MIT
Design Standards

DIVISION 25 —— Integrated Automation

Issued 2022

Department of Facilities

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1. INTRODUCTION TO INTEGRATED AUTOMATION AT MIT

1.1 Goal of this Document

To provide guidance and insight into MIT's minimum standards and recommended best practices for Integrated Automation of Building Management Systems (BMS) design and implementation.

1. This document shall be used by MEP design consultants to supplement their traditional BMS specification. It is imperative that certain aspects of this document are incorporated into a traditional specification produced by MEP design consultants.
2. This document shall be used by BMS contractors to tailor their work to meet the expectations of MIT. During the design phase and RFP process, enough detail is given to price MIT specific alarm strategies, reports, and graphics development, but often certain nuances inherent in a BMS are not defined well enough to execute these tasks. This document will define those nuances and ultimately provide MIT with a finished product that meets our expectations.

1.2 Current Challenges or Questions this Document Will Address

1. Which BMS shall be used for new construction, retrofit, or buildings with mixed BMS platforms.
2. Expectations for A/E design firms when designing a BMS at MIT:
    a. Drawing requirements.
    b. Points list.
    c. Sequences of Operation.
    d. Scope matrix for use by Construction Manager.
    e. Coordination completeness.
3. Expectations for BMS contractors when implementing a BMS at MIT:
    a. Hardware design.
    b. Network design.
    c. Software design.
    d. Installation.
    e. Commissioning including:
        1) Installation verification.
        2) Start-up testing.
        3) Operational verification including:
            a) System tests.
            b) Integrated system tests.

4. Expectations for Commissioning Authority (CxA) when testing a BMS at MIT:

    a. Pre-requisites from BMS contractors.

1.3 Brief History of Building Management Systems at MIT

1. In the 1980s as the MIT campus transitioned from pneumatic receiver/controllers to DDC, the primary BMS product was Carrier Comfort Network (CCN). This product was installed as an overlay of the local pneumatic controls in approximately 50+ buildings. The software platform was phased out between 2017 and 2019 in one of two ways:
    a. CCN hardware still exists in 24 buildings on campus with the software platform migrated to the ALC WebCTRL platform.
    b. CCN hardware and software was replaced by one of the Schneider Electric platforms depending upon the building.
2. In the early 1990s, Andover Controls was introduced to the MIT campus as a competitor of CCN. The legacy Andover Controls BMS product now known as Schneider Electric Continuum exists in 39 buildings. Schneider Electric Continuum is accessed through hard client workstations spread among the campus as well as WebClient interface. In the future, Continuum will be migrated to the EcoStruxure platform.
3. In 2013, Schneider Electric's latest BMS product known as EcoStruxure was introduced to the MIT campus. EcoStruxure currently exists in over 49 buildings EcoStruxure can be accessed by a web browser interface.
4. In 2013, Carrier's BMS product known as iVu was introduced to the MIT campus. iVu has been migrated into a newer ALC platform called WebCTRL and currently exists in 28 buildings. WebCTRL can be accessed by a web browser interface.
5. In 2012, Siemens' BMS product known as APOGEE was introduced to the MIT campus. APOGEE currently exists in two buildings. APOGEE is accessed through hard client workstations spread among the campus as well as a remote desktop application.

1.4 Current State of Building Management Systems at MIT

1. The following BMS platforms are in place (see Appendix A for Building List):

    a. Automated Logic WebCTRL.
    b. Schneider Electric Continuum.
    c. Schneider Electric EcoStruxure.
    d. Siemens Apogee.

2. Pneumatic controls are not permitted to be installed in any equipment replacement, renovation or new construction project. Pneumatic controls are an obsolete technology, and MIT has been replacing pneumatic controls with BMS systems since the late 1970's. By 1996 the technology's life cycle cost reached the point where room level BMS control became practical and was implemented in the renovation of Buildings 16 and 56. Hundreds of thermostats and relays which would require annual calibration to operate with accuracy were eliminated from that project as a result.

3. Pneumatic controls continue to be available on the marketplace as repair and replacement items for existing older buildings. They are not suitable for new installations for the following reasons:

    1) Occupant thermal comfort goals are unobtainable in the long run due to the instrument recalibration requirements mentioned above.

    2) Excessive and unnecessary maintenance and energy expense is required to maintain tight, clean compressed air systems.

    3) Energy conservation and MIT 2030 carbon reduction goals rely on the implementation of relaxed room temperature standards in the unoccupied mode. These unoccupied temperature setpoints are unobtainable with pneumatic controls. See Section 3.12 "Room Control" for more information.

    4) Feedback from controlled devices and their associated sensors allow for non-invasive remote repair and maintenance troubleshooting. The data which can be harvested and archived from the BMS system can be integrated with analytical platforms which identify faulty equipment operation and quantify the benefit of corrective actions. Also this data archive can be mined to develop additional energy saving and carbon reduction strategies.

    5) AI applications must interface with digital networked systems. Pneumatic controls preclude the ability to leverage AI technology to reduce building energy consumption and carbon emissions.

1.5 Future State of Building Management Systems at MIT

1. CCN hardware and software has been replaced by Schneider Electric or migrated to ALC WebCTRL.
2. Schneider Electric Continuum will eventually be merged into Schneider Electric EcoStruxure.
3. As of 2020, the implementation plan per building will be as follows:

    a. For complete building new construction acceptable BMS platforms shall be:

        6) Schneider Electric EcoStruxure.
        7) Automated Logic WebCTRL.

4. For buildings with a single BMS platform requiring additional controls or partial retrofits, the incumbent platform shall dictate the future. Refer to the matrix in Appendix A to determine if a building has a single platform. The following platforms will be allowed to expand within a building that they already have a presence in:

    a. Schneider Electric Continuum.
    b. Schneider Electric EcoStruxure.
    c. Automated Logic WebCTRL.

d. Siemens APOGEE.

5. For buildings with a mix of BMS platforms, requiring additional controls or partial retrofits, the incumbent platforms shall dictate the future. Refer to the matrix in Appendix A to determine if a building has multiple platforms. The mixed buildings include the following combinations:

   a. Automated Logic WebCTRL / Schneider Electric Continuum:

      1) The following platforms will be allowed to expand within these buildings depending upon air or water source:

         a) Automated Logic WebCTRL.
         b) Schneider Electric Continuum.

   b. Automated Logic WebCTRL / Schneider Electric EcoStruxure:

      1) The following platforms will be allowed to expand within these buildings depending upon air or water source:

         a) Automated Logic WebCTRL.
         b) Schneider Electric EcoStruxure.

   c. Schneider Electric Continuum / Schneider Electric EcoStruxure:

      1) The following platforms will be allowed to expand within these buildings depending upon air or water source:

         a) Schneider Electric EcoStruxure.
         b) Schneider Electric Continuum.

2. MIT'S EXPECTATIONS OF MEP DESIGN CONSULTANTS

2.1 BMS Design Requirements

MIT expects MEP design consultants to include the following in BMS designs:

1. BMS specification.
2. Network riser diagram clearly distinguishing MIT Information Systems and Technology (IS&T) scope from BMS.
3. P&ID type instrumentation drawings for each typical system requiring control
4. Points list for each typical system (when not clear from the P&ID drawing)
5. Points list for miscellaneous systems (plumbing, electrical, lab monitoring)
6. I/O list to be mapped to the BMS from software interfaces
7. Sequence of operations for each typical system requiring control incorporating alarms and long-

term trending requirements either in separate specification form or on the control diagrams listed.

8. Metering one-line diagram outlining scope delineation.
9. Incorporation of MIT standards into BMS design. The above items listed must reflect an understanding of the MIT BMS standards.
10. Items involving requiring multiple trades are recommended to be addressed in a detailed scope matrix that clearly delineates each piece of work that could be handled by a different contractor. (Examples include: installation, and implementation of fire/smoke dampers, power wiring).

A sample of the expectation is shown below:

Description	Furnish	Install	Control	Control Wiring	Power Wiring
Air Flow Stations & Transmitters	BMS	Mechanical	BMS	BMS	BMS
Combination Fire/Smoke Damper & Actuators	Mechanical	Mechanical	Fire Alarm	Electrical	Electrical
Control Dampers	BMS	Mechanical	N/A	N/A	N/A
Control Damper Actuators	BMS	BMS	BMS	BMS	BMS

11. Where a building is "locked in" by a certain BMS contractor it is expected that the MEP design consultant work closely with the BMS contractor in the design stages to ensure that design meets MIT expectations.

2.2 Design Review Milestones

MIT expects that the following BMS deliverables will be ready for initial review at the design phase listed or sooner. The deliverables are expected to mature with each phase.

1. Schematic Design Phase
   a. Identification of BMS vendor(s).
2. Design Development Phase
   a. Network Architecture.
   b. Control Schematics.
   c. Sequence of Operations (with alarming and trending information)
   d. Identification of software interfaces.
   e. BMS Specification.
3. 90% Construction Documents and Construction Documents Phase
   a. Points list for each typical system (when not clear from the P&ID drawing).
   b. Points list for miscellaneous systems (plumbing, electrical, lab monitoring).
   c. I/O list to be mapped to the BMS from software interfaces.
   d. Metering one-line diagram.
   e. Trade coordination matrix
4. As-built Documentation (if applicable).

2.3 MEP Equipment Naming Standards

Design drawings should include equipment designations in their schedules and plan views which are unique and do not duplicate existing equipment. Coordinate with construction team as required to maintain a consistent naming convention following this requirement.

Equipment names should conform to the following three-tier standard:

XXX-YYY-ZZZ whereby:

XXX = scheduled equipment type
YYY = schedule sub-type
ZZZ = scheduled unique number of sub-type

Example: the type-2 fan coil unit located in room 101: FCU-2-25

If a unique number for equipment sub-type is not scheduled, check the floor plan drawings. If unique numbers for equipment sub-types are not on the floor plan drawings, please request such specific information to be included on the record set of plans from the MEP design consultant, via the RFI process.

Buildings which have no letter prefix assigned in the MIT naming convention (Buildings 1, 2, 3, etc.) will be preceded with an "M".

Note that system, equipment, and number are combined as one text string.
The following is the standardized list of system, equipment, and other abbreviations:

Air Handling Unit	AHU
Exhaust Air Handling Unit	EAHU
Exhaust Fan	EF
Return Fan	RF
Pump	PMP
Air Cooled Condensing Unit	ACCU
Heat Exchanger	HX
Heating Converter (shell and tube)	CV
Chilled Water	CHW
Process Chilled Cooling Water	PCHW
Hot Water	HW
Condenser Water	CND
Domestic Hot Water	DHW
Domestic Cold Water	DCW
Supply	S
Return	R
Temperature	TEMP

Pressure	PRESS
Flow	FLOW

For example, Domestic Hot Water Return Temperature in Building 2 would be:
M02_DHWRTEMP

3. BUILDING MANAGEMENT SYSTEM DESIGN GUIDELINES

3.1 Building Management Systems Design Guidelines - General

BMS designs and installations for MIT under this specification shall include the following:

1. The BMS shall be based on an open implementation of BACnet using ASHRAE 135 exclusively as the communications protocol for communication between BMS hardware devices.
2. The BMS hardware and software shall perform the control sequences as specified and shown in the MEP design consultant's control drawings and sequence of operation.
3. The engineering workstations must run the standard workstation software developed and tested by the manufacturer of the BMS controllers. No third party front-end workstation software shall be acceptable. Engineering workstations must conform to the B-OWS BACnet device profile.
4. Web-based users shall have access to all system points and graphic display screens, shall be able to receive and acknowledge alarms, and shall be able to control setpoints and other parameters, based on their access credentials. All engineering work, such as trends, reports, that are accomplished from the engineering workstation shall be available for viewing through the web browser interface. The web-based interface must conform to the B-OWS BACnet device profile. There shall be no need for additional computer based hardware to support the web-user interface.
5. All BMS controllers shall be connected to an ASHRAE 135 BACnet/IP or MSTP control network.
6. Control sequence logic for a particular system shall reside in that system's dedicated BMS controller. The hardware in conjunction with the software residing on the controller shall, where possible, execute the sequence of operation without relying on the building network.
7. The BMS shall be designed and installed such that MIT is able to perform repair, replacement, upgrades, and expansions of the system without further dependence on the original BMS contractor. BMS implementation documentation, configuration information, configuration tools, application programs (with comments explaining program logic), and other software used by the BMS shall be licensed to and remain property of MIT.
8. Exceptions to BACnet compliant requirements will be allowed only when expanding a legacy proprietary Continuum BMS within a building.
9. The BMS shall interface with MIT's web-based Building Analytics System called KGS Clockworks. The work associated with this interface is not part of the BMS contractor's scope.

The following are additional guidelines of how MIT expects certain equipment to work on campus.

3.2 Network Level

1. The BMS shall reside on the protected MIT Ethernet Network also known as the MIT BMS VLAN.
2. The BMS shall be an extension of the campus approved BMS platforms listed above.
3. The BMS shall be web-based.
4. The BMS shall be native BACnet (except where proprietary Continuum expansion is required).
5. The BMS shall be capable of being polled by KGS Clockworks.
6. The BMS shall be capable of communication with the PI data historian.
7. The BMS shall be capable of Modbus IP communication.
8. Workstations and printers for buildings are not generally required.

3.3 Uninterruptable Power Supply

1. All network controllers and critical system controllers shall be on UPS power. A critical system controller is defined as one that controls:

    a. Chilled Water, Hot Water, & Steam Generation and Distribution.
    b. Air Handlers (Supply AHUs, Make-up Air AHUs, Exhaust AHUs, Energy Recovery Units).
    c. Rooftop Units.
    d. Air Distribution for Critical Rooms: Labs, Vivariums, Executive Offices, IS&T Data Rooms.

2. The UPS strategy can be designed and implemented as a small UPS per controller or one standalone UPS dedicated for the critical controls for an entire building. Additionally, a building UPS used for other systems may be used for the BMS as well.
3. The UPS shall be monitored by the BMS for “low battery” and “battery on” status.
4. Individual UPSs used for controllers shall be similar to APC Model #SUA500PDR-S and mounted underneath the controller in an enclosure of similar specifications to the controller enclosure.

3.4 Field Controllers

1. Field controllers shall be BACnet compliant (except where proprietary Continuum expansion is required).
2. All field controllers must contain all of the I/O and sequence logic for the particular system that they serve. For example, it is not acceptable to split an air handling unit between two field controllers.
3. Airflow tracking control for a laboratory or vivarium shall reside on one controller and not rely on the network to function.
4. The hardware in conjunction with the software residing on the controller must execute the sequence of operation as specified. Controllers that contain “canned” uneditable programs that do not meet the sequence of operations will not be acceptable.
5. The hardware in conjunction with the software residing on the controller shall, where possible,

execute the sequence of operation without relying on the building network.

6. IP based field controllers that control major HVAC equipment (Air Handlers, Heating and Cooling Equipment) shall be acceptable.

3.5 BMS Controller Enclosures

1. Control enclosures shall be as follows:

    a. Single keyed locking twistable knob(s).

    b. Ratings:

        1) Enclosures located outside: NEMA Type 4X.

        2) Mechanical and Electrical Rooms: NEMA Type 1.

        3) Other Locations: NEMA Type 1.

3.6 Field Devices

1. **Control Valves:**

    a. Chilled water and hot water control valves for air handling unit applications and terminal unit applications shall be pressure-independent:

        1) Valves 2 inch and smaller: Pressure independent characterized ball valve, 400# WOG, bronze body, stainless ball and stem, pressure and temperature ports, reinforced PTFE seats & seals, screwed ends, 250°F rating, 200 psig close-off pressure, and a maximum differential pressure rating of not less than 50 psig.

            a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

        2) Valves 2-1/2 inch and larger: Pressure independent ball valves. The valve body shall be of cast iron and rated for 150 PSI working pressure. Internal parts shall be of stainless steel.

            a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

    b. Steam control valves shall be characterized control valves including:

        1) Valves 2 inch and smaller: Characterized ball valve, 400# WOG, bronze body, stainless ball and stem, pressure and temperature ports, reinforced PTFE seats and seals, screwed ends, 250°F rating, close-off pressure rating of 150% of total system head pressure, and a maximum differential pressure rating of not less than 50 psig.

            a) Acceptable Manufacturers: Schneider Electric, Belimo.

2) Valves 2-1/2 inch and larger: Characterized ball valve, the valve body shall be of cast iron and rated for 150 PSI working pressure. Internal parts shall be of stainless steel.

a) Acceptable Manufacturers: Belimo or MIT Approved Equal (prior to bid).

c. Two-way modulating valves used for liquids and steam shall have an equal percentage flow characteristic that yields a linear heat output.

d. Automated two-position isolation valves for CHW and HW (above 6” line size) shall be butterfly type as follows:

1) Threaded lug type suitable for dead-end service to the fully-closed position, with carbon-steel bodies and non-corrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from -20°F to plus 250°F.
2) Valve assembly including actuator and limit switches, if required, shall be assembled by the valve manufacturer.
3) Acceptable Manufactures: Bray, Belimo, or MIT Approved Equal (prior to bid).

e. Valve Actuators:

1) Valve actuators shall be electric and integrated with the valve body.
2) Valve actuators shall provide shutoff pressures and torques as required.
3) Valve actuators for major equipment and laboratory and vivarium applications shall be spring return.
4) Valve actuators for terminal unit control (with the exception of laboratory and vivarium applications) shall be non-spring return.
5) Valve actuators shall be fail open (FO) or fail closed (FC) as shown.
6) Valve actuators shall have an electronic cut off or other means to provide burnout protection if stalled.
7) Valve actuators shall have a visible position indicator.
8) Valve actuators for major equipment shall provide position feedback to the BMS controller.
9) Valve actuators shall smoothly open or close the devices to which they are applied.
10) Valve actuators shall have a full stroke response time in both directions of 90 seconds or less at rated load
11) Valve actuators located outside shall be provided with internal heaters.
12) Tri-state actuation is not acceptable.

2. Control Dampers:

a. Opposed or parallel blade type that at a minimum match the materials of construction of the associated ductwork.
b. See Division 23 for additional damper requirements.

c. Damper actuators:

1) Damper actuators shall be electric and integrated with the valve body.
2) Damper actuators shall provide shall provide the torque necessary per damper manufacturer's instructions to modulate the dampers smoothly over their full range of operation.
3) Damper actuators shall be spring return.
4) Damper actuators shall be fail open (FO) or fail closed (FC) as shown.
5) Damper actuators shall have an electronic cut off or other means to provide burnout protection if stalled.
6) Damper actuators shall have a visible position indicator.
7) Damper actuators shall be capable of providing position feedback to the BMS controller.
8) Damper actuators shall smoothly open or close the devices to which they are applied.
9) Damper actuators shall have a full stroke response time in both directions of 90 seconds or less at rated load.
10) Damper actuators located outside shall be provided with a weather shield.
11) Tri-state actuation is not acceptable.
12) Fail last position is not acceptable.
13) Acceptable Manufacturers: Schneider Electric, Belimo, or MIT Approved Equal (prior to bid).

3. Temperature Sensors:

a. All temperature sensors shall be thermistors.
b. Sensors shall be accurate to +/- 0.5°F for space applications and +/- 1.0°F for duct and pipe applications.
c. Where local room level manual overrides are required, the sensor housing shall feature both a setpoint adjustment and a push button for selecting after hours operation.
d. Where local displays are required, the sensor shall incorporate an LED or LCD display for viewing the temperature, setpoint, and other operator selectable parameters. If the setpoint adjustment is integral to the LED or LCD display, the BMS contractor should align the high and low limits from the front end workstation so that they are in synchronization with the BMS software.
e. Averaging Sensors shall be sized to ensure sensing element has a minimum length equal to 1 foot / 2 square feet of duct cross-sectional area at the installed location.
f. Outside air temperature shall be measured by the MIT weather station(s).

4. Relative Humidity Sensors:

a. Relative humidity sensors shall use thin film capacitive type. The transmitters shall have replaceable sensing elements.
b. Duct mounted relative humidity sensing element shall be encapsulated in potting material within a stainless steel probe.

c. Relative humidity sensors shall be +/- 3% accurate.
d. Outside air relative humidity temperature shall be measured by the MIT weather station(s).
e. Veris or equal.

5. Pressure Sensors:

a. Pressure sensor range shall be as shown or as required for the application. Pressure sensor ranges shall not exceed the high end range shown by more than 50 percent.
b. Provide remote sensing element(s) whenever operating temperature exceeds the transmitter's maximum allowable temperature.
c. Air pressure measurements in the range of 0 to 10" w.c. shall be +/- 1% of full scale accurate.
d. Pressure measurements of liquids or gas shall be +/- 1.5% of full scale accurate.
e. Transmitter shall have provision for zeroing by pushbutton or digital input.
f. Wet differential pressure sensors/transmitters for water and steam applications shall be provided with 3-valve manifold for servicing. If an electronic differential pressure sensor is used, there must be isolation valves installed and a take-off for bleeding of the system.
g. Space differential pressure elements/pick-ups required to measure pressure shall be constructed of appropriate material for the space and application and shall be ceiling mounting or wall mounted.

6. Air Flow Stations:

a. Ebtron Gold Series thermal dispersion type.

7. Flow Meters:

a. Liquid and gas flow meters shall adhere to the MIT metering specification.

8. Current Sensors:

a. Split-core current sensors shall be used to monitor fan and pump motors.
b. Measurement of electric feeds shall adhere to the MIT metering specification.

9. Current Switches:

a. Split-core current switches shall be used to monitor fan coil units with EC motors.

10. Floor or Pan Mounted Leak Detectors:

a. Corrosion and abrasion resistant.
b. Adjustable height.
c. Configured for normally open or normally closed as required by the application.
d. Form C output relay.
e. Operating temperature range of (-20°F to 120°F).

11. Low Limit Temperature Switches (Freezestats):

a. Automatic reset type.
b. Minimum element length of 1 foot/square-foot of coverage which shall respond to the coldest 12 inch segment.
c. Field-adjustable setpoint with a range of at least 15°F to 55°F.
d. Two sets of contacts, with each contact having a rating greater than its connected load. Contacts shall open or close upon drop of temperature below setpoint as shown and shall remain in this state until reset automatically.
e. Johnson/Penn, Schneider Electric or MIT approved equal (prior to bid).

12. Damper Limit Switches:

a. Limit switch shall be integral to the damper actuator.

13. Level Switches:

a. Solid state electronic level sensing probes and SPDT contacts for indication of switch point actuation
b. Measurement probe shall detect rising water in cooling coil condensate drain pan (where required).
c. Probe shall be designed to be installed on drain pan (where required).

14. Capacitance Level Transmitters:

a. Radio Frequency (RF) type continuous level probe shall have a 4-20 mA transmitter. Output shall be linear to measured level. Probe shall have probe shielding to reject a build-up of conductive, sticky or viscous material. Probe length shall match vessel dimensions to measure within 6" of bottom.
b. Include probe brace every 4 feet if probe length exceeds 6 feet and is not installed in stilling well.
c. Supply Voltage: 120 VAC/60 Hz
d. Output: 2 wire, 4-20 mA DC
e. Fail Safe: Low Level output on instrument failure
f. Ambient Temperature Limits: -40°F to 160°F
g. Minimum Enclosure Rating: NEMA 4
h. Local Indicator: LCD meter
i. Transmitter Mounting: Remote
j. Performance:

    1) Accuracy: ± 2% nominal.
    2) Linearity: ± 1% nominal.
    3) Repeatability: ± 1% nominal.
    4) Response Time: 20 milliseconds.
    5) Ambient Temperature Effect: 2% per 100°F maximum.
    6) Voltage Variation Effect: ± 0.2% maximum per 10 V change.

15. CO2 Space Sensors:

a. Sensor type shall be Non-dispersive infrared (NDIR).
b. Accuracy: ±30 ppm ±2% of measured value with annual drift of ±10 ppm.
c. Repeatability: ±20 ppm ±1% of measured value.
d. Response Time: <60 seconds for 90% step change.
e. Outputs: Field selectable 4-20mA or 0-5/0-10VDC with SPDT Relay 1A@30VDC.
f. Power: 12-30 VDC or 24 VAC supply power.
g. Output range: programmable to 0-2000 or 0-5000 ppm.
h. Transmitter shall be available in an enclosure for mounting on a standard electrical box.
i. Transmitter shall have integrated temperature sensor and humidity sensor where applicable.
j. Veris or equal.

16. CO2 Duct Sensors:

a. Sensor type shall be Non-dispersive infrared (NDIR).
b. Accuracy: ±30 ppm ±2% of measured value with annual drift of ±10 ppm.
c. Repeatability: ±20 ppm ±1% of measured value.
d. Response Time: <60 seconds for 90% step change.
e. Outputs: Field selectable 4-20mA or 0-5/0-10VDC with SPDT Relay 1A@30VDC.
f. Power: 12-30 VDC or 24 VAC supply power.
g. Output range: programmable to 0-2000 or 0-5000 ppm.
h. Enclosure shall not require remote pickup tubes and make use of integrated H-beam probe to channel air flow to the sensor.
i. Enclosure lid shall require no screws and make use of snap on features for attachment.
j. Enclosure shall be made of high impact ABS plastic.
k. Transmitter shall have integrated temperature sensor and humidity sensor where applicable.
l. Veris or equal.

17. Gas Monitoring Systems:

a. The system shall be a complete package with local or remote sensor(s), monitor, alarm contacts, local audible/visual alarm, local indication of current measured value for sensor, and status indicator lights for power and status of sensor. All status indicators shall be mounted on panel faceplate. Where multiple sensors are located in single space, provide single monitoring panel which incorporates display for multiple sensors. Units shall have adjustable setpoints and self-test diagnostics. Multiple gases can be measured by the same master panel.

    1) Gas to be Detected: Carbon Monoxide (CO):

        a) Power Requirements: 120 VAC, 50/60 Hz, 50 VA.
        b) Signal Input: Integral Sensor.

c) Signal Output: 4-20 mA DC.
d) Alarm Relays: 3 Amps, 120 VAC (1 Warning relay and 1 Alarm relay).
e) Alarm Setpoint: Two field adjustable setpoints for Warning (25 ppm) and Alarm (200 ppm).
f) Range: 0-250 ppm CO.
g) Sensor: Electrochemical CO Sensor.
h) Sensor Life: 1 year minimum.

2) Gas to be Detected: Oxygen (O2):

a) Power Requirements: 120 VAC, 50/60 Hz, 50 VA.
b) Signal Input: Integral Sensor.
c) Signal Output: 4-20 mA DC.
d) Alarm Relays: 3 Amps, 120 VAC (1 Warning relay and 1 Alarm relay).
e) Alarm Setpoint: Two field adjustable setpoints for Warning (20%) and Alarm (19.5%).
f) Range: 0-25% O2.
g) Sensor: Electrochemical O2 Sensor.
h) Sensor Life: 1 year minimum.

b. Panel mounted audible alarm horn with silence switch and display for indication of full scale range, sensor, zone, warning, alarm, and fault status.
c. Remote mounted audible/visual alarm (red) as indicated on plans.
d. The system shall have to be ability to send alarms to the BMS for warning, alarm, and system fault.
e. Honeywell Vulcain or MIT approved equal (prior to bid).

18. Refrigerant Detection Systems:

a. Infrared type refrigerant detection and alarm systems detecting refrigerant in listings at adjustable detection points to provide both visual and audible alarms.
b. System shall conform to ANSI/BSR ASHRAE Standard 15 Safety Code for Mechanical Refrigeration including alarm light and horn outside room at each door to room and inside space as indicated on drawings.
c. Sensor shall be compound specific and calibrated for refrigerant used in chillers.
d. System shall be automatically zero at set intervals by sensing air from and uncontaminated air source. Auto zero cycle may be manually or remotely initiated.
e. Latched alarms shall be capable of being reset locally by remote contact closure.
f. System malfunction alarm shall be non-latching contact annunciated locally and remotely.
g. System shall require no more than annual recalibration and monthly confirmation of clean air source for auto-zero.
h. Provide local alarm and control panel to accept these inputs and provide outputs for system fault alarm, warning alarm and critical alarm, which shall energize emergency ventilation system. Each alarm shall have DPDT relays. Warning and critical level alarms

shall energize local horn-strobe alarm. Provide contact for each alarm for monitoring by the BMS.

i. Refrigerant leak detection system to have the following minimum performance:

1) Minimum Enclosure Rating: NEMA 4.
2) Power: 120 VAC/60 Hz.
3) Operating Temperature: 60°F to 105°F.
4) Operating Humidity: 10% to 90% RH.
5) Contact Ratings: 5 amp 120 VAC.
6) Contact(s): 2 sets DPDT independently configured for different concentrations.
7) Performance:

a) Minimum measurable: 1 ppm as tested per UL2075.
b) Response time: 20 seconds at 99%.
c) Accuracy: Error $< \pm 2\%$ full scale.

8) Operating Temperature: 0°F to 120°F.
9) Display: 3 digit LED or LCD displaying refrigerant gas concentration.

j. Quantity of Required Monitor Points: Two monitoring points per chiller.
k. Output: 4-20 mA/24VDC

19. Photocells:

a. Non-corroding and weatherproof housing with sensor shield suitable for exterior installations.
b. 4-20 mA or 0-10 VDC output proportional to the ambient light level.
c. Accuracy at room temperature: 1%, 100°F temperature: 2.5%.
d. Solid-state photo diode circuitry and transducer as required.
e. Sensor reading from 0 to 750 foot candles.
f. Temperature and humidity independent.
g. Temperature range of 10°F to 120°F.

20. Push Buttons:

a. Illuminated red mushroom heads shall be used for emergency stop switches. The push buttons shall be illuminated with the switch is engaged.
b. Contact Type: Two contact blocks for 2 N.O. and 2 N.C. contacts each.
c. Unit shall be provided complete with enclosure, contact unit, and legend plate.

21. Control Relays:

a. Coil ratings of 120 VAC, 50 mA or 10-30 VAC/VDC, 40 mA as suitable for the application.
b. Complete isolation between the control circuit and the digital output.
c. Pickup rating, time and hold rating as required for individual applications.

d. Rated for a minimum of ten (10) million mechanical operations and a minimum of 500,000 electrical operations.
e. Internal status LED.

22. Electronic Thermostats:

a. Multifunction devices incorporating a temperature sensor and a temperature indicating device.
b. Electronic or other types of Thermostats shall not contain mercury. In addition, the thermostat shall have the following as applicable:

1) External setpoint adjustment.
2) Push button override.

3.7 Wire and Cable

1. The BMS contractor shall provide complete electrical wiring for the BMS, including 120 VAC power wiring from circuit breaker provided by Division 26 to BMS panel or device.
2. The BMS contractor shall provide control wiring, including conduit, to control devices from appropriate BMS controller enclosures.
3. The BMS contractor shall provide communications wiring, including conduit, for the BACnet MSTP network.
4. The BMS contractor shall provide final power connections, including conduit, wire, and/or disconnect switches, to control devices and control panels from the appropriate electrical distribution panels.
5. Final connection points at devices and panels shall be made either at terminal blocks integral to the device or at separate terminal blocks mounted inside of BMS controller enclosures. Crimped connections are not allowed for termination of control wiring.
6. All wire and cable shall meet the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification.
7. Terminal blocks which are not integral to other equipment shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, shall be suitable for rail mounting, and shall have end plates and partition plates for separation or shall have enclosed sides.
8. Control Wiring for Analog Signals:

a. Control wiring for analog signals shall be 18 AWG, copper, single or multiple-twisted, minimum 2 inch lay of twist, 100 percent shielded pairs, and shall have 300-volt insulation. Each pair shall have a 20 AWG tinned-copper drain wire and individual overall pair insulation. Cables shall have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.
b. Stranded twisted/shielded control conductors are required with shields to be terminated within variable frequency drive enclosures to reduce effects of noise from the VFD. The BMS contractor shall follow the VFD manufacturer's installation instructions for wiring

control conductors to the VFD.

9. Control Wiring for Digital Signals:

   a. Control wiring for digital signals shall be 18 AWG copper and shall be rated for 300-volt service.

10. Control Wiring and Power Wiring for 120-Volt Circuits:

    a. Wiring for 120-volt circuits shall be 12 AWG stranded copper and shall be rated for 600-volt service.

11. Transformers:

    a. Transformers shall be UL 1585-3 approved. Transformers shall be sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

12. BMS Ethernet Network Cable shall be provided by the telecom contractor to a jack located in the network panel.

    a. BMS Ethernet network cable shall meet or exceed all requirements of Category 6 cable as specified in TIA/EIA-568-B.2. Terminations, patch panels, and other hardware shall meet or exceed Category 6 specifications and shall be as specified in Telecommunications specification.
    b. Cabling products shall be tested and certified for use at data speeds up to at least 100 Mbps.

3.8 Sensing Tubing

1. The BMS contractor shall provide MIT sensing tubing required for a complete and functional BMS, including sensing tubing required for:

   a. Air Flow Stations.
   b. Air Flow Sensing for VAV Boxes (if not provided with the VAV box).
   c. Static Pressure Sensors and Switches (for air applications).
   d. Differential Pressure Sensors and Switches (for air applications).
   e. Differential Pressure Sensors and Switches (for water applications).
   f. Refrigerant Detection Monitoring.
   g. Gas Detection Monitoring.
   h. Differential Pressure Sensors and Switches (for water applications).

2. Copper:

   a. Copper tubing shall conform to ASTM B 88 and ASTM B 88M.

3. Stainless Steel:

a. Stainless steel tubing shall conform to ASTM A 269.

4. Plastic:

   a. Plastic tubing shall have the burning characteristics of linear low-density polyethylene tubing, shall be self-extinguishing when tested in accordance with ASTM D 635, shall have UL 94 V-2 flammability classification or better, and shall withstand stress cracking when tested in accordance with ASTM D 1693.
   b. Plastic-tubing bundles shall be provided with Mylar barrier and flame-retardant polyethylene jacket.

3.9 Sequences of Operation and I/O Lists

1. Air Handling Units.
2. Exhaust/Supply Fan.
3. Room Control:

   a. Key Concepts.
   b. Room Combinations.
   c. VAV Boxes:

      1) VAV Box Sample I/O.
      2) VAV Box w/o Reheat Coil.
      3) VAV Box w/o Reheat Coil and Radiation.
      4) VAV Box with Reheat Coil.
      5) VAV Box with Reheat Coil and Radiation.
      6) VAV Box (Return Air).

   d. Fan Coil Units:

      1) Fan Coil Unit Sample I/O.
      2) Fan Coil Unit (2-pipe Cooling Only).
      3) Fan Coil Unit (2-pipe) and Radiation.
      4) Fan Coil Unit (4-pipe).
      5) Fan Coil Unit (4-pipe) and Radiation.

   e. Finned Tube Radiation:

      1) Chilled Beam Sample I/O.
      2) Chilled Beam with Zone Pump (2-pipe Cooling Only).
      3) Chilled Beam with Zone Pump (4-pipe).
      4) Chilled Beam (2-pipe Cooling Only).
      5) Chilled Beam (4-pipe).

4. Hydronic or Electric Unit Heaters.

5. Split DX Units.
6. Hot Water Systems.
7. Secondary Chilled Water Systems.
8. Life Safety Equipment.
9. Equipment Restart Following a Fire Alarm.
10. Equipment Restart Following a Power Failure.
11. Miscellaneous Monitoring.

3.10 Air Handling Units (AHU)

1. Key Concepts:

   a. Air Handling Units (AHU) including Variable Frequency Drives (VFD) on graphic shall have a separate tab for software values.
   b. VFD shall have four hardwired points (start/stop, status, speed modulation signal, and fault).
   c. BMS shall have full direct control of the heat recovery wheel. Hardwired I/O to the BMS is preferable to a packaged heat wheel and BMS integration.
   d. Damper end switches, static pressure switches, and smoke detectors shall be hardwired to the respective fan safety circuit.
   e. Freezestat shall be auto-reset type and shall be hardwired to the respective fan safety circuit.

      1) When freezestat is tripped, unit must still be capable of running in firemen's override mode.
      2 When freezestat is tripped heating valve will control to maintain a case temperature in the unit.

   f. As a second level of protection, devices that are hardwired to a safety circuit should, when active, also be part of a software shutdown sequence.
   g. Firemen's override "fan on" switch (if required) shall be tied into the safety circuit such that the unit will run in all safety conditions except for high (or low) static pressure.
   h. Firemen's override "fan off" switch (if required) shall be tied into the safety circuit for fan shutdown
   i. Firemen's override "fan on" position switch shall be monitored by the BMS for switch "on" and switch "off" position.
   j. Firemen's override "fan off" position switch shall be monitored by the BMS for switch "on" and switch "off" position.
   k. Filter differential pressure is not required to be monitored by the BMS.
   l. Where applicable, the system shall employ the following energy savings strategies:

      1) Economizer Control.
      2) Energy Recovery.
      3) Demand Control Ventilation.
      4) Supply Air Static Pressure Setpoint Reset.

5) Supply Air Temperature Setpoint Reset (based on outside air).

2. Sequence of Operation (generic sequence that includes all components):

a. The unit shall have the following occupancy related modes:

1) Occupied.
2) Unoccupied.
3) Start-up.
4) Morning warm up.
5) Shut down.

b. The unit shall have the following control modes in addition to occupied and unoccupied:

1) Heating.
2) Cooling.
3) Dehumidification.
4) Economizer.

c. If a sensible heat wheel exists, it shall be capable of the following modes in addition to those above:

1) Reheat.
2) Purge.

d. If an enthalpy heat wheel exists, it shall be capable of the following modes in addition to those above:

1) Anti-Frost.
2) Purge.

e. Occupied System Start Up/Shut Down:

1) Occupied mode will be determined via BMS schedule supplied by MIT.
2) Start Up:

a) Supply fans and return fans shall be enabled by automatic or manual command at the BMS.
b) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall be commanded open via hardwire interlock to their system start circuits.
c) The supply and return fan VFDs shall be enabled via their respective smoke isolation damper end switches.
d) The individual fan isolation dampers shall be opened via hardwired interlock to their respective VFDs.

e) When the individual fan isolation dampers are proven open via hard wired end switches, the BMS will start the supply and return fans and ramp them to their minimum speed.

f) When fan status is proven on for the supply and return fans via current transducers, the BMS shall enable the discharge air temperature control loop.

g) When the heating coil discharge temperature has achieved setpoint, the BMS shall enable the supply fan and return fan speed control loops.

h) If either supply or return fans have been called to start but the status shows that the fans are not running 120 seconds (adjustable) after their respective smoke isolation damper proves open, the BMS shall lock out the unit. An alarm shall be sent to the operator workstation and the unit will only be enabled to run after the alarm is manually reset at the BMS.

i) When an application requires multiple AHUs feeding a common plenum (for system redundancy), the fans and dampers shall be staged appropriately to prevent the fan(s) from spinning backwards.

j) When an application requires a negative pressure for a space (i.e., laboratory, vivarium) the AHU return/exhaust fan shall be proven on prior to starting the supply fan.

3) Single Fan Failure (when there are two or more fans):

a) If a supply or return fan fails or is shut off locally during regular operation, as determined through the BMS by the fan status sensors, the BMS shall close the failed fan's isolation damper.

b) If fans are sized for N+1 configuration, the BMS shall modulate the other operable fans' VFD(s) to match the total unit CFM (or in some cases a static pressure setpoint for the supply fan with the return fan continuing to track CFM) of the unit in normal operation mode.

c) Once the failed fan is ready to start again and enabled by the user, upon receiving fan status via current transducer, the BMS shall release all fans back into the speed control loop.

4) Shut Down:

a) The BMS shall modulate each fan down to minimum speed and de-energize the fans. The BMS shall close the individual fan isolation dampers.

b) Once the individual fan isolation dampers are proven closed, the supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close.

c) The BMS shall turn off the heat wheel(s).

d) The BMS shall close the cooling coil valve.

e) The BMS shall modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.

f. Occupied Mode Control:

1) Supply Static Pressure Control:

a) Once started, the BMS shall modulate the AHU supply fan VFDs speed signals from the same control loop to maintain supply static pressure setpoint in the supply duct as measured by the remote mounted supply air static pressure sensors. When there are multiple static pressure sensors, the sensor whose value is furthest from the setpoint should be used as the control sensor.

2) Return Static Pressure Control:

a) Once started, the BMS shall modulate the AHU return fan VFDs speed signals from the same control loop to maintain return static pressure setpoint in the return duct as measured by the remote mounted supply air static pressure sensors. When there are multiple static pressure sensors, the sensor whose value is furthest from the setpoint should be used as the control sensor.

Equipment and Action	Cooling	Heating
Economizer	1	1
Heat Recovery	2	2
Hot Water Coil	N/A	3
Chilled Water Coil	3	N/A

b) In some cases the BMS shall modulate the return fans to track the supply fans to maintain a CFM offset.

3) Priority for Temperature Control:

a) The matrix below simply summarizes the text that follows for each piece of equipment. The matrix is explained as follows:

g. Unoccupied System Start Up/Shut Down:

1) Unoccupied mode shall be enabled based on a date/time schedule. The AHUs shall be off (reference shutdown sequence above) when in unoccupied mode with the following exceptions:

a) Unoccupied Occupant Override: The pushbutton on any three (adjustable) building space temperature sensors shall cause the BMS to restore the AHU to occupied mode (reference startup sequence above) for a period of two hours (adjustable).

b) Zone Temperature: If outside air temperature is below 55°F (adjustable) and multiple zone temperatures (exact strategy to be determined by MEP design consultant) drop below the unoccupied setpoint, the BMS shall start the AHUs and restore occupied mode until the zone temperature rises to 3°F above the unoccupied setpoint, at which point the AHUs shall shut down and restore unoccupied mode.

c) High Dew Point: If outside air dew point is above 53°F (adjustable), the BMS will control the AHUs in dehumidification mode with the fans at minimum speed. When outside air dew point reduces below 53°F (adjustable), the unoccupied high dew point mode will be disabled and the BMS shall shut down the AHUs.

h. Morning Warm Up/Cool Down: The AHU shall have optimized morning warm-up and cool-down control.

1) Once morning warm-up or cool-down is complete, the BMS shall operate the AHU under normal occupied control.

i. Freeze Protection Pump Operation:

1) MIT requires a freeze protection pump and an associated check valve in the bypass between coil supply and return for all AHUs with hot water heating coils.

a) The BMS shall only energize the freeze protection pump when the outside air temperature is 40°F or less.

b) Once the hot water coil control valve is proven to be more than 60% open (adjustable), the BMS shall de-energize the freeze protection pump.

c) If the hot water coil control valve is proven to be less than 50% open (adjustable), the BMS shall energize the freeze protection pump.

d) The BMS shall de-energize the freeze protection pump when the outside air temperature is 40°F or more.

e) If the pump is commanded to run and is not proven by current switch, the BMS shall de-energize the AHU and follow the same steps as in a freezestat alarm condition listed below.

j. Safeties:

1) **Freezestat (Auto Reset):**

a) The auto reset freezestat shall be set at 38°F.

b) In the event of a freezestat trip the following will occur:

1) The supply and return fans will stop via hardwired interlock.

2) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close via hardwired interlock.
3) The BMS shall fully open the cooling coil valve.
4) The BMS will modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.

c) When the freezestat auto resets the unit will restart as described in the Start/Stop section of this sequence. In some cases, if the unit trips and tries to restart three times in a half hour, subsequent software code will be implemented, such that a manual software reset via the BMS will be required for the unit to restart again.

2) **Supply or Return Static Pressure Switches (Manual Reset):**

a) In the event of a static switch trip on any fan the following will occur:

1) The supply fan(s) or return fan(s) will stop via hardwired safety.
2) The return fans will be commanded off.
3) The supply smoke isolation, return smoke isolation, exhaust and outside air dampers shall close.
4) The cooling valve shall close.
5) The BMS will modulate the heating coil valve to maintain plenum temperature setpoint as sensed by the cooling coil averaging temperature sensor.
6) When the static pressure switch is manually reset and the alarm is reset at the BMS, the unit will restart as described above.

3) **Fire Alarm System:**

a) The BMS will adjust the control mode of the AHU based on signals received from the fireman's HOA (FHOA) contacts. An alarm will be generated to the BMS anytime a FHOA override is activated. The following contacts will be monitored per AHU:

1) General Fire Alarm (Complete AHU Shut Down).
2) Supply Fans "Hand":

a) Supply Fans On.
b) Supply fans run to preset speed or static pressure control.
c) Supply smoke isolation and outside air damper open.
d) Safeties bypassed except high and/or low static.
e) BMS maintains supply air temperature.

3) Supply Fans "Off":

a) Supply Fans "Off".
b) Supply smoke isolation and outside air damper closed.
c) All temperature control devices in normal positions.

4) Return Fans "Hand":

a) Return Fans On.
b) Return fans run to preset speed or static pressure control.
c) Return smoke isolation and exhaust air damper open.
d) Safeties bypassed except high and/or low static.

5) Return Fans "Off":

a) Return Fans "Off".
b) Return smoke isolation and outside air damper closed.
c) All temperature control devices in normal positions.

Air Handling Units Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Fan Status	SW	Yes	Yes	Yes	Yes
Fan Runtime	SW	No	No	No	Yes
Fan Amps	AI	No	Yes	Yes	Yes
HOA Switch	DI	Yes	Yes	Yes	Yes
Fireman's Override On	DI	Yes	Yes	Yes	Yes
Fireman's Override Off	DI	Yes	Yes	Yes	Yes
Space Temperature	AI	Yes	Yes	Yes	Yes
Supply Air Temperature	AI	Yes	Yes	Yes	Yes
Return Air Temperature	AI	Yes	Yes	Yes	Yes
Mixed Air Temperature	AI	Yes	Yes	Yes	Yes
Supply Air Humidity	AI	Yes	Yes	Yes	Yes
Return Air Humidity	AI	Yes	Yes	Yes	Yes
Return CO2	AI	Yes	Yes	Yes	Yes
Cooling Coil Temperature	AI	Yes	Yes	Yes	Yes
Heating Coil Temperature	AI	Yes	Yes	Yes	Yes
Heat Recovery Temperature	AI	Yes	Yes	Yes	Yes
Cooling Coil Water Supply Temperature	AI	Yes	Yes	Yes	Yes
Cooling Coil Water Return Temperature	AI	Yes	Yes	Yes	Yes
Preheat Coil Valve Position	AI	No	Yes	Yes	Yes
Heating Coil Valve Position	AI	No	Yes	Yes	Yes
Cooling Coil Valve Position	AI	No	Yes	Yes	Yes
HR Wheel Status	AI	Yes	Yes	Yes	Yes
HR Wheel Runtime	SW	No	No	No	Yes
Dewpoint Sensor	AI	No	Yes	Yes	Yes
Static Pressure	AI	Yes	Yes	Yes	Yes

Damper End Switch	DI	Yes	Yes	Yes	Yes
Pressure Switch	DI	Yes	Yes	Yes	Yes
Smoke Detector	DI	Yes	Yes	Yes	Yes
VFD Fault	DI	Yes	Yes	Yes	Yes
VFD Bypass	DI	Yes	Yes	Yes	Yes
Fan Flow	AI	Yes	Yes	Yes	Yes
Freeze Protection Pump Status	DI	No	Yes	Yes	Yes
VFD Modulation	AO	No	Yes	Yes	Yes
Preheat Coil Valve	AO	No	Yes	Yes	Yes
Heating Coil Valve	AO	No	Yes	Yes	Yes
Cooling Coil Valve	AO	No	Yes	Yes	Yes
Heat Recovery Wheel	DO	No	Yes	Yes	Yes
Fan Start/Stop	DO	No	Yes	Yes	Yes
Damper Open/Close	DO	No	Yes	Yes	Yes
Freeze Protection Pump Start/Stop	DO	No	Yes	Yes	Yes
Freeze Protection Pump Runtime	SW	No	No	No	Yes
Flow Setpoint	SW	No	Yes	Yes	Yes
Temperature Setpoint	SW	No	Yes	Yes	Yes
Pressure Setpoint	SW	No	Yes	Yes	Yes
VFD Speed Feedback	SW	No	Yes	Yes	Yes
System Enable	SW	No	Yes	Yes	Yes
Occupied Status	SW	No	Yes	Yes	Yes

3.11 Exhaust/Supply Fans

1. Key Concepts:

   a. VFD on graphic shall have a separate tab for software values.
   b. VFD shall have four hardwired points (start/start, status, speed modulation signal, and fault).
   c. Damper end switch and static pressure switch be hardwired to the fan safety circuit.
   d. As a second level of protection, devices that are hardwired to a safety circuit should, when active, also be part of a software shutdown sequence.
   e. Firemen’s override “fan on” switch if required shall be tied into the safety circuit such that the unit will run in all safety conditions except for high (or low) static pressure.
   f. Firemen’s override “fan off” switch if required shall be tied into the safety circuit for fan shutdown
   g. Firemen’s override “fan on” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   h. Firemen’s override “fan off” position switch shall be monitored by the BMS for switch “on” and switch “off” position.
   i. Sequence of Operation
   j. Temperature Control (if applicable)
   k. On a high temperature, the BMS shall energize the fan.
   l. Static Pressure (if applicable)
   m. The BMS shall modulate the fan VFD to maintain static pressure setpoint.

Exhaust/Supply Fans Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Fan Status	SW	Yes	Yes	Yes	Yes
Fan Amps	AI	No	Yes	Yes	Yes
Fan Runtime	SW	No	No	No	Yes
HOA Switch	DI	Yes	Yes	Yes	Yes
Fireman's Override On	DI	Yes	Yes	Yes	Yes
Firemen's Override Off	DI	Yes	Yes	Yes	Yes
Space Temperature	AI	Yes	Yes	Yes	Yes
Static Pressure	AI	Yes	Yes	Yes	Yes
Damper End Switch	DI	Yes	Yes	Yes	Yes
Pressure Switch	DI	Yes	Yes	Yes	Yes
VFD Fault	DI	Yes	Yes	Yes	Yes
VFD Bypass	DI	Yes	Yes	Yes	Yes
Fan Flow	AI	Yes	Yes	Yes	Yes
VFD Modulation	AO	No	Yes	Yes	Yes
Fan Start/Stop	DO	No	Yes	Yes	Yes
Damper Open/Close	DO	No	Yes	Yes	Yes
VFD Speed Feedback	SW	No	Yes	Yes	Yes
Flow Setpoint	SW	No	Yes	Yes	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Pressure Setpoint	SW	No	Yes	Yes	Yes
Occupied Status	SW	No	Yes	Yes	Yes

3.12 Room Control

1. Key Concepts:

a. All heating and cooling units serving one space shall be connected and controlled to prevent simultaneous heating and cooling.

b. When there a terminal unit serves multiple rooms each with a space temperature sensor, one sensor shall act as a master. The BMS shall not use an average of the temperature sensors to maintain a certain space temperature setpoint.

c. Spaces shall have dual setpoints for occupied heating and cooling of 70°F and 74°F respectively with a deadband between the setpoints.

d. Spaces shall have dual setpoints for daytime unoccupied heating and cooling of 68°F and 76°F respectively with a deadband between the setpoints.

e. Spaces shall have dual setpoints for unoccupied heating and cooling of 65°F and 80°F respectively.

1) When the space temperature reaches 80°F, the BMS shall go to unoccupied cooling mode until room temperature reaches 77°F.

2) Conversely, when the space temperature reaches 65°F, the BMS shall go to unoccupied heating mode until room temperature reaches 68°F.

f. For applicable spaces (usually offices and residences), room temperature sensors shall have a physical setpoint adjustment of +/- 1.5°F (software adjustable) integral to the room temperature sensor.

g. For applicable spaces (usually offices), room temperature sensors shall have an occupancy override pushbutton (software adjustable) integral to the room temperature sensor which shall but the system into temporary occupancy mode for two hours (adjustable).

h. For applicable spaces (usually offices and residences), room temperature sensors shall have local display showing actual temperature, mode (heating or cooling), occupancy status, and setpoint.

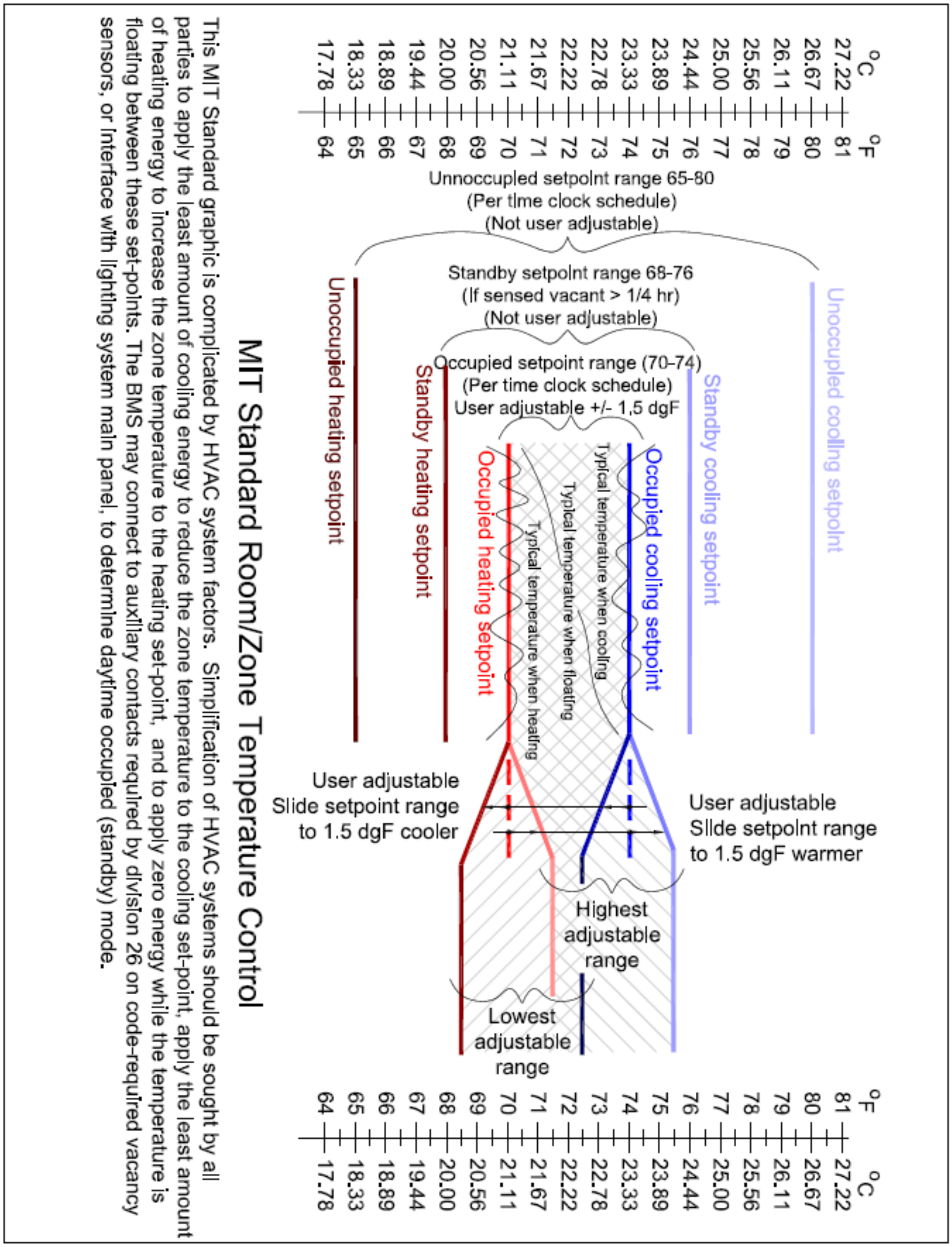
i. Operator shall have the ability to modify room base setpoint without changing a program or disabling a setpoint.

j. Applicable spaces (usually high occupant density areas like classrooms, conference rooms, and auditoriums) shall have CO_2 sensors. The CO_2 can be integrated into the room temperature sensor.

k. Fan coil units shall have electronically commutated motors (ECMs) and shall not have packaged control. Due to accuracy at low current draws, fan coil unit manufacturer dry contact for fan status shall be preferable to current switch.

l. Local fan control speed switches are not required for fan coil units with ECMs.

2. Standard Room Temperature Control Diagram (follows this page)



3.

3.13 Sequence Matrix Summaries

1. The matrix below simply summarizes the text that follows for each piece of equipment. The matrix is explained as follows:

a. In the Cool Priority or Heat Priority, the lower number dictates the first action by the BMS (i.e., in heat mode with a VAV (with Reheat Coil), the BMS will first use the damper (1), then use the HW Valve (2) in an attempt to maintain setpoint.

Equipment and Action	Occupied/ Daytime Unoccupied Cool Mode Priority	Occupied/ Daytime Unoccupied Heat Mode Priority
CV (without Reheat Coil) Supply or Return	N/A	N/A
CV (without Reheat Coil) and Radiation		
Radiation Valve Modulates Toward Open	N/A	1
CV (with Reheat Coil)		
HW Valve Modulates Toward Open	N/A	1
CV (with Reheat Coil) and Radiation		
Radiation Valve Modulates Toward Open	N/A	1
HW Valve Modulates Toward Open	N/A	2
VAV (without Reheat Coil)		
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A
VAV (without Reheat Coil) and Radiation		
Radiation Valve Modulates Toward Open	N/A	2
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A
VAV (with Reheat Coil)		
HW Valve Modulates Toward Open	N/A	2
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A
VAV (with Reheat Coil) and Radiation		
Radiation Valve Modulates Toward Open	N/A	2
HW Valve Modulates Toward Open	N/A	3
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A
VAV (Return Air)		
Damper Modulates Toward Minimum	N/A	N/A
Damper Modulates Toward Maximum	N/A	N/A
Fan Coil Unit (2-pipe Cooling Only)		
Fan On Turns with ECM @Minimum Speed	1	N/A
CHW Valve Modulates Toward Open	2	N/A
ECM Modulates Toward Minimum	N/A	N/A
ECM Modulates Toward Maximum	3	N/A
Fan Coil Unit (2-pipe Cooling Only) w/ Radiation		
Fan On Turns with ECM @Minimum Speed	1	N/A
Radiation Valve Modulates Toward Open	N/A	1
CHW Valve Modulates Toward Open	2	N/A
ECM Modulates Toward Minimum	N/A	N/A
ECM Modulates Toward Maximum	3	N/A
Fan Coil Unit (4-pipe)		
Fan On Turns with ECM @Minimum Speed	1	1
HW Valve Modulates Toward Open	N/A	2
CHW Valve Modulates Toward Open	2	N/A
ECM Modulates Toward Maximum	3	3

Fan Coil Unit (4-pipe Cooling Only) w/ Radiation		
Fan On Turns with ECM @Minimum Speed	1	2
Radiation Valve Modulates Toward Open	N/A	1
HW Valve Modulates Toward Open	N/A	3
CHW Valve Modulates Toward Open	2	N/A
ECM Modulates Toward Maximum	3	4
Chilled Beam with Zone Pump (2-pipe Cooling)		
CHW Valve Modulates Toward Open	1	N/A
CHW Pump Turns On	2	N/A
Chilled Beam with Zone Pump (4-pipe)		
CHW Valve Modulates Toward Open	1	N/A
CHW Pump Turns On	2	N/A
HW Valve Modulates Toward Open	N/A	1
HW Pump Turns On	N/A	2
Chilled Beam (2-pipe Cooling)		
CHW Valve Modulates Toward Open	1	N/A
Chilled Beam (4-pipe)		
CHW Valve Modulates Toward Open	1	N/A
HW Valve Modulates Toward Open	N/A	1
Finned Tube Radiation		
Radiation Valve Modulates Toward Open	N/A	1

2. In many cases the above items will work together to control the temperature in a space. Special care must be given to stage the pieces of control properly. Some common occurrences are detailed in the matrix below. MIT has tried to address a couple common cases with the most parts so that if for example finned tube radiation is not present, the line time can be removed and the other parts can be renumbered accordingly.

Equipment and Action	Occupied / Daytime Unoccupied Cool Mode Priority	Occupied / Daytime Unoccupied Heat Mode Priority
4-pipe Chilled Beam w/ VAV w/ Reheat and FTR		
VAV Damper Controls to Constant Volume	Yes	Yes
CB HW Valve Modulates Toward Open	N/A	1
CHW Pump Turns On	2	N/A
CB CHW Valve Modulates Toward Open	1	N/A
HW Pump Turns On	N/A	N/A
Radiation Valve Modulates Toward Open	N/A	2
VAV HW Valve Modulates Toward Open	N/A	3
2-pipe FCU w/ VAV w/ Reheat and FTR		
Fan On Turns with ECM @Minimum Speed	2	N/A
Radiation Valve Modulates Toward Open	N/A	2
FCU CHW Valve Modulates Toward Open	3	N/A
FCU ECM Modulates Toward Maximum	4	N/A
VAV HW Valve Modulates Toward Open	N/A	3
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A
4-pipe FCU w/ VAV and FTR		
Fan On Turns with ECM @Minimum Speed	2	3
Radiation Valve Modulates Toward Open	N/A	2
FCU CHW Valve Modulates Toward Open	3	N/A
FCU HW Valve Modulates Toward Open	N/A	4
FCU ECM Modulates Toward Maximum	4	5
Damper Modulates Toward Minimum	N/A	1
Damper Modulates Toward Maximum	1	N/A

3.14 CV Boxes

CV Boxes Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Space Temperature Adjustment	AI	No	No	No	Yes
Space Humidity	AI	Yes	Yes	Yes	Yes
Space CO2	AI	Yes	Yes	Yes	Yes
Velocity Measurement	AI	No	Yes	Yes	No
Discharge Temperature	AI	No	Yes	Yes	Yes
Reheat Valve	AO	No	Yes	Yes	Yes
VAV Damper	AO	No	Yes	Yes	Yes
Radiation Valve	AO	No	Yes	Yes	Yes
VAV Flow	SW	Yes	Yes	Yes	Yes
VAV Flow Setpoint	SW	No	Yes	Yes	Yes
Base Temperature Setpoint	SW	No	No	No	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Discharge Temperature Setpoint	SW	No	Yes	Yes	Yes
Heating Setpoint	SW	No	No	No	No
Cooling Setpoint	SW	No	No	No	No
Mode	SW	No	No	No	Yes
Occupied Status	SW	No	Yes	Yes	Yes

1. CV Box (without Reheat Coil) Sequence of Operation:

    a. The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
    b. When the source AHU is off, the BMS shall modulate the CV box closed.

2. CV Box (without Reheat Coil) and Radiation Sequence of Operation

    a. Occupied Cooling Mode:

        1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
        2) The BMS shall start to close the radiation control valve to maintain occupied space temperature setpoint.

    b. Occupied Heating Mode:

        1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
        2) The BMS shall start to open the radiation control valve to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall start to close the radiation control valve to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall start to open the radiation control valve to maintain occupied space temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the radiation control valve fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the radiation control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the CV box closed and close the radiation control valve.

3. CV Box (with Reheat Coil) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall start to close the reheat coil control valve to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall start to close the reheat coil control valve to maintain occupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil control valve fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the VAV box closed and close the reheat coil control valve.

4. CV Box (with Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the reheat coil control valve to maintain occupied discharge temperature setpoint.
4) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to open the radiation control valve to maintain discharge temperature setpoint.

4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil and radiation control valves fully closed until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the CV box flow to maintain a constant flow setpoint.
2) The BMS shall modulate the reheat coil and radiation control valves fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation and reheat coil control valves.

5. CV (Return Air) Box Sequence of Operation

a. The BMS shall modulate the CV box flow to maintain a constant flow setpoint.

3.15 VAV Boxes

VAV Boxes Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Space Temperature Adjustment	AI	No	No	No	Yes
Space Humidity	AI	Yes	Yes	Yes	Yes
Space CO2	AI	Yes	Yes	Yes	Yes
Velocity Measurement	AI	No	Yes	Yes	No
Discharge Temperature	AI	No	Yes	Yes	Yes
Reheat Valve	AO	No	Yes	Yes	Yes
VAV Damper	AO	No	Yes	Yes	Yes
Radiation Valve	AO	No	Yes	Yes	Yes
VAV Flow	SW	Yes	Yes	Yes	Yes
VAV Flow Setpoint	SW	No	Yes	Yes	Yes
VAV Flow Maximum	SW	No	No	No	Yes
VAV Flow Minimum	SW	No	No	No	Yes
Base Temperature Setpoint	SW	No	No	No	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Discharge Temperature Setpoint	SW	No	Yes	Yes	Yes
Heating Setpoint	SW	No	No	No	No
Cooling Setpoint	SW	No	No	No	No
Mode	SW	No	No	No	Yes
Occupied Status	SW	No	Yes	Yes	Yes

1. VAV Box (without Reheat Coil) Sequence of Operation:

   a. Occupied Cooling Mode:

      1) The BMS shall start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

   b. Daytime Unoccupied Cooling Mode:

      1) The BMS shall start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

   c. Unoccupied Cooling Mode (with the source AHU on):

      1) The BMS shall modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

d. CO2 Control (applicable in Occupied Mode only):

1) The BMS shall prioritize CO2 override over cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

e. When the source AHU is off, the BMS shall modulate the VAV box closed.

2. VAV Box (without Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first start to close the radiation control valve to maintain occupied space temperature setpoint.
2) Once the valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain occupied space temperature setpoint.
2) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first start to close the radiation control valve to maintain daytime unoccupied space temperature setpoint.
2) Once the valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain daytime unoccupied space temperature setpoint.
2) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain occupied daytime unoccupied space temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the radiation control valve fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode:

1) The BMS shall modulate the radiation control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation control valve.

3. VAV Box (with Reheat Coil) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first start to close the reheat coil control valve to maintain occupied space temperature setpoint.
1) Once the reheat coil control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first start to close the reheat coil control valve to maintain daytime unoccupied space temperature setpoint.
2) Once the reheat coil control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its

maximum flow setpoint to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil control valve fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil control valve fully open and modulate the VAV box flow to its minimum flow setpoint until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the reheat coil control valve.

4. VAV Box (with Reheat Coil) and Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain occupied discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain discharge temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to close the reheat coil control valve to maintain discharge temperature setpoint.
3) Once the reheat coil control valve is fully closed, the BMS shall then start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to modulate the VAV box flow from its minimum flow setpoint up toward its maximum flow setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
2) The BMS shall first start to modulate the VAV box flow from its maximum flow setpoint down toward its minimum flow setpoint to maintain discharge temperature setpoint.
3) Once the VAV box is at its minimum flow, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the reheat coil control valve to maintain discharge temperature setpoint.

e. Unoccupied Cooling Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil and radiation control valves fully closed and modulate the VAV box flow to its maximum flow setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode (with the source AHU on):

1) The BMS shall modulate the reheat coil and radiation control valves fully open and modulate the VAV box flow to its minimum flow setpoint until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the VAV box flow toward its maximum to maintain acceptable room CO2 levels (<825 ppm).

h. When the source AHU is off, the BMS shall modulate the VAV box closed and close the radiation and reheat coil control valves.

5. VAV (Return Air) Box Sequence of Operation:

a. In most cases, the BMS will control the return VAV to track the corresponding supply VAV CFM to provide a room offset.
b. Occupied Mode:

1) The BMS shall modulate the VAV box damper to maintain airflow setpoint.

c. Unoccupied Mode (with the source AHU on):

1) The BMS shall modulate the VAV box damper to maintain airflow setpoint.

d. When the source AHU is off, the BMS shall modulate the VAV box closed.

3.16 Fan Coil Units

Fan Coil Units Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Space Temperature Adjustment	AI	No	No	No	Yes
Space Humidity	AI	Yes	Yes	Yes	Yes
Discharge Temperature	AI	Yes	Yes	Yes	Yes
Fan Status	SW	No	Yes	Yes	Yes
ECM Minimum Setpoint	SW	No	No	No	Yes
ECM Maximum Setpoint	SW	No	No	No	Yes
Fan Current Switch	DI	No	No	No	Yes
Condensate Level Switch **for all TeleComm Room Applications and** where required elsewhere	DI	Yes	No	No	Yes
Heating Valve	AO	No	Yes	Yes	Yes
Cooling Valve	AO	No	Yes	Yes	Yes
Radiation Valve	AO	No	Yes	Yes	Yes
Fan Start/Stop (not required with ECM)	DO	No	Yes	Yes	Yes
Fan EC motor control	AO	No	Yes	Yes	Yes
Base Temperature Setpoint	SW	No	No	No	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Discharge Temperature Setpoint	SW	No	Yes	Yes	Yes
Heating Setpoint	SW	No	No	No	No
Cooling Setpoint	SW	No	No	No	No
Mode	SW	No	No	No	Yes
Occupied Status	SW or DI	No	Yes	Yes	Yes

* Refer to MIT Design Standards 230000-HVAC for further details.

1. Fan Coil Units (2-pipe Cooling Only) Sequence of Operation:

   a. When space the temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil control valve fully closed, for fifteen minutes, the BMS shall de-energize the fan.

   b. Occupied Cooling Mode:

      1) The fan shall be on in occupied mode with the ECM in its minimum position.
      2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.

3) The BMS shall first start to modulate the cooling coil control valve open to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in occupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to modulate the cooling coil control valve open to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

e. CO2 Control (applicable in Occupied Mode only):

1) The BMS shall prioritize CO2 override over cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).

2. Fan Coil Units (2-pipe) and Radiation Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil and radiation control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.
b. Occupied Cooling Mode:

1) The fan shall be on in occupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Occupied Heating Mode:

1) The fan shall be off in occupied heating mode.
2) The BMS shall then start to open the radiation control valve to maintain occupied space temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then start to modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

e. Daytime Unoccupied Heating Mode:

1) The fan shall be off in daytime unoccupied heating mode.
2) The BMS shall then start to open the radiation control valve to maintain daytime unoccupied space temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the radiation control valve fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) With the fan off and the cooling coil control valve fully closed, the BMS shall modulate the radiation control valve fully open, until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).

3. Fan Coil Units (4-pipe) Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil and hot water coil control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.

b. Occupied Cooling Mode:

1) The fan shall be on in occupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the heating coil control valve to maintain discharge temperature setpoint.
4) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
5) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Occupied Heating Mode:

1) The fan shall be on in occupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully closed, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the heating coil control valve to maintain discharge temperature setpoint.
4) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.

5) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

e. Daytime Unoccupied Heating Mode:

1) The fan shall be on in daytime unoccupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling coil control valve is fully closed, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil control valve fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil control valve fully open, and modulate the cooling coil control valve fully closed until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO2 levels (<825 ppm).

4. Fan Coil Units (4-pipe Heating & Cooling) and Radiation Sequence of Operation:

a. When the space temperature is in the deadband and the ECM has been at its minimum position, with the cooling coil, hot water coil, and radiation control valves fully closed, for fifteen minutes, the BMS shall de-energize the fan.
b. Occupied Cooling Mode:

1) The fan shall be on in occupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to close the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
6) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

c. Occupied Heating Mode:

1) The fan shall be on in occupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain occupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling control valve is fully closed, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
5) Once the radiation control valve is fully open, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
6) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

d. Daytime Unoccupied Cooling Mode:

1) The fan shall be on in daytime unoccupied cooling mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the radiation control valve to maintain discharge temperature setpoint.
4) Once the radiation control valve is fully closed, the BMS shall then start to close the heating coil control valve to maintain discharge temperature setpoint.
5) Once the heating coil control valve is fully closed, the BMS shall then start to open the cooling coil control valve to maintain discharge temperature setpoint.
6) Once the cooling coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

e. Daytime Unoccupied Heating Mode:

1) The fan shall be on in daytime unoccupied heating mode with the ECM in its minimum position.
2) The BMS shall use actual space temperature to reset the discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint.
3) The BMS shall first start to close the cooling coil control valve to maintain discharge temperature setpoint.
4) Once the cooling control valve is fully closed, the BMS shall then start to open the radiation control valve to maintain discharge temperature setpoint.
5) Once the radiation control valve is fully open, the BMS shall then start to open the heating coil control valve to maintain discharge temperature setpoint.
6) Once the heating coil control valve is fully open, the BMS shall then modulate the fan coil unit ECM from its minimum speed setpoint up toward its maximum speed setpoint to maintain discharge temperature setpoint.

f. Unoccupied Cooling Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil and radiation control valves fully closed, and modulate the cooling coil control valve fully open until space temperature has reached 3°F below unoccupied space temperature setpoint.

g. Unoccupied Heating Mode:

1) The BMS shall energize the fan, modulate the fan coil unit ECM to its maximum speed setpoint, modulate the heating coil and radiation control valves fully open, and modulate the cooling coil control valve fully closed until space temperature has reached 3°F above unoccupied space temperature setpoint.

h. CO_2 Control (applicable in Occupied Modes only):

1) The BMS shall prioritize CO_2 override over heating and cooling.
2) The BMS shall modulate the ECM toward its maximum speed setpoint to maintain acceptable room CO_2 levels (<825 ppm).

3.17 Chilled Beams

Chilled Beam Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Space Temperature Adjustment	AI	No	No	No	Yes
Space Humidity	AI	Yes	Yes	Yes	Yes
Space CO2	AI	Yes	Yes	Yes	Yes
Booster Pump Start/Stop	DO	Yes	Yes	Yes	Yes
Booster Pump Status	DI	Yes	Yes	Yes	Yes
Pump Discharge Temperature	AI	Yes	Yes	Yes	Yes
Heating Valve	AO	No	Yes	Yes	Yes
Cooling Valve	AO	No	Yes	Yes	Yes
Radiation Valve	AO	No	Yes	Yes	Yes
Base Temperature Setpoint	SW	No	No	No	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Heating Setpoint	SW	No	No	No	No
Cooling Setpoint	SW	No	No	No	No
Mode	SW	No	No	No	Yes
CHW Discharge Setpoint	SW	No	Yes	Yes	Yes
HW Discharge Setpoint	SW	No	Yes	Yes	Yes
Space Dewpoint	SW	No	Yes	Yes	Yes
Occupied Status	SW or DI	No	Yes	Yes	Yes

1. Chilled Beam with Zone Pump (2-pipe Cooling) Sequence of Operation:

   a. Occupied Cooling Mode:

      1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain occupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations, outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F:

<u>**Outside Air Dewpoint**</u>	<u>**CHW Discharge Setpoint**</u>
55°F	59°F

Outside Air Dewpoint	CHW Discharge Setpoint
52°F	55°F

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

b. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

Outside Air Dewpoint	CHW Discharge Setpoint
55°F	59°F
52°F	55°F

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

c. Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

Outside Air Dewpoint	CHW Discharge Setpoint
55°F	59°F
52°F	55°F

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.
3) The BMS shall then energize the CHW booster pump.

d. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

e. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall first de-energize the CHW booster pump.
2) The BMS shall then modulate the cooling coil control valve fully closed.

2. Chilled Beam with Zone Pump (4-pipe Heating & Cooling) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain occupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

Outside Air Dewpoint	**CHW Discharge Setpoint**
55°F	59°F
52°F	55°F

2) The BMS shall first start to modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump
4) The BMS shall then modulate the heating coil control valve fully closed.

b. Occupied Heating Mode:

1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F.

2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.
3) The BMS shall then modulate the cooling coil control valve fully closed.
4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain daytime unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

Outside Air Dewpoint	**CHW Discharge Setpoint**
55°F	59°F
52°F	55°F

2) The BMS shall first start to modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint.
3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump
4) The BMS shall then modulate the heating coil control valve fully closed.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F.
2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.
3) The BMS shall then modulate the cooling coil control valve fully closed.
4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

e. Unoccupied Cooling Mode:

1) The BMS shall use actual space temperature to reset the CHW pump discharge temperature setpoint and use this to maintain unoccupied space temperature setpoint. The BMS shall reset the CHW pump discharge temperature setpoint between its maximum setpoint of 74°F and a minimum setpoint established by

taking the maximum of two dew point calculations. Outside air dew point reset calculation in following table, space dew point (as calculated from T&RH sensors in return duct) plus 2°F.

Outside Air Dewpoint	CHW Discharge Setpoint
55°F	59°F
52°F	55°F

2) The BMS shall first modulate the cooling coil control valve open to maintain CHW pump discharge temperature setpoint until space temperature has reached 3°F below unoccupied space temperature setpoint.
3) The BMS shall then energize the CHW booster pump and de-energize the HW booster pump.
4) The BMS shall then modulate the heating coil control valve fully closed.

f. Unoccupied Heating Mode:

1) The BMS shall first start to modulate the heating coil control valve open to maintain HW pump discharge temperature setpoint of 120°F until space temperature has reached 3°F above unoccupied space temperature setpoint.
2) The BMS shall then energize the HW booster pump and de-energize the CHW booster pump.
3) The BMS shall then modulate the cooling coil control valve fully closed.
4) Additionally, the heating mode utilizes a VAV box with reheat coil and/or perimeter radiation control valve as described above in the VAV section.

g. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

h. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall de-energize the CHW booster pump.
2) The BMS shall modulate the cooling coil control valve fully closed.

3. Chilled Beam (2-pipe Cooling) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall modulate the cooling coil control valve open to maintain occupied space temperature setpoint.

b. Unoccupied Cooling Mode:

1) The BMS shall modulate the cooling coil control valve fully open until space temperature has reached 3°F above unoccupied space temperature setpoint.

c. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

d. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall modulate the cooling coil control valve fully closed.

4. Chilled Beam (4-pipe Heating & Cooling) Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open to maintain daytime unoccupied space temperature setpoint.

e. Unoccupied Cooling Mode:

1) The BMS shall first modulate the heating coil control valve fully closed.
2) The BMS shall then modulate the cooling coil control valve open until space temperature has reached 3°F below unoccupied space temperature setpoint.

f. Unoccupied Heating Mode:

1) The BMS shall first modulate the cooling coil control valve fully closed.
2) The BMS shall then modulate the heating coil control valve open until space temperature has reached 3°F above unoccupied space temperature setpoint.

g. Unoccupied Dewpoint Control Mode:

1) If space dewpoint in any of the rooms in the zones served rises above 59°F, the BMS shall modulate the associated VAV box fully open until the space dewpoint reaches 56°F.

h. Extreme Humidity Control Mode (dewpoint >57°F (occupied mode), dewpoint >59°F (unoccupied mode) as measured in the space or return duct):

1) The BMS shall modulate the cooling coil control valve fully closed.

3.18 Finned Tube Radiation

Finned Tube Radiation Typical Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Space Temperature Adjustment	AI	No	No	No	Yes
Radiation Valve	AO	No	Yes	Yes	Yes
Base Temperature Setpoint	SW	No	No	No	Yes
Space Temperature Setpoint	SW	No	Yes	Yes	Yes
Heating Setpoint	SW	No	No	No	No
Cooling Setpoint	SW	No	No	No	No
Mode	SW	No	No	No	Yes
Occupied Status	SW or DI	No	Yes	Yes	Yes

1. Finned Tube Radiation Sequence of Operation:

a. Occupied Cooling Mode:

1) The BMS shall start to modulate the radiation control valve closed to maintain occupied space temperature setpoint.

b. Occupied Heating Mode:

1) The BMS shall start to modulate the radiation control valve open to maintain occupied space temperature setpoint.

c. Daytime Unoccupied Cooling Mode:

1) The BMS shall start to modulate the radiation control valve closed to maintain daytime unoccupied space temperature setpoint.

d. Daytime Unoccupied Heating Mode:

1) The BMS shall start to modulate the radiation control valve open to maintain daytime unoccupied space temperature setpoint.

e. Unoccupied Cooling Mode:

1) The BMS shall modulate the radiation control valve fully closed to maintain unoccupied space temperature setpoint.

f. Unoccupied Heating Mode:

1) The BMS shall modulate the radiation control valve fully open to maintain unoccupied space temperature setpoint.

3.19 Unit Heaters

1. Hot Water, Steam, or Electric Unit Heater / Cabinet Unit Heaters:

a. Key Concepts:

1) Unit heaters and cabinet unit heaters shall have local control.
2) A temperature sensor, located in each room served by the unit heaters or cabinet unit heaters, shall be monitored by the BMS.

b. Sequence of Operation (Hot Water and Steam)

1) Unit Heaters and cabinet unit heaters are locally controlled by a room thermostat, pipe mounted aqua-stat (hydronic) or pressure switch (steam), and two-position control valve.
2) When the temperature in the space is below the room thermostat setpoint, the control valve shall open. On a rise in water temperature above the aqua-stat or pressure switch setpoint, the fan shall be energized.
3) When the temperature in the space is below the room thermostat setpoint, the control valve shall close. On a fall in water temperature below the aqua-stat or pressure switch setpoint, the fan shall be de-energized.

Typical Unit Heaters Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes

2. Hot Water, Steam, or Electric Unit Heater / Cabinet Unit Heater (BMS Controlled):

a. Key Concepts:

1) If the project requires, unit heaters and cabinet unit heaters shall be controlled by the BMS.

b. Sequence of Operation (Hot Water and Steam):

1) The BMS shall control the unit heaters and cabinet unit heaters as follows:
2) When the temperature in the space is below the space temperature setpoint, the control valve shall open and the fan shall be energized.
3) When the temperature in the space is above the space temperature setpoint, the control valve shall close and the fan shall be de-energized.

Typical BMS Controlled Unit Heaters Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes
Unit Heater Fan Status	DI	Yes	Yes	Yes	Yes
Unit Heater Fan On/Off	DO	No	Yes	Yes	Yes
Control Valve Open/Closed	DO	No	Yes	Yes	Yes

3. Split DX Units:

a. Key Concepts:

1) Split air conditioning units shall have local control.
2) A temperature sensor, located in each room served by the split DX units, shall be monitored by the BMS.
3) DX units shall be capable of being integrated to the BMS via a common communication protocol such as Modbus or BACnet.

b. Sequence of Operation:

1) Packaged Control.

Typical Split DX Units Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Space Temperature	AI	Yes	Yes	Yes	Yes

4. Building Heating Hot Water Systems:

a. Key Concepts:

1) In most cases, steam and medium temperature hot water are supplied from MIT's central plant.
2) The pumps are designed to operate in a duty/standby arrangement.

b. Sequence of Operation, General:

1) The BMS shall energize the duty pump. Only one pump is required to run to maintain the system.
2) The BMS shall switch the duty/standby alternation bi-monthly.
3) Upon, pump failure, the BMS shall energize the standby pump and generate an alarm.
4) The BMS shall linearly reset the hot water supply temperature setpoint as follows:

Outside Air Temperature	HW Supply Temperature Setpoint
32°F	180°F (adjustable)
65°F	140°F (adjustable)

c. Differential Pressure Controls:

1) The BMS shall first modulate the pump VFD to maintain system differential pressure setpoint.
2) If the VFD is at its minimum for five minutes (adjustable) and the system differential pressure is still above setpoint, the BMS shall then begin to modulate the differential pressure valve open to maintain system differential pressure setpoint.
3) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached,

the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain differential pressure setpoint. The BMS shall de-energize the duty pump and generate a pump failure alarm.

d. Temperature Controls:

1) The BMS shall modulate the 1/3, 2/3 steam valves to maintain hot water supply temperature setpoint. In order to keep the steam load stable, the BMS shall sequence the valves in the following arrangement:

1/3 Valve (%Open)	**2/3 Valve (%Open)**
0-75%	0%
0%	0%-100%
0-100%	100%

Typical Building Heating Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Pump Status	SW	Yes	Yes	Yes	Yes
Pump Amps	AI	No	Yes	Yes	Yes
Pump Runtime	SW	No	No	No	Yes
HOA Switch	DI	Yes	Yes	Yes	Yes
HWS Temperature	AI	Yes	Yes	Yes	Yes
HWR Temperature	AI	Yes	Yes	Yes	Yes
1/3 Steam Valve Position	AI	No	Yes	Yes	Yes
2/3 Steam Valve Position	AI	No	Yes	Yes	Yes
Differential Pressure Valve Position	AI	No	Yes	Yes	Yes
Differential Pressure	AI	Yes	Yes	Yes	Yes
VFD Modulation	AO	No	Yes	Yes	Yes
VFD Fault	SW	Yes	Yes	Yes	Yes
Pump Start/Stop	DO	No	Yes	Yes	Yes
1/3 Steam Valve	AO	No	Yes	Yes	Yes
2/3 Steam Valve	AO	No	Yes	Yes	Yes
Differential Pressure Valve	AO	No	Yes	Yes	Yes
HWS Temperature Setpoint	SW	No	Yes	Yes	Yes
Differential Pressure Setpoint	SW	No	Yes	Yes	Yes
VFD Speed Feedback	SW	No	Yes	Yes	Yes

5. Building Chilled Water Systems:

a. Key Concepts:

1) In most cases, chilled water is supplied from MIT's central plant directly to HVAC loads and chilled water booster pumps are not required.
2) Building pump pairs are designed to operate in a duty/standby arrangement.
3) Pump sets can either be booster pumps (in series with the central plant pumps) or they can be deployed to create a recirculating loop within the building to serve process loads and other situations such as chilled beam operation or environmental rooms (simulating a condenser water loop) where an elevated temperature is required.

b. Sequence of Operation, General:

1) The BMS shall energize the duty pump. Only one pump is required to run to maintain the system differential pressure.
2) The BMS shall switch the duty/standby alternation bi-monthly.
3) Upon, pump failure, the BMS shall energize the standby pump and generate an alarm.

c. Booster Pumps in Series – Differential Pressure Control:

1) The BMS shall monitor differential pressure across the load. The supply (high) pressure sensor shall be located after the pump discharge but before the building load. The return (low) pressure sensor shall be located on the common circuit return line.
2) The BMS shall modulate the pump VFD to maintain system differential pressure setpoint.
3) If the differential pressure is greater than 5 psi (adjustable) above setpoint for more than 10 minutes (adjustable) while the duty pump is running at minimum speed, the shall de-energize the duty pump.
4) If the differential pressure is below setpoint, the BMS shall energize the duty pump (initially at its lowest speed).
5) The BMS shall then begin to increase the duty pump VFD speed to maintain system differential pressure setpoint.
6) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain differential pressure setpoint. The BMS shall de-energize the duty pump and generate a pump failure alarm.

d. Secondary Loops with Heat Exchanger:

1) The BMS shall monitor supply temperature to the process load after the heat exchanger.
2) The BMS shall modulate the primary side control valve to maintain secondary supply temperature setpoint.
3) If primary pumps are required they shall operate as follows:

    a) If the control valve has been commanded to 90% or greater for more than 5 minutes (adjustable) without the secondary supply temperature setpoint being reached, the BMS shall first energize the primary side duty pump (initially at minimum speed) and modulate the chilled water valve fully open, and then modulate the VFD speed to maintain the secondary supply temperature setpoint.
    b) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the secondary supply temperature setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin to increase VFD speed to maintain secondary supply temperature setpoint.
    c) If the secondary supply temperature is below setpoint for more than ten minutes (adjustable) while the duty pump is running at minimum speed, the BMS shall de-energize the duty pump. The BMS shall modulate the chilled water valve toward fully closed to maintain secondary supply temperature setpoint.
4) The preferred method is to control the process temperature at a fixed offset from primary chilled water supply temperature (because the primary chilled water temperature varies throughout the year from 42°F to 50°F). Ideally process supply temperature should be as high as possible in order to have better year round stability (55°F or higher is preferred for stability and better primary chilled water utilization. Temperatures above 55°F also reduce condensation on process equipment piping and components.

e. Secondary Loops (with elevated temperatures) without Heat Exchanger:

1) These systems commonly utilize a pump set with a modulating control valve returning chilled water to the central plant. The BMS controls the temperature supply to the process by modulating this valve which allows plant chilled water supply to bleed into the system.
2) The BMS shall monitor supply temperature to the load after the circulating pump.
3) The BMS shall modulate the chilled water return valve to maintain recirculated system supply water temperature setpoint.
4) The BMS shall modulate the duty pump VFD speed to maintain system differential pressure setpoint.
5) If the BMS modulates the duty pump VFD speed to 90% or greater for more than five minutes (adjustable) without the differential pressure setpoint being reached, the BMS shall energize the standby pump (initially at minimum speed) and begin

to increase VFD speed to maintain differential pressure setpoint. The BMS shall de-energize the duty pump and generate a pump failure alarm.

Typical Chilled Water Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Pump Status	SW	Yes	Yes	Yes	Yes
Pump Amps	AI	No	Yes	Yes	Yes
Pump Runtime	SW	No	No	No	Yes
HOA Switch	DI	Yes	Yes	Yes	Yes
VFD Fault	DI	Yes	Yes	Yes	Yes
VFD Bypass	DI	Yes	Yes	Yes	Yes
CHWS Temperature	AI	Yes	Yes	Yes	Yes
CHWR Temperature	AI	Yes	Yes	Yes	Yes
Differential Pressure Valve Position	AI	No	Yes	Yes	Yes
Supply Temperature Valve Position	AI	No	Yes	Yes	Yes
Differential Pressure	AI	Yes	Yes	Yes	Yes
VFD Modulation	AO	No	Yes	Yes	Yes
Pump Start/Stop	DO	No	Yes	Yes	Yes
Differential Pressure Valve	AO	No	Yes	Yes	Yes
Differential Pressure Setpoint	SW	No	Yes	Yes	Yes
Supply Temperature Valve	AO	No	Yes	Yes	Yes
Supply Temperature Setpoint	SW	No	Yes	Yes	Yes
VFD Speed Feedback	SW	No	Yes	Yes	Yes

6. Life Safety Equipment Control:

a. Stairwell Pressurization Fan:

1) The fire alarm system shall control and monitor the fan.

b. Stairwell Pressurization Fan with Temperature Control (if required due to stack effect – to be determined by MEP design consultant)

1) The fire alarm system shall control and monitor the fan.
2) The BMS shall modulate the reheat coil to maintain a discharge temperature setpoint (as determined by the MEP design consultant).

c. Fire/Smoke Dampers:

1) The fire alarm system shall control and monitor the fire/smoke dampers.
2) It is MIT's preference that when BMS has no integration to the fire/smoke dampers that power and control wiring for the fire/smoke dampers shall be installed by the division 26 electrical contractor.

d. Fireman’s Override Panel:

1) If required, a fireman’s override panel will allow for firefighter override of selected fans and dampers.
2) The BMS shall monitor fireman’s override fan position switch status (both on and off) from the fireman’s override panel.
3) Power wiring for the fireman’s override panel shall be installed by the division 26 electrical contractor.
4) Control wiring from the fireman’s override panel to the respective fans and dampers shall be installed by the division 26 electrical contractor and closely coordinated with BMS contractor.
5) Control wiring from the fireman’s override fan position switches to the BMS shall be installed by the BMS contractor.

7. Equipment Restart Following a Fire Alarm:

a. Provide a software program that will restart equipment shut down as the result of a fire alarm system (FAS) event following the return to normal conditions. When equipment is shut down by the FAS the BMS controlled relay shall be immediately placed in the “OFF” state such that the equipment cannot restart when the FAS relay enables startup of the equipment.
b. If equipment is shut down by the FAS or by the BMS as the result of a fire alarm, then the shutdown shall not be annunciated as an alarm condition.
c. Following the return to normal indication at the FAS, the BMS shall automatically initiate the restart of all equipment shut down by the FAS.
d. The restart of the equipment shall be subject to all the software protection functions such as the minimum "off" time and the operator defined time delay requirements between successive equipment starts. Provide timing delays between equipment restart after a whole building shut down.
e. The BMS shall turn on the equipment in a logically ordered sequence to avoid power surges and mechanical shortcomings (i.e., CHW/HW equipment should start before AHUs).
f. Special care must be given to buildings with mixed BMS platforms to ensure the equipment responds appropriately after the fire alarm is cleared.

8. Equipment Restart Following a Power Failure:

a. Provide a program that will facilitate the restart of equipment following a power failure.
b. Equipment restart following a power failure shall be determined by monitoring of the associated automatic transfer switch.

c. Following the restoration of power, the BMS shall automatically initiate the restart of all equipment.

d. The restart of the equipment shall be subject to all the software protection functions such as the minimum "off" time and the operator defined time delay requirements between successive equipment starts. Provide timing delays between equipment restart after a whole building shut down.

e. The BMS shall turn on the equipment in a logically ordered sequence to avoid power surges and mechanical shortcomings (i.e., CHW/HW equipment should start before AHUs).

f. Special care must be given to buildings with mixed BMS platforms to ensure the equipment responds appropriately after the power is restored.

3.20 Miscellaneous Monitoring

1. Provide the following Miscellaneous Monitoring:

a. Key Concepts:

1) Miscellaneous monitoring will vary from project to project depending on the criticality of the space and user requirements.

Typical Miscellaneous Monitoring Hardwired and Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On Graphic
Lab Equipment Status (i.e. Freezers)	DI	Yes	No	No	Yes
Dust Collector Start/Stop	DO	No	Yes	Yes	Yes
Dust Collector Status	AI	Yes	Yes	Yes	Yes
Air Compressor Alarm	DI	Yes	No	No	Yes
Air Compressor Supply Pressure	AI	No	Yes	Yes	Yes
Air Compressor Receiver Tank Pressure	AI	No	Yes	Yes	Yes
PRV Alarms (if applicable)	DI	Yes	No	No	Yes
Low Pressure Steam Pressure	AI	Yes	Yes	Yes	Yes
Heat Trace Loss of Power Alarm	DI	Yes	No	No	Yes
Heat Trace Low Temperature Alarm	DI	Yes	No	No	Yes
Heat Trace Trouble Alarm	DI	Yes	No	No	Yes
Generator Alarm	DI	Yes	No	No	Yes
Vacuum Pump Alarm	DI	Yes	No	No	Yes
Sewage Ejector Pump Alarm	DI	Yes	No	No	Yes
Sewage Ejector Pump High Level Alarm	DI	Yes	No	No	Yes
Sump Pump Alarm	DI	Yes	No	No	Yes
Pit High Level Alarm	DI	Yes	No	No	Yes
Condensate Pump Alarm	DI	Yes	No	No	Yes
Condensate High Level Alarm	DI	Yes	No	No	Yes
Condensate Tank Conductivity	AI	Yes	No	No	Yes
Domestic Water Heater Status	DI	Yes	No	No	Yes
Domestic Water Temperature	AI	Yes	Yes	Yes	Yes

Miscellaneous Tank Level	AI	Yes	Yes	Yes	Yes
Miscellaneous Tank Low Level	DI	Yes	No	No	Yes
Miscellaneous Tank High Level	DI	Yes	No	No	Yes
Specialty Water (RO/DI) General Alarms	DI	Yes	No	No	Yes
Controller UPS On	DI	Yes	No	No	Yes
Automatic Transfer Switch (Normal)	DI	Yes	Yes	Yes	Yes
Automatic Transfer Switch (Emergency)	DI	Yes	Yes	Yes	Yes
Specialty Lab Exhaust Filter Differential Pressure	AI	Yes	Yes	Yes	Yes
Emergency Shower Flow Switch	DI	Yes	Yes	Yes	Yes

3.21 BMS Integration with Other Systems

It is recommended the BMS integrates to the systems listed below when present. BMS integration with other standalone systems should be reviewed on a case by case basis to with the project team to ensure that they meet design requirements and align with project budgets.

1. Phoenix Celeris Laboratory Airflow and Control System (LAFCS).
2. Aircuity Air Quality System.
3. Boiler(s).
4. Chiller(s).
5. VFD(s).
6. Computer Room Air Conditioning (CRAC) Units.
7. Emergency Generator / Fuel Oil System.
8. PI Metering Platform.
9. Building Uninterruptible Power Supply.
10. Weather Services.
11. Lighting Control System.
12. BTU Meters.
13. Gas Monitoring.
14. Packaged Air Handling Units.
15. Building Analytics.

The following page describe each system above in more detail.

1. **Phoenix Celeris Laboratory Airflow and Control System (LAFCS):**

a. The communication interface shall allow the BMS read/write capabilities.

b. The BMS shall be able to ramp back the LAFCS for the purpose of energy saving schemes without impact on safety or the working environment.

c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the LAFCS contractor for this integration. This integration shall be done via BACnet IP or LonWorks IP.

d. Typical LAFCS Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Space Temperature	SW	Yes	Yes	Yes	Yes
Space Temperature Setpoint	SW	Yes	Yes	Yes	Yes
Space Humidity	SW	Yes	Yes	Yes	Yes
Space Humidity Setpoint	SW	Yes	Yes	Yes	Yes
Volumetric Airflow Offset	SW	Yes	Yes	Yes	Yes
Volumetric Airflow Offset Setpoint	SW	Yes	Yes	Yes	Yes
Exhaust Air Valve Airflow Setpoint	SW	Yes	Yes	Yes	Yes
Exhaust Air Valve Airflow	SW	Yes	Yes	Yes	Yes
Supply Air Valve Airflow Setpoint	SW	Yes	Yes	Yes	Yes
Supply Air Valve Airflow	SW	Yes	Yes	Yes	Yes
Return Air Valve Airflow Setpoint	SW	Yes	Yes	Yes	Yes
Return Air Valve Airflow	SW	Yes	Yes	Yes	Yes
Supply Air Discharge Temperature	SW	Yes	Yes	Yes	Yes
Local Alarm	SW	Yes	Yes	Yes	Yes
Fume Hood Airflow Alarm	SW	Yes	Yes	Yes	Yes
Fume Hood Control Air Valve Position	SW	Yes	Yes	Yes	Yes
Fume Hood Sash Position	SW	Yes	Yes	Yes	Yes
Fume Hood Face Velocity	SW	Yes	Yes	Yes	Yes
Fume Hood Purge Mode	SW	Yes	Yes	Yes	Yes
Fume Hood Exhaust Air Valve Airflow	SW	Yes	Yes	Yes	Yes
Fume Hood Exhaust Air Valve Airflow	SW	Yes	Yes	Yes	Yes
Occupancy Status	SW	Yes	Yes	Yes	Yes
Communication Alarm	SW	Yes	Yes	Yes	Yes

2. **Aircuity Air Quality System:**

a. The communication interface shall allow the BMS read capabilities.

b. The BMS shall be able to adjust the HVAC systems based on data from the air quality system for the purpose of energy saving schemes without impact on the safety or the working environment.

c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the Air Quality System contractor for this integration. This integration shall be done via BACnet IP or LonWorks IP.

d. Typical Aircuity Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Outside Air Temperature	SW	Yes	Yes	Yes	Yes
Outside Air Humidity	SW	Yes	Yes	Yes	Yes
Outside Air Enthalpy	SW	Yes	Yes	Yes	Yes
Supply Air Temperature	SW	Yes	Yes	Yes	Yes
Supply Air Humidity	SW	Yes	Yes	Yes	Yes
Supply Air Enthalpy	SW	Yes	Yes	Yes	Yes
Return Air Temperature	SW	Yes	Yes	Yes	Yes
Return Air Humidity	SW	Yes	Yes	Yes	Yes
Return Air Enthalpy	SW	Yes	Yes	Yes	Yes
Space Temperature	SW	Yes	Yes	Yes	Yes
Space Humidity	SW	Yes	Yes	Yes	Yes
Carbon Monoxide	SW	Yes	Yes	Yes	Yes
Carbon Dioxide	SW	Yes	Yes	Yes	Yes
VOC	SW	Yes	Yes	Yes	Yes
Sensor Suite Trouble Alarm	SW	Yes	Yes	Yes	Yes
System Trouble Alarm	SW	Yes	Yes	Yes	Yes
Communication Alarm	SW	Yes	Yes	Yes	Yes

3. **Boiler(s):**

a. The BMS shall be able to start and stop boilers via a hardwired point based on the sequence of operations program. This start / stop command shall not override any internal safeties that are for the purpose of protecting the equipment or people in the vicinity.

b. The communication interface shall allow the BMS read capabilities.

c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the boiler manufacturer for this integration. This integration shall be done via BACnet IP, BACnet MSTP, or Modbus IP.

d. Typical Hardware/Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Boiler Enable/Disable Command	DO	No	Yes	Yes	Yes
Burner Status	SW	Yes	Yes	Yes	Yes
Burner Control	SW	No	Yes	Yes	Yes
Hot Water Supply to Building	SW	Yes	Yes	Yes	Yes
Hot Water Supply from Boilers	SW	Yes	Yes	Yes	Yes
Hot Water Return to Boilers	SW	Yes	Yes	Yes	Yes
Hot Water Return from Building	SW	Yes	Yes	Yes	Yes
Boiler Alarm	SW	Yes	Yes	Yes	Yes
Stack Temperature	SW	Yes	Yes	Yes	Yes
Boiler Isolation Valve	SW	Yes	Yes	Yes	Yes
Boiler Isolation Valve Status	SW	Yes	Yes	Yes	Yes

4. **Chiller**(s):

a. The BMS shall be able to start and stop chillers via a hardwired point based on the sequence of operations program. This start / stop command shall not override any internal safeties that are for the purpose of protecting the equipment or people in the vicinity.

b. The communication interface shall allow the BMS read capabilities.

c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the chiller manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.

d. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Chiller Start/Stop Command	DO	No	Yes	Yes	Yes
Chiller Reset Signal	AO	No	Yes	Yes	Yes
Local Schedule	SW	No	Yes	Yes	Yes
Occupancy	SW	Yes	Yes	Yes	Yes
Remote Start Control	SW	No	Yes	Yes	No
Run Status Code	SW	Yes	Yes	Yes	Yes
Alarm Value	SW	Yes	Yes	Yes	No
System Alarm Code	SW	Yes	Yes	Yes	No
Entering Condenser Temperature	SW	No	Yes	Yes	Yes
Leaving Condenser Temperature	SW	No	Yes	Yes	Yes
Condenser Water Flow	SW	No	Yes	Yes	Yes
Condenser Refrigerant Temperature	SW	No	Yes	Yes	Yes
Condenser Pressure	SW	No	Yes	Yes	Yes
Line Current	SW	No	No	No	Yes
Line Voltage	SW	No	No	No	Yes
Line Frequency	SW	No	No	No	Yes
Line Power Factor	SW	No	No	No	Yes
Demand Limit	SW	No	No	No	Yes
System Load	SW	No	No	No	Yes
System Demand Limit	SW	No	No	No	Yes
Guide Vane Command	SW	No	No	No	Yes
Guide Vane Position	SW	No	No	No	Yes
VFD Speed Command	SW	No	No	No	Yes
VFD Speed Feedback	SW	No	No	No	Yes
Evaporator Saturation Temperature	SW	No	No	No	Yes
Evaporator Refrigerant Temperature	SW	No	No	No	Yes

Oil Sump Temperature	SW	No	No	No	Yes
Communications Status	SW	Yes	Yes	Yes	Yes
Communications Alarm	SW	Yes	Yes	Yes	Yes
Equipment Alarm	SW	Yes	Yes	Yes	Yes
Compressor Discharge Temperature	SW	No	No	No	Yes
Motor Winding Temperature	SW	No	No	No	Yes
Thrust Bearing Temperature	SW	No	No	No	Yes
Chiller Runtime	SW	No	Yes	Yes	Yes
Leaving CHW Temperature	SW	No	Yes	Yes	Yes
CHW Temperature Setpoint	SW	No	Yes	Yes	Yes
Control Temperature Setpoint	SW	No	Yes	Yes	Yes
Chilled Water Temperature	SW	Yes	Yes	Yes	Yes
Entering Chilled Water Temperature	SW	No	Yes	Yes	Yes
Chilled Water Deadband	SW	No	No	No	Yes
Chilled Water Delta T	SW	No	No	No	Yes

5. **VFD(s):**

a. The BMS shall be able to start and stop and control the VFD speed via a hardwired point based on the sequence of operations program.

b. The communication interface shall allow the BMS read capabilities.

c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the VFD manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.

d. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Start / Stop	DO	No	Yes	Yes	Yes
Speed Modulation	AO	No	Yes	Yes	Yes
Status (Current Sensor)	AI	Yes	Yes	Yes	Yes
VFD Fault	DI	Yes	Yes	Yes	Yes
HOA Not in Auto	DI	Yes	Yes	Yes	Yes
VFD in Bypass	DI	Yes	Yes	Yes	Yes
Forward / Reverse Status	SW	No	No	No	Yes
Drive Ready Status	SW	No	No	No	Yes
At Setpoint Status	SW	No	No	No	Yes
Resets Faults	SW	No	No	No	Yes
Output Speed min-1	SW	No	No	No	Yes
Output Frequency Hz	SW	No	No	No	Yes
DC Bus Voltage V	SW	No	No	No	Yes
Motor Voltage V	SW	No	No	No	Yes
Motor Current A	SW	No	No	No	Yes
Motor Torque %	SW	No	No	No	Yes
Motor Power %	SW	No	No	No	Yes
Drive Thermal State %	SW	No	No	No	Yes
Energy Counter kWh	SW	No	No	No	Yes
Run Time	SW	No	Yes	Yes	Yes
Last Error Code	SW	No	No	No	Yes

6. **Computer Room Air Conditioning (CRAC) Units:**

a. The communication interface shall allow the BMS read capabilities.

b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the CRAC manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.

c. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Space Temperature	SW	Yes	Yes	Yes	Yes
Space Humidity	SW	Yes	Yes	Yes	Yes
Unit Status	SW	No	Yes	Yes	Yes
Unit Runtime	SW	No	Yes	Yes	Yes
General Alarm	SW	Yes	Yes	Yes	Yes

7. **Emergency Generator / Fuel Oil Systems:**

a. The communication interface shall allow the BMS read capabilities.

b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the emergency generator / fuel oil system manufacturer for this integration. This integration shall be done via BACnet IP, Modbus TCP/IP, or Modbus RTU.

c. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
AC Voltmeter	SW	No	No	No	No
AC Ammeter	SW	No	No	No	No
AC Frequency Meter	SW	No	No	No	No
DC Voltmeter (Alternator Battery Charging)	SW	No	No	No	No
Running-time Meter	SW	No	No	No	No
Generator Running	SW	Yes	No	No	Yes
Generator Control 'not-in-auto' Mode Alarm	SW	Yes	No	No	Yes
Generator Current, per-phase	SW	No	No	No	No
Generator Voltage, phase-to-phas & phase-neutral	SW	No	No	No	No
Generator Real Power (kW), per phase & three-phase total	SW	No	No	No	No
Generator Reactive Power (kVAR) per phase & three phase total	SW	No	No	No	No
Generator Apparent Power (kVA), per phase & three phase total	SW	No	No	No	No
Generator Power Factor (true),	SW	No	No	No	No

per-phase & three-phase total					
Generator Frequency readings	SW	No	No	No	No
Engine RPM	SW	No	No	No	No
Engine Oil Pressure	SW	No	No	No	No
Engine Oil Temperature	SW	No	No	No	No
Engine Coolant Temperature	SW	No	No	No	No
Engine Run Hours	SW	No	No	No	No
Battery Voltage	SW	No	No	No	No
Emergency Stop Switch Activated	SW	Yes	No	No	No
Over Speed Alarm	SW	Yes	No	No	No
Coolant High-Temperature Alarm	SW	Yes	No	No	No
Coolant Low-Level Alarm	SW	Yes	No	No	No
Oil Low-Pressure Alarm	SW	Yes	No	No	No
Fuel Tank Level	SW	No	No	No	Yes
Fuel Tank Low-Level Alarm	SW	Yes	No	No	Yes
Fuel Tank High-Level Alarm	SW	Yes	No	No	Yes
Fuel Tank Water Alarm	SW	Yes	No	No	Yes
Fuel Tank Interstitial alarm	SW	Yes	No	No	Yes
Fuel Oil Leak Detection (multiple points)	SW	Yes	No	No	Yes
Fuel Oil Pump Status	SW	Yes	Yes	Yes	Yes
Fuel Oil Overfill Alarm	SW	Yes	No	No	Yes
Generator Overload Alarm	SW	Yes	No	No	Yes
Failure of Communication Link	SW	Yes	No	No	Yes
Engine Exhaust Temperature	SW	Yes	No	No	No

8. **PI Metering Platforms:**

a. Meters that measure incoming chilled water flow, incoming hot water flow, incoming steam flow, incoming natural gas flow, electrical data, are wired to a data gathering PLC and communicated to the PI historian located in the central plant.

b. The provision of meters and the gathering panel vary from project, however, the BMS contractor generally wires these meters to the PI gathering data panel.

c. The communication interface shall allow the BMS read capabilities.

d. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the PI manufacturer for this integration. This integration shall be done via Modbus TCP/IP.

Typical PI Metering Platform Software Points

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
WATER					
Chilled Water Consumption	SW	No	No	No	Yes
Chilled Water Flow	SW	No	No	No	Yes
Chilled Water Pressure	SW	No	No	No	Yes
Chilled Water Temperature	SW	No	No	No	Yes
Chilled Water Delta T	SW	No	No	No	Yes
Condensate Flow	SW	No	No	No	Yes
STEAM					
Steam Consumption	SW	No	No	No	Yes
Steam Flow	SW	No	No	No	Yes
Steam Pressure	SW	No	No	No	Yes
Steam Temperature	SW	No	No	No	Yes
GAS & FULE					
Natural Gas Consumption	SW	No	No	No	Yes
Natural Gas Flow	SW	No	No	No	Yes
ELECTRICAL					
Real Energy kWhr	SW	No	No	No	Yes
Demand Real Power D kW	SW	No	No	No	Yes
True Power Factor Total	SW	No	No	No	No
Current Ph A	SW	No	No	No	Yes
Current Ph B	SW	No	No	No	Yes
Current Ph C	SW	No	No	No	Yes
Current Neutral	SW	No	No	No	No
Current 3-Ph Average	SW	No	No	No	No
Current Apparent RMS	SW	No	No	No	No
Voltage A-B	SW	No	No	No	Yes
Voltage B-C	SW	No	No	No	Yes
Voltage C-A	SW	No	No	No	Yes
Voltage Average	SW	No	No	No	No
Voltage A-N	SW	No	No	No	No
Voltage B-N	SW	No	No	No	No
Voltage C-N	SW	No	No	No	No
Real Power Ph A kW	SW	No	No	No	No
Real Power Ph B kW	SW	No	No	No	No
Real Power Ph C kW	SW	No	No	No	No
Real Power Total F kW	SW	No	No	No	No
Reactive Power Ph A kVAR	SW	No	No	No	No
Reactive Power Ph B kVAR	SW	No	No	No	No
Reactive Power Ph C kVAR	SW	No	No	No	No
Reactive Power Total kVAR	SW	No	No	No	No
Apparent Power Ph A kVA	SW	No	No	No	No
Apparent Power Ph B kVA	SW	No	No	No	No
Apparent Power Ph C kVA	SW	No	No	No	No
Apparent Power Total kVA	SW	No	No	No	No
Frequency	SW	No	No	No	No

9. **Building Uninterruptible Power Supply (UPS):**

a. The communication interface shall allow the BMS read capabilities.

b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the lighting control system manufacturer for this integration. This integration shall be done via BACnet IP.

c. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Communication Alarm	SW	Yes	No	No	Yes
Battery Circuit Open	SW	Yes	No	No	Yes
Batter Discharging	SW	No	No	No	No
Low Battery Shutdown	SW	Yes	No	No	Yes
Mains 1 Input Switch Open	SW	No	No	No	No
Mains 1 Voltage Alarm	SW	Yes	No	No	Yes
Emergency Off Switch	SW	No	No	No	No
Operating On Battery	SW	Yes	No	No	Yes
Forced Inverter Shutdown	SW	No	No	No	No
Inverter Output Switch Open	SW	No	No	No	No
Inverter Stack Overload	SW	No	No	No	No
Inverter Sync with Mains 2	SW	No	No	No	No
Inverter Thermal Override	SW	No	No	No	No
Maintenance Bypass	SW	No	No	No	No
Rectifier Charge Input Volt Alarm	SW	No	No	No	No
System Not Normal	SW	No	No	No	No
Transfer Lockout	SW	No	No	No	No
Unsafe Operation	SW	No	No	No	No
KVA	SW	No	No	No	No
Load Voltage A-B	SW	No	No	No	No
Load Voltage B-C	SW	No	No	No	No
Load Voltage C-A	SW	No	No	No	Yes
KW	SW	No	No	No	Yes
Mains 1 Voltage A-B	SW	No	No	No	No
Mains 1 Voltage B-C	SW	No	No	No	No
Mains 1 Voltage C-A	SW	No	No	No	No

10. **Weather Services:**

a. The communication interface shall allow the BMS read capabilities.
b. This weather station will replace the more traditional approach of employing a small weather station per building. Each new building will be mapped to this data.
c. In the near future, the predictive weather modeling will be utilized by MIT.

1) Weather Modeling Optimization – By integrating the BMS with weather modeling for the facility, location predictive analytics can adjust central plant control algorithms and other key mechanical equipment sequences based on approaching weather fronts. The BMS learns and understands the terminal load value of a facility. Then, based on local weather forecasts, the BMS will reduce energy usage by not over compensating for sudden changes that trigger systems to react when not required to do so to maintain comfort and safety. During certain seasons of the year, frequent rapid weather changes can account for substantial excess energy usage.
2) Approaching Storm Forecasting – By integrating the BMS with weather modeling for the facility, the risk of approaching storms can be evaluated. There is an opportunity under extreme weather conditions with high lightning output approaching, to have generators started to ensure no outages occurs.
3) The BMS shall display via a graphical user interface all approaching weather patterns including rain, wind, lightning, etc. Weather occurrences shall be tracked in near real time.
4) MIT shall have the ability to manually or via automated sequences take action based on this weather data for the purpose of saving energy or initiating actions to reduce the risk of power failures.

d. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the weather services provider for this integration. This integration shall be done via web services and Modbus IP.

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Outside Air Temperature	SW	No	Yes	Yes	Yes
Outside Air Humidity	SW	No	Yes	Yes	Yes
Outside Air Dewpoint	SW	No	Yes	Yes	Yes
Wind Speed	SW	No	Yes	Yes	Yes
Wind Direction	SW	No	Yes	Yes	Yes

11. **Lighting Control Systems:**

a. The communication interface shall allow the BMS read capabilities.
b. The BMS shall be able to monitor the occupancy status of rooms
c. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the lighting control system manufacturer for this integration. This integration shall be done via BACnet IP.
d. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Occupancy Switch	SW	No	Yes	Yes	Yes

12. **BTU Meters:**

a. The communication interface shall allow the BMS read capabilities.
b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
c. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Water BTU	SW	Yes	Yes	Yes	Yes
Water Flow	SW	Yes	Yes	Yes	Yes
Water Temperature	SW	Yes	Yes	Yes	Yes

13. **Gas Monitoring:**

a. The communication interface shall allow the BMS read capabilities.
b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
c. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Gas Level	SW	Yes	No	No	Yes
Gas High Level Alarm	SW	Yes	No	No	Yes
System Alarm	SW	Yes	No	No	Yes

14. **Packaged Air Handling Units:**

a. The communication interface shall allow the BMS read/write capabilities.
b. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
c. The list of software points shall be similar to those listed in the Air Handling Unit section (3.a.viii.1.c.).

15. **Building Analytics (KGS Clockworks)**

a. A consistent point naming convention shall be used such that KGS Clockworks can poll the BMS network and gather the correct information necessary for building analytics.

4. BUILDING MANAGEMENT SYSTEM IMPLEMENTATION GUIDELINES

4.1 BMS Hardware Engineering

The purpose of the documentation is to provide relevant information to those responsible for designing, installing, implementing, and maintaining the BMS.

The MEP design consultant shall thoroughly review the documentation and identify as many potential areas of non-conformance as possible.

4.2 Coordination Drawings

1. If applicable, the BMS contractor shall participate in the development of coordinated drawings with the mechanical and electrical contractors. The mechanical contractor shall indicate all mechanical, plumbing, and fire protection work on the drawings. The electrical contractor shall then add the electrical, fire alarm, and communication system work to the drawings. The BMS contractor shall indicate the required BMS work on the drawings for the following:

    a. Cable tray installed by the BMS contractor.
    b. Conduits over 2” installed by the BMS contractor.
    c. Sleeves required for BMS work.
    d. Devices above the ceiling or below a raised floor requiring access.
    e. Control panels.
    f. Sensor locations.

2. The BMS contractor shall assist and cooperate with the other trades to ensure a complete and coordinated set of drawings has been generated.

4.3 Building Information Modeling (BIM)

1. If applicable, the BMS contractor shall participate in the development of a Building Information Model with the architects, mechanical and electrical contractors. The mechanical contractor shall indicate all mechanical, plumbing, and fire protection work on the model. The electrical contractor shall then add the electrical, fire alarm, and communication system work to the model. The BMS contractor shall indicate the required BMS work on the model for the following:

    a. Cable tray installed by the BMS contractor.
    b. Conduits over 2 inch installed by the BMS contractor.
    c. Sleeves required for BMS work.
    d. Devices above the ceiling or below a raised floor requiring access.
    e. Control panels.
    f. Sensor Locations.

2. The BMS contractor shall assist and cooperate with the other trades to ensure a complete model has been generated.

4.4 Shop Drawings

1. The BMS contractor shall prepare all shop drawings in Visio Professional or AutoCAD software. Drawings shall be 11”x17”. The BMS contractor shall furnish an electronic copy (in PDF format) of the shop drawings. Information shall have appropriate indices and tabs.
2. The BMS hardware design package shall include the following:

    a. **Valve Schedule:** The valve schedule shall contain each valve's unique tag name, size, flow coefficient Kv (Cv), pressure drop at specified flow rate, spring range, actuator size and close-off pressure to torque data. The valve schedule shall contain actuator selection data supported by calculations of the force required to move and seal the valve, access and clearance requirements.
    b. **Damper Schedule:** The damper schedule shall contain each damper's unique tag name, type (opposed or parallel blade), nominal and actual sizes, orientation of axis and frame, direction of blade rotation, actuator size and spring ranges, operation rate, location of actuators and damper end switches, arrangement of sections in multi-section dampers, and methods of connecting dampers, actuators, and linkages. The damper schedule shall include the AMCA 500-D maximum leakage rate at the operating static-pressure differential.
    c. **Flow Meter Schedule:** The flow meter schedule shall contain the unique tag name, manufacturer, model number, part number, descriptive name, and sizing information for each flow meter
    d. **Air Flow Station Schedule:** The air flow station schedule shall contain the unique tag name, manufacturer, model number, part number, descriptive name, and duct size for each air flow station.
    e. **Drawing Index and Drawing Legend:** The drawing index shall list all BMS contractor drawings, including the drawing number, sheet number, drawing title. The drawing

legend shall show and describe all symbols, abbreviations, and acronyms used on the BMS drawings.

f. **Riser Diagram of Building Control Network:** The riser diagram of the building control network shall show all network cabling, BMS hardware, and network hardware including:

1) All BMS hardware with room number, unique identifiers, and common descriptive names including:

a) Network controller naming format shall include the building number and successive instance number (within the building) and shall be similarly named in software. Examples include: M01_AS01, M01_AS02, M05_LGR01.

b) Field controller naming format shall include the building, location, and system and shall be similarly named in software. Examples include: M01_ Rm701_AH1, E62_Rm305_FCU.

2) All computer and network hardware with room number, unique identifiers, and descriptive names.

3) All BMS network cabling and power wiring (can be shown as a depiction on each piece of BMS hardware and does not have to depict the actual routing of the network).

4) All other devices connected to the BMS IP or MSTP network.

5) IP address(es) as applicable for each piece of network hardware and computer hardware.

6) If a small project is done within an existing building, the BMS contractor shall add the necessary revisions to an overall building riser. The added architecture can be circled or redlined with a project description to show when it was added. A riser showing one controller with a note saying to connect to nearest existing controller is not acceptable.

3. **Control System Schematic Drawings**: The control system schematic drawings shall be in the same form as the MEP design consultant's control system schematic drawings with the BMS contractor providing updated information and detail as required. A control system schematic shall be submitted for each system controlled or monitored by the BMS.

4. **Controller, Motor Starter and Relay Wiring Drawing:** The controller wiring drawings shall be functional wiring drawings which show the interconnection of conductors and cables to each controller and to the identified terminals of input and output devices, starters and package equipment. The wiring drawings shall show all necessary jumpers, ground connections, and the labels of all conductors. Sources of power required for control systems and for packaged equipment control systems shall be identified back to the panel board circuit breaker number, controller enclosures, magnetic starter, or packaged equipment control circuit. Each power supply and transformer not integral to a controller, starter, or packaged equipment shall be shown. Wiring drawings shall be

submitted for each system controlled or monitored by the BMS. Typical wiring drawings shall be acceptable as long as the systems they represent are clearly marked.

5. **Control Panel Layout Drawing:** Control panel layout drawings shall be to scale with all devices shown in their proposed positions. All control devices shall be identified by name. All terminal strips, control transformers, IP connection points, devices and wire channels shall be shown.
6. **Points List:** A Points List shall be submitted for each system controlled or monitored by the BMS. The Points List shall include, name, description, range, engineering units, and alarm(s). An effort shall be made to streamline the point naming convention for similar points from similar systems. This will facilitate MIT's ability to use BMS global search and replace tools make mass changes should our standards evolve and requiring functionality or setpoint changes.
7. **Sequence of Operation:** The HVAC control system sequence of operation shall be in the same format as the MEP design consultant's sequence of operation and shall refer to the devices by their unique identifiers/tags. No operational deviations from specified sequences shall be permitted without prior written approval of the MEP design consultant. Sequence of operation shall be submitted for each system controlled by the BMS.

3. Submit electronic copy (in PDF format) of the hardware submittal data and shop drawings (Item #2) to the MEP design consultant for review prior to ordering or fabrication of the equipment.
4. A piecemeal hardware submittal process shall be acceptable prior to complete comprehensive final submission as follows:

   a. Equipment submittals (if applicable).
   b. In-line device schedules (i.e., valves, dampers, flow stations, flow meters requiring long times).
   c. First shop drawing submission of each typical system.
   d. Control panel layout drawings.
   e. Sample software graphic display screens.

5. The MEP design consultant shall make corrections, if required, and return to the BMS contractor. The BMS contractor shall then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the MEP design consultant and the shop drawings are fully approved.
6. The following is a list of post construction submittals that shall be updated to reflect any changes during construction and re-submitted as "As-Built":

   a. System architecture/riser drawing.
   b. System control schematic drawing for each controlled system.
   c. Points list for each controlled system.
   d. Wiring drawing for individual components.
   e. Control panel layout drawings.
   f. Sequence of operation.

4.5 Software Engineering

1. The BMS software design package shall include the following:

    a. Graphic Samples: A representation of each type of graphic for the project. At a minimum include one of each different type for MIT approval:

        1) Riser Diagram or Summary Page.
        2) Floor Plan.
        3) Air Handling Units.
        4) Hydronic Systems.
        5) Terminal Units.
        6) Miscellaneous Monitoring.

    b. Comprehensive Alarm List: A matrix or spreadsheet containing full alarm list of new alarms to be used, containing the following:

        1) Root Point.
        2) Alarm Name.
        3) Alarm Type.
        4) Alarm Level.
        5) Alarm Messaging.
        6) Alarm Routing.
        7) Alarm Value / Return to Normal Value / Deadband.
        8) Alarm Time Delay.
        9) Alarm Log Display Parameters.

        Alarms already established and approved can be reused. It is expected that each approved BMS vendor maintain an as-built database of their approved alarms with associated details.

    c. Integration Matrix: A detailed listing of each type of interface/integration (i.e., BACnet, Modbus, etc.) required for the project showing all available points and the following for each point:

        1) Is point mapped to graphic?
        2) Is point alarmed?
        3) Is point trended?

2. Submit electronic copy (in PDF format) of the software submittal data (Item #i) to MIT prior to software implementation.
3. A piecemeal software submittal process shall be acceptable prior to complete comprehensive final submission as follows:

    a. Graphics submittals.
    b. Alarm list.

c. Integration matrix.

4. All communication between the BMS File Servers, BMS Workstations, and Network Controllers shall be via BACnet/IP and in accordance with ASHRAE 135 (except where proprietary Continuum expansion is required).
5. For equipment requiring IP addresses, the BMS contractor shall coordinate with MIT to obtain IP addresses.
6. The BMS contractor shall use a consistent software naming convention from system to system and campus-wide that is easily understood. An example would be that "SupAirTemp" is used to represent supply air temperature.
7. The BMS contractor shall create modular programs that meet the intent of the sequence of operation. The software code shall be commented such that it is easily understood. A consistent software coding approach should be for similar systems campus-wide.
8. The BMS contractor shall establish network object bindings as necessary to support software functionality:

   a. BACnet objects used for display on currently active displays shall be updated (via COV) as necessary to meet display requirements.
   b. BACnet objects used for currently active trends shall be updated (via COV) as necessary to meet trend interval requirements.
   c. BACnet alarm objects shall be bound from the device originating the alarm to the software. Alarms shall use the acknowledged service.

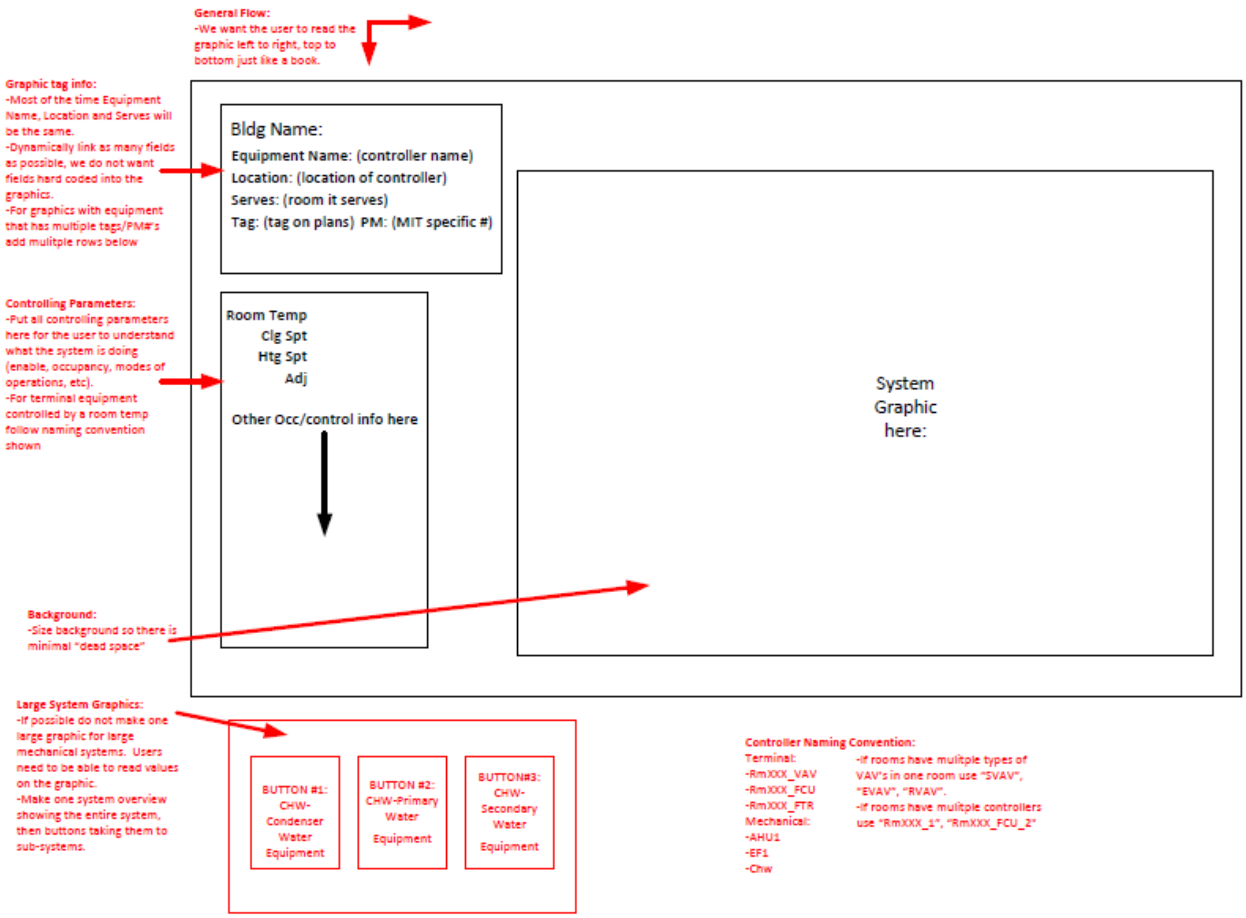
9. The BMS contractor shall create color graphic display screens as follows:

   a. Color graphic display screen of a listing of buildings. Include "hot link" navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to a specific building.
   b. Color graphic display screen of building riser. Include "hot link" navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to specific floor or equipment displays, and critical monitoring displays.
   c. At least one color graphic display screen per floor. The status of environmental condition on the floor as well as smoke conditions and lighting conditions shall be displayed on the graphic. Include "hot link" navigation buttons (activated with one mouse click) on the graphics and outlined equipment blocks that allow MIT to get to a default home page as well as systems that are on the floor.
   d. One color graphic display screen for each system controlled or monitored by the BMS. The status of each input and output shall be displayed on the graphic. Include "hot link" navigation buttons (activated with one mouse click) on the graphics that allow MIT to get to the home page graphic, a floor level graphics, parent and child equipment, and critical monitoring displays.

      1) Graphic display screens for similar systems should be similar (i.e., similar sizing and layout).
      2) Graphic display screens for applicable systems should contain system PM

numbers.

3) Graphic display screens for systems should contain a link to the applicable sequence of operations.



e. "Hot link" buttons shall get the user to the respective graphics page in one front end keyboard or mouse click.

f. Special attention shall be given to match existing graphic color schemes and layouts already in use at MIT. Graphics added to existing buildings (which already contain graphics) shall maintain to same look and feel.

g. Graphics file name format shall be as follows:

1) ABCD_123456789_abc:

a) Where ABCD = Building (i.e., M02).
b) Where 123456789 =

1) Riser or,
2) Floor# or,
3) System Description (i.e., Rm169, AHU2).

c) Where abc = additional text after room or additional equipment (i.e., VAV, FCU).

d) Examples include: M02_AHU01, E15_Rm239_FCU.

2) The file name of the graphic should support being used as inventory management field and fall into one of the following categories:

a) Navigation.
b) Riser.
c) Floor Plan.
d) System.
e) Room.
f) User Interface.
g) Template.
h) Balancing
i) Test Graphic.

h. Separate tabs shall be employed for less critical points, such as those from the BMS BACnet interface to a VFD.

i. Points that are derived from a software interface as opposed to hardwired that are not on a separate tab must be clearly identified as such through either notes or a specific color scheme/strategy.

j. Text box backgrounds of contrasting color shall be used for points or values that are typically grouped together (i.e., fan control).

k. Units for values shall be aligned according to established vendor standards.

l. Graphics orientation shall be as follows (see appendix for examples):

1) Building riser graphics shall be in 2-D.
2) Air handling unit graphics shall be 2-D with a 3-D “shadow effect”.
3) Room level component graphics (i.e., VAVs, FCUs, and Chilled Beams) shall be 2-D with a 3-D “shadow effect”.
4) Hydronic and specialty systems shall be in 2-D.

m. The BMS vendor shall fill out the title box information completely prior to acceptance by MIT.

Colors shall be as detailed below.

Graphic	Color
1) Background	Black
2) Floor Plans	**Black w/ White Outline & Gray Overlay (EcoStruxure)** **Yellow or Sky Blue (Continuum)** Gray (Siemens) **Black w/ White Outline & Thermographic Colors (ALC)**
3) Systems	
Ductwork	Light Gray

Graphic	Color
Chilled Water S&R	Blue/Light Blue
Hot Water S&R	Red/Light Red
Glycol S&R	To follow CHW and/or HW
Steam Line	Gray
Condensate Line	Gray
Fuel Oil	Orange
Other Gases	TBD
Process Lines	TBD
4) Equipment	
Boilers	Manufacturer's Standard
Water Chillers	Manufacturer's Standard
Glycol Chillers	Manufacturer's Standard
Cooling Towers	Manufacturer's Standard
Air Compressors	Manufacturer's Standard
Air Dryers	Manufacturer's Standard
All Fire Fighting	Manufacturer's Standard
Pumps & Motors	Manufacturer's Standard
Fire Pumps	Manufacturer's Standard
Switch Gear	Manufacturer's Standard
Transformers	Manufacturer's Standard
Air Handlers	Gray
Exhaust Fans	Gray
VAVs	Manufacturer's Standard
Fan Coil Units	Manufacturer's Standard
Chilled Beams	Manufacturer's Standard
Tanks	Manufacturer's Standard
4) Instrumentation	
Temperature	Purple
Humidity	Orange
CO2	Yellow
Pressure	Green
Airflow	Bronze
Water Flow	Bronze
Fire/Smoke	**Gray**
Control Valves	**Red (HW), Blue (CHW), Purple (HRC)**

10. The BMS contractor shall configure user accounts which include usernames, passwords, and permission levels for all authorized users. After final acceptance of system, the BMS contractor shall work with MIT to remove all temporary user names and passwords that were required for commissioning purposes. User accounts shall be as follows:

    a. BMS Administrator / BMS Analyst (access to everything available).
    b. Engineer (access to everything available except administrator privileges).
    c. Technician (same as engineer except no ability to modify programs).

d. View Only.
e. Special Cases (i.e., a professor wants control of his space).

11. The BMS contractor shall configure alarm handling as detailed in the sequence of operation. The BMS contractor shall coordinate alarm strategy with MIT via the submittal process described above.

a. Alarm levels shall be as follows (how they appear in the alarm log is detailed under each (a, b, & c are applicable to Ecostruxure, while d is applicable to WebCTRL):

1) Life Safety (Toxic Gas):

a) Alarm: Bold Black Text w/ Orange Color Band.
b) Acknowledged (in alarm): Italic Black w/ Orange Color Band.
c) Unacknowledged RTN: Normal Black Text w/ Orange Color Band.
d) WebCTRL: Orange "TG" Icon

2) Life Safety (Fire Alarm):

a) Alarm: Bold White Text w/ Red Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Red Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Red Color Band.
d) WebCTRL: Red "FA" Icon

3) Animal Labs:

a) Alarm: Bold White Text w/ Dark Blue Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Dark Blue Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Dark Blue Color Band.
d) WebCTRL: Dark Blue "AQ" Icon

4) Clean Rooms:

a) Alarm: Bold Black Text w/ Medium Blue Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Medium Blue Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Medium Blue Color Band.
d) WebCTRL: Medium Blue "CR" Icon

5) Environmental Rooms:

a) Alarm: Bold Black Text w/ Blue/Gray Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Blue/Gray Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Blue/Gray Color Band.
d) WebCTRL: Blue/Gray "ER" Icon

6) BSL Laboratories:

a) Alarm: Bold Black Text w/ Light Blue Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Light Blue Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Light Blue Color Band.
d) WebCTRL: Light Blue "BSL" Icon

7) Standard Alarming:

a) Alarm: Bold Black Text w/ White Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ White Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ White Color Band.
d) WebCTRL: White "S" Icon

8) Standard Alarming (Higher Priority):

a) Alarm: Bold White Text w/ Purple Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Purple Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Purple Color Band.
d) WebCTRL: Purple "S" Icon

9) Maintenance Alarm:

a) Alarm: Bold Black Text w/ Yellow Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Yellow Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Yellow Color Band.
d) WebCTRL: Blue "Fan" Icon (Default)

10) Trouble Alarm:

a) Alarm: Bold Black Text w/ Yellow Color Band.
b) Acknowledged (in alarm): Italic Gray Text w/ Yellow Color Band.
c) Unacknowledged RTN: Normal Gray Text w/ Yellow Color Band.
d) WebCTRL: Black "T" Icon

b. Alarms shall be as detailed as per the vendor's approved alarm databases. These are living documents and should be amended periodically to reflect new alarms. In general the alarm types should be as follows:

Alarm Type	**Alarm Functionality**	**Application Information**
Change of State	The change of state alarm monitors the state of changes of digital values. You configure the alarm to trigger when the variable changes its state to true or	This type of alarm is used for digital status alarming or alarms configured in code that trigger digital alarm flags.

	false.	
Change of Value	The change of value alarm occurs under the following conditions: • The absolute value of the monitored variable changes by an amount that is equal to or greater than the value displayed in the Increment property and the condition remains in that state for the time identified in the time delay property.	This type of alarm is used for alarms where the values can have the same +/- alarm values.
Floating Limit	This alarm is triggered when the monitored value exceeds or falls below the values as determined by the current value of the setpoint referenced, upper deviation limit, lower deviation limit and the deadband.	This type of alarm is used this for point values that require different offset values for the high and low alarm limits.
Out of Range	This alarm is triggered when the referenced point falls outside the upper limit and lower limits.	This alarm type is used for values where the normal range may float but the alarm is a hard value such a critical space temperature alarm, high alarm of 80°F, low alarm of 60°F.
Communication Alarm	This alarm is triggered when a controller loses it communication.	This alarm should be used for all controllers.

c. Alarms should generally have to adhere to the following guidelines (refer to the appendix for further detailed information):

1) AHU Supply Temperature +5°F from setpoint.
2) AHU/EF Static Pressure +20% from setpoint.
3) AHU Discharge Relative Humidity > 85%.
4) AHU Heating Coil Discharge Temperature < 40°F.

5) Hydronic Differential Pressure +20% from setpoint.
6) Hydronic Supply/Return Temperatures +5°F from setpoint.
7) Animal Quarters Airflow +20% from setpoint.
8) Animal Quarters Differential Pressure +0.0001" w.c. from setpoint.
9) Animal Quarters Temperature +3°F from setpoint.
10) Animal Quarters Relative Humidity +10% from setpoint.
11) Laboratory Airflow +20% from setpoint.
12) Laboratory Temperature +5°F from setpoint.
13) Laboratory Relative Humidity +20% from setpoint.
14) Office Temperature +10°F from setpoint.
15) Classroom Temperature +10°F from setpoint.
16) Conference Room CO2 > 825 ppm.

d. Alarm shunting strategies should be implemented in applicable areas and systems. For example an office temperature will not alarm if the source AHU is off or CHW or HW is not available.
e. Alarms shall be set up with suitable time delays to avoid nuisance alarms.
f. Alarms shall be linked to their applicable graphic, such that upon alarm indication, a user can open the graphic link from the alarm viewer.

12. The BMS contractor shall configure the scheduling function of the BMS software to schedule systems as shown in the sequence of operation and as required for the building.

a. For critical buildings that must be on 24/7, no schedules are required.
b. For systems that turn on and off, provide daily occupancy schedules 8:00AM-6:00PM, exclusive of any required start-up/transition time.

13. The BMS contractor shall create trends and reports for required points as shown in the sequence of operation and as specified. The approach shall be as follows:

a. Short term trending (done at the controller level): Trends shall be set for up all hardwired I/O and setpoint variables, and other key calculated values (i.e., enthalpy) as follows:

1) For mechanical systems, instantaneous reading at every fifteen minute interval for a total period of three days.
2) For room level systems, instantaneous reading at every fifteen minute interval for a total period of one day minimum. Ideally MIT would prefer this to be three days, if the controller has the memory to support this.
3) Digital value and non-resetting setpoints may be trended on change of value, while analog values and resetting setpoints shall be instantaneously trended.

b. Long term trending (at the server or workstation): All short term trends shall be archived for 365 days, at which time they can be written over by the newest data.
c. Grouping of trends strategy shall be deployed for short term trending to assist in troubleshooting via trend graphs as follows:

1) **Terminal Unit Distribution for Offices:**

a) Temperature (contains all key trended values related to temperature).
b) Flow (contains all key trended values related to flow).
c) Occupancy (contains all key trended values related to occupancy).

2) **Terminal Unit Distribution for Laboratories and Animal Quarters:**

a) Temperature (contains all key trended values related to temperature).
b) Flow (contains all key trended values related to flow).
c) Room Pressure/Offset (contains all key trended values related to room pressure).
d) Occupancy (contains all key trended values related to occupancy and lighting).
e) Fume Hood operating parameters.

3) **AHU:**

a) Supply Air Temperature (contains all key trended values related to temperature).
b) Economizer Control.
c) Pre-heat Coil Valve Control (includes Face and Bypass control).
d) Cooling Coil Valve Control.
e) Heating Coil Valve Control.
f) Heat Recovery Control.
g) Supply Air Fan Control (contains all key trended values related to fan control).
h) Return Air Fan Control (contains all key trended values related to fan control).
i) Humidification Control (contains all key trended values related to humidification).
j) Occupancy (contains all key trended values related to occupancy).

4) **Exhaust Fans:**

a) Exhaust Air Fan Control (contains all key trended values related to fan control).

5) **Heat Exchangers:**

a) Supply Temperature (contains all key trended values related to temperature).
b) Return Temperature (contains all key trended values related to temperature).
c) Pump Control (contains all key trended values related to pump control).
d) Differential Pressure (contains all key trended values related to pump

control).

6) **Chilled Water:**

a) Pump Control (contains all key trended values related to pump control).
b) Differential Pressure {plant and local} (contains all key trended values related to pump control).

14. BACnet Naming and Address Convention:

a. The BMS contractor shall coordinate with MIT and provide unique naming and addressing for BACnet networks and devices as follows:

1) **Controller-Device/Network Numbering:**

a) The BMS contractor shall assign unique numbers to each new network and controller/device installed on the BACnet network based on the following:

Manufacturer	Instance ID	Network #
SE	100,000-299,999	30,000-49,999
Siemens	300,000-399,999	50,000-59,999
Lutron	400,000-599,999	same as manufacturers
ALC	600,000-799,999	50,000-69,999

2) **MAC Addresses:**

a) Every BACnet device shall have an assigned and documented MAC Address unique to its network.
b) For Ethernet networks, the BMS contractor shall document the MAC Address assigned at its creation.
c) For MSTP networks, the BMS contractor shall assign from the MAC Address from a range as indicated by manufacturer’s documentation.

3) **UDP Port Number:**

a) The BMS contractor shall set every BACnet Building Controller (B-BC) and BACnet Router UDP port number to 47808 (BAC0) or a different UDP legal port number if needed.

4) **Device Object Identifier Property Number:**

a) The BMS contractor shall assign unique Device "Object_Identifier" property numbers or device instances for each device on the BACnet network.

5) **Object Name Property Text (Other than Device Objects):**

   a) The Object Name property field shall support 32 minimum printable characters.
   b) The BMS contractor will provide object naming convention consistent with BMS manufacturer’s standards.

6) **Object Identifier Property Number (Other than Device Objects):**

   a) The BMS contractor shall assign Object Identifier property numbers as shown or at the BMS contractor's discretion.

15. Minimum BACnet Object Requirements:

a. **Use of Standard BACnet Objects:**

   1) For the following points and parameters, the BMS contractor shall use standard BACnet objects:

      a) Hardwired I/O wired to native BACnet controllers.
      b) Setpoints.
      c) Calculated values.
      d) Equipment status.
      e) PID loop parameters.
      f) Alarms.
      g) Trends.
      h) Schedules.

b. **BACnet Object Description Property:**

   1) The Object Description property shall support 32 minimum printable characters.
   2) For each BACnet object, the BMS contractor shall complete the description property field using a brief, narrative, plain English description specific to the object and project application (i.e., "AHU On").

c. **Analog Input, Output, and Value Objects:**

   1) The BMS contractor shall create Description and/or Device Type text strings that match the signal type and engineering units shown on the drawings.

d. **Binary Input, Output, and Value Objects:**

   1) The BMS contractor shall create Inactive Text and Active Text property descriptions that match the conditions shown on the drawings.

e. **Calendar Objects:**

1) For devices with scheduling capability, the BMS contractor shall create Calendar Objects as required with ten-entry capacity and enable the writeable Date List property and support all calendar entry data types.

f. **Schedule Objects:**

1) The BMS contractor shall use Schedule Objects for all building system scheduling.

g. **Loop Object or Equals:**

1) The BMS contractor shall use Loop Objects or equivalent BACnet objects in each applicable field device for PID control.

h. **Trend Objects:**

1) The BMS contractor shall use Trend Objects for all building system trending.

16. Minimum BACnet Service Requirements:

a. **Command Priorities:**

1) The BMS contractor shall use commandable BACnet objects to control machinery and systems, providing the priority levels listed below:

Priority Level	Application
1	Manual-Life Safety
2	Automatic-Life Safety
3	(User Defined)
4	(User Defined)
5	Critical Equipment Control
6	Minimum On/Off
7	(User Defined)
8	Manual Operator
9	(User Defined)
10	(User Defined)
11	Load Shedding
12	(User Defined)
13	(User Defined)
14	(User Defined)
15	(User Defined)
16	(User Defined)

b. **Alarming:**

1) Alarm Priorities:

a) The BMS contractor shall coordinate alarm and event notification with MIT.

2) Notification Class:

The BMS contractor shall enable writeable Priority, Ack Required, and Recipient List properties of Notification Class objects.

3) Event Notification Message Texts:

The BMS contractor shall use condition specific narrative text and numerical references for alarm and event notification.

4) Updating Displayed Property Values.

5) The BMS contractor shall create the graphic display screens to receive property values based on receipt of confirmed and unconfirmed Change of Value notifications. The COV increment shall be adjustable using BACnet services and shall be setup as 0.5 for all values except differential or static pressure which should be 0.1.

4.6 BMS Installation

1. General Installation Requirements:

a. **Building Management System:**

1) The BMS shall be completely installed, tested in accordance with the commissioning section of this standards document, and ready for operation.
2) The BMS contractor shall ensure penetrations and mounting holes in the building exterior required for the BMS installation are watertight.
3) The BMS contractor shall ensure that there is sufficient access for all BMS devices. All control system devices shall be located such that they can be accessed for to calibration, removal, or repair.
4) The BMS contractor shall ensure that the BMS installation does not interfere with the clearance requirements for mechanical and electrical system operation and maintenance.

b. **BMS Controller Requirements:**

1) All BMS controllers shall be installed in enclosure except for BMS controllers used to control terminal units.
2) The BMS contractor shall provide a unique BMS controller for each major piece of equipment. Exhaust fans and miscellaneous monitoring may reside on

controllers designated for other major equipment.

3) Control software algorithm and inputs and outputs for a single system or piece of equipment shall reside on a single controller. Control loops shall not rely on the network for control.
4) The quantity of controllers connected on one secondary MSTP network shall not exceed 75 percent of maximum node capacity published by the BMS manufacturer. If necessary, provide additional hardware, over and above that shown on MEP design consultant's drawings, to meet this requirement.
5) I/O Point Capacity:

    a) BMS contractor shall provide I/O point capacity required for system control plus spare I/O points in each control panel. Spare I/O shall not be required for terminal unit controllers.
    b) Spare I/O point capacity shall be defined as terminal connections, which are ready to accept digital or analog inputs, dry contacts for digital outputs, and variable voltage or current terminals for analog outputs. Universal type points are acceptable for both discrete and analog type points.
    c) Minimum spare I/O points in each control panel shall be as follows:

        1) (1) Digital Input.
        2) (1) Digital Output.
        3) (1) Analog Input.
        4) (1) Analog Output.

c. **BMS Controller Enclosure Layout:**

1) BMS controller enclosure shall be built to UL508A Standards in a UL certified panel factory with appropriate labels.
2) Terminal strips shall be located either horizontally in upper half of the back panel or vertically.
3) All power greater than 50VAC shall not be exposed in panel. In order to prevent accidental shock or Arc Flash, this power must be covered so that it cannot be touched when BMS controller enclosure door is open.
4) The control panel shall contain a utility 3 prong 120VAC outlet that is individually overload protected.
5) 24 VDC and 120 VAC, wire, cable, and devices shall be separated by 6 inches minimum.
6) Wire and cable shall be enclosed in wireways or bundled w/ wire ties and secured to the back panel. This does not apply to wire exiting wireways, to terminal strips, or to panel mounted devices.
7) BMS controllers shall be spaced according to manufacturer's requirements with at least 2 inches minimum between controllers and other devices on panel and 1 inch between controller front and door mounted devices. Ensure adequate space is allowed for device heat dissipation and for future expansion modules.

8) Each BMS controller in the enclosure should have its own power toggle switch as well as a master power switch to shut off power in the entire panel.
9) Each BMS controller in the enclosure should have an inline circuit overload protection device (Circuit Breaker).
10) BMS controller or control devices shall not be mounted on the sides of the enclosure.
11) BMS controller enclosures shall not be used as a wire pass-through to an adjacent panel.
12) Labels inside enclosures shall be attached using adhesive and shall not be hand written.

d. **BMS Controller Enclosure Mounting:**

1) The BMS contractor shall mount BMS controller enclosures on walls with suitable brackets or on a self-supporting stand. Where possible, the top of the BMS controller enclosures shall be no higher than six feet above the finished floor. There may some exceptions such as when a fan coil unit controller is mounted above the ceiling near the actual fan coil unit.
2) BMS controller enclosure locations shall be field coordinated with the architect/MEP design consultant and adhere to applicable codes and regulations.
3) The BMS contractor shall mount the BMS controller enclosures so that the panel door can swing fully open without obstruction.
4) All penetrations on BMS controller enclosures installed outside shall be made at the bottom of the enclosure.

e. **BMS Field Devices:**

1) General:

a) All control devices shall be installed in accordance with their manufacturer's instructions and as specified and shown.
b) Control devices installed in piping shall be provided with required manual valves for shutoff, equalization, purging, and calibration.
c) Control devices located outside shall have a weather shield.

2) Control Valves:

a) The BMS contractor shall work with the mechanical contractor to ensure that the control valves are installed in accordance with the manufacturer's installation instructions.
b) Control valves for steam shall be installed such that their actuators are orientated at a 45° angle.

3) Dampers:

a) The BMS contractor shall work with the mechanical contractor to ensure that the dampers are installed in accordance with the manufacturer's installation instructions.

b) Dampers shall move freely without undue stress due to twisting or other installation error.

c) Damper blades shall open completely and close completely.

4) Damper Actuators:

a) Damper actuators shall not be mounted in the air stream.

b) Actuators shall be installed so that their action seals the damper and moves the blades smoothly.

c) Multiple actuators shall not be connected to a common drive shaft.

5) Room Sensors:

a) Room sensor locations shall be field coordinated with the architect/MEP design consultant for best coverage, access for the user, and adherence to applicable codes and regulations.

b) Room sensor backboxes shall be sealed to provide air tight separation from the wall cavity.

c) Temperature and humidity sensors for vivarium spaces or critical laboratory areas shall be mounted in the exhaust air duct.

d) All other thermostats, temperature, humidity, and CO2 room sensors for non-critical areas shall be wall mounted.

6) Duct Averaging Temperature Sensors:

a) Sensors mounted in air streams where stratification exists shall be averaging type as specified.

b) The BMS contractor shall mount the averaging sensor across the duct area in a "Z" pattern using appropriate mounting clips.

7) Duct Humidity Sensors:

a) If possible, the BMS contractor shall install duct humidity sensors in supply air ducts at least 10 feet downstream of the humidifier.

8) Air Flow Stations:

a) The BMS contractor shall work with the mechanical contractor to ensure that the air flow stations are installed in accordance with the manufacturer's installation instructions.

9) Flow Meters:

a) The BMS contractor shall work with the mechanical contractor to ensure that the flow meters are installed in accordance with the manufacturer's installation instructions.

10) Low Limit Temperature Switches (Freezestats):

a) Freezestats shall be provided on AHUs with cooling coils to sense the temperature at the location shown.
b) A sufficient number of freezestats shall be installed to provide complete coverage of the duct section.
c) A minimum of two freezestats per coil shall be required even if coverage size only requires one.
d) Built-in manual reset switches shall be accessible locations so they can be easily be reset.
e) The BMS contractor shall install the freezestat sensing element in a serpentine pattern and in accordance with the manufacturer's installation instructions. The installation of a freezestat shall allow for full coverage of a coil including the bottom six inches.

11) Duct Smoke Detectors:

a) Duct smoke detectors shall be provided by the fire alarm contractor and located in supply and return air ducts in accordance with the fire alarm system specification.
b) The BMS contractor shall connect the BMS to the auxiliary contacts of the air handling unit's duct smoke detectors or dedicated ZAMs as required for system safeties and to provide alarms to the BMS.

f. **Labels and Tags:**

1) Labels and tags shall match to the naming convention shown on the as-built drawings.
2) Laminated plastic nameplates shall be provided for all BMS controller and transformer enclosures. Laminated plastic shall be 0.125 inch thick, white with black center core. Nameplates shall be a minimum of 1 by 3 inch with minimum 0.25 inch high engraved block lettering. Enclosures shall be named as shown on drawings or as follows:

a) BMS Controller Enclosures: BMS-X where X represents the controlled system.
b) BMS Transformer Enclosures: BMS-PWR-X, where X represents the equipment being powered.

3) All BMS hardware located in enclosures shall be properly labeled.
4) All BMS sensors and actuators shall be tagged.

a) Room sensors shall have a laminated index card sized sheet with instructions for use as approved by the MIT project manager.

b) Each room sensor shall have an identification number tag in a discrete location.

5) Tags shall be plastic or metal and shall be attached directly to each device (i.e., sensors) or attached by a metal chain (i.e., valves), when not in finished spaces. In finished spaces, tags can be put inside the cover of the device.

g. **Wires and Cables:**

1) Wire and Cable shall be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A.
2) Penetrations required in fire-rated construction shall be firestopped in accordance with the firestopping specifications.
3) Instrumentation grounding shall be installed per the device manufacturer's instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system.
4) Cables and wires shall be tagged at both ends, with tagging matching the tags on the BMS control drawings.
5) Electrical work shall be as specified in the electric section of this standards document. Wiring external to enclosures shall be run as follows:

   a) Wiring required in mechanical spaces and inside air handling unit casings shall be installed in conduit.
   b) Wiring other than low-voltage control and low-voltage network wiring shall be installed in conduit.
   c) Low-voltage control and low-voltage network wiring not in accessible suspended ceilings shall be installed in conduit unless there is another means of access (i.e., access doors.)
   d) Low-voltage control and low-voltage network wiring in accessible suspended ceilings over occupied spaces can be installed in conduit or can be plenum rated cable as detailed:

      1) Plenum rated cable in accessible suspended ceilings over occupied spaces may be run without conduit or raceways.
      2) Plenum rated cable shall be routed along building structure lines using Bridal Rings, J-hooks or other mounting methods as approved by the MEP design consultant.
      3) Use of wire-ties for attaching cabling to duct brackets, piping, ceiling grid supports or structure is not acceptable. Diagonal routing is also not allowed.

h. **Sensing Tubing:**

1) General:

a) Sensing tubing installed outside shall be hard copper.
b) Sensing tubing shall be concealed except in mechanical rooms and other areas where other tubing and piping is exposed.
c) Sensing tubing in mechanical/electrical rooms shall be routed so that the lines are easily traceable.
d) All sensing tubing and sensing tubing bundles, exposed to view shall be installed neatly in lines parallel to the lines of the building.
e) Sensing tubing shall be purged prior to final connection to control devices.
f) Sensing tubing shall be tagged at both ends, with tagging matching the tags on the BMS control drawings.

2) Copper Tubing:

a) Copper tubing shall be hard-drawn in exposed areas and either hard-drawn or annealed in concealed areas.
b) Only tool-made bends shall be used.
c) Fittings for copper tubing shall be brass or copper solder joint type except at connections to apparatus, where fittings shall be brass compression type.

3) Plastic Tubing:

a) Plastic tubing shall be run within covered raceways or conduit except when otherwise specified.
b) Plastic tubing shall not be used for applications where the tubing could be subjected to a temperature exceeding 130°F.
c) Fittings for plastic tubing shall be for instrument service and shall be brass or acetal resin of the compression or barbed push-on type.
d) Except in walls and exposed locations, plastic multi-tube instrument tubing bundle without conduit or raceway protection may be used where a number of air lines run to the same points. The multi-tube bundle must be enclosed in a protective sheath, run parallel to the building lines, and adequately supported.

4) Sensing Tubing for Space Pressure:

a) Sensing tubing for space pressure applications shall be plastic or copper tubing. Horizontal and vertical runs of plastic tubing or soft copper tubing shall be installed in raceways or rigid conduit dedicated to tubing. Dedicated raceways, conduit, and hard copper tubing not installed in raceways shall be supported every 6 feet for horizontal runs and every 8 feet for vertical runs.

5) Sensing Tubing for Liquid and Steam:

a) Sensing tubing for connection of sensing elements and transmitters to liquid and steam lines shall be copper with brass compression fittings.

6) Sensing Tubing for Duct Pressure or Flow:

a) Connections to sensing elements in ductwork shall be plastic tubing.

4.7 Existing Controls Coordination

1. The BMS contractor shall ensure that existing controls which are to be reused are tested and calibrated for proper operation. Existing controls which are found to be defective shall be noted to MIT and the CM. The BMS contractor shall not be responsible for any material or labor costs associated with the repair of existing controls.
2. Switchover from the existing control system to the new BMS must be coordinated with MIT.
3. The BMS contractor shall include demolition of the existing controls no longer required after the new BMS is in place and functioning properly.
4. When the incumbent/existing BMS for a building is replaced, superseded hardware as-builts and software code/graphics shall edited/removed by MIT.

4.8 BMS Commissioning

1. General:

a. This section details the procedures required to ready the BMS for the CxA's Functional Performance Testing. There shall be three main parts to this effort. The first part shall be an Installation Verification, the second part shall be Start-up Testing, and the third part shall be an Operational Verification that shall include executing Sequence of Operation Tests which are intended to be similar to the CxA's Functional Performance Testing.

b. A turnover checklist similar to the one in Appendix C shall be prepared by the BMS contractor. It is expected that this checklist will be filled out by the BMS contractor and signed-off by MIT's BMS personnel. The first part of the checklist should be complete prior to the last walkthrough steps. When completed and signed off this checklist will be part of the as-built documentation.

2. Coordination:

a. Coordination with the Testing & Balancing (TAB) contractor:

1) Coordinate with the TAB contractor to obtain and fine tune control settings that are determined from balancing procedures. Record and implement the following control settings as obtained from TAB contractor:

a) Calibration parameters (including coefficients and offsets) for flow control devices such as VAV boxes and flow measuring stations.
b) Optimum duct static pressure setpoints for VAV air handling units.
c) Optimum differential pressure setpoints for variable speed pumping

systems.

b. **Coordination with CxA and MIT:**

1) The BMS contractor shall prepare a list of all point types and recommended alarming strategies and setpoints for review by the CxA and MIT. Points list with alarming strategy shall be provided prior to the first applicable Sequence of Operation Test. MIT shall use this alarm list to provide direction to the BMS contractor for alarm strategies and setpoints. The BMS contractor shall have alarm setpoints entered and documented in the testing protocols prior to execution of any applicable Sequence of Operation Tests.
2) The BMS contractor shall submit screenshots of all graphic displays (only one example of a graphic display screenshot is required for repetitive equipment like VAV boxes or fan coil units) with points displayed for review by the CxA and MIT. Graphic display screenshots with attached points shall be provided prior to execution of any applicable Sequence of Operation Tests. MIT shall use these graphic display screenshot samples to provide direction to the BMS contractor for the required final graphic display screens.

3. Installation Verification:

a. General:

1) Each I/O device and local device (both field mounted as well as those located in control panels) shall be inspected and verified for proper installation.
2) A checkout sheet itemizing each device shall be filled out, dated, and submitted to the CxA as part of the Installation Verification test documentation. These can be screen shots of electronic checkout sheets as well.
3) The BMS contractor shall perform a full-loop test at each I/O point. Each point shall be tested back to its respective graphic display screen. While performing the loop test the BMS contractor shall also:

a) Verify proper electrical voltages and amperages.
b) Verify that all control circuits are free from faults.
c) Verify integrity/safety of all electrical connections.
d) Check and set zero and span adjustments for all transducers and transmitters.
e) For actuators and associated valves and dampers:

1) Verify the stroke and range is as required and matches the programmed ranges.
2) Verify adequate installation including free movement throughout full stroke of the actuator.
3) From the BMS graphic display screen, command the valve or damper closed and verify that valve or damper is fully closed.

4) From the BMS graphic display screen, command the valve or damper open and verify position is fully opened.
5) From the BMS graphic display screen, command the actuator to one halfway position. If actual valve or damper position doesn't reasonably correspond, troubleshoot the problem.
6) Where dampers work in unison, verify proper control without overlap.
7) Verify the appropriate fail position both for device power failure and system failure.

f) Verify each digital output is wired and configured correctly by making a comparison between the control command at the graphic display screen and the status of the controlled device.
g) Verify each digital input point is wired and configured correctly by making a comparison of the state of the sensing device and the graphic display screen.
h) For outputs to control devices not provided by the BMS (i.e. VFDs) and feedback from them, verify that ranges of operation match at the BMS. When applicable, coordinate with representative of the respective manufacturer and obtain their approval of the proper installation.
i) Verify that all safety devices trip at appropriate conditions. Adjust setpoints as required.
j) Calibrate, set, and test all digital and analog sensing and actuating devices. The BMS contractor shall calibrate each sensor per the procedure in detailed below.
k) For BMS control panels:

1) Verify that devices are properly installed with adequate spacing for maintenance.
2) Verify that all devices are properly labeled in accordance with the BMS panel drawings.
3) Verify that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in panduit.
4) Verify that terminations are safe, secure, and labeled in accordance with the BMS panel drawings.
5) Verify that power supplies have proper voltage ranges in accordance with the BMS panel drawings.
6) Verify adequate grounding of all BMS control panels and devices.
7) Run self-diagnostic routines and ensure BMS controllers are functional.
8) Verify controller is properly communicating on communication network.

b. Sensor Checkout and Calibration:

1) General Checkout: Verify that all sensor locations are appropriate for the tolerances specified for the device and are away from causes of erratic operation.

2) General Calibration (for applicable areas and devices):

a) Calibrate each device by making a comparison between the BMS graphic display screen and the reading at the device, using a calibrated test instrument. (Calibration certificates for test instruments shall be provided if requested.) Record the measured value and displayed value for each device on the check-out sheet.

b) For precision grade instrumentation, a factory calibration certificate is required.

3) Air and water flow sensor calibration shall be performed in collaboration with the TAB contractor. The TAB contractor or the mechanical contractor shall be responsible for the coordination of the entry of calibration coefficients into the BMS and for recording of the parameters entered.

4. Start-up Testing:

a. Current Switch Status Adjustment:

1) Adjust all current switches to indicate status at minimum flow condition and show no status when device is off.

b. Loop Tuning:

1) The BMS contractor shall tune each control loop in a manner consistent with that described in the ASHRAE FUN IP. Tuning shall consist of adjustment of the proportional, integral, and where applicable, the derivative (PID) settings to provide stable closed-loop control.

2) For all control loops, the BMS contractor shall tune the loops to ensure the fastest stable response without hunting, offset, or overshoot with the tolerances defined below. Except from a startup, maximum allowable variance from setpoint for controlled variables under normal load fluctuations shall be as follows:

a) Duct air temperature: ±1°F.
b) Space temperature: +/- 3°F within 3 minutes and control within +/- 2°F.
c) Chilled water temperature: +/- 1°F.
d) Hot water temperature: +/- 2°F.
e) Duct pressure: +/- 0.25" w.g.
f) Water pressure: +/- 1 psid.
g) Duct humidity: +/- 3 percent when adding humidity.
h) Space humidity: +/- 5 percent when adding humidity to control.
i) Terminal air flow control: +/- 5 percent of setpoint.
j) Space Pressurization: +/- 0.03" w.g. with no door or window movements.
k) Steam Pressure: +/- 3 psig.

l) Water Level: +/- 5 percent tank height.

3) Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, the tolerances shall be maintained with exceptions as noted.
5) Maintain a record of control loops that require tuning at alternate times of year.
6) Document all loop tuning by capturing text, short interval trends, or screen shots of trend graphs documenting the final response.

a) Trend Logs:

1) Trends logs are historical archives stored in the BMS that document the operation of the systems and equipment. Trends can be interval recordings of system I/O parameters or Change of Value based trends that record when a system value changes by more than a specified threshold.
2) Sample times indicated as COV (±) or change of value mean that the changed parameter only needs to be recorded after the value changes by the amount listed. When output to the trending file, the latest recorded value shall be listed with any given time increment record.
3) Data shall include a single row of field headings and the data thereafter shall be contiguous. Each record shall include a date and time field. Recorded parameters for a given piece of equipment or component shall be trended at the same intervals.
4) Trending Requirements: As described in previous sections
5) Trending to document Sequence of Operation Tests may require a more frequent interval than final trending requirements. Coordinate with the CxA to determine the correct intervals to prove operational testing and modify intervals as required.
6) The BMS contractor shall set up the trends logs, ensure they are being stored properly, and then, if requested by the CxA, forward the data in electronic format to the CxA. Data shall be forwarded in one of the following formats:

a) Microsoft EXCEL Spreadsheet (.xls)
b) Comma Separated Value (.csv or .txt) preferably with quotes delimiting text fields and # delimiting date/time fields

7) The CxA shall analyze trend logs of the system operating parameters to evaluate normal system functionality.
8) The BMS contractor shall allow the CxA BMS access to view the trend log data and allow downloading to a remote location. The BMS contractor shall also provide instruction for accessing

the trend logs.

b) Trend Graphs:

1) Trend graphs are generally used to facilitate and document testing. The BMS contractor shall prepare controller and workstation software to display graphical trends.
2) On the trend graphs, lines shall be labeled and shall be distinguishable from each other by using either different line types, or different line colors.
3) Indicate engineering units of the y-axis values; e.g. °F, inches w.g., Btu/lb, percent wide open, etc. The y-axis scale shall beset such that all trended values are in a readable range.
4) Trend outside air temperature, humidity, and enthalpy during each period in which any other points impacted by these parameters are trended.
5) All points trended for one HVAC subsystem (e.g. air handling unit, chilled water system, etc.) shall be trended during the same trend interval. On renovation projects with existing to remain controls on air or water generation equipment, these trend graphs need only address the new BMS renovation work.
6) Each graph shall be clearly labeled with HVAC subsystem title, date, and times.
7) The BMS contractor shall forward the trend graphs as part of the CxA BMS Pre-Requisite Package to the CxA for review.

5. Operational Verification:

a. For BMS control panels:

1) Verify the spare memory allocation to ensure adequate capacity is available for the intended function.
2) With the BMS operating normally, verify the reporting time to the BMS graphic display screen for an alarm trigged at the controller is within the tolerances specified.
3) Verify standalone performance of controllers by disconnecting the controller from the BMS network. Verify the loss of communications is reported to the BMS and upon restoration of communication the alarm clears and locally stored trending information is sent to the BMS.
4) Disconnect power from the controller.

a) Verify that all outputs and devices fail to their proper positions/states.
b) Verify that buffered memory is held through power outage.

b. From Graphical User Interface:

1) Verify that all hot buttons on the graphic display screens are functional and that the navigation strategy is logical.

   a) I/O bindings to graphic display screens shall be verified in the loop testing section.

2) Duplicate I/O bindings such as temperature readings on a floor plan shall be verified.
3) Verify that trend archiving is functional.
4) Verify that real time and historical trends are accessible and viewable in graph format.
5) Verify that the alarm logging and printing (if applicable) is functional.
6) Verify alarm functionality and proper time delays. (Actual individual alarms are tested in the Sequence of Operation Tests).
7) Verify that outgoing alarm annunciation is functional (i.e., text, phone, email).
8) Verify that required third party software applications are installed and are functional.
9) Verify software interfaces communicate and check response time. If applicable, test watchdog programs.
10) Verify the following response times:

   a) It shall take no more than ten seconds from the time an alarm is generated at a device or controller until the BMS software provides notification and the alarm is displayed.
   b) It shall take no more than twenty seconds from the time of initiation of a control action command from the workstation to display of the resulting status change on the workstation.

11) Verify that all custom programs are editable from the operator workstation.
12) Verify upload, download, and backup and restore capabilities from the operator workstation.
13) Verify schedules are set up and working.
14) Verify security and permissions are set up and functional.
15) Verify all required BMS reports are set up and functional.
16) Where operator interface displays information mapped via a software interface:

   a) Verify the displayed points are correct and the values are properly bound.
   b) Verify delays in displaying changes of state are as specified.
   c) Verify BACnet object properties and parameters are readable and writable as required.
   d) Verify all BACnet services are provided as required.
   f) Verify that after a resumption of normal state after a power failure, the interfaces resume normal communication without manual intervention.

17) Verify all specified actions in the sequence of operation control by using the

Sequence of Operation Tests to record results. The test protocols shall explain, step-by-step, the actions and expected results that shall demonstrate that the control system performs in accordance with the sequence of operation. If required for execution of the testing protocols, BMS test equipment used shall be properly documented. The documentation shall include manufacturer, model number, calibration parameters, calibration expiration, and on what test the device was used.

a) 100% of major equipment (AHUs, hydronics) must be sequence tested.
b) 20% of each different sequence instance for terminal equipment must be tested.

18) Verify that the BMS can be accessed from the internet and the display is consistent with a hard client workstation.

6. CxA BMS Pre-Requisite Package:

a. The BMS contractor shall prepare a CxA BMS Pre-Requisite Package that includes the following:

1) Installation Verification Check-Out Sheets (Full Loop Test Check-Out Sheets).
2) Start-up Testing Trend Graphs (proving tuned loops).
3) Operational Verification Sequence of Operation Tests (proving adherence to sequence).

b. Failures and repairs shall be documented with test results that prove compliance. This shall be completed, submitted, and approved prior to Cx activities.

7. CxA Review of BMS Implementation:

a. Commissioning related training session is specified below:

1) BMS Final Systems Operation Training: The BMS contractor shall conduct a session to present the final sequence of operation programmed into the control system. This session is typically presented on site by the primary BMS technician that implemented the BMS for the project. The session shall basically present:

a) Control System Architecture.
b) Location of BMS control panels.
c) Schematic control configuration of the systems.
d) Final programmed sequence of operation: The BMS contractor shall present the written sequence of operation and explain the programming that accomplishes the sequence of operation.
e) Start-up and shut down procedures.
f) Common troubleshooting tips.
g) Log-on and BMS graphic display screen navigation.

h) Alarm viewing.
i) Trend viewing.
1) Report generation.

2) The BMS contractor shall use the project control drawings as training guide.

8. BMS Readiness Testing:

a. Demonstrate the readiness of the BMS and all related components and systems for Cx activities to the satisfaction of the CxA and MIT.
b. Demonstration shall not be scheduled unless:

1) All BMS hardware and software submittals are approved.
2) The CxA BMS Pre-Requisite Package is approved.

c. The BMS contractor shall supply all required personnel and test equipment for the demonstration. The BMS personnel performing the demonstration must be competent with and knowledgeable of all project-specific hardware, software, as well as the systems the BMS controls and monitors.
d. Readiness testing shall involve a small representative sampling of testing selected by MIT and the CxA that has already been completed as part of the Installation Verification, Start-up Testing, and Operational Verification.
e. The selected sampling of tests shall again be executed following the same procedures used in the Installation Verification, Start-up Testing, and Operational Verification. Sample testing may include:

1) Verify graphic display screens, alarms, trends, and reports are installed as specified.
2) Verify that I/O on control drawings is displayed on the correct BMS graphic display screen and can be commanded as required.
3) Verify correct calibration of input devices using the same methods specified in the Start-up Testing.
4) Verify all BMS software programs and hardwired I/O exist at respective field panels.
5) Verify the BMS controllers automatically recover from power failures, as specified.
6) Verify the stand-alone operation of BMS controllers upon loss of connectivity to the network.
7) Re-execution of the Sequence of Operation Tests.
8) Verify required trend graphs and logs are set up and perform per the requirements.

9. Proof of BMS Stability:

a. Performance Test:

1) The system shall operate properly for three days (or a mutual agreeable duration) without malfunction, without alarms caused by control action or device failure, and with smooth and stable control of systems and equipment.
2) Special care must be given to address nuisance alarms. Projects will not be accepted by MIT with unexplained alarms and/or nuisance alarms.

10. BMS Cx Phase Activities:

a. After receipt and/or review of the CxA BMS Pre-Requisite Package and approval of the BMS readiness testing and stability testing, the CxA shall determine if the system is ready for formal Functional Performance Testing.

1) If the systems are not ready for functional performance testing, the BMS contractor shall issue items that are not completed and include in their readiness report. The proof of BMS stability period shall be restarted at a mutually scheduled time. This process shall be repeated until the CxA issues notice that the BMS is ready for Functional Performance Testing.
2) At the discretion of the CxA, minor issues highlighted by the CxA may be addressed by the BMS contractor and not prevent the Functional Performance Testing from starting.
3) It is also possible for partial submission and approval, so that certain systems may be started in accordance with the overall Cx schedule.

b. Requirements for assistance with Functional Performance Testing are specified in the commissioning specification. The BMS contractor shall provide support to the CxA during testing as specified.
c. During the Cx phase, the BMS contractor shall allow remote access by the CxA to view trend logs or trend graphs.

11. Additional Cx Support (System Optimization Assistance):

a. In addition to the support required during the Cx phase, the BMS contractor shall provide the services of a BMS controls technician to the CxA at the project site for a total of at least 8 hours (depending on the project size). The purpose of this resource is to make changes, enhancements, additions to the BMS and to create reports recommended by the CxA during the Cx phase. Requests for assistance shall be in 4 hour blocks at a minimum. The CxA shall notify the BMS contractor at least one week in advance of each day of requested assistance.
b. The BMS controls technician provided shall be thoroughly trained in the programming and operation of the BMS as it is specifically implemented on this project.

12. Additional Testing:

a. Opposite Season Testing (if required): Within six months of completion of the Cx phase, the CxA shall schedule and conduct opposite season functional testing. The BMS contractor shall support this testing and address any deficiencies identified.

4.9 Training

1. General:

   a. Training courses shall be conducted as described below in the maintenance, service, and operation of the system, including specified hardware and software. The training shall be oriented to the specific system(s) provided for this project.

   b. The length of the training sessions detailed below shall be determined by the MEP design consultant and MIT on a project by project basis. MIT's System Performance and Turnover group shall coordinate the training.

   c. Training Course Documentation:

      1) The BMS contractor shall prepare training documentation that shall consist of:

         a) Course Attendee List.

         b) Training Manuals: Training manuals shall include an agenda, detailed objectives for the course, and a description of the subject matter for part of the course. Training manuals shall be delivered for each trainee with two additional manuals turned over to the project site.

2. BMS Instrument Technician Training:

   a. The BMS Instrument Technician training course shall be taught at the project site. This training shall be targeted towards the BMS Instrument Technicians in the day-to-day operation and basic maintenance of the BMS. Typical HVAC systems shall be treated as a group, with instruction on the physical layout of one such system. This course shall be taught to three shifts. The training at a minimum shall include:

      1) General system architecture.
      2) Functional operation of the system.
      3) System start-up procedures.
      4) Graphics navigation.
      5) Schedule configuration.
      6) Trend configuration.
      7) Reports generation.
      8) Alarm reporting and acknowledgements.
      9) Perform point overrides and override release.
      10) Retrieval of historical trends and logs.
      11) Web-access to BMS.
      12) Maintenance procedures:

          a) Locations and layout of typical BMS controller enclosure.
          b) Locations and layout of sampling of terminal equipment.
          c) Location of typical control end devices.

d) Calibration, adjustment, commissioning, tuning, repair procedures.
e) Calibration frequency.
f) Troubleshooting and diagnostic procedures for end devices.
g) Troubleshooting and diagnostic procedures for controllers.
h) Preventive maintenance procedures and schedules.

3. BMS Analyst Training:

a. The BMS Analyst training course shall be taught at the project site. This training shall be targeted towards the BMS Analysts in management of the BMS. This course shall be taught to one shift. The training at a minimum shall include:

1) General system architecture.
2) Functional operation of the system.
3) System start-up procedures.
4) Graphics navigation.
5) Schedule configuration.
6) Trend configuration.
7) Reports generation.
8) Alarm reporting and acknowledgements.
9) Perform point overrides and override release.
10) Retrieval of historical trends and logs.
11) Web-access to BMS.
12) Software diagnostics.
13) Disaster recovery procedures.

4. BMS Operator Training:

a. The BMS Operator training course shall be taught at the project site. This training shall be targeted towards the BMS Operators in the day-to-day operation of the BMS. This course shall be taught to three shifts. The training at a minimum shall include:

1) Functional operation of the system.
2) Graphics navigation.
3) Schedule configuration.
4) Alarm reporting and acknowledgements.
5) Perform point overrides and override release.

4.10 Final Documentation (Operations and Maintenance Manuals)

1. The intent of the operation and maintenance documentation is to provide MIT with complete information on the BMS as it was installed. The record documentation shall be in such detail that a person familiar with a BMS installation of this nature shall be able to perform any operating, maintenance, or engineering functions with respect to this BMS without having to contact the BMS contractor or obtain any additional documentation.

2. The BMS contractor shall submit electronic copy (in PDF format) of the operation and maintenance manual that include the following three sections:

   a. **Project Completion/Closeout for BMS Document (Part A &B).**

   b. **BMS Hardware As-Built Information:**

      1) Riser Diagram of Building Control Network.
      2) As-built control schematic drawing for each controlled system.
      3) As-built wiring drawings for all components.
      4) As-built drawings for each control panel layout.
      5) Installation details for each I/O device.
      6) Product data sheet for each component.
      7) Installation data sheet for each component.
      8) As-built sequence of operation for each system.
      9) Procedures for HVAC system start-up, operation, and shut-down.
      10) Printouts of configuration settings for all devices.
      11) Routine maintenance/calibration checklist: The routine maintenance checklist shall be arranged in a spreadsheet with the device tag, type of device, maintenance frequency, calibration frequency, and a notes field.
      12) Start-Up Testing Report.

   c. **BMS Software As-Built Information:**

      1) Copy of all graphic display screens created during the execution of the project.
      2) Alarm list.
      3) List of virtual points configured from each software interface.

   d. **BMS Operational Information**

      1) Product manuals for the key software tasks (<u>if new</u>):

         a) Operating the system.
         b) Administrating the system.
         c) Application programming.
         d) Setting up the report server.
         e) Report creation.
         f) Graphics creation.

      2) List of recommended maintenance tasks associated with the system servers, operator workstations, data servers (<u>if new</u>):

         a) Define the task with recommended frequency.
         b) Reference the product manual that includes instructions on executing the task.

      3) Contact information of the BMS contractor and service representatives for

equipment and control systems (<u>if new</u>).

4) Licenses, guarantees, and warranty documents for equipment and systems (<u>if new</u>).

APPENDIX A: BUILDING LIST

Main Campus Buildings	Siemens	Schneider Continuum	Schneider Struxureware	ALC WebControl
M01			x	
M02			x	
M03			x	
M04			x	x
M05			x	
M06			x	x
M06C				x
M07			x	
M07A			x	
M08			x	x
M09			x	
M10			x	
M11			x	
M12			x	
M13		x		
M14				x
M16		x		
M18		x		
M24		x	x	
M26			x	
M31				x
M32		x	x	
M33		x		
M34				x
M35		x		
M36			x	
M37			x	x
M38		x		x
M39				x
M41			x	
M42			x	
M43			x	
M46		x		
M48				x
M50			x	
M54			x	x
M56		x		x
M57				x
M62			x	
M66			x	
M68			x	
M76		x		
Totals >	0	11	26	14

East Campus Buildings	Siemens	Schneider Continuum	Schneider Struxureware	ALC WebControl
E01			x	
E02		x		
E14		x		
E15			x	
E17		x	x	
E18		x	x	
E19		x	x	
E23			x	x
E25		x		
E37/E38				x
E40			x	
E51		x		
E52	x			
E53		x	x	
E55		x		
E60		x		
E62		x		
Totals >	1	11	8	2

West Campus Buildings	Siemens	Schneider Continuum	Schneider Struxureware	ALC WebControl
W01		x		
W04				x
W07		x		
W08			x	
W11			x	
W15			x	
W16	x			
W20				x
W31		x		
W32				x
W34				x
W35		x		
W46			x	
W51				x
W53a		x		
W59		x		
W61				x
W64			x	
W70			x	
W71		x		
W79		x		
W84		x		
W85				x
W91		x		
W92				x
W97			x	
W98		x		
Totals >	1	11	7	8

North Campus Buildings	Siemens	Schneider Continuum	Schneider Struxureware	ALC WebControl
N16			x	
N51		x		
N52		x		
Totals >	0	2	1	0

Northwest Campus Building	Siemens	Schneider Continuum	Schneider Struxureware	ALC WebControl
NW10				x
NW12			x	
NW13			x	
NW14		x		
NW15		x	x	
NW16			x	
NW17				x
NW21				x
NW22			x	
NW23			x	
NW30		x		
NW35				x
NW61			x	
NW86		x		
Totals >	0	4	7	4

APPENDIX B: ALARM TABLE

Alarm Name	Type	Messaging	Time Delay	Increment	High	Low	Deadband	Shunt
AHU Air Flow	Change of Value	Alarm AHU Air Flow is Out of Range	10m	100 CFM	n/a	n/a	n/a	n/a
		RTN AHU Air Flow has Returned to Normal						
		Fault System config malfunction						
Cooling coil Supply Temp Alarm	Out of Range	Alarm Cooling coil Supply Temp is Out of Range	20m	n/a	+5°F	-5°F	n/a	n/a
		RTN Cooling coil Supply Temp has Returned to Normal						
		Fault System config malfunction						
Energy Wheel Status	Change of State	Alarm Energy Wheel status does not equal command	15s	n/a	n/a	n/a	n/a	n/a
		RTN Energy Wheel status has Returned to normal						
		Fault Energy Wheel status sensor malfunction						
Enth. Wheel Leaving Air Temp Low	Out of Range	Alarm Enthalpy Wheel Discharge Air Temp Low Alarm	5m	n/a	n/a	35°F	2°F	n/a
		RTN Enthalpy Wheel Discharge Air Temp Return to Normal						
		Fault Enthalpy Wheel Discharge Air Temp Sensor Malfunction						
Fan Status	Change of State	Alarm Fan Status does not Match Command	20s	n/a	n/a	n/a	n/a	n/a
		RTN Fan Status has Returned to Normal						
		Fault System config malfunction						
Fan Status	Change of State	Alarm Fan status does not equal command	30s	n/a	n/a	n/a	n/a	n/a

		RTN Fan status has Returned to normal						
		Fault Fan status sensor malfunction						
Fire HOA Return Fan in "Hand"	Change of State	Alarm Return Fan Firemans HOA in "Hand" Alarm	0s	n/a	n/a	n/a	n/a	n/a
		RTN Return Fan Firemans HOA in "Hand" has Returned to normal						
		Fault System config malfunction						
Fire HOA Return Fan in "Off"	Change of State	Alarm Return Fan Firemans HOA in "Off" Alarm	0s	n/a	n/a	n/a	n/a	n/a
		RTN Return Fan Firemans HOA in "Off" has Returned to normal						
		Fault System config malfunction						
Fire HOA Supply Fan in "Hand"	Change of State	Alarm Supply Fan Fireman's HOA in "Hand" Alarm is Active	0s	n/a	n/a	n/a	n/a	n/a
		RTN Supply Fan Fireman's HOA in "Hand" has Returned to Normal						
		Fault System config malfunction						
Fire HOA Supply Fan in "Off"	Change of State	Alarm Supply Fan Firemans HOA in "Off" Alarm	0s	n/a	n/a	n/a	n/a	n/a
		RTN Supply Fan Firemans HOA in "Off" has Returned to normal						
		Fault						
Fire System AHU Shutdown	Change of State	Alarm Fire System AHU Shutdown Alarm	0s	n/a	n/a	n/a	n/a	n/a
		RTN Fire System AHU Shutdown has Returned to normal						
		Fault						
Fire System AHU Shutdown	Change of State	Alarm Fire System AHU Shutdown Alarm	0s	n/a	n/a	n/a	n/a	n/a
		RTN Fire System AHU Shutdown has Returned to normal						
		Fault						
Freezestat	Change of State	Alarm Freezestat Is Active (Manual Reset)	5s	n/a	n/a	n/a	n/a	n/a

		RTN Freezestat has Returned to Normal						
		Fault System config malfunction						
Heat Wheel Diff. Pressure Low	Out of Range	Alarm Heat Wheel Differential Pressure Low Alarm	5m	n/a	n/a	0.1" w.c.	0.2" w.c.	n/a
		RTN Heat Wheel Differential Pressure Return to Normal						
		Fault Heat Wheel Differential Pressure Sensor Malfunction						
Low Static Pressure Switch	Change of State	Alarm Low Static Pressure Switch Is Active	5s	n/a	n/a	n/a	n/a	n/a
		RTN Low Static Pressure Switch has Returned to Normal						
		Fault System config malfunction						
MAHU has failed off	Change of State	Alarm MAHU has Failed Off	15m	n/a	n/a	n/a	n/a	n/a
		RTN MAHU status has Returned to Normal						
		Fault						
MAHU Low air flow	Out of Range	Alarm MAHU SA CFM not meeting setpoint	15m	n/a	n/a	-25%	n/a	n/a
		RTN MAHU SA CFM Returned to normal						
		Fault						
Modulating Damper Position	Out of Range	Alarm Damper Position Deviation From Command	5m	n/a	+10%	-10%	5%	n/a
		RTN Damper Position Normal						
		Fault Damper Malfunction						
Modulating Valve Position	Out of Range	Alarm Valve Position Deviation From Command	5m	n/a	+10%	-10%	5%	n/a
		RTN Valve Position Normal						
		Fault Valve Malfunction						
Return Air Dew Point High	Out of Range	Alarm Return Air Dew Point High Alarm	5m	n/a	58°F	n/a	2°F	n/a
		RTN Return Air Dew Point Return to Normal						

		Fault						
Return Air Dew Point High	Out of Range	Alarm Return Air Dew Point High Alarm	5m	n/a	58°F	n/a	2°F	n/a
		RTN Return Air Dew Point Return to Normal						
		Fault						
Static Pressure	Out of Range	Alarm System Static Pressure Out Of Range	5m	n/a	+30%	- 30%	10%	n/a
		RTN Heat Wheel Differential Pressure Return to Normal						
		Fault Heat Wheel Differential Pressure Sensor Malfunction						
Supply Air Dew Point High	Out of Range	Alarm Supply Air Dew Point High Alarm	5m	n/a	58°F	n/a	2°F	n/a
		RTN Supply Air Dew Point Return to Normal						
		Fault						
Supply Air Temp	Out of Range	Alarm Supply Air Temp is Out of Range	20m	n/a	+10°F	- 10°F	n/a	n/a
		RTN Supply Air Temp has Returned to Normal						
		Fault Supply Air Temp Sensor Malfunction						
Supply Air Temp	Change of Value	Alarm Supply Air Temp is Out of Range	20m	10°F	n/a	n/a	n/a	n/a
		RTN Supply Air Temp has Returned to Normal						
		Fault Supply Air Temp Sensor Malfunction						
Supply Humidity Alarm	Out of Range	Alarm Supply humidity is Active	15m	n/a	+10%	- 10%	n/a	n/a
		RTN Supply humidity has Returned to Normal						
		Fault System config malfunction						
Two Position Damper Status	Change of State	Alarm Damper status does not equal command	120s	n/a	n/a	n/a	n/a	n/a
		RTN Damper Position Normal						

		Fault Damper Malfunction						
Two Position Damper Status	Change of State	Alarm Damper Status does not Match Command	120s	n/a	n/a	n/a	n/a	n/a
		RTN Damper Status has Returned to Normal						
		Fault System config malfunction						
Unit Chamber Temp Alarm	Out of Range	Alarm Unit chamber temp is in Alarm	5m	n/a	+10°F	-10°F	n/a	n/a
		RTN Unit chamber temp has Returned to Normal						
		Fault System config malfunction						
Unit High Static Alarm	Change of State	Alarm High Static Pressure Switch is Active (Manual Reset)	5s	n/a	n/a	n/a	n/a	n/a
		RTN High Static Pressure Switch has Returned to Normal						
		Fault System config malfunction						
VFD Fault	Change of State	Alarm VFD Fault Alarm is Active	5s	n/a	n/a	n/a	n/a	n/a
		RTN VFD Fault Alarm has Returned to Normal						
		Fault System config malfunction						
Hood Low air flow	Change of State	Alarm Hood face velocity Low	15s	n/a	n/a	n/a	n/a	n/a
		RTN Hood face velocity Return to normal						
		Fault Hood velocity sensor malfunction						
Generator Day Tank Low level Alarm	Change of State	Alarm Generator day tank Low Level alarm active	0s	n/a	n/a	n/a	n/a	n/a
		RTN Generator day tank Low level alarm RTN						
		Fault						
Generator Day Tank Hi Level Alarm	Change of State	Alarm Generator day tank Hi Level alarm active	0s	n/a	n/a	n/a	n/a	n/a
		RTN Generator day tank Hi Level alarm RTN						

		RTN Generator day tank Hi Level alarm RTN						
		Fault						
Level Alarm	Change of State	Alarm Sump Level is active	15s	n/a	n/a	n/a	n/a	n/a
		RTN Sump level has Returned to normal						
		Fault Sump level sensor malfunctioned						
Sump Alarm	Change of State	Alarm Sump Alarm	1m	n/a	n/a	n/a	n/a	n/a
		RTN Sump Alarm Return to Normal						
		Fault Sump alarm sensor Malfunction						
Sump Alarm	Change of State	Alarm Sump Alarm	1m	n/a	n/a	n/a	n/a	n/a
		RTN Sump Alarm Return to Normal						
		Fault Sump alarm sensor Malfunction						
Elevator Shaft Space Temp	Out of Range	Alarm Elevator Shaft Space Temp Out Of Range	10m	n/a	+95°F	50°F	2°F	n/a
		RTN Elevator Shaft Space Temp Returned to Normal						
		Fault Elevator Shaft Space Temp sensor out of range						
Mech. Room Space Temp High	Out of Range	Alarm Mech. Room Space Temp High	10m	n/a	95°F	n/a	2°F	Yes
		RTN Mech. Room Space Temp Returned to Normal						
		Fault Mech. Room Space Temp sensor out of range						
Space CO2 High	Out of Range	Alarm Space CO2 High	5m	n/a	1200 ppm	n/a	200 ppm	Yes
		RTN Space CO2 Returned to normal						
		Fault Space CO2 sensor malfunction						
Space Dew	Floating	Alarm Space Dew Point Critical	1m	n/a	CHWS+1°	n/a	1°F	Yes

		RTN Space Dew Point Returned to normal						
		Fault Space Dew Point sensor malfunction						
Space Dew Point High	Floating Limit	Alarm Space Dew Point High	5m	n/a	CHWS-1°F	n/a	1°F	Yes
		RTN Space Dew Point Returned to normal						
		Fault Space Dew Point sensor malfunction						
Space Temp	Change of Value	Alarm Space Temp Out of Range	10m	10°F	n/a	n/a	n/a	Yes
		RTN Space Temp back to Normal						
		Fault Space Temp sensor malfunction						
Stairwell Space Temp	Out of Range	Alarm Stairwell Space Temp Out Of Range	10m	n/a	90°F	50°F	2°F	n/a
		RTN Stairwell Space Temp Returned to Normal						
		Fault Stairwell Space Temp sensor out of range						
Chilled Water Hi Temp Alarm	Out of Range	Alarm Hi Chilled water temp	15m	n/a	60°F	45°F	2°F	n/a
		RTN Hi Chilled water Temp Returned to Normal						
		Fault CHW sensor malfunction						
Chilled Water Hi Temp Alarm	Out of Range	Alarm Hi Chilled water temp	15m	n/a	60°F	45°F	n/a	n/a
		RTN Hi Chilled water Temp Returned to Normal						
		Fault CHW sensor malfunction						
Differential Pressure	Out of Range	Alarm Differential Pressure is Out of Range	5m	n/a	+5 PSI	-5 PSI	2 PSI	n/a
		RTN Differential Pressure has Returned to Normal						
		Fault System config malfunction						
Differential Pressure	Out of Range	Alarm Differential Pressure is Out of Range	5m	n/a	+5 PSI	-5 PSI	2 PSI	n/a

		RTN Differential Pressure has Returned to Normal						
		Fault System config malfunction						
Hot Water Supply Temp	Out of Range	Alarm HW Supply Temp is Out of Range	5m	n/a	+95°F	50°F	2°F	n/a
		RTN HW Supply Temp has Returned to Normal						
		Fault System config malfunction						extreme
HX 1,2 Pumps off	Change of State	Alarm Both HX Pumps have Failed	15s	n/a	n/a	n/a	n/a	n/a
		RTN Pump flow has been Re-established						
		Fault						
MAHU SA temp out of range	Out of Range	Alarm MAHU SA Temp out of Range	15m	n/a	+10°F	-10°F	n/a	n/a
		RTN MAHU SA Temp has Returned to Normal						
		Fault						
Modulating Valve Position	Floating Limit	Alarm Valve Position Deviation From Command	5m	n/a	+10%	-10%	5%	n/a
		RTN Valve Position Normal						
		Fault Valve Malfunction						
Modulating Valve Position	Out of Range	Alarm Valve Position Deviation From Command	5m	n/a	+10%	-10%	5%	n/a
		RTN Valve Position Normal						
		Fault Valve Malfunction						
Pump Status	Change of State	Alarm Pump status does not Match Command	30s	n/a	n/a	n/a	n/a	n/a
		RTN Pump status has Returned to Normal						
		Fault System config malfunction						
Steam Pressure Low	Out of Range	Alarm Steam Pressure is in Alarm	5m	n/a	n/a	7 PSI	2 PSI	n/a
		RTN Steam Pressure has Returned to Normal						
		Fault Steam Pressure Sensor Malfunction						

		Fault Steam Pressure Sensor Malfunction						
VFD Fault	Change of State	Alarm VFD Fault Alarm is Active	5s	n/a	n/a	n/a	n/a	n/a
		RTN VFD Fault Alarm has Returned to Normal						
		Fault System config malfunction						

MIT Project Completion/Closeout for BMS (Part A Completion Checklist)

Project Name: ___________________
Project Manager: _________________

Checklist shall be turned in by BMS contractor Project Manager to MIT at completion. A software scan of the completed checklist shall reside on the server with the as-builts.

Item:	**Responsible:**	**Date:**	**Signed off by:**	**Notes:**
Pre-Walkthrough				
Installation Complete	Hardware Engineer			
Check-out sheet complete	Hardware Engineer			
Graphics Complete All links completed All floor plans completed	Software Engineer			
Alarms Enabled & Complete***	Hardware Engineer and/or Software Engineer			
Mechanical/Electrical Deficiency list required & forwarded to MIT	Hardware Engineer and/or Software Engineer			
Sequence of Operation Tests Complete	Hardware Engineer and/or Software Engineer			
Balance Report Complete	Hardware Engineer and/or Software Engineer			
All project P&ID Loops are tuned	Hardware Engineer and/or Software Engineer			
72 Hour Trends Complete **	Hardware Engineer and/or Software Engineer			
Project Fully Commissioned by Schneider Electric	Hardware Engineer and/or Software Engineer			
Sequence As-Built (red line)	Hardware Engineer and/or Software Engineer			
As-Built (red line) into PM	Hardware Engineer			
As-built PDF posted to MIT Server	Hardware Engineer			
As-Built delivered to MIT	Project PE/SWE			
Drawings in Panel	Hardware Engineer			

Panel Labeled	Hardware Engineer			
Ready for Walkthrough	Hardware Engineer and/or Software Engineer			
Pre-Walkthrough				
Walkthrough Complete	Project Manager			
Final Punch List Sign Off	Project Manager			

** Provide PDF of (72) hours of trends for each system.

*** See next page and attached documents (if any) for alarms that will not reset because of mechanical / electrical design flaws or any other issues that would cause alarms not to reset.

MIT Project Completion/Closeout for BMS (Part A Completion Checklist)

Meeting Date: ____________________
Project Name: ____________________
Project Manager: ___________________

Checklist shall be turned in by BMS contractor Project Manager to MIT **BMS** at completion.

Item:	**Date:**	**Signed off by:**	**Notes:**
Installation verification complete			
Start-up testing complete			
Operational verification complete			
Mechanical/Electrical Deficiency list forwarded to MIT			
Sequence of Operation Tests Complete			
Graphics Complete • **All links completed and tested** • **All floor plans completed** • **All title blocks filled in**			
Alarming properly setup according to MIT / vendor standard and enabled			
Project free from unexplained or nuisance alarms ***			
Trending properly setup according to MIT / vendor standard and enabled			
P&ID As-Builts ready and attached to system			
Sequence As-Builts ready and attached to system			

*** See next page and attached documents (if any) for alarms that will not reset because of mechanical / electrical design flaws or any other issues that would cause alarms not to reset

MIT Project Outstanding Punchlist for BMS

Project Name: ______________________
Project Manager: ______________________
Date: ______________________

Action Items			
Item	**Person Responsible**	**Completion Date**	**Action**

END OF DOCUMENT