Appendix A – Design Standards: BMS Control Applications

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Scope

This design guide deals with HVAC control applications which are programmed in the BMS. From the date of its issue this guide should be followed as far as practicable accepting the need for existing work in progress to follow previous guidelines.

The design guide consists of six sections covering the following content.

- Temperature Control
- Humidity Control
- Variable Air Volume Systems
- Face-Bypass Air Handling Systems
- Secondary Chilled Water Systems
- Chiller Systems
- Heating Hot Water Systems

Purpose

The purpose of this guide is to create a degree of uniformity in the development of HVAC control applications to promote operational consistency, energy efficiency and to aid in troubleshooting. The intention is to develop a suite of control modules which embed best practice into the HVAC installations at UQ. Though the guide is targeted at the latest range of BMS field controllers, there is scope to apply the control principles to older field controllers that make up the existing Metasys system.

Related Guides and Standards

This guide should be used in conjunction with the following related guides:

- UQ Design Standards - Mechanical: Mechanical Plant & Equipment Numbering R1.1
- UQ Design Standards - Mechanical: BMS User Interface R1.1
- UQ Design Standards - Mechanical: BMS Critical Alarms R1.1

BMS Control modules

The BMS incorporates a library of control modules which can be selected as required to configure the control logic for a particular application. The following specific modules should be used wherever possible to provide the control functions described in this document:

- Zone Temperature Error
- Supply Air Temperature Reset
- Supply Air Pressure Reset
- Secondary CHW Pressure Reset
- Cooling tower setpoint reset

1. Temperature Control

Room Temperature Control Setpoints

The setpoints listed below represent the university temperature control policy and are determined to provide universally accepted comfort levels.

The control points nominated in this document should not be confused with equipment design criteria. BMS programmers and mechanical contractors are required to achieve specification nominated setpoints at the time of commissioning, the setpoints nominated below do not override any other technical specification. Mechanical specifications may well call for equipment performance to achieve different design temperatures. Though the equipment may be built with this additional capacity the control setpoints nominated below should still apply once commissioned.

Standard Room Temperature Setpoints

Each controlled temperature zone has a common setpoint with cooling and heating setpoint offsets. There are further offsets for standby mode and unoccupied mode which should always be provided in the controller even if they are not to be immediately utilized. There is no need to map the additional offsets to the network engine unless they are specifically required. The effective cooling and heating setpoints should always be mapped so that it is immediately obvious what the current control points are:

Common Setpoint	Cooling Offset	Heating offset	Effective Cooling	Effective Heating
22.5°C	+1.5°C	-1.5°C	24.0°C	21.0°C
Standby Mode	+2.5°C	-2.5°C	25.0°C	20.0°C
Unoccupied Mode	+4.5°C	-4.5°C	27.0°C	18.0°C

Laboratory Temperature Setpoints

Laboratory air conditioning runs continuously but may still have setpoint relaxation dependent on the laboratory application. The setpoint relaxation is required to be programmed in the controller even if they are not to be immediately utilized as the laboratory function may change in the future.

Common Setpoint	Cooling Offset	Heating offset	Effective Cooling	Effective Heating
22.0°C	+1.0°C	-1.0°C	23.0°C	21.0°C
Standby Mode	+2.0°C	-2.0°C	24.0°C	20.0°C

Johnson Controls Specific Implementation Requirements

When using the default zone temperature setpoint determination module in the CCT configuration tool, the default behaviour is to use a network setpoint input, and a heating and cooling setpoint for each occupancy mode. These heating and cooling setpoints work in an unintuitive manner when the network setpoint is changed during operation. As such, when using the CCT setpoint determination module, occclg-sp and occhtgsp should be set to the same value and not bacnet exposed. The occ-clg-shift and occ-htg-shift points should be used to define the setpoint offsets tabled above. This configuration should be applied to all occupancy states (ie unocc and stdby).

Temperature setpoints for Specific Spaces

The following spaces have non-standard setpoints:

Specific Space	Common Setpoint	Heating offset	Effective Cooling	Effective Heating
Comms Room	24.0°C	N/A	24.0°C	N/A
Electrical Switch Rooms	26.0°C (1.0°C hysteresis)	N/A	26.0°C	N/A
Server Rooms	As Advised	N/A	Common Setpoint	N/A
Lift motor rooms	28.0°C	N/A	28.0°C	N/A
Specialist equipment Rooms	As Advised	N/A	Common Setpoint	Common Setpoint
CT Rooms	As Advised	N/A	Common Setpoint	Common Setpoint

Temperature Control Elements

The temperature control for all air handling equipment (including fan coil units etc) should be activated when the unit is scheduled to run and a fan status is received. This helps guard against heaters being called to operate when the fan does not start as normal and also allows the fan to run on to dissipate heat in the duct when the unit is scheduled to stop. Note: HPTs and hardwired fan interlocks are required.

Chilled water valves or compressor cooling call should be closed / off when the unit is scheduled to stop or a fan status is off.

VAVs and zone dampers should be closed when the unit is not operating. Appropriate time should be allowed during the startup routine to ensure the damper actuators have opened sufficiently to prevent damage from over-pressurization or damper shaft stress / slippage.

Zone Temperature Sensors

Zone sensors should be located away from supply air vents, direct sunlight and heat generating equipment. Sensors should not be located on external walls, ceilings or bulkheads. The preferred location will be generally in the return air path and if no suitable location can be found then a sensor in the return air duct is acceptable, keeping in mind that the sensor needs to represent the space within which occupants reside.

Room sensors should be mounted at about 1.5m above finished floor level (or 1.2m where a setpoint adjustment or after hours button is included – for accessibility for persons with disability).

Room sensors should be mounted in an enclosure which insulates from the surface which it is mounted and all penetrations should be sealed to prevent wall cavity, conduits, etc from influencing the sensor reading.

Where multiple sensors are provided then the control logic should include the ability to ignore sensors with unreliable readings. The ability to manually de-select a specific sensor from the control sensor should also be included. If the sensor value falls outside the normal range for the space, then this should be indicated on the graphics.

When multiple sensors are used the control function must be clearly recorded on the graphics pages (average, high select, low select or other combination).

Supply Air Temperature

Supply air temperature sensors should be included for any air handling unit above 300 l/s supply air. The monitored supply air temperature can be used to confirm chilled water valve operation and can be used for supply air reset control where required.

Mounting locations of supply air temperature sensors should represent the mixed temperature in the supply air duct and should be located accordingly. Access to the sensor and a calibration hole (plugged) should be considered during installation.

Operating modes

Standby Mode

The intent of Standby Mode is to allow a relaxation of conditions to save energy in such a way that when the space is required it can quickly return to normal operating temperatures. When a space is not required it should be scheduled to Unoccupied mode which will turn off the air conditioning completely.

Standby operating mode is usually employed with some determination for occupancy such as motion detectors, local switches or central room booking systems. It is not desirable to use AMX interfaces for this purpose.

All temperature control applications should include standby mode capability even if this is not immediately utilized. In standby mode the unit supply fan continues to run but the cooling and heating setpoints are relaxed to conserve energy. Standby mode would typically be used for the following purposes:

- To provide out of hours setpoint set back where continuous air turnover is required in the space but not tight temperature control.
- To provide out of hours setpoint setback in pressure controlled spaces.
- To provide occupancy setpoint setback.
- To disable heating where this is not a built in function of the controller
- To provide temperature relaxation during the half hour pre-start for rooms scheduled from syllabus plus.

Unoccupied Mode

The intent of Unoccupied Mode is to relax setpoints for spaces which are not being used but share air-conditioning equipment with spaces which are occupied. When all spaces served by an air-conditioning unit are not required it should be scheduled OFF.

Fire Alarm Mode

When a fire alarm is activated, the BMS control of fans should replicate the requirements of the fire matrix. The BMS cannot be used for fire control functions. The BMS should suppress the standard alarms related to the fan status and room temperatures. All VAVs should drive their actuators to 100% open position.

Sensor selection and installation

Sensors need to be selected with a range and resolution appropriate to the application. Each sensor will be installed in an accessible location which is accurately representative of the medium being measured. Each sensor will be labelled and marked on drawings and graphics pages (every field point should be shown on graphics). Sensors need to be installed in locations which are not effected by upstream or downstream devices. For example, a velocity grid on a VAV cannot be installed directly after a damper. Another example is, supply air temperature sensors installed too close to a coil.

Control equipment selection and installation

Control valves

Control valves need to be of a suitable type and sized specifically for the application. For chilled water and heating hot water control, characterized ball valves should be used for their superior performance and low pressure drop. Butterfly valves typically are not suitable for temperature or pressure control action. On large units, multiple valves may be required to achieve accurate control at low loads. In such cases the valves should be controlled in series with the first valve opening fully before the second valve.

Damper actuators

Like the control valves, dampers and their actuators need to be selected to achieve design requirements. Keep in mind that opposed blade dampers are often limited in their ability to control accurately when less than 30% from their fully closed position. Their control action is not linear to the actuator position.

Tuning Parameters for Room temperature control

Temperature control will typically use proportional and integral terms (PI). Tuning parameters should be set to avoid slow response or hunting. For JCI zone temperature control, a proportional band of 4.0 and integral term of 0.1 repeats per minute are a good starting point and the integral deadband set to 0.2.

Control systems which utilize auto-tuning should ensure that the auto-tune process itself is carried out when all control elements are fully commissioned and functioning in normal operating conditions. Thus the chilled water supply should be operating normally. Some auto-tune systems can de-tune when there is little control activity. This can be avoided by capturing the tuning parameters derived during the auto-tune process, saving these as default values for the tuning parameters and then disabling auto-tune. Auto tune does not indemnify the contractor from their tuning responsibilities.

When commissioning or tuning control loops, the technician is required to ensure the plant serving the system being tuned is operating normally and able to meet the required setpoints for the system. For example, when tuning an AHU, the chillers, heaters and ambient conditions are within normal design. Before tuning, carefully consider the equipment being controlled and the ability for the system to follow a setpoint. For example, an actuator with a motor drive time of 120 seconds may not have a response time suitable for tight temperature control.

Once the measured value is stable the setpoint should be changed by at least 2°C and the loop allowed to settle at the new setpoint. Once complete, return the setpoint to its normal position to perform a final check of the loop’s operation. If the output signal operation is stable and the control variable (measured value) is following setpoint, PI commissioning is complete. If any instability is observed, adjust the PI control setting and continue to re-test.

Commissioning will include documented tuning data, including:

- initial and final settings for PI
- sensor calibration data (offsets and measured values)
- the setpoint, output and measured values when adjusted
- screen shots of the final “tuned” control including measured value, setpoint and output signal

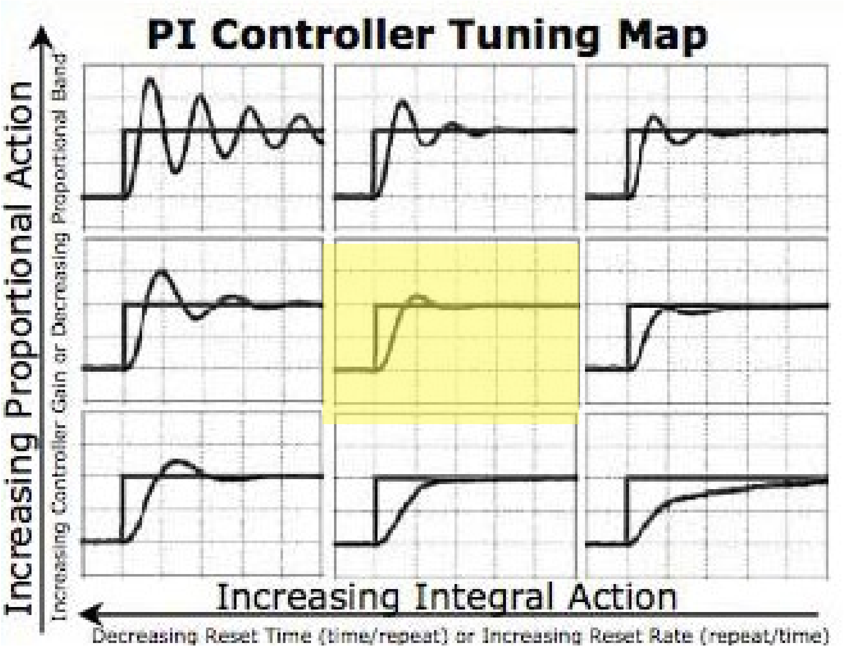


Figure 1 - PI - Highlighted preferred control

Narrow Temperature Dead-bands

Cooling and heating control is typically administered by a dual control module with the requirement to heat or cool determined from separate cooling and heating setpoints. For some systems the transition from cooling to heating takes place half way between the two setpoints. This can cause instability when the offset between cooling and heating is very narrow. If the space requires such a narrow dead-band, such as a constant temperature room, then steps should be taken to allow the cooling or heating control to drop to zero before changing control regime. This is an inbuilt function for most modern field controllers.

Johnson Controls Applications: Use of CCT MSC module for control of staged duct heaters

The default control program for control of duct heaters in CCT-programmed field controllers utilises a set of modules called multi-stage controllers (MSC). These modules operate in a similar way to a duration adjust output, wherein they pulse an on/off device to emulate analog 0-100% capacity control

These modules must be configured correctly based on the parameters of the switching equipment for the heater. The parameter of most importance is the control band input to the MSC module. The actual interaction of the control band variable is complex and best explained in the white paper provided by the JCI R&D department. In practice, there are two key effects:

- The control band acts as an additional deadband around the heating setpoint. The heating PID will never ramp and the DO will never stage on unless the temperature < (setpoint – controlband/2.)
- The smaller the control band, the more frequently the heater will be pulsed, subject to the specified minimum on and minimum off times.

Experience with previous installations on campus is that when process ID is set to ZN-T in the default staged heating module, the control band and minimum on/off times are unnecessarily large for an SCR-controlled heater, which is designed to be switched every ~10 seconds for many years. In addition, with older installations controlled via mechanical relay, the extra setpoint relaxation introduced by the control band was found to significantly increase the response time of the system, in a way that PRAC tuning did not respond to.

Based on the above, recommended MSC parameters for SCR-controlled heaters are:

- Control band: <0.5 degrees
- Minimum on/off time: 10-20 seconds

Recommended MSC parameters for mechanical relay-switched heaters are:

- Control band: 0.5 degrees
- Minimum on/off time: 3-4 minutes

Alarms

The “UQ Design Guide BMS Critical Alarms” should be read in conjunction with this guide.

The size of the UQ Building Management System has led to the alarm handling system becoming unmanageable. Any alarms that are considered critical should be posted to the UQ St Lucia Security alarm handling system. See UQ Design Guide BMS Critical Alarms for more detail.

Any other alarms should be configured such that they only appear on the BMS graphics or are sent to the alarm repository as pre-acknowledged alarms. The following tables summarise the alarm categories and the corresponding action.

Alarm Group	Alarm Justification
1 Critical	Immediate action is required to minimise risk, protect mechanical plant, equipment or environments, save experiments or the contents of cold rooms and freezers
2 Important	Timely action is required to address mechanical plant or equipment faults which have the potential to escalate if not addressed
3 Notification	Maintenance is required to rectify HVAC malfunction, mechanical plant or equipment faults

The following table specifies the alarm handling for each group.

Alarm Group	Alarm Handling
1 Critical	Alarm posted to the campus alarm callout system for action by Security Auto-acknowledged alarm sent to the ADX event repository Data object highlighted by red exclamation mark and graphic symbol.
2 Important	Alarm sent to the ADX event repository with specific priority and category Alarm filtered to user, email or SMS based on category and priority Data object highlighted by red exclamation mark and graphic symbol.
3 Notification	Alarm not sent to event repository Data object highlighted by red exclamation mark and graphic symbol.

In general, alarms will be configured with appropriate alarm inhibits to prevent false alarms when equipment is not operating. For example, room temperature alarms will not activate when the unit serving the space is not enabled; additionally, a delay before the alarm is activated will apply to allow the unit time to bring the space to the setpoint after start-up.

2. Humidity Control

Humidity Control Setpoints

Typically, humidity is achieved through the normal cooling process and additional de-humidification or re-humidification is not required on the majority of spaces throughout the university. It is anticipated that unit selection and standard control practice will achieve 50% RH +/- 10% through standard design practice. This may include the provision of separate units to precondition outside air. This section applies where the space has close control requirements or specific humidity requirements.

The control points nominated in this document should not be confused with equipment design criteria. BMS programmers and mechanical contractors are required to achieve specification nominated setpoints at the time of commissioning, the setpoints nominated below do not override any other technical specification. Mechanical specifications may well call for equipment performance to achieve different design conditions. Though the equipment may be built with this additional capacity the control setpoints nominated below should still apply once commissioned.

Humidity control setpoints will vary depending on the specific use of the room and whether high and low humidity control is required. Setpoints are listed below for a typical laboratory with high humidity control only and a controlled environment room with full humidity control.

Standard Laboratory Humidity Setpoints

Laboratory air conditioning runs continuously but may still have setpoint relaxation.

Common Setpoint	Dehum Offset	Humidifier offset	Effective Dehumidifying	Effective Humidifying
65.0%RH	0.0%RH	N/A	65.0%RH	N/A
Standby Mode	+10.0%RH	N/A	70.0%RH	N/A

Controlled Environment Room

The setpoints for these spaces are specific to the requirements of the room and tend to have tighter dead-bands and no relaxation. The common setpoint below uses 50%RH as an example only:

Common Setpoint	**Dehum Offset**	**Humidifier offset**	**Effective Dehumidifying**	**Effective Humidifying**
50.0%RH	+5.0%RH	-5.0%RH	55.0%RH	45.0%RH

Humidity Control Elements

The humidity control for an air handling unit should be activated when the unit is scheduled to run and a fan status is received. This guards against heaters being called to operate when the fan does not start as normal and also allows the fan to run on to dissipate heat in the duct when the unit is scheduled to stop.

Zone Humidity Sensors

Zone sensors should be located away from supply air vents, direct sunlight and heat or humidity generating equipment. The preferred location will be generally in the return air path and if no suitable location can be found then a sensor in the return air duct is acceptable.

Where multiple sensors are averaged then the control logic should include the ability to ignore sensors with unreliable readings. The ability to select a specific sensor to be the control sensor should also be included.

Reheat Dehumidification

A common form of dehumidification control is to over-cool the supply air below the ambient dew-point causing water to condense on the cooling coil and reduce the absolute humidity in the supply air. Downstream heating is then used to restore temperatures to normal comfort levels. This is the preferred method at UQ. A second approach to drive the heating on first to create a false heat load within the space which in turn creates a call for cooling should not be used. The selection of equipment which is able to provide this functionality with higher energy efficiency is preferred in order to reduce the ongoing operating costs.

In applications requiring dehumidification, it is most energy efficient to use as low an off coil temperature as possible. For example, in a face/bypass air handler, a 0-100 dehumidification PID output should reset the off coil temperature down to ~10 degrees over the first few percent of output.

Reheat dehumidification requires that both cooling and heating are operational and that the cooling capacity does not greatly exceed the heating. A limit should be implemented to prevent the overcooling dehumidification from excessively cooling the space in the event of a heater failure. This is most easily achieved by limiting dehumidification output as temperature drops significantly below the heating setpoint.

Tuning Parameters

Humidity control should typically use proportional and integral terms but proportional only is acceptable for older controllers limited by process module capacity. Tuning parameters should be selected to avoid conflict with the temperature control which operates in parallel. The temperature control should be given precedence and set to be faster than the humidity control action. This encourages a system which will quickly achieve stable temperature and then graduate towards the correct the humidity without unduly affecting the temperature control functionality.

Dehumidifiers and Humidifier Plant

Dedicated dehumidifying and humidifying plant is used when precise and reliable humidity control is required. These will have specific control interfaces dependent on the equipment installed and can have operational anomalies which need to be adjusted for.

Steam humidifiers heat water to produce steam so there is a delay before any steam is produced when they are first activated. This can cause reset wind-up where the control output continues to ramp up during this initial heating period. This can be avoided with proportional only control or imposing a time delay between turning the humidifier on and commencing control.

Outside Air Pre-Conditioning

Where outside air pre-conditioning units are installed, all dehumidification control should be undertaken by the preconditioning unit.

The off coil temperature setpoint of the pre-conditioner should be scaled such that it quickly resets to minimum when a high select of the zone humidity sensors rise above setpoint. This control loop should be implemented as PI where controller capacity allows.

High Select Zone Humidity	Pre-Conditioner Off Coil Temperature Setpoint
60.0%RH	22.0°C
70.0%RH	10.0°C

The scale setpoints and all other operational data should be displayed on a dedicated graphics page for the pre-conditioning unit.

The pre-conditioner should run on a time schedule so that it stops during unoccupied periods where the outside air conditions are not high in humidity.

3. Variable Air Volume

VAV Operating Modes

The scheduled operating mode for each VAV Box is set according to the state of the associated air handling unit. The following diagram captures the different box operating modes relative to the associated air handling unit.

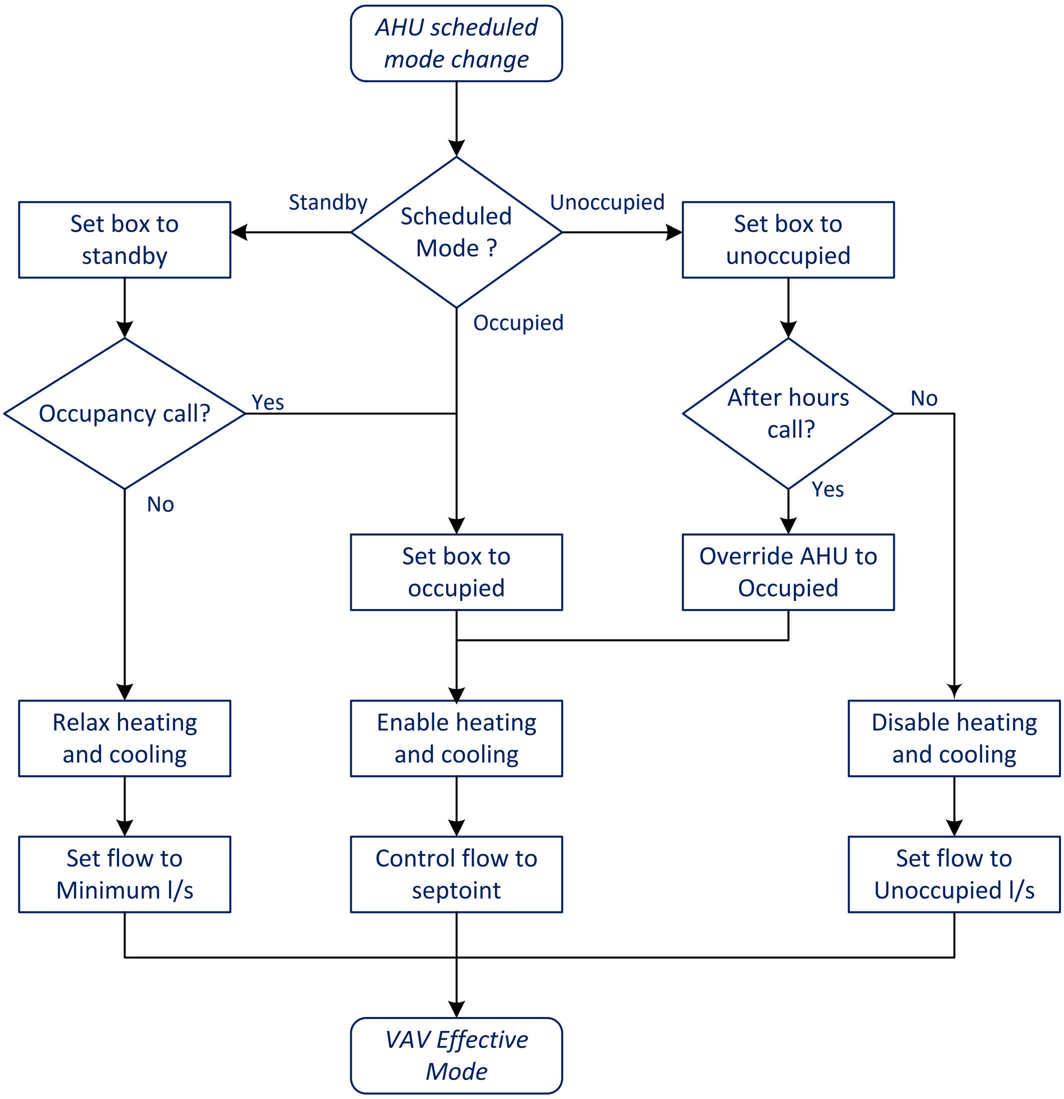


Figure 2 - VAV occupancy mode determination

If a VAV box receives a call for after-hours air conditioning then its scheduled mode is bypassed and it becomes occupied for the duration of the after-hours timer. During this time, the air handling unit is started via an occupied mode override flag. It is important that the remaining VAV boxes are left unoccupied unless they also receive an after-hours call. Hence the subsequent demand on the air handling unit temperature and pressure control is minimized. Similarly, spaces that use occupancy sensors will only trigger the occupied operation for VAV boxes to which the motion detector is attached.

Zone Temperature Setpoints

Zone setpoints should be set as listed in Section 1. It is important that the standby and unoccupied setpoints are set as this is an integral part of the supply air temperature reset. Multi-zone systems work best when setpoints are consistent from zone to zone. If one zone is independently set to a lower value then this will cause the supply air temperature to drop and other zones to reheat which is energy inefficient and can lead to occupancy comfort issues.

Zone Air Flow Setpoints

The VAV box controller has a set of flow set-points for each operating mode. The value entered for these setpoints dictate the extent of the control for each mode. It is therefore important that the setpoints are consistent with the required control strategy and are visible so that the subsequent control can be verified. The table below lists the flow setpoints which are entered for each VAV box and the conventions which should be followed.

Setpoint	Convention	Example Value
Max Occupied Flow	Maximum box design flow	300 l/s
Min Occupied Flow	Minimum box design flow	100 l/s
Occupied Heating Flow	Minimum box design flow	100 l/s
Standby Cooling Flow	*Minimum box design flow	100 l/s
Standby Heating Flow	Minimum box design flow	100 l/s
Unoccupied Cooling Flow	50% of minimum design flow	50 l/s
Unoccupied Heating Flow	50% of minimum design flow	50 l/s

The standby cooling flow stays at minimum unless the temperature rises above the relaxed cooling setpoint in which case the flow control emulates occupied mode. This ensures that the zone temperature is not too far from setpoint when the mode switches to occupied.

A tabular graphics page should be created for each AHU showing the associated VAVs and their relative live values and setpoints.

Cooling Mode - Supply Air Temperature Reset

Any multi-zone system includes an algorithm to determine the best temperature setpoint for the air supplied to the Variable Air Volume boxes. The preferred method at UQ is to determine the zone which is struggling most to maintain the zone cooling setpoint. This is achieved by subtracting the zone temperature from the effective zone cooling setpoint. This is called the zone cooling error and the highest zone cooling error is used to determine the supply air temperature.

Ideally the zone cooling error is calculated in the VAV controller, the reset logic lies in the AHU controller, and a signal select block in the NAE is used for network passthrough. For older VMA controllers, the entire calculation must reside in the network engine. Note the use of the effective cooling setpoint in the cooling error calculation. This means that any zone in standby mode or unoccupied will tend to have a low zone cooling error and is essentially discounted from the supply air temperature reset when a maximum select is used.

Example: Supply Air Temperature Reset with different operating modes

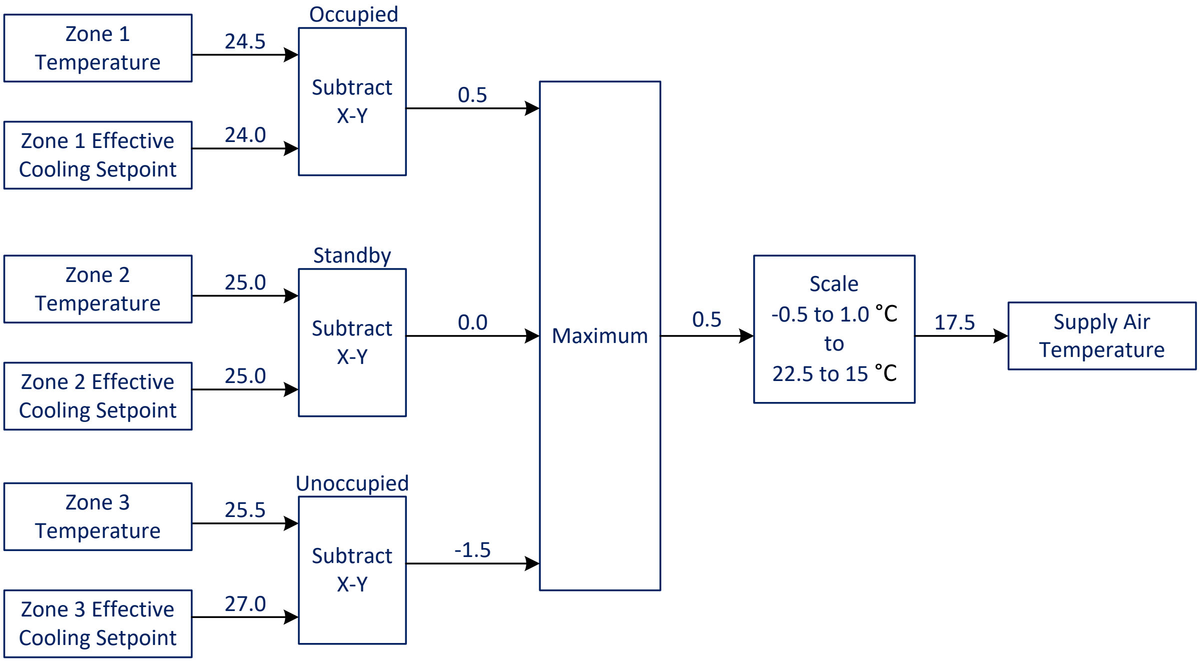
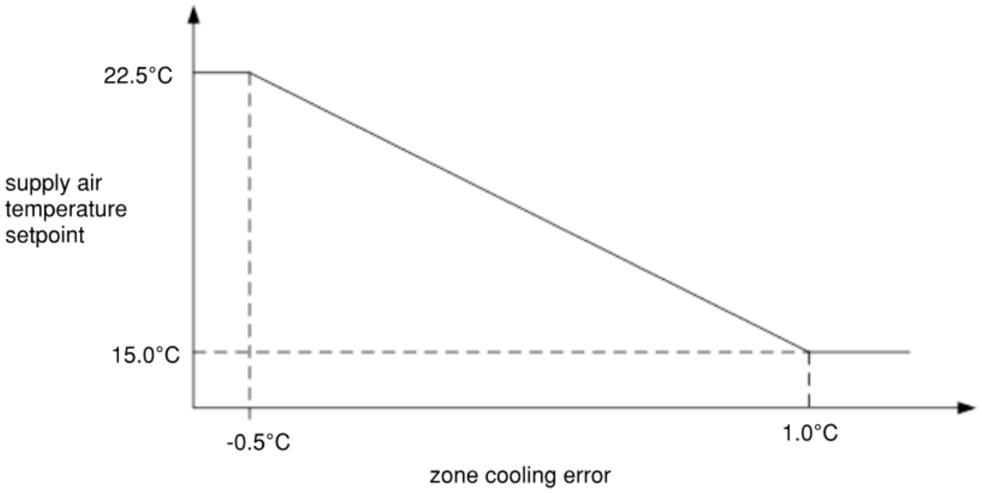


Figure 2: Supply Air Temperature Reset logic

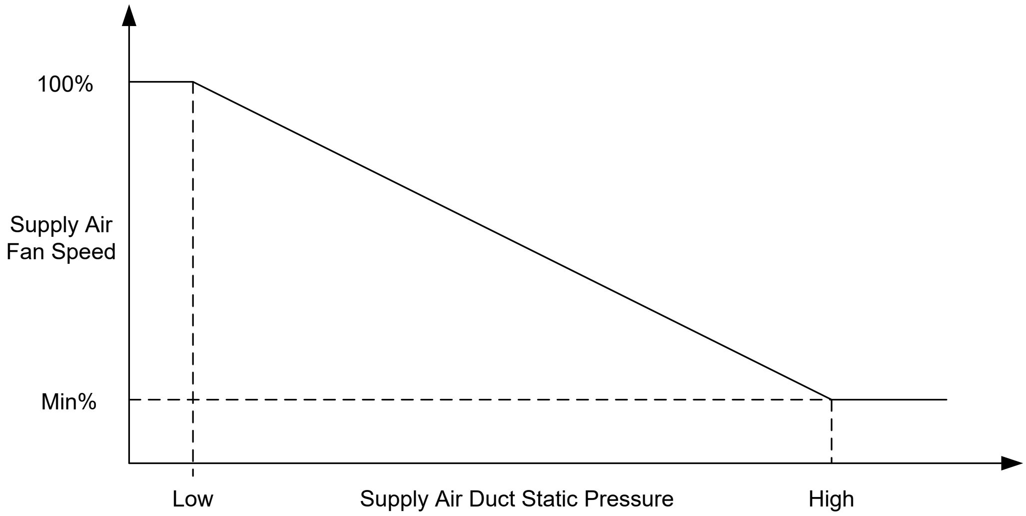


An alternative strategy is to use the average zone error. However, this does not work well where VAV boxes can be in standby or unoccupied mode. Instead some additional logic is required to eliminate zones which are not occupied form the average calculation. A combination strategy is also possible where both maximum and average calculations are used in combination with a percentage weighting applied to the contribution of each.

Supply Air Pressure Reset

Air handling units which serve VAV systems usually have variable speed drives on the supply air fans which control to maintain a pre-determined duct pressure. During commissioning each VAV box is driven to the maximum design air flow and the supply fan VSD is gradually ramped until the highest VAV damper position is around 90%. When this is achieved, the reading of the duct pressure sensor is captured as the supply air pressure setpoint.

When the box dampers are released to control temperature the duct pressure will rise as dampers become more closed and the fan will slow down accordingly. However, if all boxes drive to full flow then the pressure setpoint ensures that no box is starved of air.



Supply air pressure reset takes this one stage further by reducing the setpoint based on VAV box damper position. By maintaining the highest damper position to be between 80% and 90% it ensures that fan energy is primarily used to provide air flow rather than create unnecessary static pressure in the ductwork. The upper setting of the pressure setpoint should still be determined as described above to prevent starving boxes of air. The lower setpoint can be set by reducing all boxes to minimum flow and decreasing the fan speed until the most open damper is at 90%.

The Supply air pressure calculation should operate slowly, ideally recalculated every 5 minutes. Note that there are some legacy issues with damper position reporting on older vintage VAV Box controllers. In these circumstances the damper positions will not be sufficiently reliable for this supply air pressure reset logic to be successful.

Also note that pressure setpoints will be significantly lower for VAV diffuser systems that are operate best around 80 to 100 Pa whereas traditional VAV systems are typically around 200 to 250 Pa.

Example: Supply Air Temperature Reset with different operating modes

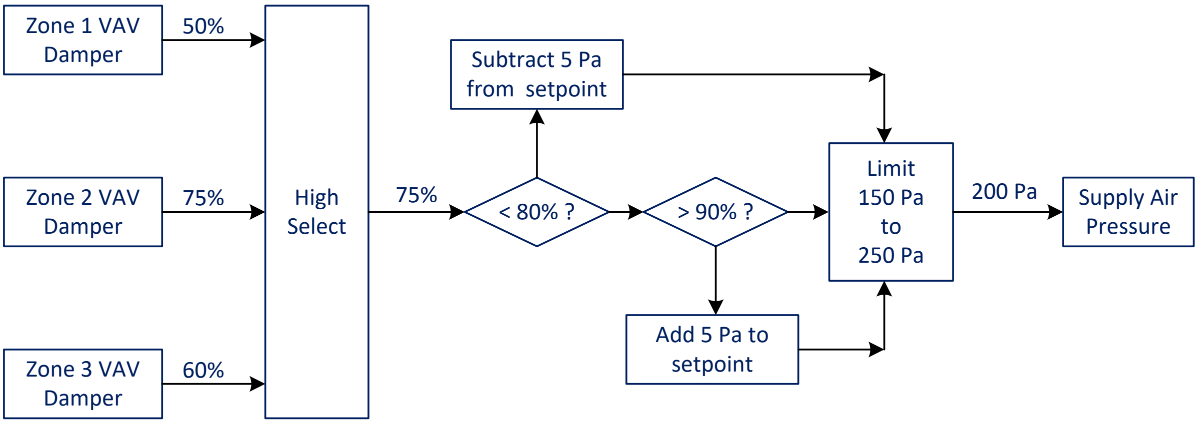


Figure 3: Example Supply Air Pressure Reset logic

All values are to be represented on a graphics page were the above logic is displayed with live values and adjustable setpoints.

4. Face Bypass Systems

These systems are typically used in laboratory spaces and serve multiple zones with face-bypass dampers to vary how much supply air is cooled for each zone.

Zone Temperature + Humidity Control, Fixed Speed Fans

Face bypass units with humidity control and fixed speed fans should be controlled as described in the following section. Each zone should have 3 0-100 PI loops, noted as cooling, heating, and dehumidification (dehum) outputs. Each of these outputs is linearly spanned to a number of actuators to achieve zone temperature/humidity control as follows:

- Cooling PID: 0-40% drives the zone face bypass damper from 0-100%. 0-65% resets the off coil temperature setpoint from 23-14.5 deg. 65-100% resets the off coil temperature setpoint from 14.5-12 deg.
- Heating PID: 0-100% corresponds to 0-100% heater output. Staged heaters are pulsed by PWM or similar to emulate an analog output.
- Dehum PID: 0-20% resets off coil temperature from 23-10 deg. 0-20% opens zone face bypass damper from 0-5%. 20-100% open face bypass damper from 5-100%.

All spanning parameters should be bacnet exposed for simple tuning. A max select should employed between the cooling and dehum PID outputs to determine the face bypass damper output.

The off coil temperature setpoint should be maintained via a separate PI loop driving the chilled water valve(s). The effective off coil setpoint should be the minimum of all zone resets.

Zone Temperature + Humidity Control, VSD Fans

Face bypass units with humidity control and fixed speed fans should be controlled as described in the following section. Each zone should have 3 0-100 PI loops, noted as cooling, heating, and dehumidification (dehum) outputs. Each of these outputs is linearly spanned to a number of actuators to achieve zone temperature/humidity control as follows:

- Cooling PID: 0-30% drives the zone face bypass damper from 0-100%. 0-40% resets the off coil temperature setpoint from 23-14.5 deg. 40-65% drives the VSD from 0% to 100%. 65-100% resets the off coil temperature setpoint from 14.5-12 deg.
- Heating PID: 0-100% corresponds to 0-100% heater output. Staged heaters are pulsed by PWM or similar to emulate an analog output.
- Dehum PID: 0-30% resets off coil temperature from 23-10 deg. 0-65% opens zone face bypass damper from 0-100%. 65-100 increases VSD from 0-100%

All spanning parameters should be bacnet exposed for simple tuning. A max select should employed between the cooling and dehum PID outputs to determine the face bypass damper output. 0-100% VSD corresponds between 20 and 50Hz fan speed. A max select should be employed between cooling and dehum loops to determine effective VSD speed.

The off coil temperature setpoint should be maintained via a separate PI loop driving the chilled water valve(s). The effective off coil setpoint should be the minimum of all zone resets. The effective VSD speed from each zone should also be max selected, and the final speed output to the VSD should be the result of this max select.

Zone Temperature + Pre-conditioning Humidity Control

Where preconditioners are installed, zone based humidity control should be removed, and all dehumidification control should be undertaken by the pre-conditioning coil. A single 0-100 PI loop controls the average of all zone sensors to the dehumidification setpoint. 0-100 output is linearly spanned to a pre-con off coil setpoint of 22-10 degrees. The pre-conditioner coil chilled water valve is then controlled to the off coil setpoint by a PI loop.

Zone Temperature Setpoints

Zone setpoints should be set as listed for laboratories in Section 1. Face-bypass systems work best when setpoints are consistent from zone to zone so that the supply air temperature can be set to satisfy a majority of zones. It is also important to avoid an imbalance of heat load between zones. A typical example is where a space set aside for -80 freezers. The heat generated from the freezers will tend to drive the off coil temperature control to the detriment of other zones. Such spaces should have a dedicated fan coil unit to address the higher heat load.

Zone Temperature Control

The zone face-bypass damper modulates to achieve the right balance of cooled air and bypassed air to meet the cooling needs of the zone. If the temperature drops below the heating setpoint then the face-bypass damper closes completely and the downstream heater is energized to maintain comfort levels.

Zone Humidity Control

For face-bypass systems dehumidification control takes precedence over the control of the face-bypass dampers and the off coil temperature setpoint. The off coil temperature is quickly driven to minimum when a high select of the zone humidity sensors rises above setpoint. This maximizes the amount of water which condenses on the cooling coil and reduces the absolute humidity.

High Select Zone Humidity	Off Coil Temperature Setpoint
60.0%RH	22.0°C
65.0%RH	10.0°C

The zone face-bypass dampers are then controlled according to the humidity measured in each zone to utilize as much of the low humidity air as is required. The damper control is limited to 70% so there is also some air bypassing the coil to limit over-cooling. Thus a stream of cold dry air from the coil mixes with some warmer bypass air and this helps to lift the supply air temperature and reduces the amount of electrical duct heating required to restore normal comfort levels.

5. Secondary Chilled Water Systems

Secondary CHW Building Differential Pressure

This applies to the control of secondary chilled water pumps in a primary-secondary (decoupled loop) system. A typical installation will have identified an index point in the building chilled water system where the building CHW differential pressure is measured. During the building chilled water balance, all chilled water valves are fully opened and the CHW pump VSD ramped up until all coils in the system are achieving their design flows. At the point where this is achieved, the building Chilled water Differential Pressure is captured and becomes the setpoint for the pump control.

Where the DP index point is remote from the CHW Pumps but proportional and integral control of the pump speed is desired, the remote pressure should not be passed by TCP/IP. The best way to accommodate this situation is to have a system DP which is more local to the pumps and reset the setpoint via the network. The preference is to hardwire the signal to the same controller as the pump control.

Secondary CHW Differential Pressure Reset

Chilled water pressure reset takes this one stage further by reducing the setpoint based on chilled water valve position. By maintaining the highest valve position to be between 80% and 90% it ensures that pump energy is primarily used to provide chilled water flow rather than create unnecessary static pressure in the pipework. The upper setting of the pressure setpoint should still be determined as described above to prevent starving air handling units of chilled water. The lower setpoint should initially set to 100 kPa below the water balance setpoint and tuned by observing the system performance during low chilled water demand.

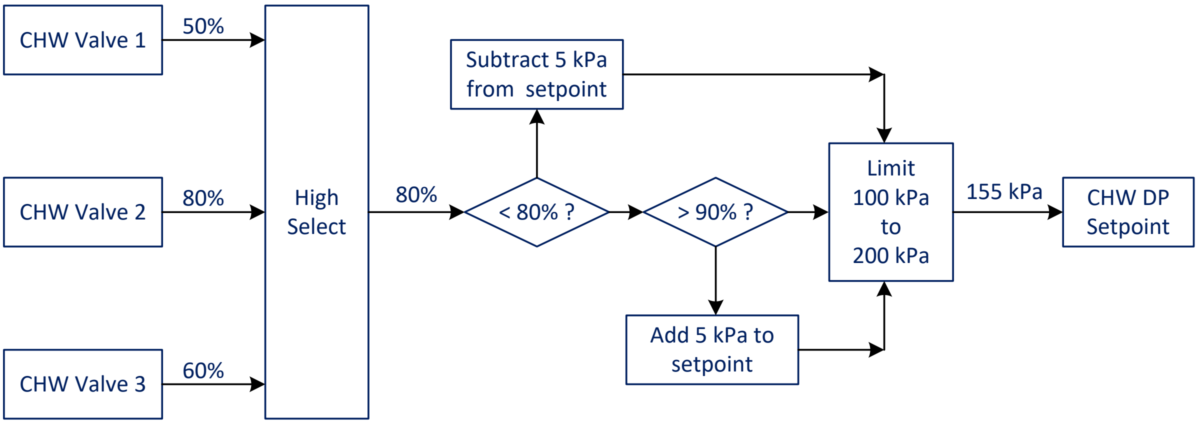


Figure 4: Secondary CHW Differential Pressure Reset logic

Most buildings have 50 to 100 chilled water valves which can make this control unduly complex. It is recommended that a selection of larger air handling units, particularly those running 24/7 are nominated to be included in this control. Care should be taken to identify valves which are overridden or consistently run at 100%.

A tabular graphics page should be created for secondary system showing the associated AHUs and their relative live values and setpoints.

Secondary CHW Dual Pump Control

Some secondary systems require more than one pump to achieve the required flow range. Where dual pump control is required it is still based on maintaining the building differential pressure with the pumps operating in a lead-lag arrangement.

When the building chilled water valves become increasingly open, the secondary CHW flow increases and the system pressure will drop. In response, the lead pump speed will increase to maintain the system pressure setpoint and ensure the required flow is met for each unit. When the lead pump is operating at 100% for 15 minutes the lag pump starts. When both pumps have been operating at 40% for 15 minutes the lag pump is stopped.

A tabular graphics page should be created for secondary system showing the associated pumps and their relative live values and setpoints.

Pump VSD Mapping

All CHW pump variable speed drives should be connected to a BMS field trunk to provide monitoring in addition to the hardwired control interface. The following points should be mapped as a minimum with example point mapping shown for ABB and Danfoss drives which are commonly used at UQ.

VSD Point mapping	ABB BACnet object	ABB N2 object	Danfoss BACnet object	Danfoss N2 Object
Energy MWh	AV-9	AI-9		-
Energy kWh (Reset)	AV-8	AI-8	AV-14	AI-21
Power kW	AV-6	AI-6	AV-15	AI-7
Current	AV-4	AI-4	AV-6	AI-6
Output Voltage	AV-3	AI-12	AV-5	AI-9
Output Frequency	AV-1	AI-1	AV-50	AI-4
Speed Reference	AI-0	AI-2	AV-0	AI-1
Drive Ready	BV-7	BI-20	BV-10	BI-12
Manual/Auto Mode	BV-4	BI-17	BV-13	BI-98
VSD Fault	BV-2	BI-3	BV-0	BI-10
VSD Run Enable	BV-9	BI-22	BV-1	BI-11
VSD Run Status	BV-0	BI-1	BV-16	BI-5

6. Chiller Systems

Chiller Staging

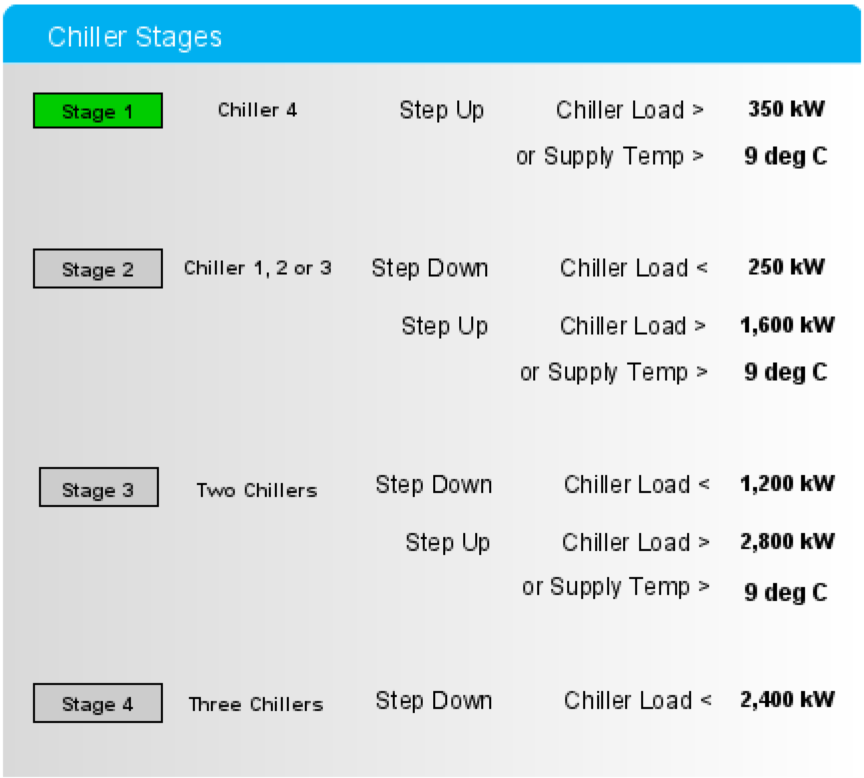
The chilled water systems are generally configured so the BMS provides staging and chilled water pump control and the chiller controls the loading characteristics of the machine, to a leaving water temperature setpoint. The leaving water setpoint is altered by the BMS if required but generally defaults to 6°C.

Initially the cooling call is derived by the highest chilled water valve position being greater than 40% for 10 minutes. The first stage for cooling is to enable the chilled water pump only for the lead (or low load) chiller. The following stages should be added based on the calculated chilled water load and/or the supply water temperature. For critical chilled water system, the first stage of cooling should ignore pump only operation and immediately start the lead chiller.

The chiller step up and step down should be based primarily on the sum of the running chiller loads measured as kilowatts of refrigeration (kWr). The kWr calculation must take place in the field controller which is interfaced to the magnetic flow meter and temperature sensors and be connected to the chiller supervisory control by a serial trunk rather than a network connection.

The setpoint values for step up and step down should be selected to promote energy optimization. This can be initially determined from the integrated part load values for the chiller but should then be tuned based on system performance. As a back-up measure the step up should also consider supply water temperature to protect against a scenario where the running chillers are unable to achieve their normal capacity.

The following example is taken from AEB which has a low load chiller 4 of capacity 750 kWr and 3 main chillers of each 1700 kWr. The step change setpoints have been deliberately tuned to promote the running of chiller 1, 2 or 3 which have a higher efficiency than chiller 4.



Chiller Stages

Stage 1	Chiller 4	Step Up	Chiller Load >	350 kW
			or Supply Temp >	9 deg C
Stage 2	Chiller 1, 2 or 3	Step Down	Chiller Load <	250 kW
		Step Up	Chiller Load >	1,600 kW
			or Supply Temp >	9 deg C
Stage 3	Two Chillers	Step Down	Chiller Load <	1,200 kW
		Step Up	Chiller Load >	2,800 kW
			or Supply Temp >	9 deg C
Stage 4	Three Chillers	Step Down	Chiller Load <	2,400 kW

If the system unloads to the smallest operating chiller and the demand kWr is below the minimum load capacity of the chiller (for 10 minutes) the preference is for the BMS to remove the enable for the chiller and allow the circulating water to provide the thermal inertia for the remaining low load, rather than the chiller cycling on its internal controls. Once the field load increases above 70% of the operating low load chiller's capacity, the chiller should be re-enabled.

When the chilled water valves have closed / reduced to a point where the highest chilled water valve position is less than 15% for 15 minutes the chilled water pump can be disabled (assuming this is less than the load required for the low load chiller nominated above.

Variable Primary Flow Control

It is common for the primary chilled water flow to exceed the secondary building flow with the excess circulating through the bypass or decoupling line. This creates a circumstance where the building load may well match an efficient operating point for the chiller but the mixed return water temperature is lowered by the bypass flow to the point where it is prohibitive to the continued operation of the chiller. Under these circumstances it is desirable to introduce variable primary flow through the chiller to avoid excess bypass flow. This can only be achieved where the chiller flow is being reliably and accurately measured and the primary CHW Pump has a variable speed drive.

Variable primary flow introduces energy savings by improving the operating efficiency of the chiller and reducing the running speed of the CHW pump.

The chiller flow control must have safe minimum and maximum settings for the chiller and minimum speed protection configured for the variable speed drive. The flow control needs to take account of the present chiller operating conditions, prevailing chiller load, cooling tower conditions and the bypass or decoupling line flow. This control should only be administered by the chiller control system and not by an independent BMS.

Condenser Water Flow Control

This control requires the Condenser Water Pump to have a variable speed drive but it is not essential to have a condenser water flow meter. The pump speed is controlled directly by the chiller's internal controls based on chiller head pressure or maintaining specific differential pressure between the evaporator and condenser.

This strategy needs to include / consider the cooling tower temperature reset strategy.

Generally speaking, the reduction in cooling tower fan energy is preferred to condenser water pump energy as the pump is normally a more efficient device. Additionally, most cooling towers do not operate effectively when below design flow, so cooling tower isolation valves may be required.

Chiller High Level Interface

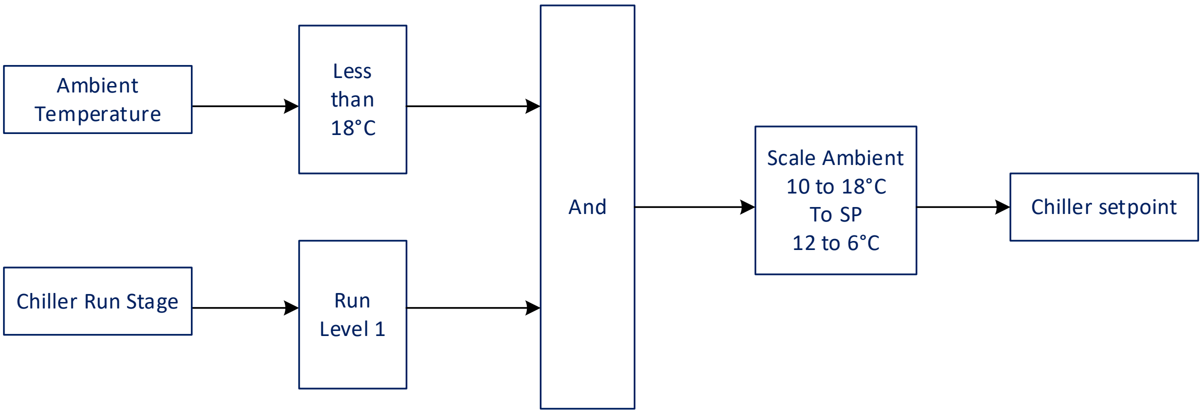
Wherever possible there will be a high-level interface from the BMS to the chiller controls to allow extensive monitoring of the operation of the chiller. The following parameters should be included if available.

Chiller control	Evaporator	Condenser	Compressor
Run Enable	CHW Pump Start	CW Pump Start	VFD Start
Run Status	CHW Pump Status	CW Pump Status	Compressor Status
Fault Status	CHW Flow Switch	CW Flow Switch	VFD Frequency
Operating Mode			Run Hours
Cooling Setpoint	Entering Water Temp	Entering Water Temp	Motor kWe
Demand Limit	Leaving Water Temp	Leaving Water Temp	Line kW
Percent FLA	Refrigerant Temp	Refrigerant Temp	Average Line Amps
	Saturated Temp		Average Line Volts
Chilled Water Delta T	Evaporator Approach	Condenser Approach	Motor Winding Temp
HP Reference	Evaporator Pressure	Condenser Pressure	Head Pressure

Chiller Cooling Setpoint Reset

The chiller cooling setpoint of 6°C is set to meet standard chilled water coil design and promote dehumidification at prevailing summer ambient conditions in south-east Queensland. Where ambient conditions are low temperature and dehumidification is not a priority, then it is possible to relax the supply water temperature setpoint to promote energy savings. Keeping in mind that the chiller is often the most efficient machine in the HVAC system and warmer supply water temperatures may cause additional AHU fan energy.

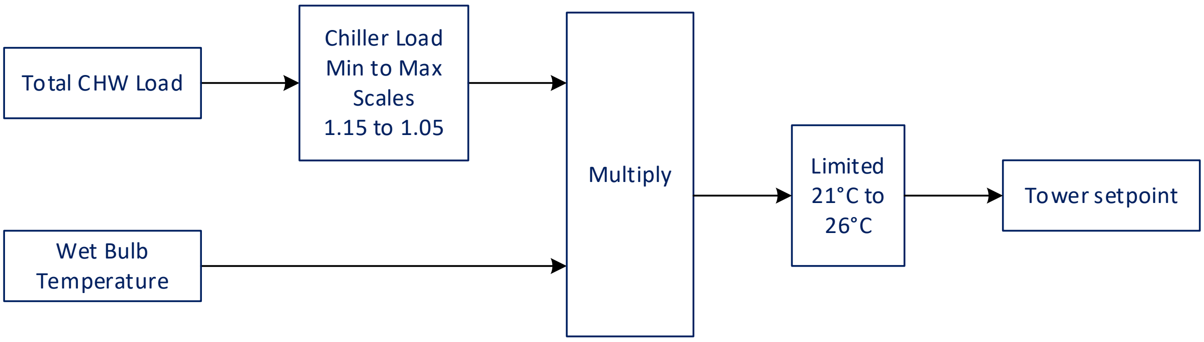
The algorithm which determines the chiller cooling setpoint is based on the campus ambient temperature as determined in Metasys-42-2. Setpoint reset is only enabled when the chiller run stage is at level 1.



All values are to be represented on a graphics page were the above logic is displayed with live values and adjustable setpoints.

Cooling Tower Setpoint Reset

The ideal return condenser water temperature is dependent on the type of chiller. However, where there is opportunity to reset the cooling tower control setpoint can be done so between minimum and maximum settings specific for the operating chiller. The suggested algorithm is based on ambient wet bulb temperature and is also influenced by chiller load.



All values are to be represented on a graphics page were the above logic is displayed with live values and adjustable setpoints.

7. Heating Hot Water Systems

Heat Pump Control

There are significant energy savings to be made by providing space heating using heating hot water instead of electric duct heating. Heat pumps are becoming more sophisticated, efficient and reliable and should be considered particularly where heating requirements are likely to be all year round due to dehumidification control.

The heating hot water systems are generally configured such that the BMS provides circulating pump control and the heat pump controls the compressors and evaporator fans to maintain the leaving water temperature setpoint. Typically a buffer tank will be installed to prevent short cycling at low loads and a bypass will ensure minimum flow to the heat pump.

The call for heating call is derived by the highest hot water valve position being greater than 40% for 10 minutes. The heating hot water pump is started and circulates water through the heat pump and buffer tank. The heat pump is then called to run to maintain the buffer tank between low and high thresholds around the setpoint. The heat pump is usually set to provide 50°C water with the heating coils designed for 49°C supply and 42°C return. The heat pump load as kWr should be calculated in a field controller which is interfaced to a magnetic flow meter and matching pair temperature sensors.

Where possible, a water source heat pump should be installed so that simultaneous water cooling is provided as a side benefit of the installation. If there is insufficient year round cooling demand then a combined air and water source heat pump should be considered with heat pump switching mode of operation based on the chilled water inlet temperature.