall control to its minimum unoccupied airflow (adj.).
- When the zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the damper is rated for 100 cfm, the controller shall send 100 requests when it is fully open. The operator shall have the ability to suppress requests for any damper that is deemed to be out of service.

1.8.3.1 Cooling energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{EC\% * CFM * (ZONE - SAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run}\left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

EC% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan times the VFD fan speed
ZONE = Zone temperature
SAT = Supply Air Temperature

1.8.4 Fan Control - Parallel:

The fan shall run whenever the zone controller calls for heat. The fan shall run for a minimum user definable time (adj.). If the AHU is not running, the zone damper will close completely to prevent the unit fan from blowing air back into the supply duct. In the unoccupied mode, the damper will remain closed and fan will cycle on when the space temperature drops below the effective heating setpoint.

1.8.4.1 Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = ECM\%^3 \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

ECM% = Fan Speed Command Signal (or feedback)
Volts = Equipment supply voltage
Amps = The sum of all fan loads
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.8.5 Fan Control - Series:

The fan shall run anytime the unit is commanded to run. The fan shall run for a minimum user definable time (adj.). The zone damper will close completely before the fan starts to prevent air from the AHU from causing the fan to spin backward. The zone damper will return to automatic control after the fan starts. In the unoccupied mode, the damper will remain closed and fan will cycle on when the space temperature drops below the effective heating setpoint.

1.8.5.1 Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = ECM\%^3 \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run} \left(kW * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

ECM% = Fan Speed Command Signal (or feedback)
Volts = Equipment supply voltage
Amps = The sum of all fan loads
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.8.6 Reheating Coil Valve:

The controller shall measure the zone temperature and modulate the reheating coil valve open on dropping temperature to maintain its heating setpoint

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

1.8.6.1 Reheating - High Discharge Air Temperature Limit:

The controller shall measure the discharge air temperature and limit reheating if the discharge air temperature is more than 15°F (adj.) above the zone temperature.

1.8.6.2 Coil energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{CFM * (SAT - DAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run}\left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

CFM = The measured flow of terminal box
SAT = Supply air temperature from AHU
DAT = Discharge Air Temperature

1.8.7 Discharge Air Temperature:

The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

1.9 LABORATORY ROOM PRESSURIZATION SYSTEMS

1.9.1 Run Conditions - Scheduled:

The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: Scheduled times when the facility is deemed to be fully occupied (>25% capacity), the unit shall maintain
    - A 74°F (adj.) cooling setpoint with a 2°F hysteresis
    - A 70°F (adj.) heating setpoint with a 2°F hysteresis
    - Occupied ventilation rates

- Standby Mode: Scheduled occupied times when the facility is deemed to be lightly occupied by an occupancy sensor (if present) or time of day schedule. During Standby mode the unit shall maintain
  - A +2°F (adj.) offset from occupied cooling setpoint
  - A -2°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates
- Unoccupied Mode (night setback): The unit shall maintain
  - A +6°F (adj.) offset from occupied cooling setpoint
  - A -6°F (adj.) offset from occupied heating setpoint.
  - Unoccupied ventilation rates

If at any time, the occupancy sensor (if present) detects people in the space, the zone shall be indexed to Occupied Mode until the detected occupancy plus any delays again detects no occupancy.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

1.9.1.1 Demand Limiting - Zone Setpoint Optimization:

To lower power consumption, the zone temperature setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

1.9.1.2 Zone Setpoint Adjust:

The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

1.9.1.3 Zone Optimal Start:

The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

1.9.1.4 Zone Unoccupied Override:

A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

1.9.2 Supply Air Damper Control:

The unit shall maintain zone setpoints by controlling the airflow through one of the following:

Occupied:

- When zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is less than the cooling setpoint, the zone damper shall maintain the minimum required zone ventilation (adj.).

Standby:

- When zone temperature is greater than its standby cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is less than the standby cooling setpoint, the zone damper shall control to its minimum unoccupied airflow (adj.).

Unoccupied:

- When the zone is unoccupied the zone damper shall control to its minimum unoccupied airflow (adj.).
- When the zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the damper is rated for 100 cfm, the controller shall send 100 requests when it is fully open.

1.9.2.1 Cooling energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{EC\% * CFM * (ZONE - SAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run}\left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

EC% = Fan Speed Command Signal (or feedback)
CFM = The rated flow of the fan times the VFD fan speed
ZONE = Zone temperature
SAT = Supply Air Temperature

1.9.3 Reheating Coil Valve:

The controller shall measure the zone temperature and modulate the reheating coil valve open on dropping temperature to maintain its heating setpoint. Upon an initial call for control, hold the valve closed until the PID calls for at least 15% control signal in order to extent valve life.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the coil is rated for 10 gpm, the controller shall send 10 requests when it is fully open. The operator shall have the ability to suppress requests for any valve that is deemed to be out of service.

1.9.3.1 Reheating - High Discharge Air Temperature Limit:

The controller shall measure the discharge air temperature and limit reheating if the discharge air temperature is more than 15°F (adj.) above the zone temperature.

1.9.3.2 Coil energy reporting (air-side calculation)

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days. and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- kBtu/hr – Instantaneous energy demand
- kBtu – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kBtu/hr = \frac{CFM * (SAT - DAT) * 1.08}{1000}$$

$$kBtu = \sum_{Run} \left(kBtu/hr * \left(\frac{10\ min}{60\ min/hr} \right) \right)$$

Where:

CFM = The measured flow of terminal box
SAT = Supply air temperature from AHU
DAT = Discharge Air Temperature

1.9.4 Discharge Air Temperature:

The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

1.9.5 Fume Hood Flow Control

The fume hood controller shall monitor the sash position of the fume hood and modulate the fume hood exhaust dampers as follows:

- The controller shall calculate the total open area as indicated by sash position.
- The controller shall calculate the fume hood exhaust cfm required to maintain the average face velocity at the airflow velocity setpoint for the open area of the fume hood.
- The controller shall modulate the fume hood exhaust terminal box to maintain the fume hood exhaust setpoint.

1.9.6 Laboratory Exhaust Control

The laboratory controller shall measure the laboratory general exhaust cfm and modulate the laboratory exhaust damper as follows:

- The controller shall totalize the exhaust airflow of all fume hoods in the laboratory.
- The controller shall calculate the general exhaust cfm required to maintain the room pressurization offset cfm at its setpoint. The exhaust cfm setpoint is equal to the laboratory pressurization offset cfm, plus the sum of all fume hood cfm, minus the supply air cfm.
- The controller shall modulate the general exhaust terminal box to maintain the laboratory exhaust cfm setpoint.
- If the exhaust damper is at its minimum position and the laboratory cfm offset is not met, override the supply damper to maintain the laboratory offset cfm at its setpoint.

The controller shall send a setpoint request value proportional to its rated capacity to its parent equipment for setpoint optimization. For example, if the damper is rated for 100 cfm, the controller shall send 100 requests when it is fully open.

1.10 Laboratory Exhaust Systems (N+1 Fans)

1.10.1 Exhaust Fans Lead/Lag/Standby Operation:

The exhaust fans shall operate in a lead/lag/standby fashion.

- The lead fan shall run first.
- Upon start up, the lead fan isolation dampers shall open. When the lead fan dampers have been proven open, the lead fan shall run at its minimum speed. Index the fan and dampers for exhaust duct static pressure control.
- On failure of the lead fan, the standby fan isolation dampers shall modulate open. When the standby fan dampers have been proven open, the standby fan shall run and the lead fan shall turn off.

- On decreasing duct differential pressure, the lag fans shall stage on in sequence and run in unison with the lead fan to maintain duct differential pressure setpoint.
- On rising differential pressure, if the bypass damper exceeds 75% open (adj.), the fans shall stage off in sequence.

The designated lead fan shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Upon a command to rotate the fans, start the standby fan at 25% and open the standby isolation damper. Allow the bypass damper to maintain exhaust duct static pressure. Ramp the standby fan up to match the lead fan and disable the lead fan while closing its isolation dampers. Designate the standby fan as the new lead fan.

Alarms shall be provided as follows:

Exhaust Fan 1

- Failure: Commanded on, but the status is off.
- Running in Hand: Commanded off, but the status is on.
- Runtime Exceeded: Status runtime exceeds a user definable limit.
- VFD Fault.

Exhaust Fan 2

- Failure: Commanded on, but the status is off.
- Running in Hand: Commanded off, but the status is on.
- Runtime Exceeded: Status runtime exceeds a user definable limit.
- VFD Fault.

1.10.1.1 Exhaust Duct Static Pressure Control:

The controller shall measure exhaust duct static pressure and exhaust plenum static pressure, and modulate the exhaust fan VFD speed first, and bypass dampers second to maintain an exhaust duct static pressure setpoint of 2 in H2O (adj.). If the exhaust duct static pressure sensor becomes unreliable, the exhaust plenum static pressure sensor shall become the controlled sensor. If the exhaust fan is running at its minimum speed, the bypass damper shall be indexed for operation and shall modulate to maintain exhaust duct static pressure at its setpoint.

Once the fans have reached a steady state condition, the static pressure setpoint shall be reset based on zone cooling requirements.

- The initial duct static pressure setpoint shall be 1.0 in H2O (adj.).
- As airflow demand increases, the setpoint shall incrementally reset up to a maximum of 2.0 in H2O (adj.).
- As airflow demand decreases, the setpoint shall incrementally reset down to a minimum of 0.35 in H2O (adj.).

An example calculation is as follows, all actual values to be selected based on the existing system requirements:

Every 2 minutes (adj.) the controller will poll the zone dampers and determine the # of requests (dampers above 90% open). The controller will trim the setpoint by 20% (adj.) of the setpoint span. The controller will respond by adding the trim value divided by 10% (adj.) of the dampers, multiplied by the total number of open dampers (approximately 10% of your system dampers to balance out the trim & respond equation).

$$Setpoint_{New} = Setpoint_{Old} - Trim + Respond(Requests)$$

Example Values:

- $\text{Setpoint}_{\text{Min}}$ = 0.35 in H2O
- $\text{Setpoint}_{\text{Max}}$ = 2.0 in H2O
- TotalZones = 50 zone dampers
- $\text{Setpoint}_{\text{Span}}$ = 2.0 in H2O – 0.35 in H2O = 1.65 in H2O
- Trim = $\text{Setpoint}_{\text{Span}}$ * 20% = 0.33 in H2O
- Respond = Trim/(50 dampers * 10%) = 0.066 psi/request

Alarms shall be provided as follows:

- High Exhaust Duct Static Pressure: If the exhaust duct static pressure is 25% (adj.) greater than setpoint.
- Low Exhaust Duct Static Pressure: If the exhaust duct static pressure is 25% (adj.) less than setpoint.

1.10.1.2 Variable Volume Fan Runtime Energy reporting

The controller shall determine the energy demand by trending the following points at 10-minute intervals and shall be historically archived for a minimum of 365 days.

- Runtime – Run – Actual equipment runtime
- Equip kW – Instantaneous energy demand
- Equip kWh – Energy usage over time calculated as a least squares integration (or similar)

These values are calculated as follows:

$$kW = \text{VFD\%}^3 * \frac{Volts * Amps * \sqrt{Phase} * PF}{1000}$$

$$kWh = \sum_{Run}\left(kW * \left(\frac{10\ min}{60\ min/hr}\right)\right)$$

Where:

Volts = Equipment supply voltage
Amps = The sum of all fan loads
VFD% = The output speed of the VFD
Phase = 1 or 3 phase
PF = Power Factor, assumed or measured

1.11 ENERGY TRACKING

1.11.1 Energy Meters and Calculations:

The controller shall monitor the KW, chilled water kBtu, hot water kBtu, steam, and any other energy calculations for energy consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the energy meter.

1.11.2 Peak Demand History:

The controller shall monitor and record the peak (high and low) demand readings from the energy meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.11.3 Usage History:

The controller shall monitor and record energy meter readings so as to provide an energy consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

1.11.4 Energy Normalization

The controller shall have the ability to display all energy meters and calculations in the facility's billable units (i.e.: kW, kWh, ccf, Btu, lbs/hr, etc.). In addition, the controller shall normalize all units to kBtu for EUI (Energy Use Index) calculations.

1.11.5 Energy Totalizations

The system shall totalize the peak demand and consumption data for each area in the facility as well as a total energy rollup. An area is defined as a space or collection of spaces with similar usage and scheduling patterns. The BAS submittal shall include proposed totalizations and an example of the energy dashboards for approval.

Examples of Facility Areas may include:

- Floors – All of the equipment serving a floor of a multi-story building
- HVAC System Zones – Zones served by an AHU and all of its child equipment

- Category Loads – A totalization of all loads that fit within HVAC, Lighting, Plug Load, etc. categories
- HVAC energy types – A totalization of all energy meters and calculations that originate from a main source. Examples include Electrical kWh and kw; chilled water kBtu, hot water kBtu, etc.

1.12 SYSTEM DASHBOARDS

1.12.1 Energy Dashboards

Energy Dashboard graphics shall be provided at each totalization location. The dashboard shall display energy data in a graphical format. Tabular data shall not be acceptable. The dashboards shall display the following information at a minimum:

- Instantaneous demands for each energy monitored
- Peak historic demand and the date the peak was set for each energy monitored
- Instantaneous demand as a percent of its peak.
- Total energy normalized to kBtu and a chart comparing each energy source (stacked bar chart, pie chart, etc.)

1.12.2 Energy Intensity Floorplan Graphic

Energy intensity graphics shall be provided at each totalization location. The dashboard shall display energy intensity data in a thermographic floorplan. Tabular data shall not be acceptable. The dashboards shall display the following information at a minimum:

- Each zone shall have a color corresponding to the energy used as a percentage of its peak load.
- Links to each totalization zone or equipment

1.12.3 Air Handling Systems Dashboard

The intention of an Air Handling Systems Dashboard is to display on a single screen Key Performance Indicators (KPI) for all the AHUs in a building.

In addition to the standard air handling unit graphics, provide AHU system dashboard graphics which display information from all the AHUs in the building. The dashboard shall display AHU data in a graphical format. Tabular data shall not be acceptable. The dashboards shall display the following information at a minimum:

- Source Hot and Chilled Water supply temperatures
- AHU Supply Air Temperature, Airflow, Down Duct Static Pressure, Fan Speed
- VAV Box summary information per AHU: # zones in heating, cooling, satisfied
- Links to each piece of equipment

1.12.4 VAV System Dashboard

The intention of a VAV System Dashboard is to display on a single screen Key Performance Indicators (KPI) for an entire VAV terminal box system.

In addition to the standard air handling unit graphics, provide VAV box system dashboard graphics which display information from the VAV boxes served by each AHU in real time. The dashboard shall display vav box data in a graphical format. Tabular data shall not be acceptable. The dashboards shall display the following information at a minimum:

- AHU Supply Air Temperature, Airflow, Down Duct Static Pressure, Fan Speed
- VAV Box Zone Temperature, Zone Temperature Setpoints, Damper Position, Airflow, Airflow Setpoint, Reheat status (if applicable), Fan Status (if applicable)
- Links to each piece of equipment

1.12.5 Chilled Water System Dashboard

The intention of a Chilled Water System Dashboard is to display on a single screen Key Performance Indicators (KPI) for an entire chilled water system.

In addition to the standard chilled water graphic, provide a chilled water system dashboard graphic to display information about the cooling coils in real time. The dashboard shall display cooling coil data in a graphical format. Tabular data shall not be acceptable. The dashboards shall display the following information at a minimum:

- Chiller Status(s), Chilled Water Supply Temperature and Setpoint
- Chilled Water Pump(s) Status, Chilled Water Differential Pressure and Setpoint
- Each Cooling Coil Valve Position, Each Cooling Coil Leaving Temperature, Each Cooling Coil Leaving Water Temperature if available
- Links to each piece of equipment

2 ALARMS AND REPORTING ACTIONS

2.1 ALARM CATEGORIZATION

Alarms shall be configured within the following categories. The commissioning authority and owner shall have final approval on all alarm setup and activation.

- HVAC Critical – Alarms that indicate that HVAC equipment is potentially damaged or that damage is imminent. Examples include: Freezestats, Smoke Detectors, Fan Failure.
- HVAC General – Alarms that indicate an HVAC condition is out of normal operation. Examples include: Zone Temperature Alarms, Setpoint alarms, and most other alarms.
- HVAC Maintenance – Alarms that indicate HVAC equipment maintenance is required. Examples include: Dirty Filters, and Motor Runtime.
- HVAC Energy - Alarms that indicate HVAC energy is being wasted. Examples include: Motor in Hand, Leak Detection, and PID Hunting.

2.2 ALARM ACTIVATION

When the BAS is merged into the main database, Alarms shall be activated according to their Category

- HVAC Critical – Alarms shall be enabled for reporting and shall require operator acknowledgement. A reporting action shall be assigned. A return-to-normal notification shall be received at the head end but shall not require acknowledgement. Escalations shall be configured. All alarms shall be historically archived to the alarms database.
- HVAC General – Alarms shall be initially disabled for reporting. If the alarm is enabled, a reporting action shall be assigned, and it shall require operator acknowledgement. A return-to-normal notification is not necessary. Escalations shall not be configured.
- HVAC Maintenance – Alarms shall be initially disabled for reporting. If the alarm is enabled, a reporting action is not necessary and it shall not require operator acknowledgement. A return-to-normal notification is not necessary. Escalations shall not be configured.
- HVAC Energy - Alarms shall be initially disabled for reporting. If the alarm is enabled, a reporting action shall be assigned, and it shall require operator acknowledgement. A return-to-normal notification is not necessary. Escalations shall not be configured.

All enabled alarms shall be historically archived to the alarms database.

2.3 ALARM REPORTING ACTIONS

Reporting actions are notifications through various platforms in order to elicit a response from facilities staff and service contractors. Reporting actions shall be configured as needed and the commissioning authority and owner shall have final approval on all alarm setup and activation.

Examples of reporting actions are as follows:

- Alarm Popup: A pop-up window shall display on the front end computer screen.
- Email: An email shall be sent to a user or user group
- Text: A text message shall be sent to a user or user group
- Alphanumeric Page: A pager message shall be sent to a user or user group
- Print: The alarm shall be sent to a print service. This can either be a physical printer which prints to a spool of media, or a virtual print service which appends a file.
- 3rd Party Database Write: The alarm information shall be sent to a software platform residing in the cloud or on another server. An example might be a maintenance dispatching service or an analytics platform
- Run an External Program: An external program can be run upon activation of the alarm. A typical example is a sound being played through the computer's speakers or a light illuminating.

2.4 ALARM TEMPLATES

All alarms shall be configured so that the operator can easily determine the source of the alarm. Each alarm reporting action shall contain the following information:

1. Building code
2. Equipment Code
3. Alarm Name
4. Alarm Details
5. Timestamp
6. Link to the source equipment within the BAS

2.5 ALARM ESCALATIONS

Alarms reporting actions shall have the ability to escalate if the alarm has not been acknowledged. Escalations shall have a user definable delay before an additional reporting action is triggered.

An example escalation is as follows:

1. First Notification: The alarm is received at the front end. A pop-up notification is displayed on the operator's screen and a visual indication is shown within the graphic of the equipment. Upon acknowledgement, the alarm, timestamp, and operator acknowledging the alarm are archived to the alarms database.
2. Second Notification: If the alarm has remained unacknowledged for 10 minutes, a text shall be sent to the operators on duty.
3. Third Notification: If the alarm has remained unacknowledged for 20 minutes, a text shall be sent to the manager on duty.
4. Fourth Notification: If the alarm has remained unacknowledged for 30 minutes, a text shall be sent to the facilities director.
5. Etc.