Building Management Systems

(BMS)

DESIGN GUIDELINES

at the
University of British Columbia

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FOR THE

BMS GUIDELINES **(INDEX ADDED 2009)**

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1. OVERVIEW

1.1 General

A. The University of British Columbia is a large campus with numerous buildings of various ages. A significant number of these buildings are of a vintage that predates modern microprocessor based HVAC control systems and these older building control systems are continuously being upgraded. New buildings are also being constructed at the UBC Campus on an on-going basis. To assist in the operation and maintenance of campus buildings, UBC Plant Operations provide centralized monitoring and control of UBC buildings from a central location via microprocessor based DDC controls. To facilitate the centralized BMS monitoring and control standards have been applied to the selection of BMS equipment and for the application of BMS installations in buildings. The UBC BMS Design Guidelines serve to identify typical standards for the application of BMS's in UBC buildings. These Design Guidelines have also been developed to assist UBC in ensuring that UBC buildings are provided with high quality BMS installations that fully meet their requirements.

1.2 Application of these BMS Design Guidelines

A. This document is intended to serve as a guideline for the Design of Building Management System (BMS) installations in buildings at the University of British Columbia (UBC). The guideline serves to generally identify the existing UBC Campus BMS infrastructure and installed components and to record BMS design requirements specific to UBC installations. The UBC Design Guidelines may be used by BMS Designers for guidance in the design of UBC BMS installations but shall not be reproduced, in whole, or part, for inclusion in BMS Design Specifications, or Tender or Contract Documents. The UBC BMS Design Guidelines are not Design Specifications and do not include sufficient detail to be used as such. BMS Designers will be required to include additional detailed information in BMS Design Specifications to clearly identify all aspects of the BMS installation.

B. BMS Designs shall be based on sound industry standard practices. BMS Designers shall provide BMS Designs that have been specifically engineered for the application and shall exercise discretion in the application of these guidelines. All new building construction at UBC will utilize DDC BMS monitoring and control of building equipment and systems to some degree. Existing buildings are also being upgraded with retrofits to mechanical and electrical systems as well as to the building control and monitoring facilities. BMS Design Documents shall clearly identify the nature of the BMS installation work and shall include the contractual documentation and requirements where applicable.

C. All new BMS installations shall comprise equipment, data and data communications that are fully compliant with ANSI/ASHRAE Standard 135-2001 "BACnet".

1.3 List of Abbreviations

A. The following are a list of abbreviations used throughout these design guidelines and are also abbreviations used by the University of British Columbia relating to Building Management Systems.

ACC -	UBC Auxiliary Control and Alarm Centre
ANSI -	American National Standards Institute
ASC -	Application Specific Controller
ASHRAE -	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM -	American Society for Testing Materials
AWG -	American Wire Gauge
BMS -	Building Management and Control System
BACnet -	Building Automation and Controls Network - ANSI/ASHRAE Standard 135-2001
CBMS -	Campus Building Management System

CCF - BMS Central Computer Facility
CCP - Communications Control Panel
CPU - Central Processing Unit
DCP - Distributed Control Panel
DDC - Direct Digital Control
FAS - Fire Detection, Alarm and Communication System
FTS - Field Termination Schedule
H/O/A - Hand/Off/Auto Motor Control Switch/Circuit
HVAC - Heating, Ventilating and Air Conditioning
IEEE - Institute of Electrical and Electronics Engineers
I/O - Input/Output
JCI - Johnson Controls, Inc.
LAN - Local Area Network
LCD - Liquid Crystal Display
LED - Light Emitting Diode
LON - Local Operating Network
LonTalk - The open control networking protocol developed by Echelon Corporation
LONWORKS – Echelon's family of hardware and software products
MACC- BMS Master Alarm and Control Centre
NDS - Network Data Server
NEC - National Electrical Code
NEMA - National Electrical Manufacturers Association
OIW - Operator Interface Workstation
PC - Personal Computer
POT - Portable Operator Workstation
PIM - Process Interface Module
RAM - Random Access Memory
RFI - Radio Frequency Interference
RH - Relative Humidity
ROW - Remote Operator Workstation
RTD - Resistance Temperature Device
SCU - System 600 Standalone Control Unit DCP
SVGA - Super Video Graphics Adapter
UBC - University of British Columbia
cUL - Underwriters Laboratory Canada
UPS - Uninterruptible Power Supply Unit
VDU - Video Display Unit

1.4 Existing BMS Facilities

A. There are two separate and autonomous BMS's installed and operating on the UBC Campus, both with individual central alarm monitoring and control facilities, interconnecting network communications facilities and BMS monitoring and control facilities installed within campus buildings. BMS installations within individual buildings are configured as stand-alone BMS installations capable of real-time monitoring and control. Each of the stand-alone building BMS installations communicates with central computer equipment at the MACC and AAC in the University Services Building. The existing BMS facilities are as manufactured by Johnson Controls, Inc. (JCI) and as manufactured by Siemens Building Technologies, Ltd. (SBT). The two different BMS's utilize separate communication network facilities.

B. There are two locations with OIW's for central BMS monitoring and control. The control centres are as follows:

1. MACC located in room number 1003 on the second floor of the UBC Plant Operations Building.
2. ACC located in room number 003 on the ground floor of the UBC Plant Operations Building.

C. The following is a list of existing Johnson Controls, Inc. BMS facilities and equipment at UBC:

1. Metasys Operator Workstation (OWS) software (Rev. level 12.3) running on a Microsoft Windows 2000 Professional Operating System PC complete with VDU and archiving facilities in the MACC.
2. Metasys Operator Workstation (OWS) software (Rev. level 12.3) running on a Microsoft Windows 2000 Professional Operating System PC complete with VDU in the ACC.
3. Metasys Application Data Server (ADX) computer running Metasys ADX software with Microsoft Windows 2000 Server and Microsoft SQL Server 2000. The server computer is a desktop PC computer. The ADX is the web server for the Metasys extended architecture.
4. Metasys DCP's and ASC's installed in distributed standalone building BMS installations.
5. Metasys OWS software installed on a laptop computer and configured as a portable operator workstation. The portable operator workstation (POT) also has the JCI Metasys software (HVACPro) installed for Operator interface to ASC's.

D. The following is a list of existing Siemens Building Technologies, Ltd. BMS facilities and equipment at UBC:

1. Server PC running Microsoft Windows Server 2003 Operating System and System 600 Insight Apogee 3.5 complete with VDU and archiving facilities in the MACC.
2. Seven (7) Apogee Operator Workstations with Client Software running on a Microsoft Windows 2000 or XP Pro Operating System.
3. Two (2) Apogee Operator Workstations with Client Software running on a Microsoft Windows 2000 Professional Operating System.
4. Network interconnection and signal conditioning facilities for central network communication with four separate physical network segments.
5. SBT System 600 DCP's and ASC's installed in distributed standalone building BMS installations.
6. Two (2) Laptop computers with terminal emulation software and application software for Operator direct connect interface to System 600 DCP's and ASC's.

1.6 Existing BMS Communication Network Facilities at UBC

A. The JCI Metasys BMS and the SBT System 600 BMS at UBC utilize separate network communication facilities. Existing BMS Network Communications facilities are generally as follows:

1. JCI Metasys BMS Data Communication within Building
   a. Automation Level communication LAN (N1 Bus) for data communication between CCP's/DCP's (and local OWS's where applicable) within building installations utilizes either ArcNet or Ethernet communications. The BMS Automation Level communication networks within buildings are dedicated BMS network segments and are not shared with other building data communications.
   b. Proprietary, dedicated Field Level communications network (N2 Bus) for communication between ASC's and between ASC's and DCP's.
2. JCI Metasys Campus BMS Data Communications
   a. Management Level communication LAN (N1 Bus) utilizes UBC campus enterprise Ethernet Network for communication between remote building BMS installations and the central monitoring and control equipment. The dedicated standalone BMS network is interconnected to the UBC Campus Enterprise Network at a location within the building.
3. SBT System 600 BMS Data Communications within Building
   a. Automation Level communication LAN (labelled the "Building Network" or P2 Bus) for data communication between DCP's (and local OWS's where applicable) within building installations utilizes a proprietary dedicated

communications network. The BMS primary communication networks within buildings are dedicated BMS network segments and are not shared with other building data communications.

b. Proprietary, dedicated Field Level communications network (labelled the "Floor Network") for communication between ASC's and between ASC's and DCP's.

4. SBT System 600 BMS Campus Data Communications

a. Management Level communications LAN (Building Network/P2 Bus) for data communications between campus buildings is via a proprietary communications network. The Management Level communications network utilizes copper telephone grade cable between the remote buildings and the UBC telephone central exchange in the Henry Angus Building. Signal conditioning and network interface equipment is required to transmit the data communications via the telephone grade lines. There are four System 600 primary communication network segments at the UBC campus. All of the network segments are connected to the System 600 Apogee Server. Individual building BMS's are interconnected to one of the network segments based on a number of criteria including the building geographical location.

b. There are a number of newer System 600 building installations that utilize TCP/IP Ethernet data communications over the UBC campus enterprise Ethernet Network for communication between the remote building BMS installations and the central monitoring and control equipment. The dedicated standalone BMS network is interconnected to the UBC Campus Enterprise Network at a location within the building.

2. BMS INSTALLATION GUIDELINES

2.1 General BMS Installation Requirements

A. This section of the UBC Design Guidelines identifies minimum requirements for BMS field installations. BMS designs shall include these requirements and BMS designers shall ensure that design specifications include these requirements.

B. BMS installations shall be based on sound industry standard practices that are in compliance with all applicable codes, statutes and ordinances.

C. Design Specifications for BMS Installations shall provide detailed specifications for the all components of the BMS including equipment, field devices, wire/cable, conduit, pneumatic tubing, mounts, terminations, etc.

D. The BMS Designer shall fully coordinate BMS design requirements with the other project design team parties (where applicable). The BMS Designer shall coordinate field panel mounting locations, intended DCP/ASC locations, power supply requirements, communications outlet requirements, etc.

E. The following are general installation guidelines for BMS installations:

1. All equipment and materials furnished shall be new.

2. All equipment and materials shall be cUL and/or UL listed and/or CSA approved where applicable. Equipment and components shall be labelled accordingly.

3. Wherever possible all similar components (e.g. temperature sensors, differential pressure transducers, current transformer/relay combinations, signal transmitters, etc.) in a BMS installation shall be by the same manufacturer.

4. Components shall be provided which are suitable for the intended application. Components shall be capable of maintained operation in the applicable environmental conditions and operation in contact with the controlled/monitored medium.

5. With the exception of field mounted instrumentation and devices, all BMS components shall be installed in field panels. Panels and enclosures shall meet, at minimum, the following requirements:

   a. Painted steel panels with hinged locking door. All panels shall be keyed to the UBC standard key.
   b. Ventilated to prevent excessive heat build-up, where required.
   c. Field cabling shall be terminated on terminal stripes. Cable within enclosures shall be installed in cable trays with snap on covers.
   d. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal or replacement.
   e. Panel or enclosure shall be suitable rated for the environment for which it is to be installed. Exterior enclosures shall be, at minimum, NEMA-4 rated.

6. Panels and enclosures shall only be located within mechanical rooms or at approved locations. Panel locations shall be coordinated during design by the BMS Consultant and shall be identified on project design drawings. For new construction projects the BMCS panel locations shall be identified in the project mechanical design drawings. For retrofit applications the BMCS panel locations shall be identified on building floor plan drawings to be included in the project BMS Specifications/Contract Documents.

7. All components of the BMS shall be Identification tagged. Identification tags shall be plastic lamacoid labels or plastic laminated “luggage style” tags securely fastened to

the end device. Tags shall be of a minimum size of 80 x 25 mm engraved with 12 mm bold lettering. Identification tags shall be provided for, at minimum, the following;

a. Sensors.
b. Transmitters.
c. BMS controlled valve and damper actuators.
d. End-Devices.
e. Distributed Control Panels (DCP)'s.
f. Application Specific Controllers (ASC)'s.
g. Field panels.

8. Warning notices shall be provided at all equipment controlled by the BMS and at all associated motor starters. The warning notices shall state that the equipment is under the control of the BMS and may start or stop at any time without warning. Provide warning notices at minimum at all MCC's, at local disconnect switches, at AHU plenum doors, and electrical motors. UBC Plant Operations shall furnish the warning notices to the BMS Contractor for use on each project. BMS Contractors shall be instructed to obtain the warning labels from UBC and to return unused labels at the end of the project.

9. Provide warning notices on all DCP control panel doors indicating that hand held radio transmitters are not to be keyed within 3 meters or the DCP.

10. All BMS wire and cable and pneumatic control tubing shall be identification tagged. Wire/cable shall be identification tagged at every termination location. Wire/cable and tubing terminating at DCP's and ASC's shall be tagged with the DCP/ASC controller termination number. Wire/cable and tubing terminating at field devices shall be tagged with both the DCP/ASC number and the DCP/ASC termination number. At any splices or terminal strips between the field device and DCP/ASC, the wiring shall be tagged on both sides of the termination point the same as for a field device termination.

11. 120 VAC power supply sources shall be provided to all BMS field panel and DCP mounting locations. The selection of normal power supply or emergency power supply facilities shall be based on project and application specific requirements. In general, however, BMS DCP's/ASC's (and associated network interface equipment) monitoring designated building critical alarm points shall be provided with emergency power supplies. The DCP/ASC at which the critical building alarms are terminated shall be designated at the "tie-in" panel for the building. Where no emergency power is available in the building, the tie-in panel shall be provided with uninterruptible power supply equipment. The BMS tie-in panel is required to remain operational in the event of loss of normal power supply to the building. The tie-in panel shall continue to operate in the event of a power supply failure for thirty minutes and shall provide alarm annunciation, monitoring, and control of connected systems/devices from the MACC and ACC. The electrical power supply circuit shall be clearly labelled at the electrical distribution panel and at the BMS field panel location. As built documentation shall detail power supply circuit source panels and termination locations.

12. All installations shall be provided to readily allow access for maintenance.

13. All BMS data point value engineering units shall be the International System of Units (SI).

F. Facilities shall be provided for the mounting of UBC Plant Operation Telephone and Data Communications facilities. The BMS Contractor shall provide the following "blue board" mounting facilities at all BMS field panel and DCP mounting locations:

1. A 560 mm W x 600 mm H x 18 mm T fir plywood intercom mounting board. The bottom edge shall be 1200 mm from the floor. Each board is to be primed and painted

with two coats of navy blue enamel. The “blue board” is intended for the installation of UBC Plant Operation Telephones and communication interfaces.

2. A shelf 350 mm deep running the length of each plywood mounting board. The shelf shall be mounted at a 30 Degree angle from the horizontal approximately 1000 mm AFF. The shelf shall include a 25 mm high lip along the bottom end. The shelf shall be painted to match the mounting board. The shelf shall be hinged and provided with support straps which can be removed from the shelf to allow the shelf to fold down when not in use. The shelf shall be capable of supporting a laptop computer and BMS record documentation for BMS Operator interface work.

3. BMS Data and Telephone Interface facilities including conduit and back boxes shall be installed immediately adjacent to the “blue board” mounting facilities.

G. The BMCS specifications shall identify requirements for all work to be provided by the BMS Contractor including all boring, saw cutting, fire stopping, sleeves, equipment mounting and supporting, etc.

2.2. BMS Electrical Installation Requirements

A. The following are minimum requirements related to BMS electrical installations:

1. All installations shall be in accordance with the National Electric Code, the British Columbia (BC) electrical code, and all governing codes, statutes and ordinances.

2. With the specific exception identified within this document, all BMS wire and cable shall be installed in conduit.

3. In new construction projects exposed conduit installations are not permitted in normally occupied building spaces. In retro-fit applications exposed conduit shall only be allowed in specific applications as approved by the BMS Consultant and UBC.

4. Wire/cable for space temperature sensors, VAV terminal unit damper actuator, zone coil control valve actuator, VAV terminal unit ASC automation LAN and (where applicable) 24VAC power supply distribution wiring may be installed in ceiling spaces without conduit where code permits. Wire/cable installed in ceiling spaces without conduit shall be suitably rated and labelled. Wire/cable shall be securely supported and installed in a neat and workmanlike manner following building lines. Sleeves shall be provided for all wire/cable that penetrates wall partitions, concrete slabs, or rated partitions.

5. BMS low voltage monitoring and control wiring shall meet the following minimum requirements;

a. Minimum #20 AWG stranded copper conductors (larger gauge wire/cable shall be provided where required by BMS equipment and where applications warrant e.g. long runs, etc.).
b. Twisted pair conductors.
c. All BMS input/output point wire/cable and communication cable shall be shielded. Non-shielded cables may be approved for BMS input and output field point wiring following certification from the BMS manufacturer that non-shielded cables will function satisfactorily for the life of the building and that the use of non-shielded cables will not negatively affect other building systems/cabling. The manufacturers certification shall guarantee to UBC that should it be determined that BMS system performance is negatively affected or another building system or equipment is negatively affected due to the non-shielded cable, the BMS manufacturer shall replace the cable at no cost to UBC. Certification to be obtained for each building application of non-shielded cable prior to approval. All data communication cabling shall be shielded.

d. BMS wire/cable shall not share conduit with other building wiring. Low voltage cable shall not be installed in conduit with line voltage or higher voltage carrying cable. BMS data communication and network cable shall be installed in dedicated conduit and shall not share conduit with any other wire/cable.

6. All wire/cable terminations shall be made at screw type terminal stripes. Wire nut terminations and butt splices shall not be acceptable. Wiring runs shall be continuous runs without splices.

7. All BMS equipment and components shall be grounded to building ground facilities.

8. Coordinate installation of conduit with building structure and other trades. Conduit installation above accessible ceilings shall be such that there will be no interference with the installation of lighting fixtures, fire protection, air outlets or other devices. Color code all conduit and fittings with a unique color at every junction box and at least every 3,000 mm (10 feet) along the conduit.

B. All BMS wiring, conduit, junction boxes, pull boxes, cable tray, etc. shall be provided by the BMS Subcontractor as required for a complete installation. The BMS Contractor shall provide all required access panels, coring, saw cutting, fire stopping, mounting, etc.

C. The BMS Contractor shall coordinate installation of conduit with building structure and other trades. Conduit installation above accessible ceilings shall be such that there will be no interference with the installation of lighting fixtures, fire protection, air outlets or other devices. Color code all conduit and fittings with a unique color at every junction box and at least every 3,000 mm (10 feet) along the conduit. BMS conduit shall be identified by a blue colour code.

D. BMS shall only be capable of controlling electric motors when the associated hand/off/auto (HOA) motor control switches are in the "auto" position. BMS control shall be wired into the auto circuit of the hand/off/auto motor control circuit only. Where hand/off/auto switches do not exist they shall be provided by the BMS Controls Contractor.

E. Life safety and equipment protection interlocks shall be wired to override equipment whenever it is in operation.

F. Existing interlocks and override control facilities should typically not be removed or overridden by the application of new BMS control facilities without the specific instruction of the BMS Design Consultant and the approval of UBC Plant Operations.

G. Current transformer and relay combination devices shall generally be used for BMS status monitoring of electric motors. There may be applications where other devices are more suitable. This shall be evaluated by the BMS Design Consultant for the application. BMS status monitoring of fractional horsepower motors less than 1/8 h.p. shall be provided by auxiliary contacts at the motor control circuit. The BMS Contractor shall be instructed to utilize spare auxiliary contacts if they exist or to provide new where required.

2.3. BMS Communication Provisions

A. The following minimum requirements shall be provided for UBC telephone system and data communication interfaces:

1. Four telephone communication outlets at the designated BMS “tie-in” panel location. Two of these communication outlets may be used by the BMS Contractor for connection to the UBC Campus BMS network. The remaining two communication outlets will be utilized by UBC Plant Operations for telephone communications and future data communications.

2. Two telephone communication outlets at all other BMS DCP locations. These communications outlets will be utilized by UBC Plant Operations for telephone communications and future data communications.

3. The BMS telephone and data communication facilities shall be provided complete with suitable back boxes, cover plates and connection jacks, etc. mounted immediately adjacent to the BMS "blue board".

4. In a UBC new construction project the BMS Designer shall coordinate with the appropriate design team consultants for the provision of the required communication facilities to be provided by others. In a retrofit application the BMS Controls Contractor shall provide empty conduit and back boxes complete with pull tapes for the future installation of wire and terminations by others.

2.4. BMS Pneumatic Control Installation Requirements

A. The following are minimum requirements related to BMS pneumatic controls installations:

1. All installations shall be in accordance with applicable codes, statutes and ordinances. All pneumatic controls air tubing shall be specified to comply with minimum operating temperatures and pressures.

2. Pneumatic control air tubing installed concealed within walls and concrete slabs shall be installed in suitable conduit. Pneumatic mains and signal control air lines run in pipe chases, hallway ceiling spaces, etc. shall be installed in conduit or dedicated cable type tray with cover. Pneumatic control air lines installed within mechanical rooms may be copper tubing and/or Polyethylene type tubing installed within conduit. Exposed polyethylene tubing will not be permitted within mechanical rooms. All Polyethylene tubing shall be rated for the installation application and shall be suitably labelled.

3. In new construction projects exposed conduit installations are not permitted in normally occupied building spaces. In retro-fit applications exposed conduit shall only be allowed in specific applications as approved by the BMS Consultant and UBC.

4. Pneumatic control air tubing may be installed in ceiling spaces without conduit where code permits. Tubing installed in ceiling spaces without conduit shall be suitably rated and labelled. Tubing shall be securely supported and installed in a neat and workmanlike manner following building lines. Sleeves shall be provided for all tubing which penetrates wall partitions, concrete slabs, or rated partitions.

5. In retrofit applications three-way switch over valves shall be provided on existing pneumatic control air lines to controlled devices for switching between new BMS control and existing pneumatic control facilities. Existing pneumatic control facilities shall remain installed and operational until the work of the BMS is complete and demonstrated to the Owner. The BMS Designer shall specify the requirement for the removal of redundant pneumatic controls components.

6. BMS pneumatic control air facilities shall meet the following minimum requirements:

a. Tubing shall be installed suitably supported using standard fittings and connections and shall run parallel to building lines.
b. Tubing shall be installed protected from ambient and outdoor temperature effects. Where required tubing shall be installed with stand-offs, insulation, etc.
c. Multiple tubing runs shall be installed run parallel shall be suitably supported and tie-wrapped in tube bundles.
d. Pneumatic control air tubing shall be terminated with standard fittings at panel mounted devices or at pneumatic bulkhead fittings within panels. Field device connections may be run in steel protective spring or BX conduit.

e. Rubber grommets shall be provided wherever control tubing passes through ducts or plenum walls.
f. A pressure gauge shall be provided at each tapping off the main air line. If a pressure reducing valve is required then the gauge shall be positioned after the valve.
g. BMS pneumatic control output lines to each controlled device shall be provided with two minimum 40 mm diameter pressure gauges. The gauges shall be mounted at the DCP/ASC control output location and at the input to the control actuator.

7. Pilot positioners shall be provided for all BMS controlled pneumatic actuators that are controlled in sequence (e.g. mixed air dampers, 1/3 - 2/3 steam valves, etc.).

8. In line desiccant filters shall be provided on all main pneumatic control air lines supplying DCP's and ASC's with BMS pneumatic control outputs. The in line desiccant filters shall be provided in addition to the building mains pneumatic control air dryer/filter facilities.

9. Refrigerated type air dryers shall be provided on all building pneumatic control supply air mains. In a BMS retrofit application the existing building pneumatic control air facilities shall be inspected during design phase to ensure that air dryer and filter equipment are installed and operational. If the building is not equipped with satisfactory pneumatic control air filtration and dryer equipment this equipment shall be installed as part of the BMS installation project. The following are minimum pneumatic controls air dryer and filtration equipment requirements:

a. Two refrigerant type air dryers shall be provided in a duty/standby configuration.
b. Installed in discharge air line from controls air compressor set and storage tank.
c. Complete with air inlet and outlet pressure gauges and automatic moisture removal trap.
d. Complete with three-way valve manifold and piped in a duty/standby configuration to allow the operation of one dryer at a time with the second (standby) dryer valve off and switched off.
e. Installation shall be complete with dual air filtration to remove moisture, oil, and particulate matter from the controls air supply.
f. BMS monitored low pressure alarm indication device. Low pressure alarm condition shall be annunciated at the BMS NDS and CBMS.

2.5 BMS Installation Training Requirements

A. The BMS Specifications shall specify requirements for CBMS/BMS training to be provided as part of the work of all CBMS/BMS projects. CBMS/BMS Contractor shall submit an outline of the training courses to be given. The training outline shall be submitted with the initial shop drawing and submittals packages.

B. Training sessions shall include classroom type instruction and "hands on" instruction and shall be given by the BMS Subcontractor on site using the completed installations. Arrange for additional meeting room space with the Owner.

C. Provide training tailored to the various Owner operations personnel requirements. Duration and number of training sessions to be determined by the BMS Consultant and shall be specified to accommodate the installation requirements. Provide training in phases tailored to the following groups:

1. Basic monitoring and control operations.
2. Advanced monitoring and control operations.
3. Field maintenance and troubleshooting.

D. The BMS Contractor shall provide initial basic monitoring and control training to the Owners personnel to provide them with sufficient knowledge of the BMS installations such that they can use the BMS for the day-by-day monitoring and control of the BMS.

E. The BMS Contractor shall provide advanced supervisor level training on the details of BMS. Provide training related to advanced functions, programming, safety features, integration, database development, network facilities, etc.

F. The advanced BMS training shall, at minimum, cover the following topics:

1. BMS hardware details.
2. System software and applications programs.
3. CCP and DCP controller software development and installation.
4. Graphics and applications program development.
5. Calibration and functional testing of the BMS.
6. Trouble shooting and replacement of faulty components at CCP, DCP and UC's.

G. Provide field maintenance and trouble shooting training for the Owner's Maintenance staff on the operation, calibration, troubleshooting, maintenance and repair of BMS field devices including, but not limited to, all instrumentation, valves and valve actuators, dampers and damper actuators, thermostats, etc.

I. Training sessions shall be designed on the basis of experience and knowledge of the attendees scheduled to participate and shall differentiate between the requirements of supervisory, operations and maintenance personnel. The training shall be specific to the project and shall cover, at minimum, the following:

1. Data base features.
2. Operating sequence programming.
3. Operator interface features.
4. Details related to the BACnet device and data object point mapping, identification naming/numbering, alarm point definitions, etc.
5. Other subjects necessary to ensure that the operators, maintenance and supervisory staffs will be able to operate the BMS without any on-going assistance from any outside party.

J. The CBMS Contractor shall provide Owner Training on the CBMS monitoring and control facilities provided for each project. CBMS training shall be project specific and shall at minimum include the following:

1. Details related to the network interconnection and data communications with the remote BMS.
2. Details related to the point mapping, database development, programming, BACnet BMS device and object identification, point naming, integration, etc.
3. VDU graphics set up and modification.
4. Alarm monitoring, display, annunciation and modification facilities.

K. The BMS Subcontractor may provide computer based, self directed training accomplish the portions of the UBC training requirements. Provide on site training for details specific to the particular BMS installation project (i.e. device locations, sequences of operation, safety devices, life safety system interlocks, maintenance procedures, etc.). Provide site training for any new products, equipment, devices, and software.

2.6 BMS Documentation Requirements

A. The BMS Specifications shall specify requirements for CBMS and BMS documentation to be provided as part of the work of all CBMS/BMS projects.

B. The following information shall be included on the cover page for each shop drawing and

equipment documentation submittal:

1. Project name.
2. Date.
3. Submittal number and resubmittal number as appropriate.
4. Name and address of Architect/Consultant.
5. Name and address of Owner.
6. Name and address of BMS Subcontractor.
7. Name and address of supplier or vendor if appropriate.
8. Name of manufacturer.

C. Shop drawings shall be CAD generated, minimum plot size of 11 x 17 inches. Drawings shall include diagrams, mounting instructions, installation procedures, equipment details and software descriptions for all aspects of the system to be installed. At minimum, the shop drawings shall include:

1. BMS topology/network architecture schematic(s).
2. Installation drawings and schedules.
3. CCP, DCP, UC and other panel layouts, including floor plan location and interconnection drawings.
4. Field instrumentation locations on floor plan drawings.
5. Schematic of systems indicating instrumentation locations.
6. Installation details.
7. Schedule of cabling including details of proposed cable types.
8. Composite drawings of all motor starter terminal strips and damper terminal strips indicating all wiring by all contractors on the motor terminal strip.

D. Equipment submittals shall include design, performance and installation details for all aspects of the system to be installed. Equipment submittals shall be in hardcover binders with a table of contents and indexing tabs. At minimum, the equipment documentation submittals shall include:

1. Equipment technical data sheets with mounting and installation details.
2. The documentation shall include comprehensive and complete details of the Automation Level data communications, data objects, and devices including address, associated controller type, etc. as required and for the interface to the CBMS. Provide Protocol Implementation Statements (PICS) for all devices.
3. Details of networks/communications equipment, cabling and protocols proposed.
4. Software specifications and descriptions including operating sequences.
5. Field sensor and instrumentation specification sheets.
6. Damper and actuator specification sheets.
7. Valves and valve actuator specification sheets.

E. Provide record documentation in manuals as indicated below:

1. Specifications, maintenance requirements and installation requirements for all hardware components.
2. Record drawings and schedules of the completed installation including location of devices, mounting details, and cabling details.
3. Field Instrumentation and End Device Hardware Manuals
4. Software Documentation Manuals.
5. Maintenance Manuals.
6. Control Drawings.
7. Other supporting documentation.

F. Manuals shall be placed in hardcover binders with index page and indexing tabs. Binders are to be as manufactured by ACCO Canadian Company Limited, or approved equal, as follows:

1. 1 and 2 inch binders shall be According "Customizer" Binder 11 x 8 1/2 inch Beige,

types 13401 and 13403 respectively.

G. Provide Operators' and Supervisors' Manuals with, at minimum, the following information:

1. Details of all features and functions available to the Operators.
2. Details of all alarm, diagnostic, error and other messages. Detail the Operator action to be taken for each instance.
3. Detail special programs provided and provide a complete programming instruction manual. Detail operation of all software applications.
4. Detailed listing of the database for all installed devices.
5. Details of all data base management functions and features.
6. All details and descriptions shall be in a step-by-step format such that an Operator/ Manager would be able to undertake the respective actions solely on the basis of information provided in the manuals and drawings.

H. Provide hardware manuals that shall include, at minimum, the following:

1. Specifications, maintenance requirements and installation requirements for all hardware components.
2. Record drawings and schedules of the completed installation including location of devices, mounting details, and cabling details.
3. Operating sequences and interlocks.
4. Names and addresses of spare parts suppliers.

I. Provide field instrumentation and end device manuals that shall include, at minimum, the following:

1. Control Drawings
   a. Description of the point identification tag format used.
   b. All applicable point termination diagrams i.e. typical wiring and termination of all field devices, controllers and networks.
   c. Riser Diagram with equipment listed on opposing page - see specimen in Appendix 1.
   d. Network architecture diagram.
   e. System drawing for each mechanical and electrical system with equipment list and sequences of operation on opposing page for easy reference.
2. Control drawings shall be record drawings for the completed installation including the following:
   a. Location reference to mechanical drawing number and adjacent grid line number for instrumentation.
   b. Location of conduit, tubing and wiring.
   c. Details of process interface unit termination.
   d. Details of BMS controlled valves, dampers and actuators including normal position (open or closed), operating spring/voltage/current ranges and use of pilot positioners.
3. Sequences of operation and interlocks shall be provided on the "as-built" drawings such that a single drawing will enable easy cross-reference to the sequences and associated field equipment, instrumentation and interlocks.

J. Provide Software documentation manuals that shall include, at minimum, the following:

1. System programming supervisor manuals.
2. Complete programming instruction and reference details.
3. Application software program information.
4. Sequences of operation program flowcharts provided in plastic sleeves within the manual.
5. Control Sequence
   a. Full description to support all BMS monitored and controlled systems and controllers. Provide in plastic sleeves within the manuals. Printout of control

language statements, complete with detailed comment lines to enable the Owner to undertake changes to sequences without vendor support. Comment lines shall be provided at the beginning of each program to identify the use and function of all variables.

6. Point Reports
   a. Log of all point identification names and descriptors.
7. Printout of the BMS point database for all installed and calculated points.
8. Other relevant software information.

K. Provide maintenance manuals that shall include, at minimum, the following topics:

1. Maintenance, calibration and installation details for all instrumentation, valves, dampers and actuators furnished under this Subcontract.
2. Maintenance instructions for all BMS hardware equipment including but not limited to CCP, DCP, UC, distributed DDC controllers, modems, printers, ROW, etc.

L. Provide one sharp, clean photocopy of each new or revised drawing, schedule or prepared instruction sheet to the Owner for microfilming. Maximum size for any sheet is 11 x 17 inches. Drawings shall be on 11" x 17" sheets. The title block of each drawing shall have provision for a UBC project number and UBC drawing number.

M. Documentation shall be neatly typed or printed on 8 1/2 x 11 inch heavy bond or offset book paper. Page quality must be such as to ensure good microfilm reproduction.

N. Provide a copy of each as-built system drawing in 8½" x 11" drawing format and laminated in plastic. A set of laminated "as-built" drawings shall be provided at each CCP and DCP controller location. Laminated as-builts for VAV terminal unit controllers shall be provided at the CCP they are connected to. Each set of laminated "as-built" drawings shall be held together by a metal ring through a grommet hole in the top left hand corner of each drawing. The ring shall be attached to approximately 3 metres of light duty chain, which shall in turn be securely fastened to the intercom mounting board at the same location as the associated CCP. A hook shall be provided in the intercom mounting board on which to hang the drawings by the metal ring.

O. Manuals shall be provided in hard covered loose leaf binders with index pages and indexing tabs. Binders are to be as manufactured by ACCO Canadian Company Limited, or approved equal, as follows:

1. 1 and 2 inch binders shall be According "Customizer" Binder 11 x 8 1/2 inch Beige, types 13401 and 13403 respectively.

P. Manuals shall be updated whenever the Subcontractor makes changes to the Work.

Q. Comply with and additional project requirements for documentation.

R. Record drawings shall be CAD generated and shall include, at minimum, the following:

1. Details required by the shop drawings.
2. Final locations and point ID for each monitored and controlled device.

S. Provide one (1) complete set of all record documentation in printed hardcopy and one (1) complete set of all record documentation in .pdf electronic computer data file format.

T. All BMS and CBMS Record Documentation shall be provided in electronic .pdf file format on a CD or DVD.

2.7 BMS Installation Commissioning and Testing

A. BMS specifications shall clearly specify the requirements for Contractor testing and

commissioning of the BMS including test documentation and requirements for testing and demonstration with other project commissioning personnel and the BMS design consultant.

B. The BMS Subcontractor shall conduct full end-to-end testing and commissioning of the BMS installations and the overall monitoring and control of the building systems. , BMS Contractor testing shall include the monitoring and supervisory control and data communications with the associated campus NDS.

C. The BMS Subcontractor shall undertake joint testing of the BMS integration with the CBMS with the CBMS Integration Contractor. The BMS Specifications shall specify requirements for the joint BMS/CBMS Contractor Testing and Commissioning.

D. The BMS Contractor shall perform a complete and detailed operational check of each BMS component. Tests shall be documented on Contractor Commission Record Sheets. The Owner, Consultant and Engineer shall undertake such random testing as the Owner, Consultant and Engineer considers necessary to verify the acceptability of the components.

E. Point to point checks shall be proven from the field device/interface operation to the controller/outstation and from the controller to the presentation of the point on the graphics. The results from the point-to-point tests shall be submitted for approval.

F. Point to point checks shall verify (at minimum) the following:

1. Correct location of the field device for the application.
2. Correct installation of the control device/interface with reference to the manufacturer's literature and check that sufficient access has been provided for maintenance.
3. That the control device has the correct range for the application, that the range is correctly entered in the controller and is correctly engineered on the operator's terminal.
4. Correct operation of the controls device/interface, including any associated alarm and alarm text.
5. Correct installation of each valve and damper actuator, and ensure that each valve and damper actuator is stroked correctly when checked against the BMS output.
6. Calibration of the control device.
7. Labels provided on the control devices and mechanical equipment is correct.

G. Systems testing shall commence once all component testing has been successfully undertaken and approved by the Consultant.

H. System testing shall be undertaken by the BMS Subcontractor and the BMS Subcontractor shall complete and submit the BMS Contractor Commission Record Sheets. The following shall be demonstrated as a minimum:

1. Each and every point on the system including calibration checks and the stroking of actuators.
2. All dynamic graphics comply with the mechanical and control specifications.
3. All system programs comply with the specification under the normal modes of operation, emergency power, building fire detected and fireman's override operating modes.
4. All system alarms comply with the specification.
5. System stability.
6. Dynamic tests to prove control stability and those environmental conditions are being maintained.

I. The Consultant's verification tests shall be performed by the BMS Subcontractor and shall be witnessed by the Consultant who shall complete the Consultant's portion of the system performance verification test sheets as each test is successfully undertaken. The BMS Subcontractor shall remedy any deficiencies that are observed during the system

performance verification tests and shall be re-tested as required to demonstrate satisfactory performance and compliance with the specifications.

J. Integrated BMS/CBMS joint systems tests shall be undertaken to demonstrate that the interaction between the individual building BMS and the CBMS meets the UBC requirements. The BMS Subcontractor shall participate in joint verification of the integrated systems and cooperate with the Owner in the demonstration of the integrated systems.

K. The BMS Specifications shall specify the requirements for the BMS/CBMS integration joint systems verification. The BMS/CBMS Integrated System Verification shall include the following minimum requirements:

1. Test all BMS monitored and controlled field devices, BMS data points and all BMS input and output points. CBMS monitored data point values shall be verified against actual field device position/state and compared to BMS values to ensure both BMS and CBMS values are the same.
2. CBMS override control of all BMS output points and control data points shall be verified.
3. BMS network and controller device status and data communications status are accurately monitored at the CMBS. Alarms for failed controllers and failed data communications are annunciated.
4. BMS data values displayed on dynamic system graphics or in tabular data format at the CBMS are functional and accurate.
5. CBMS operator control of BMS control output points and control data points are functional via the dynamic graphic interface.
6. CBMS facilities for operator adjustment of alarm definition parameters and thresholds, set point adjustment, control parameter adjustments, point trend initiation and modification to trends, etc. are fully functional.
7. The CBMS performance requirements for the monitoring and control of BMS data and field devices meet the UBC requirements.
8. BMS device addressing and identification definitions are compatible and identical and the addressing scheme meets with UBC requirements.
9. Point naming used is compatible and conformal with the UBC requirements.

L. Test results shall be documented using test sheets. The test sheets shall be prepared in an appropriate format for the various categories of component and system to be tested. It is the responsibility of the BMS Subcontractor to provide test verification sheets for each component and system that accurately reflect the sequences of operation and appropriate data for the components and systems

M. All test documentation shall be maintained in electronic format and in hard copy.

3. BMS DESIGN GUIDELINES

3.1. General BMS Design Requirements

A. BMS installations at UBC buildings shall be turnkey installations operating fully standalone.

B. All BMS shall conform to the most recent revision of the ANSI/ASHRAE Standard 135 including all issued addenda, at minimum, at the Management data communication network level as defined within these guidelines. All BMS devices shall implement the functionality detailed in the BACnet Standard "Device Profiles". With the exception of the Johnson Controls Inc. Metasys System and the Siemens Building Technologies System 600 products, the BMS shall also be BACnet compliant at the Automation data communication network level.

C. All new BMS installation designs shall identify the requirement for two (2) separate scopes of work packages. The BMS scope of work packages shall include the following:

1. Standalone Building BMS Installation.
2. BMS Integration into the Campus BACnet BMS.

D. The existing Siemens Building Technologies System 600 Apogee System will be upgraded by UBC to incorporate the Siemens "BACnet Option" server software. The Siemens System 600 Apogee with BACnet Option software, server computer and operator workstations shall be the Campus Building Management System (CBMS). The CBMS shall be compliant with the requirements defined for a BACnet Operator Workstation Device (B-OWS). The CBMS shall provide centralized operator interface for monitoring and supervisory control of the individual building BMS.

E. The UBC Campus BMS (CBMS) shall remotely monitor the individual building BMS and shall have supervisory control of building BMS facilities using BACnet over IP data communications. The CBMS Contractor shall, as part of a separate contract, provide point capture, mapping and configuration of the BMS into the CBMS. The BMS Contactor shall provide assistance and cooperation in the integration of the BMS into the CBMS. Prior to acceptance of the BMS at the individual building project, the BMS Contractor shall prove that all specified points are available to the CBMS Contractor for the integration to the CBMS and shall provide all project documentation.

F. The BMS Specifications for each building BMS project shall specify the requirement for the BMS Contractor/Manufacturer to provide all hardware and software required for the CBMS to communicate with the BMS via BACnet IP on the UBC campus WAN. Facilities to be provided shall include any manufacturer specific software tools required for programming, point mapping, configuration, etc. of building BMS data points.

G. All BMS installations shall have a network data server computer with associated BMS manufacturer application software installed and running located in the BMS MACC room in the University Services Building. The NDS shall be rack mounted in standard 19 inch rack equipment. The NDS shall be provided by the associated BMS Contractor complete with all manufacture specific BMS operator interface software for programming, database development, data archiving and storage, and controller program backup and restore facilities. NDS mounting rack shall be provided by UBC. The NDS shall be provided with functionality detailed in these documents. The dedicated NDS shall communicate with the individual building BMS's over the UBC Management Level WAN. Data communications shall be BACnet/IP. Any BMS installation provided for a UBC building shall have a NDS dedicated to BMS equipment and installations of the same manufacturer. The manufacturer specific NDS shall be installed on site and communicating with the campus WAN prior to any proposed building installation of products from any BMS manufacturer.

H. UBC building BMS installations shall be specified to include all project design, documentation, training, installation work, software, database and logic programming, WAN

interconnection, testing, commissioning, warranty, project management and trade coordination work as required for a fully functional, standalone, turnkey BMS. The individual building BMS installation Contractor work shall include coordination and documentation work for the integration of the BMS into the CBMS via BACnet data interface by other contract. Installations shall in no way negatively affect existing BMS installations and existing campus BMS performance.

I. BMS installations shall be provided which incorporate BMS equipment and network facilities in compliance with the requirements identified in these guidelines. The BMS designer shall specify detailed BMS equipment requirements and BMS network architecture requirements in the BMS Design Specifications. BMS equipment and data communication network specifications shall incorporate good BMS engineering, design, and application practises and shall incorporate the UBC BMS Design Guideline requirements.

J. BMS installations in UBC buildings shall incorporate the following minimum requirements:

1. Equipment shall be approved components as manufactured by one of the UBC approved BMS Manufacturers and shall be in compliance with the UBC BMS Design Guidelines.
2. Management and Automation Level communication LAN's shall be provided to ensure the following:
   a. The failure of a DCP shall not affect the operation of other operating DCP. UC's supervised by the failed DCP shall continue to function and shall control associated equipment according to specified failure routines. Where information in the failed DCP is used by other DCP's, UC's, buildings, routines, etc. the non-availability of the information shall be alarmed and alternate control strategies shall be automatically initiated.
   b. The failure of an UC shall not affect the operation of other operating UC or DCP.
   c. All BMS monitored and controlled points associated with an individual HVAC System or equipment shall be terminated in the same UC or DCP. It is not acceptable for BMS monitored and controlled points associated with an individual system to be terminated at separate distributed DCP's or UC's. All required logic programming and point database facilities associated with an individual building system shall reside in the same UC or DCP to which the system input/output points are terminated. It is not acceptable for logic programming and database facilities required for BMS monitoring and control of a building system to reside in a DCP or UC other than to which the system input/output points are terminated in.
   d. UC's controlling space terminal units (e.g. VAV terminal units, fan powered terminal units, etc.) shall reside on the same automation LAN as the UC that is controlling the associated air handling unit. If an AHU is controlled directly by a DCP, the UC's controlling space terminal units shall be supervised by that DCP.

3.2 BMS Subcontractor and System Qualifications

A. BMS's to be provided for any UBC building installations shall be products as manufactured by one of the following manufacturers:

1. Delta Controls - ESC Automation
2. Johnson Controls, Inc. Metasys Extended Architecture System.
3. Siemens Building Technologies, Ltd. System 600.

B. BMS standalone building installations shall be provided by one of the following UBC approved BMS installation contractors who shall install products of one of the above approved manufacturers:

1. ESC Automation – Delta Controls
2. Johnson Controls, Inc. – Johnson Controls Metasys Extended Architecture
3. Siemens Building Technologies – System 600 BACnet Option

C. BMS installations shall be provided by BMS Contractors who meet the following requirements:

1. Must have been in operation in the BMS industry in the City of Vancouver area for a minimum of 10 years.
2. Employ qualified staff in the Vancouver area capable of undertaking a complete BMS installation project and to provide routine and emergency maintenance on all elements of the BMS.
3. Have successful project experience on similar projects for a minimum period of five (5) years.
4. Have local service and support facilities for the total BMS. BMS Contractor shall have service and support facilities available to UBC 24 hours per day, 7 days per week.
5. Have local, or access to, supplies of BMS components with a maximum delivery period of 24 hours.

D. Work and services for the integration of standalone building BMS's into the Siemens System 600 Apogee Campus Building Management System (CBMS) shall be provided by Siemens Building Technologies. BMS design specifications shall detail the work to be provided for the integration of the building BMS into the Siemens System 600 BMS.

E. BMS facilities to be provided for UBC building installations shall be fully compatible with the existing installed central monitoring and control facilities, network communications facilities, and with other UBC building BMS installations.

F. All BMS DCP's, UC's, OIW's where applicable, and other BMS Manufacturer specific equipment within a building shall be manufactured by the same manufacturer. All HVAC and building services monitoring and control shall be provided by BMS facilities from one of the approved UBC BMS manufacturers. In applications where HVAC system controls within an existing building are being retrofitted and BMS facilities of any of the approved BMS manufacturers exist within the building, BMS facilities shall be provided by the manufacturer of the BMS equipment already installed. The retrofitted BMS installation shall be provided to interconnect the new renovation work into the existing building and campus BMS facilities.

G. BMS DDC controllers shall be products manufactured by a company that is an active Corporate Member of the BACnet Manufacturers Association (BMA).

H. All BMS products proposed for installation on a UBC project shall have been previously demonstrated to UBC Plant Operations satisfaction and approved by UBC Plant Operations prior to being listed as an approved bidder. Any BMS product/equipment for which there is not a significant existing installation on campus of products from the same manufacturer that is successfully integrated with the CBMS shall be fully demonstrated to UBC's satisfaction and approved by UBC Plant Operations prior to being considered as an approved product.

3.3 BMS Network Architecture and Communications Requirements

A. The CBMS and the individual building BMS systems shall be based on multiple tier/level data communication networks utilizing different network communications technologies. The CBMS and the individual building BMS system architecture shall comprise of three layers as defined within these documents.

B. BMS design specifications shall detail the data communications network facilities to be provided and the contracting party responsible for providing the work.

C. The CBMS/BMS architecture shall comprise the following network layers:

1. Management Level (by CBMS and BMS Contracts):
   a. A Wide Area Network (the UBC Campus WAN) shall provide a means of interoperable communication between the CBMS and the individual building

BMS using BACnet/IP. This WAN is hereafter referred to as the Management Level Network. The Management Level Network shall provide a means by which the building systems throughout the UBC facilities can exchange data in the form of BACnet data objects. The Management Level Network shall be BACnet/IP over Ethernet and shall be such that an operator with the required access level shall be able to undertake monitoring and control functions for any of the integrated BMS buildings.

b. It shall be the responsibility of each BMS building contractor, to ensure that all BMS system data is available at the Management Level Network. The intent is that the CBMS shall be able to automatically read this data from the network using the BACnet automatic "find new objects" features. Each BMS building system contractor shall provide comprehensive and complete documentation regarding the installed BACnet devices, device address, controller type, databases and other pertinent information to the Owner and to the CBMS contractor. BMS Specifications shall specify the inform

c. Each BMS system shall have a dedicated NDS installed at the UBC MACC. The NDS shall be dedicated to campus building BMS's of the same manufacturer product. The NDS shall have terminal service capabilities with "Thin Client" operator interface or shall employ "web services" technology such as Microsoft .Net technology with web browser based operator interface. The NDS shall communicate with the individual building BMS's over the BMS Management Level via BACnet/IP. The NDS shall have manufacturer specific application software for operator interface. The NDS shall be configured for archiving and data storage of all associated BMS controllers and devices and for manufacturer specific controller programming, trouble shooting, data entry, configuration software tools, etc. It is not intended that the NDS be configured as the central operator monitoring and control workstation.

d. The NDS shall have Terminal Service capabilities with Thin Client operator interface, or equivalent, such that all applications software resides at the terminal servers and the entire UBC facilities are covered by a single software license regardless of the number of Personal Computers that are accessing NDS via the Management Level Network at any point in time.

e. The existing Siemens Building Technologies System 600 Apogee with BACnet Option server computer and application software shall be the operator interface for supervisory monitoring and control of the building BMS systems. The Siemens Building Technologies System 600 Apogee Server computer, application software and associated management level WAN facilities shall be the Campus Building Management System (CBMS).

f. The CBMS shall be in conformance with the requirements and functionality detailed in ANSI/ASHRAE Standard 135 (BACnet) for a BACnet Operator Workstation (B-OWS). The CBMS shall have terminal service capabilities with "Thin Client" operator interface. The CBMS shall communicate with the individual building BMS's over the BMS Management Level via BACnet/IP. CBMS applications software shall run on the existing Siemens Building Technology Apogee NDS server computer installed at the UBC MACC. The CBMS workstations, including the Portable Operator Workstations (POT), shall be Thin Clients operating through a Virtual Private Network (VPN). It shall be possible to add access from a remote location by modem and/or via the Web.

g. The Operator Interface Workstations (OIW) that serve the CBMS and BMS shall be resident on the Management Level Network, not the BMS Automation Level. If an OIW is required within a remote building, the CBMS contractor shall provide it under a separate contract.

h. The Management Level Network communications, without exception, shall be BACnet/IP. It is intended that there be a single point of interface between a building BMS and the Management Level Network (UBC WAN). If multiple CCP are required in a building due to Automation Level node quantities or limitations of CCP capabilities, the BMS Contractor shall add the additional CCP as an extension of the Management Level Network within the school.

The BMS Contractor shall provide Management Level network facilities within individual buildings.

i. The demarcation point between the CBMS and the building BMS shall be the BMS CCP connection to the WAN data outlet within the building. The BMS Contactor shall make the final terminations with supervision from UBC.

2. Automation Level (by the BMS Contract):
   a. The Communication Control Panels (CCP) shall be part of the BMS. CCP shall be software programmable and shall incorporate BACnet/IP to BACnet/MS/TP routers between the Management Level Network and the BACnet controllers on the Automation Level Network.
   b. The Automation Level shall primarily include the DDC controllers that interface with the field sensors and final control elements. It is anticipated that there will be two types of DDC controller within the CBMS architecture:
      i. Distributed Control panels (DCP).
      ii. Unitary Controllers (UC).
   c. DCP controllers shall be fully programmable controllers and shall have an I/O capability to handle major types of equipment such as air handling units, roof top units, chiller plants, heating plants, etc. The DCP shall be BACnet Building Controller (B-BC) type controllers and shall be interfaced with the Management Level Network via the CCP. DCP may incorporate CCP functionality and reside at the Management network level.
   d. UC shall be application specific or fully programmable controllers and shall be suitable for the monitoring and control of specific types of smaller equipment such as VAV terminal units and Fan Coil Units. UC shall be BACnet Advanced Application Controller (B-AAC) and/or BACnet Application Specific Controller (B-ASC) type controllers at the Automation Level. These UC shall operate on the same network as the BACnet DCP.
   e. All controllers shall be BACnet compliant. Where testing protocols and certification requirements are developed for standardized BACnet device types, devices must be tested and certified compliant by the BACnet Testing Laboratory (BTL). For BMS standardized devices where testing protocols and certification requirements are not yet finalized, the BMS product manufacturer must demonstrate committed efforts to comply with BACnet Standard requirements for the device and an ongoing commitment to undertake the future testing and certification process. All BMS controllers shall be tested and certified within a reasonable period of time of the testing and certification process being available.
   f. The BMS Automation Level Networks shall be BACnet MS/TP protocol. With the specific exceptions of Johnson Controls, Inc. Metasys System and the Siemens Building Technologies System 600 Apogee System installations, no other protocols or network architecture shall be used.
   g. Where interface to a third party controller is not BACnet compatible, the interface shall be via Modbus RTU or Lontalk. Provide Modbus RTU or LonTalk to BACnet converters as necessary to integrate the third party controller into the Automation Level Network. If third party controllers cannot be integrated into the Automation Level, they may be integrated directly to the CCP.

3. Field Level (by BMS Contract):
   a. The Field Level shall include the instrumentation interfaced to the Automation Level DDC controllers such as the temperature, humidity, level, pressure sensors and switches. It shall also include the final control elements such as the valve and damper actuators and the control relays.

4. BMS EQUIPMENT

4.1 Management Level Network

A. Extension of the Management Level Network shall meet, at minimum, the following requirements:

1. Ethernet TCP/IP network. The CCP, OIW, NDS, POT and CBMS shall communicate at 100Mbs or higher communication rates.
2. All data communications shall be BACnet/IP
3. Cabling shall be Category 6 or higher quality and shall be tested and certified for 1 Gbps data transfer rate.
4. Network equipment, configurations, and data communications shall be fully compatible with the UBC Campus WAN.

4.2 BMS Automation Level Network

A. BMS Automation Level LAN shall meet, at minimum, the following requirements:

1. BACnet IP and/or BACnet MS/TP protocol implemented via EIA-485.
2. Data transfer rate and data throughput as required to meet the alarm annunciation requirements.

B. The failure of any node on the Automation Level LAN shall in no way affect the operation of the BMS except to inhibit monitoring and control functions at the OIW for that node or any devices served by the failed node.

C. The failure of any node shall not inhibit the communication between remaining nodes.

4.3 Communication Control Panels (CCP)

A. CCP shall be BACnet compliant. CCP shall be software programmable controllers on the Management Level Network and shall be a router between the BACnet/IP Management Level Network and the BACnet/MSTP Automation Level Network.

B. Provide, at minimum, one CCP per building. Additional CCP may be required to accommodate the number of Management and Field Level Controller nodes and network segments.

C. The CCP shall incorporate software as necessary to provide communications on the Management Level Network.

D. The failure of any CCP shall be annunciated as an alarm at the CBMS.

E. Provide a real-time hardware clock at each CCP. The hardware real-time clock shall be used to synchronize all other hardware and software clocks in the local building BMS.

F. CCP shall record and store device change of state data, BMS event/transaction and alarm data, and trend data in memory within the CCP and shall automatically upload the data to the CBMS and NDS. In the event that the CBMS and/or NDS is not available, the CCP shall store the data in memory within the controller and automatically upload the data once the CBMS/NDS resume communications. CCP shall have memory facilities to hold 7 days of historic data of normal typical transactions and for 7 days of historic trend data for monitored point values at 15 minute samples.

4.4 Distributed Control Panels (DCP)

A. The BMS Contractor shall provide all DCP. DCP shall be software programmable controllers that reside/communicate via BACnet/IP on the Management Level and/or via the BACnet MS/TP Automation Level Network and shall provide an interface via Point Interface Modules (PIM) to the field instrumentation and final control elements.

B. DCP may be used for any equipment monitored and controlled by the BMS. Dedicated DCP shall be used to monitor and control the following equipment:

1. Chilled water system.
2. Cooling towers.
3. Heating water system.
4. Air handling units.

C. The DCP shall control its own communications so that the failure of any one node, including any associated PC workstation or server computer, shall not inhibit communications on the network between the remaining nodes. Provide integral network communication connections.

D. DCP shall be BACnet compliant. DCP shall be BACnet Building Controller (B-BC) type controllers and shall be interfaced with the Management Level Network via the CCP. DCP may be equipped with integral CCP functionality. All controllers shall be BACnet compliant and shall have been tested and certified compliant by the BACnet Testing Laboratory (BTL).

E. All applications programs and associated operating sequences shall reside at the DCP.

F. Provide each DCP with a battery back-up for the protection of volatile memory for a minimum of 72 hours.

G. Provide a real-time software or hardware clock at each DCP. The software clock shall have a battery back-up of at least 72 hours.

H. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that will:

1. Enable the DCP to receive signals from the digital and analog instrumentation.
2. Enable the DCP to output control signals to the final control elements.

I. Analog I/O PIM shall have a minimum 12 bit analog-to-digital conversion and shall interface to the entire signal types listed in the Point Schedules.

J. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.

K. Provide with each controller the BACnet configuration information including BIBB, address, controller configuration type, etc. to integrate the controller into the CBMS.

L. The failure of a DCP shall not affect the operation of other operating DCP. UC's supervised by the failed DCP shall continue to function and shall control associated equipment according to specified failure routines. Where information in the failed DCP is used by other DCP's, UC's, buildings, routines, etc. the non-availability of the information shall be alarmed and alternate control strategies shall be automatically initiated.

4.5 Unitary Controllers (UC)

A. The BMS Contractor shall provide all Unitary Controllers (UC). UC shall be fully programmable or applications specific controllers with pre-packaged operating sequences maintained in EEPROM or flash RAM.

B. The UC shall be a node on one of the Automation Level LANs and shall control its own communications so that the failure of any one node shall not inhibit communications on the network between the remaining nodes.

C. UC shall be BACnet Advanced Application Controller (B-AAC) and/or BACnet Application Specific Controller (B-ASC) type controllers incorporated at the Automation Level. These UC

shall operate on the same network as the BACnet DCP. All controllers shall be BACnet compliant and shall have been tested and certified compliant by the BACnet Testing Laboratory (BTL).

D. UC shall be totally independent of other LAN nodes for their monitoring and control functions.

E. Provide each UC with a battery back-up or EEPROM for the protection of volatile memory for a minimum of 72 hours. Batteries shall be rated for a seven year life.

F. All associated applications programs shall reside at the UC. UC shall not require communication to any other panel for normal operating sequences other than time scheduled base commands.

G. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.

H. Provide with each controller the BACnet configuration information including BIBB, address, controller configuration type, etc. to integrate the controller into the CBMS.

I. A dedicated UC shall be provided for the BMS monitoring and control of each individual unitary equipment such as VAV Terminal Units, Fan Coil Units, Unitary Equipment, Rooftop unit, etc. Failure of one UC shall not affect the BMS monitoring and control or operation of other unitary equipment or BMS devices.

4.6 Valves and Dampers

A. Automatic Control Valve General Requirements:

1. The BMS Subcontractor shall furnish all valves controlled by the BMS as detailed in the mechanical trade documents and as indicated on control drawings. The BMS Subcontractor shall furnish all shut-off valves for instrumentation. The Mechanical Subcontractor shall install valves, except those for instrumentation. All other valves such as check valves, relief valves, pressure reducing valves, self regulating valves, manually operated valves, etc. shall be furnished and installed by the Mechanical Subcontractor. The BMS Subcontractor shall provide details of the manufacturer's installation requirements to the Mechanical Subcontractor. The BMS Subcontractor shall coordinate the valve body type and pipe connections with the mechanical trade.

B. The BMS Subcontractor shall refer to the Mechanical plans and drawings and to the control drawings for the design conditions on which to base sizing and ratings of the valves and their actuators.

C. All valves shall be rated appropriately for the fluid, temperature and pressure.

D. Valves of similar types shall be by the same manufacturer.

E. Valves shall have the manufacturer's name and the pressure rating clearly marked on the outside of the body. Where this is not possible manufacturer's name and valve pressure rating shall be engraved on a minimum 50mm (2 inch) diameter stainless steel tag that shall be attached to the valve by a chain in such a manner that it cannot be unintentionally removed.

F. Valves 13mm to 50mm (0.5 inch to 2 inches) shall have screwed ends. Valves 63mm (2.5 inches) and larger shall have flanged ends. Flanged valves shall be furnished complete with companion flanges, gaskets and bolting materials. Flanges, gaskets and bolting materials shall meet the appropriate ANSI requirements.

G. Valves shall be suitable for continuous throttling.

H. Valve schedules shall be submitted for review and shall clearly show the following for each valve:

1. Associated system.
2. Manufacturer and model number.
3. Valve size and line size.
4. Flowrate, flow coefficient (CV) - and pressure drop at design conditions

   or

   Valve authority, flowrate and pressure drop across the valve at design conditions and pressure drop across the associated mechanical equipment, e.g., coil, heat exchanger, etc., at design conditions.
5. Valve configuration (e.g. two way, three way, butterfly).
6. Leakage rate.
7. Maximum pressure shut-off capability.
8. Actuator manufacturer and model number.
9. Valve body pressure and temperature rating.
10. Normally open/closed and failure positions.

I. Where necessary to achieve the required performance and pressure drop a control valve may be sized up to two nominal sizes below line size.

J. Valve bodies shall be cast iron, carbon steel, stainless steel or bronze subject to requirements for valve body pressure and temperature rating and suitability of material for application. Valve trim for steam service shall be stainless steel.

K. For all valves larger than one and a half inch (1 ½ inch) valve seats shall be replaceable. Valve seats shall be metal, ceramic filled PTFE or equivalent and must assure tight seating.

L. The BMS subcontractor shall certify that the materials of construction are appropriate for the application. In particular, valves used for the control of glycol solutions shall have a trim that is suitable for a glycol solution.

M. Two-Way Control Valves

1. The BMS Subcontractor shall provide two-way globe control valves as indicated on the mechanical trade documents.
2. Pressure drop shall not exceed 35 kPa and shall conform to the following requirements:

   a. Valves shall be selected such that the valve authority (N) shall not be less than 0.5 as defined by the relationship:

      $$N=P1/(P1+P2)$$

      where P1= pressure drop across the fully open valve, and
      P2= pressure drop across the remainder of the circuit (e.g. a coil, isolation valves, strainers, etc.)

3. Valve shall be capable of tight shut-off when operating at system pressure with the system pump operating at shut-off head. Leakage rate shall not exceed 0.01% of the rated valve capacity.
4. Valve shall be straight pattern type. Angle valves shall only be furnished where the piping configuration does not permit the use of a straight valve.
5. Valves shall be single seat globe type. Double seat valves shall not be furnished.
6. Two-port valves when used to control heating or cooling coil water flow shall have an equal percentage or modified parabolic characteristic. Two-port valves when used in liquid applications systems not detailed above shall have a linear / linear characteristic.

7. Ball type valves may be permitted for valves less than 2 inches. Proposed ball valves must be designed for modulating control service. BMS Consultant to specify requirements.

N. Three-way Control Valves

1. The BMS Subcontractor shall provide three-way control valves as indicated on the mechanical trade documents.
2. Pressure drop shall not exceed 35 kPa and shall conform to the following requirements:
   a. Valves shall be selected such that the valve authority (N) shall not be less than 0.5 for diverting valves and 0.3 for mixing valves as defined by the relationship:
      N=P1/(P1+P2)
      where P1= pressure drop across the fully open valve
      P2= pressure drop across the remainder of the circuit (e.g. a coil)
3. Three way control valves shall be of the mixing or diverting pattern type as indicated in the mechanical documents. The inner valve shall have a V-port parabolic or linear plug and stainless steel trim. Valves shall have metal-to-metal stainless steel seats to assure tight seating.
4. Mixing valves shall be capable of tight shut-off between each inlet port and the outlet port and diverting valves shall be capable of tight shut-off between each outlet port and the inlet port when operating at system pressure.

O. Valves for Instrumentation

1. Instrumentation, such as pressure sensors and flow rate monitors, which is provided for the monitoring of parameters associated with liquid in pipes or tanks, shall be removable and replaceable without the requirement to shut down a pump and without the requirement to drain the pipe or tank and without causing liquid to leak from the pipe or tank. To facilitate this, the BMS subcontractor shall furnish valves for installation by the mechanical trade.
2. Instrumentation that is mounted external to the pipe or tank and which is connected to the pipe or tank by one or more sampling lines shall have a manual two-way on/off valve in each sampling line meeting the following requirements:
   a. Ball type valve
   b. Valve body shall be 316 stainless steel
   c. Ball and stem shall be 316 stainless steel
   d. Zero leakage.
   e. Rated for 7000 kPa or for a pressure 50% greater then the system working pressure, whichever is the greater.
   f. Rated for a minimum of 50 deg. C (90 deg. F.) greater than the highest fluid temperature.
   g. Brass or stainless steel trim.
   h. Valve seats shall be metal, reinforced TFE or equivalent and must assure tight seating.
   i. Valve shall be Whitey 40 Series or 80 Series or approved equal it meets the requirements detailed above.
3. Valves for insertion flow meters shall be full port gate valves sized for the flow meter in accordance with the flow meter manufacturer's instructions. If the flow meter manufacturer offers the valve as an accessory then it shall be purchased by the BMS subcontractor from the insertion flow meter manufacturer and shall be installed by the mechanical trade in accordance with the insertion flow meter manufacturer's instructions. The valve shall meet the pressure and temperature requirements detailed for the control valves and shall have zero leakage at the system maximum pressure.

P. Valve Actuators - Electric

1. The BMS subcontractor shall provide electric actuators for valves that are furnished by the BMS subcontractor. Pneumatic type actuators may be acceptable for steam control valves where required to meet the shut-off and torque requirements. BMS Subcontractor shall request permission from the BMS Consultant and UBC for the proposed application of pneumatically actuated valves for each individual application.
2. Actuator shall be motor driven type. Valve stem position shall be adjustable in increments of one (1) percent or less of full stem travel.
3. Actuator shall have an integral self-locking gear train, mechanical travel stops and adjustable travel limit switches with electrically isolated contacts.
4. Actuator gear assembly shall be made of hard-anodized aluminum or steel or material of equivalent durability. No plastic components shall be acceptable. Disassembly of the gears shall not be required to remove the motor.
5. Actuator shall be rated for continuous duty and have an input voltage of 120 vac/60 Hz, or 24 V.
6. Actuators on valves located in mechanical rooms or outdoors shall have covers of aluminum or a material of equivalent strength and shall have captive bolts to eliminate loss of bolts when removing the cover from the base. Housings for valves located in a plenum and used for terminal unit or fan coil unit heating/cooling coils, may be constructed of reinforced plastic. Materials of construction for all actuator components shall be non-corroding.
7. Actuator motor shall be fully accessible for ease of maintenance.
8. Actuator shall be sized to meet the shut-off requirements when operating at the maximum system differential pressure and with the installed system pump operating at shut-off head.
9. Actuator shall control against system maximum working pressures.
10. Actuator shall fail as indicated on the control drawings that form part of these contract documents. Provide spring return to de-energized position on loss of power or loss of control signal if so required by the sequences of operation.
11. Actuator shall accept control signals compatible with the BMS analogue or digital output subsystem as appropriate. The valve stem position shall be linearly related to the control signal.
12. Actuator shall have visual mechanical position indication, showing output shaft and valve position.
13. Actuator shall operate the valve from the fully closed to the fully open position and vice versa in less than two minutes.
14. Actuator shall be constructed to withstand high shock and vibration without operations failure. Materials of construction shall be non-corroding.
15. Actuator shall be equipped with an integral position potentiometer to indicate the stem position of the valve where required by the control sequences. All valve actuators shall have integral end position indicators.
16. Actuator and valve shall be mounted and installed only in the location/orientation approved by the manufacturer. Installation drawings shall clearly indicate the valve location.
17. Actuator shall have a manual declutch lever to enable manual operation of the valve. It shall be possible for an operator to manually modulate valves located in mechanical rooms in the event of loss of power. The operator shall be able to manually modulate the valves without having to climb a ladder or other non-permanent structure. It shall be ensured that the valve installation is such that the valve cannot declutch under the influence of gravity and/or vibration.

Q. Steam Control Valves

1. The BMS Subcontractor shall provide two way control valves at all steam service locations as indicated on the Field Termination Schedules. Steam control valves shall meet, at minimum, the following requirements:
   a. Capable of tight shut-off against full system pressure.

b. Low pressure applications with an inlet steam pressure less than 15 psig shall be sized with a differential pressure equal to 80 percent of the inlet gauge pressure (psig).
c. High pressure applications with an inlet steam pressure greater than 15 psig shall be sized using a pressure drop equal to 42 percent of the absolute pressure (psia).
d. Rated for the operating pressure of the system as appropriate for the location.
e. Straight pattern single seat globe or double seated plug type suitable for steam service.
f. Suitable for continuous throttling.
g. Valve body material shall be steel, with stainless steel trim.
h. Valve packing PTFE, graphite, or equivalent and must assure tight seating.
i. Valve seats shall be metal, ceramic filled PTFE or equivalent and must assure tight seating.

R. Valve Actuators - Pneumatic

1. The BMS Subcontractor may provide pneumatic actuators for larger sized steam valves to meet shut off and torque requirements. Proposed use of pneumatic actuators shall be approved by the consultant on an individual basis. Valve actuators shall meet, at minimum, the following requirements:

a. Double acting piston driven type.
b. Pressure relief in the event of abnormally high pressures.
c. Ductile iron or other suitable material housing.
d. Pilot positioner with linear feedback with span and zero adjustments.
e. Sized to meet the shut-off requirements when operating at the maximum system differential pressure and with the installed system pump operating at shut-off head. Actuators shall control against system maximum working pressures.
f. Valves shall fail as in the last commanded position or as indicated in the Operating Sequences.
g. Accept control signals compatible with the BMCS analog or digital output subsystem as appropriate. The valve stem position shall be linearly related to the control signal.
h. Visual mechanical position indication, showing valve position which is capable of being viewed by a person standing on the adjacent floor.
i. Capable of operating the valve from the fully closed to the fully open position and vice versa in less than two minutes.
j. Constructed to withstand high shock and vibration without operations failure.
k. Housing shall have a watertight enclosure with O-ring seals.
l. Actuators and valves shall be mounted and installed only in the positions approved by the manufacturer. Shop drawings shall clearly indicate the acceptable positions.

S. DAMPERS - GENERAL

1. The BMS Subcontractor shall furnish automatic dampers (CD) as indicated in the Mechanical trade documents and in the Field Termination Schedules for installation by the Division 15 Mechanical subcontractor.
2. The BMS Subcontractor shall provide actuators for all automatic dampers furnished as part of the BMS contract and for all dampers provided by the air handling unit manufacturers, unless otherwise specified. The BMS Subcontractor shall provide all required actuator mountings, installation, drive arms, linkages and damper end switches. The BMS Subcontractor shall provide

electric or pneumatic damper actuators as specified within the BMS specifications, in the Mechanical trade documents and as detailed in the field termination schedules.

3. Multiple section two position dampers shall be controlled by one BMS output unless indicated otherwise within the Field Termination Schedules or Sequences of Operation.
4. Multiple section modulating dampers shall be controlled in sequence unless indicated otherwise within the Field Termination Schedules or Sequences of Operation.
5. Individual sections shall not be larger than 1.67 sq. m (18 square feet). Each section shall have a separate actuator. Wherever possible the use of Jackshaft extensions shall be avoided for controlling multiple damper sections. Jackshaft connection of damper sections may be permissible where required to mount damper actuators outside of the duct for applications with hazardous exhaust air flow, etc.
6. Actuators shall be mounted to allow complete access for maintenance and removal. Wherever possible provide damper actuators mounted on the exterior of the duct/damper section. The installation of actuators within air streams will be permitted only where damper configurations and site conditions require. Obtain approval for proposed installations of actuators within ductwork, plenums, airstreams, etc. Furnish access doors where required to allow access to the actuators.
7. Dampers and actuators shall be configured for normal and failure positions as indicated in the operating sequences and as indicated in the Division 15 Mechanical Drawings and Specifications.
8. The BMS Subcontractor shall provide actuators sized in accordance with manufacturers recommendations and industry standards for accurate and stable control of airflow in each application.
9. The BMS Subcontractor shall provide damper and actuator installations to comply with the acoustical requirements for the project. Noise generated from dampers and actuators in air streams shall not be detectable in occupied building spaces.
10. The BMS Subcontractor shall furnish manufacturers' installation details to the Division 15 Mechanical subcontractor. Provide details of all multiple section damper installations. Provide schematic diagrams for all multiple section damper installations indicating damper section dimensions, mounting configurations, linkages, actuator mounting locations, structural bracing/reinforcement, etc.
11. The BMS Subcontractor shall submit damper schedules that include, at minimum, the following for each damper:
    a. Associated mechanical system.
    b. Damper manufacturer and model number.
    c. Actuator manufacturer and model number.
    d. Mechanical drawing reference.
    e. Damper size for each section.
    f. Parallel or opposed blade configuration.
    g. Ratio of anticipated air stream velocity to the manufacturer's maximum recommended velocity rating.

T. CONTROL DAMPERS (CD)

1. The BMS Subcontractor shall furnish CD as detailed in the mechanical drawings.
2. Modulating dampers shall be opposed blade type unless specified otherwise. Two position dampers shall be parallel or opposed blade type.
3. The maximum leakage rate for outside air isolation CD shall not exceed 30 litres per sq. m. of overall damper face area at a differential pressure of 1kPa (equivalent to 6 cfm per square foot at 4 inches W.C.). The maximum leakage rate for all other CD shall not exceed 50 litres per sq. m. of overall damper face area at a differential pressure of 1kPa (equivalent to 10 cfm per square foot at 4

inches W.C.). Provide dampers tested and certified for leakage performance in accordance with AMCA Standard 500.

4. The BMS Subcontractor shall provide integral damper position indicator switches as required by the operating sequences and where required for interlocking to motors. Damper position switches shall be provided to indicate actual damper blade position. Damper position indication based on damper linkage position or damper drive shaft position is not acceptable.
5. Frames:
    a. 16 gauge welded galvanized steel channel, or
    b. 3.2 mm (0.125 inch) thick formed aluminum channel.
    c. Corner bracing of frames of height or width larger than 1m. (3.28 ft.).
    d. Channel dimensions shall be a minimum of 125 mm by 25 mm (5 inch by 1 inch).
    e. Constructed for flanged ductwork connection. Provide damper frames with flanges suitable for installation in interconnected ductwork or plenums.
    f. Sized to match the duct dimension including lining materials.
6. Blades:
    a. Material of construction shall be:
        i. 21 gauge galvanized steel, with four (4) breaks, or
        ii. 22 gauge double galvanized sheets, with four (4) breaks in each sheet. Sheets shall be spot welded together, or
        iii. 14 gauge airfoil shaped double skin galvanized steel, or
        iv. 16 gauge airfoil shaped double skin-extruded aluminum.
    b. 200 mm (8 inch) maximum width for galvanized steel.
    c. 150 mm (6 inch) maximum width for aluminum.
    d. 1.5 m (60 inch) maximum blade length.
    e. Replaceable edge seals made of one of the following:
        i. Neoprene.
        ii. Vinyl.
        iii. Polyurethane.
        iv. Silicone rubber.
        v. Synthetic elastomer.
    f. Side seals shall be one of the following:
        i. Continuous spring stainless steel strip.
        ii. Synthetic elastomer.
        iii. Flexible aluminium compression type.
    g. Sections shall be installed such that blades are horizontal except where specifically noted otherwise. Vertically mounted damper blades shall have suitably rated thrust bearings.
7. Axles:
    a. Materials of construction shall be:
        i. 13 mm (0.5 inch) round zinc plated steel, or
        ii. 13 mm (0.5 inch) hexagonal zinc plated steel, or
    b. Axles shall be fastened to the blades with bolts through the axle, rivets or welds.
    c. Bearings shall be one of the following:
        i. Oil impregnated sintered bronze, or
        ii. Stainless steel.
    d. Extend axle beyond the frame as necessary to match up with actuator.
8. Dampers shall be Ruskin, Nailor, Prefco, Siemens Building Technologies, Johnson Controls, Inc. or approved equal.

U. DAMPER ACTUATORS FOR Control Dampers (CD)

1. Unless otherwise specified the BMS Subcontractor shall provide electric damper actuators for all CD. Electric actuators shall meet, at minimum, the following requirements:

   a. Stroke by the rotating motion of a reversible, overload-protected synchronous motor. Actuators shall be directly coupled to damper drive blades with no intermediate linkages or shall be rotary type actuators directly coupled to the damper drive shaft.
   b. Protected against overload by an integral magnetic clutch or stall protection by non-overloading impedance protected motor.
   c. 120 Vac + or - 10% 60 Hz or 24 Vac power supply.
   d. One actuator for each damper section. Provide additional actuators to ensure sufficient torque to meet the specified close off leakage requirements. Damper actuators shall not be stacked. Multiple actuators "stacked" on a single damper drive shaft will not be accepted.
   e. Actuators shall be motorized/driven in both the open and closed directions. Where required by the sequences of operation, actuators shall have a spring return to the de-energized position upon loss of power. Damper normal and failure positions shall be as identified within the sequences of operation.
   f. BMS controlled actuators for modulating automatic dampers shall be controlled by a 0-10 Vdc, or 4-20mA signal. Provide actuators that are fully compatible with the BMS analog output subsystem. BMS controlled actuators for two position dampers shall be controlled by 24Vac, 24Vdc or single-phase 120 Vac power switched by the BMS.
   g. Complete with mounting brackets suitable for extended shaft mounting or direct damper drive shaft mounting.
   h. Stroke dampers from fully closed to fully open in accordance with the following:

Service	Timing Requirement
Two position normal service	75 seconds
Modulating normal service	120 seconds
Emergency service (stair pressurization, smoke containment, etc.)	15 seconds

   i. Rated for operation at ambient temperatures of minus 40 Deg.C. to 50 Deg.C. (-40 Deg. F. to 122 Deg. F.).
   j. Complete with damper/actuator stroke position indicator.
   k. Manual drive release mechanism and manual positioning mechanism.

2. Actuators shall be quiet in operation such that noise from actuator operation is not detectable in any occupied spaces.

3. Actuators shall be Belimo, Honeywell, Nailor, Siemens Building Technologies, Johnson Controls Inc. or approved equal.

V. DAMPER HARDWIRED INTERLOCKS

1. The BMS Subcontractor shall provide all required hardwired interlocks between fans, intake and discharge dampers, emergency generators, etc. and any motor actuated damper as identified within the BMS specifications or the Mechanical Drawings, whether or not furnished under this Section unless the fan is furnished with interlock by fan manufacturer.

2. The BMS Subcontractor shall provide all wiring as required for the control and interlocking of automatic dampers. The BMS Subcontractor shall provide control

signal and power supply wiring between any damper monitored and/or controlled by the BMS regardless of whether the BMS Subcontractor has furnished the damper/actuator assembly. The BMS Subcontractor shall also provide power supply and control signal wiring between damper actuators and interlocked motor control circuits, thermostats, duct pressure limit switches, safeties, etc.

3. Power for air handling unit automatic control dampers shall be obtained from the associated air handling unit supply fan motor control circuit. The BMS Subcontractor shall coordinate actuator power supply wiring and fire alarm system override control of dampers with the Electrical Trade.

4. Where dampers are specified to be hard wire interlocked with electric fan motors the BMS subcontractor shall provide the damper position switches and all required wiring and interconnection. Provide the damper end switch(s) hard wire interlocked to achieve the operational requirements as specified in the Field Termination Schedules and the sequences of operation in the BMS specifications, and as indicated in the Division 15 Drawings and Specifications. Provide damper end switches hard wire interlocked to prevent fan motor operation in both the hand and auto position of hand/off/auto motor control circuit.

4.7 BMS Field Devices And Instrumentation

A. This section details the minimum requirements for BMS field devices and instrumentation to be provided for UBC BMS projects. Specifications for UBC BMS projects shall detail BMS field device hardware and installation requirements.

B. The BMS specifications shall instruct the BMS Contractor to provide the field devices and all wiring, installations, interconnections, power supplies, signal conditioning equipment, field point interface equipment, etc. as required for accurate and fully functional BMS monitoring and control of the device.

C. BMS field device requirements shall be identified in the BMS project specifications. The BMS Consultant shall identify BMS monitoring and control requirements in the specifications via BMS Field Termination Schedules and BMS Systems Schematics. Individual BMS points identified in the Field Termination Schedules shall cross reference corresponding devices indicated on the associated BMS System Schematic. The BMS System Schematic and Field Termination Schedules shall be clearly titled and numbered. All required control requirements, interfaces and hard wire interlock requirements shall be identified in the Field Termination Schedules and in the BMS System Schematics.

D. All BMS components, including equipment, instrumentation, field devices, etc., shall be cUL, ULC, UL, listed, and CSA certified where applicable and shall bear the appropriate labelling. No BMS component shall be provided which contains asbestos, PBC's, or other hazardous materials.

E. BMS Field Devices and Instrumentation shall be provided in compliance with the following minimum requirements.

1. Temperature Sensors

a. Platinum or Nickel RTD type sensors.
b. Platinum RTD type temperature sensors in compliance with the following:
   i. 100 ohm Platinum at 0 Deg.C. (Coefficient of resistivity of 0.00385 ohms/ohm/Deg.C.).
   ii. 1000 ohm Platinum at 0 Deg.C. (Coefficient of resistivity of 0.00385 ohms/ohm/Deg.C.).
c. Nickel RTD sensors shall be 1000 ohm.
d. If the RTD is 100 ohm Pt, provide a transmitter located at the RTD.

e. If the RTD is 1,000 ohm Pt or Nickel, provide a transmitter at the RTD:
   i. If the I/O subsystem at the UC or DCP cannot interface directly to an RTD.
   ii. If the distance between the RTD and the associated UC or DCP exceeds 50m (160 feet).
f. Transmitter output shall be 4 to 20mA proportional to temperature and shall cover a temperature range as indicated in this Section. The analog-to-analog conversion of the transmitter shall be such that the monitored temperature is reported by the BMS within the accuracy requirements detailed for the individual temperature sensors. Provide temperature transmitters as an integral component of the field mounted temperature sensor or installed at the location of the temperature sensor.
g. The end-to-end accuracy for all BMS monitored temperature sensors shall be ± 0.5 Deg.C. (1.0 Deg.F.).
h. An exception to the above is that positive temperature coefficient thermistor type temperature sensors are acceptable for space temperature sensing associated with terminal units (e.g. VAV terminal units, reheat coils, etc.)

2. Provide outside air temperature sensors in compliance with the following additional requirements:

   a. Ventilated white PVC sun shield.
   b. Wall mount weather proof enclosure with conduit fitting.
   c. In compliance with requirements listed above.
   d. Operating temperature range of -50 Deg.C. to +50 Deg.C.

3. Provide duct temperature sensors in compliance with the following additional requirements:

   a. In compliance with requirements listed above.
   b. Single point type sensor probe. Sensor probe length shall be no less than 1/3 of duct width or diameter.
   c. Complete with duct mounting facilities and conduit fittings.
   d. Operating temperature range of 0 Deg.C. to 65 Deg.C.

4. Provide duct averaging type temperature sensors in compliance with the following additional requirements:

   a. In compliance with requirements listed above. Duct averaging probe materials may be stainless steel, copper or aluminum.
   b. Probe length of 3.66m (12 feet) minimum or 3.25m per sq.m. (one linear foot per square foot) of duct cross-sectional area., whichever is greater.
   c. Duct mounted moisture/waterproof housing with conduit fitting.
   d. Suitable supports at all bends and at intermediate points to prevent movement in the air stream.
   e. Operating temperature range of -5 Deg.C. to 50 Deg.C.

5. Provide space temperature sensors in compliance with the following additional requirements:

   a. In compliance with requirements listed above.
   b. Suitably finished wall mounted enclosure with discrete manufacturer logos and markings only. Space temperature sensors shall not have temperature indication devices.
   c. Mounted at locations approved by UBC and the BMS Design Consultant. For new construction projects the space temperature sensor locations shall be identified in the mechanical plans.

d. Provide protective enclosures for all sensors mounted in mechanical and electrical rooms, janitor closets, etc. Enclosure to be ventilated type to ensure sensor accuracy.
e. Operating temperature range of 0 Deg.C. to 50 Deg.C.
f. Button or plate type sensors where required to suit the architectural finish is public areas.
g. Sensors associated with UC's for control of Terminal Units shall comply with the following:
    i. Provide limited space temperature setpoint adjustment facilities on room sensors when the sensor serves a single office or personal space.
    ii. No setpoint adjustment facilities on sensors mounted in areas accessible to the public, in common office or shared areas, and for sensors that serve more than one occupied office or space.

6. Provide thermowell temperature sensors in compliance with the following additional requirements:

    a. In compliance with requirements listed above.
    b. Stainless steel probe. Probe length shall be at minimum 20% of the pipe width.
    c. Moisture/waterproof housing with conduit fitting.
    d. Provide complete with Brass or Stainless Steel thermowell.
    e. Provide complete with thermal transfer compound inside thermal well.
    f. Sensors required for the determination of temperature differential shall be matched with a maximum variation over the entire temperature range of 0.1 Deg.C. (0.2 Deg.F.).
    g. Operating temperature range to suit application.

7. Where required, provide temperature transmitters in accordance with the requirements identified above and in compliance with the following requirements:

    a. Two or three wire RTD input as required to achieve specified performance requirements.
    b. Factory calibrated.
    c. 4-20 mA output signal.
    d. Accuracy of +/- 0.1 % of span.
    e. Complete with integral zero and span adjustment.
    f. Complete with mounting enclosure.
    g. Compatible with the analog inputs at the DCP and UC.

8. Low Temperature Detection Device (AHU Air Service)

    a. Minimum 6.1 m (20 feet) vapor tension element, which shall serpentine the inlet face on all coils. Provide additional sensors, wired in series, to provide 3.25 m per sq.m. (One linear foot per square foot) of coil surface area.
    b. Hardwire interlock device to shut down fans and position mixing dampers to the full recirculation position. Refer to sequences of operation. Provide device hardwire interlocked such that AHU fan will shut down when HOA switch is in Hand or Auto position.
    c. Manual reset.
    d. Setpoint shall be adjustable in the range of, at minimum, 0 Deg. C. to 7 Deg. C. (32 Deg. F. to 45 Deg. F.). Provide a scale with temperature setting clearly displayed.
    e. SPDT switch contacts. Switch contacts shall be rated for duty.
    f. Provide suitable supports.
    g. Provide complete with auxillary contacts for monitoring by the BMS.

9. Relative Humidity Sensors

a. Overall accuracy of +/- 3 % reading from 0 to 95 % RH unless the individual application requires higher accuracy.
b. Operating temperature range of - 20 Deg.C. to 80 Deg.C.
c. Long term stability with less than 1 % drift per year.
d. Sensitivity of 0.5 % RH.
e. Complete with built in transmitter for 4-20 mA output proportional to RH to the BMS. Sensor to be fully compatible with BMS.
f. Humidity sensor shall be replaceable.
g. Provide complete with RH sensor calibration tool and all required connection cables.

10. Provide outdoor air relative humidity sensors in compliance with the following additional requirements:

    a. Non-corroding outdoor shield to minimize wind effects and solar heating.
    b. Wall mount weather proof enclosure with conduit fitting.

11. Provide duct mount relative humidity sensors in compliance with the following additional requirements:
    a. Duct mount moisture resistant enclosure with conduit fitting.
    b. 8 inch probe length.
    c. Operating temperature range of O Deg. C. to 50 Deg. C. (32 Deg. F to 122 Deg. F.).
    d. Sensor shall be suitable for operation in moving air streams as required to suit application.

12. Provide space relative humidity sensors in compliance with the following additional requirements:

    a. Suitably finished wall mounted enclosure with discrete manufacturer logos markings only. Enclosure shall not have temperature or RH indication devices.
    b. Mounted at locations approved by UBC and the BMS Design Consultant. For new construction projects the RH sensor locations shall be identified in the mechanical plans.
    c. Provide protective enclosures for all sensors mounted in mechanical and electrical rooms, janitor closets, etc. Enclosure to be ventilated type to ensure sensor accuracy.

13. Combination Relative Humidity and Temperature Sensors

    a. Where there is a requirement for the monitoring of both relative humidity and temperature at the same location, the BMS contractor may provide a combination relative humidity sensor and temperature sensor. The individual sensors must each meet the specifications detailed above.

14. Combination Dewpoint and Dry Bulb Temperature Transmitter

    a. Complete with mounting accessories and enclosures for interior or exterior wall or duct mounting.
    b. Stainless steel probe with NEMA 4 transmitter housing. Outside air sensor shall have a solar shield.
    c. Two wire, 4-20 mA output proportional to minimum dewpoint temperature range of -40 Deg.C. to +63 Deg.C. (-40 Deg.F. to +145 Deg.F.).
    d. Two wire, 4-20 mA output proportional to minimum dry bulb temperature range of -23 Deg.C. to +79 Deg.C. (-10 Deg.F. to +175 Deg.F.).
    e. Probe shall be a minimum of 200mm for duct application.
    f. BMCS shall report the monitored dry bulb temperature with an accuracy of ± 0.5 Deg. C. (1.0 Deg. F.).

g. BMCS shall report the monitored dewpoint temperature with an accuracy of ± 1.0 Deg. C. (1.8 Deg. F.) at 50% RH and dry bulb temperature of -25 Deg.C. to +65 Deg.C. (-13 Deg.F. to 140 Deg.F.).
h. If it meets the above requirements, provide Honeywell HyCal model HYD840, Honeywell HyCal HYDMP2 Moisture Pro or approved equal.

15. Latching Type Control Relays

a. Pickup rating, time and hold rating as required for individual applications.
b. Rated for a minimum of ten (10) million mechanical operations and a minimum of 500,000 electrical operations.
c. Provide complete isolation between the control circuit and the BMS digital output.
d. Located in the DCP, UC or other local enclosures.
e. Malfunction of an BMS component shall cause the controlled output to fail to the positions identified in the failure procedure.
f. 10 amp contact rating.
g. Pin type terminals complete with mounting bases.
h. If it meets the above requirements, provide IDEC, RR Series, Potter Bromfield, Cutler Hammer or approved equal.

16. Momentary Type Control Relays

a. Coil ratings of 120 VAC, 50 mA or 10-30 VAC/VDC, 40 mA as suitable for the application.
b. Provide complete isolation between the control circuit and the BMS digital output.
c. Located in the DCP, UC or other local enclosures.
d. 10 amp contact rating.
e. LED status indication.
f. If it meets the above requirements, provide Core Components, Model CVR or approved equal.

17. Duct Static Pressure Transmitter

a. Input pressure range to suit each individual application.
b. 4-20 mA output signal proportional to pressure input range.
c. ± 5% accuracy.
d. Operating temperature range of -7 Deg. C. to 49 Deg. C. (20 Deg. F. to 120 Deg. F.)
e. Easily accessible, integral non-interacting zero and span adjustment.
f. Minimum over pressure input protection of five times rated input.
g. If it meets the above requirements, provide MODUS, Model T40, Mamac series PR272, Setra or approved equal.

18. Space Static Pressure Transmitter

a. Input range to suit application. Typically input range of -0.25 to +0.25 inches w.g.
b. 4-20 mA output proportional to pressure input range.
c. ± 5% accuracy of range.
d. Temperature range of 0 Deg. C. to 38 Deg. C. (32 Deg. F to 100 Deg. F.).
e. Easily accessible, integral non-interacting zero and span adjustment.
f. Over pressure input protection of five times rated input.
g. Exterior static pressure references shall be monitored via a static pressure sensor dampening pot. Coordinate exact mounting locations of exterior static pressure reference points. Dampening pot shall be manufactured by Dwyer, Model A-306 or approved equal.

h. If it meets the above requirements, provide MODUS, Model T40, Johnson Controls DPT2641, Mamac series PR272 series, Setra or approved equal.

19. Air Flowrate Sensor - Duct Mounted

a. Multipoint flow cross or grid measuring device.
b. Complete with transducer. Input pressure range of pressure transducer shall be appropriate for application. Coordinate with Division 15 subcontractor.
c. Bulkhead fittings to allow sensor tubing to be connected or removed without removing ductwork.
d. Internal materials of the transducer suitable for continuous contact with air.
e. Sensing grid shall be constructed of stainless steel.
f. Integral signal integrator to minimize primary signal noise from the output signal.
g. Output signal of 4-20 mA proportional to input pressure.
h. Temperature range of -18 Deg. C. to 60 Deg. C. (0 Deg. F. to 140 Deg. F.)
i. ± 5% accuracy of measured value.
j. Transducer to be provided complete with easily accessible, integral non-interacting zero and span adjustment.

20. Air Flowrate Sensor - Fan Inlet

a. Multipoint flow cross or grid measuring device mounted at the inlet of the fan.
b. Complete with transducer. Input range appropriate to application. Coordinate with Division 15 subcontractor.
c. Bulkhead fittings to allow sensor tubing to be connected or removed without removing the device from the fan.
d. Internal materials of the transducer suitable for continuous contact with air.
e. Sensing grid shall be constructed of stainless steel.
f. Integral signal integrator to minimize primary signal noise from the output signal.
g. Output signal of 4-20 mA proportional to input pressure.
h. Temperature range of -18 Deg. C. to 60 Deg. C. (0 Deg. F. to 140 Deg. F.)
i. Combined sensor and transducer accuracy of ± 3% of measured value.
j. Transducer to be provided complete with easily accessible, integral non-interacting zero and span adjustment.

21. Current Sensing Transformer and Relay Combination - Electric Motor Status Monitoring Service

a. Rated for the applicable load.
b. SPDT Status Indication relay contacts. Status indication relay shall have an accessible trip adjustment over its complete operating range. Provide LED indication of relay status.
c. Long term drift shall not exceed 5% of full range per 6 months.
d. Current transformer and relay shall have over current and over voltage protection. Transformer and relay may be combined into a single unit or can be separate units.
e. Transformer core shall be sized for the application.
f. Accuracy-± 2% of reading from 10% to 100% of full scale range, ± 2% full scale from 0 to 10% of full scale range.
g. Temperature range of -15 Deg. C. to 60 Deg. C. (5 Deg. F. to 140 Deg. F.).
h. If it meets the above requirements, provide Hawkeye, Kele and Associates model (S)CS1150A, Electromatic SM115, Cymatic 850 Series or approved equal.
I. Relay portion shall not be installed in within the MCC tubs. Relay portion shall be installed in local field panel enclosure, in the DCP/UC enclosure, or in the wiring channel between MCC tubs. Provide device securely mounted with screw type wire terminations. Device shall be mounted for easy access.

22. Water Differential Pressure Sensor

    a. Cast aluminum NEMA 1 enclosure.
    b. Complete with transducer with output of 4-20 mA proportional to the pressure sensed.
    c. Over pressure protection of five times the rated input.
    d. Easily accessible, integral non-interacting zero and span adjustment.
    e. Operating range to suit application.
    f. Accuracy of ± 2% of full scale reading.
    g. Valved tappings shall be installed by the Division 15 subcontractor. Furnish the valves to the Division 15 subcontractor. Provide differential pressure transducer installation complete with a 3-valve manifold mounted within a suitable enclosure. Installation shall allow the transducer to be isolated for service.
    h. If it meets the above requirements, provide Setra, Model 228-1, Veris Industries Alta Labs PW series, Mamac series PR-282, modus or approved equal.

23. Differential Pressure Switch - Air Service - Duct Static Pressure Limit Devices

    a. UL, cUL, CSA listed and approved.
    b. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
    c. Adjustable setpoint with a setpoint range to suit the application.
    d. 1/4 inch compression fittings suitable for copper sensing tubing.
    e. Temperature range of -18 Deg. C. to 71 Deg. C. (0 Deg. F. to 160 Deg. F.).
    f. Manual reset.
    g. Provide sensing inputs complete with signal dampening facilities to prevent nuisance tripping where required.
    h. If it meets the above requirements, provide Kele Model AFS-460, Dwyer, or approved equal.

24. Differential Pressure Switch - Air Service - Filter Status Indication

    a. UL, cUL, CSA listed and approved.
    b. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
    c. Adjustable setpoint with a setpoint range to suit the application.
    d. 1/4 inch compression fittings suitable for copper sensing tubing.
    e. Operating range to suit application.
    f. Automatic reset
    g. If it meets the above requirements, provide devices as manufactured by Cleveland Controls, Inc. (Model AFS-222) Dwyer, or approved equal.

25. Differential Pressure Switch - Water Service

    a. UL, cUL, CSA listed and approved.
    b. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
    c. Adjustable setpoint with a setpoint range to suit the application.
    d. 1/4 inch compression fittings suitable for copper sensing tubing.
    e. Operating temperature and pressure range to suit application.
    f. Durable Nema 4 rated enclosure.
    g. Provide sensing inputs complete with signal dampening facilities to prevent nuisance tripping where required.
    h. Suitable for continuous contact with the sensed fluid and rated for operating temperature.
    i. Repeatability of +/- 1 % of span.
    j. Over pressure input protection to a minimum of five (5) times rated input.
    k. If it meets the above requirements, provide devices as manufactured by Dwyer, Penn, Delta-Pro or approved equal.

26. Water Pressure Sensor

a. Input range of 0 to 200 psi.
b. Complete with transducer with 4-20 mA output signal proportional to water pressure.
c. 0.5% accuracy over entire sensing range.
d. Temperature range of 0 Deg. C. to 38 Deg. C. (32 Deg. F to 100 Deg. F.).
e. Transducer with easily accessible, integral non-interacting zero and span adjustment.
f. Over pressure input protection of two times rated input.
g. NEMA-4 rated fittings.
h. Stainless steel wetted parts.
i. Burst pressure of 5 times rated input
j. Long-term stability of .25 percent of full scale.
k. Shall be ANSI 300 rated. (**********AUTHOR EDIT IF NEEDED**********)
l. If it meets the above requirements, provide Precise Sensor, Fisher/Rosemount, or approved equal.
m. Stainless Steel wetted parts suitable for continuous contact with the sensed medium.

27. Liquid Level Float Switch

a. Polypropylene float, PVC cable, hermetically sealed mercury switch.
b. 13 amp running current @ 120 VAC, 11 amp current @ 240 VAC.
c. SPDT switch contacts. Switch contacts shall be selected to suit required sensing/control action.
d. Operating temperature of 0 Deg. C. to 71 Deg. C. (32 Deg. F. to 160 Deg. F.).
e. Operating pressure of 26 psi.
f. If it meets the above requirements, provide MagneTek, 7010 Series, Scientific Technologies product or W.E. Anderson product, or approved equal.

28. Liquid Level Controller

a. Corrosion resistance, 316 stainless steel.
b. Type E-4 holder with rod electrodes.
c. Pressure tight.
d. Temperature range of 93 Deg. C. to 232 Deg. C. (200 Deg. F. to 450 Deg. F.).
e. Pressure range of 2000 psi @ 93 Deg. C. (200 Deg. F.), and 400 psi @ 232 Deg. C. (450 Deg. F.).
f. Provide suitable stilling well as required.
g. If it meets the above requirements, provide MagneTek, 6012 Series or approved equal.

29. Continuous Liquid Level Sensor (Float Type)

a. Corrosion resistant, 316 stainless steel.
b. Solid state float actuated sensor.
c. Complete with transducer with 4 to 20 mA signal output proportional to sensed level.
d. Temperature range of 32 Deg. F. to 125 Deg. F.
e. Pressure range of 0 to 500 psia.
f. If it meets the above requirements, provide MagneTek, 7025 Series, product or approved equal.

30. Air Quality Sensor

a. Measurement of volatile organic compounds (VOC) containing, at minimum, the following gases:

i. Methane
ii. Ethylene
iii. Hydrogen
iv. Carbon Monoxide
v. Carbon Dioxide
vi. Ammonia

b. Ventilated cover, Circuit board covered by a polycarbonate housing.
c. 135 mA max current, 4 K OHMS min. load resistance, 24 VAC + 10%-50% or 24DC. (Min. 12V, Max 24V) power supply.
d. Rate or rise circuit to filter out short term disturbances and provide a stable output.
e. Temperature range of 0 Deg. C. to 60 Deg. C. (32 Deg. F. to 140 Deg. F.).
f. Mounting and enclosure suitable for duct air or space air monitoring as specified.
g. If it meets the above requirements, provide G-Controls, Model AQS/D or approved equal.

31. Carbon Dioxide Sensor

a. Negligible temperature and humidity effect on accuracy.
b. Complete with transducer with selectable 4-20 mA or 0-10VDC output signal proportional to carbon dioxide concentration.
c. 0 - 2000 ppm CO_2 sensing range.
d. Manufacturer 5 year or longer calibration interval guarantee.
e. Accuracy- ± 3% of reading or ± 50 ppm, whichever is the more stringent requirement over 15 Deg.C. to 32 Deg.C temperature range. (60 Deg.F. to 90 Deg.F.) Accuracy of +/- 5 % or 100ppm of reading whichever is the more stringent requirement over 0 Deg.C. to 50 Deg.C temperature range. (32 Deg.F. to 122 Deg.F.).
f. Annual Drift not to exceed +/- 10 ppm.
g. Operating temperature of 0 Deg. C. to 50 Deg. C. (32 Deg. F. to 122 Deg. F.).
h. Complete with auxillary relay contacts for alarm indication.
i. For space monitoring applications provide with a white enclosure with no manufacturer Logo or LED indication. Provide complete with blank display cover.
j. For duct sensing applications provide sensor complete with aspiration box and air stream sensor.
k. If it meets the above requirements, provide Engelhard 8000 Series or approved equal.
m. Nondispersive Infrared technology based sensor.

32. Damper Position Switch

a. Mechanically actuated electrical switch.
b. Provide damper end switch which indicates actual damper blade position. Damper position switches which are actuated by damper crankshaft or actuator position will not be accepted.
c. Contacts shall be rated for the electrical load to be switched. Provide auxiliary contacts as required.

33. Electronic to Pneumatic Transducers

a. Provide current-to-pneumatic (I/P) transducers for BMS DDC control of pneumatically actuated devices
b. Output range shall be as required for the control device.
c. Provide device mounted within the associated DCP/UC controller panel or remote field panel enclosure mounted adjacent to the associated DCP/UC.

d. Operable temperature range of, at minimum, -10 Deg. C. to 50 Deg. C. with 5% to 90% RH (non-condensing).
e. Internal materials suitable for continuous contact with commercial standard controls air supply.
f. Combined non-linearity, hysteresis and repeatability effects not to exceed +/- 2% of span over the entire range.
g. Integral and accessible zero and span adjustments.
h. Complete with pressure gauge on the pneumatic control output.
i. Capable of accepting a 4-20 mA, 0-10 vdc, or other industry standard control signal and outputting a corresponding proportional output pressure.
j. Capable of manual override of output signal.
k. Provide Triatek Model CP-3000 Series devices or approved equivalent.

F. Install sensors in accordance with the manufacturers recommendations to sense the variables specified.

G. Mount sensors securely. Mountings shall be suitable for the environment within which the sensor operates.

H. Install sensors as required to properly sense the controlled medium. Sensor locations shall be such that access to the instruments can be obtained for service and removal.

I. Sensors mounted on water lines shall have isolation valves that shall enable the sensor to be easily removed without the need to drain any lines or portions of lines.

5. BMS SOFTWARE, DATABASE AND PROGRAMMING REQUIREMENTS

5.1 General

A. The BMS NDS shall be provided complete with fully functional, advanced, BMS Application Software and Database facilities in compliance with the UBC requirements. The building BMS Contractor shall provide all required programming, database development, and data communication configuration work required to incorporate new campus building BMS installations.

B. The NDS computer shall provide the capabilities for automatically archiving controller programming and database, receiving and archiving all operator transactions, trending and archiving of defined BMS data, etc.

C. The NDS and associated application specific BMS Software shall be provided with programming and configuration facilities to allow BMS operators to undertake BMS administration functions including the following:
1. Add/delete/modify data points and input/output points.
2. Configure controller data communications.
3. Add or modify automatic sequence of operations programs, database, etc.
4. Change control system data parameters.
5. Modify setpoints, etc.
6. Restore/download programming and database parameters to BMS controllers.

D. BMS installations shall be provided in a completed state fully ready for integration to the CBMS including all data point definition, addressing, naming, network configuration/connection, documentation, commissioning and training.

E. The BMS Contractor shall include, at minimum, ***two days*** **(*******AUTHOR TO EDIT******)** of work in the BMS installation to work with the CBMS Contractor for the integration of the BMS into the CBMS beyond any time required to make all system data available at the CCP connection to the WAN. The building BMS designer shall assess each installation and specify additional scope of work and time requirements for the BMS Contractor integration work required based on project size and complexity.

F. BMS installations shall be in compliance with the following requirements and shall provide the following functionality:
1. All BMS and CBMS controllers and operator interface workstations shall be devices that are conformal with the BACnet standardized device types described in Annex L of the ASHRAE Standard 135. BMS devices shall, at minimum, support the BIBB's (defined in Annex K of ASHRAE Standard 135) and the associated functionality that are defined as a functional requirement for the device in Annex L of the ASHRAE Standard 135.
2. All BMS controllers, regardless of their device type, shall communicate on the BMS and CBMS networks and shall be "visible" to the CBMS and BMS networks.
3. BMS data shall comply with the BACnet data object property requirements and, at minimum, shall support the properties defined in ASHRAE Standard 135 as "required".
4. All physical BMS monitored input points (binary and analog type) shall be readable and available for monitoring at the CBMS and by other BMS controllers.
5. All physical BMS controlled output points (binary and analog type) shall be readable and available for monitoring at the CBMS and by other BMS controllers and shall be writeable and shall be capable of being controlled/positioned by the CBMS and by other BMS controllers.
6. All software data points and control system parameters critical to the supervisory monitoring and control of the building systems shall be available for monitoring at the CBMS and by other BMS controllers and/or shall be writeable and shall be capable of being controlled/positioned by the CBMS and by other BMS controllers. Provide the following typical software data points and control parameters with the defined

functionality, at minimum. The BMS Specifications shall identify additional points and functionality where required.

a. System enable virtual points.
b. Virtual or "logical" software points.
c. Equipment and System operation Calendar/Time Schedule points and parameters.
d. Post Fire Alarm System Enable/Disable points.
e. Post Power Failure System Enable/Disable points.
f. Control loop setpoints and PID loop values.
g. Alarm setpoints and alarm limit parameters.
h. Define and modify alarm states and alarm limit threshold values for any monitored analog and digital input points and for analog output values.

7. BMS data shall be presented in both tabular "report" format and in dynamic graphical display format at the CBMS. Provide the CBMS with the capabilities for the operator to select between report and graphical data display mode.
8. Modification of the controlled output points shall be via operator interface at the CBMS dynamic report and graphical interface facilities and shall not require BMS manufacturer proprietary software or special configuration software files.
9. Performance times shall be as follows:
   a. Data values updated in dynamic report or graphical display reports within maximum interval of 5 seconds.
   b. Defined high priority or critical alarms annunciated within 3 seconds of it's sensed occurrence.
   c. CBMS Operator command outputs and data point modifications shall be executed within 5 seconds of the command initiation at the CBMS workstation or other remote BMS device.
   d. Failed BMS/CBMS data communications or controller device on the Management Data Communications Level or the Automation Data Communications Level within ten (10) seconds.
10. All BMS standard and proprietary data objects from any BMS connected device shall be available for monitoring on the BMS and CBMS. Values for all BACnet defined required property values, supported optional properties and proprietary properties shall be available to the BMS and CBMS for monitoring and display and control where applicable.
11. The BMS Specifications for each building BMS project shall specify the requirement for the BMS Contractor/Manufacturer to provide all hardware and software required for the CBMS to communicate with the BMS via BACnet IP on the UBC campus WAN. Facilities to be provided shall include any manufacturer specific software tools required for programming, point mapping, configuration, etc. of building BMS data points.

5.2 SOFTWARE

A. An operator with BMS configuration software shall be able to define a minimum time delay between successive starts of equipment so that disturbances created on the building electrical system are minimized in frequency and amplitude.

B. An operator with BMS configuration software shall be able to define the minimum time delay between the stopping of a piece of equipment and its subsequent restart. This time delay shall be in effect for motors in the BMS software control mode and for motors in the BMS manual control mode.

C. The BMS shall not override any hardwired interlocks such as those provided at motor starters for overload protection, damper interlock, pressure interlock, etc. and those provided to facilitate control by the Fire Alarm System regardless of the BMS output control mode.

D. Unless stated to the contrary, the modulation of final control elements by the BMS in the BMS software control mode shall be based on a Proportional-Integral (PI) or Proportional-Integral-Derivative (PID) control algorithm. The control constants for the PID algorithm shall

be definable by the operator. If self-tuning algorithms are provided, it shall still be possible for the operator to manually tune the control loops. The software shall incorporate facilities to enable the bumpless transfer of a modulating output from BMS manual control to BMS software control and vice versa and the prevention of integral wind-up. PID algorithms shall maintain the system operation within the desired tolerance around the setpoint.

E. Provide dynamic graphical trending software at the CBMS that emulates, at minimum, a three point strip chart recorder. This program shall concurrently display three or more plots of variables in a graphical format. The graphs shall be plotted as the values are sampled in a similar fashion to a chart recorder and when the plot reaches the right hand side of the X-axis, the X-axis shall scroll to the left so as to accommodate newly sampled data.

F. Provide an energy monitoring software facility in both the CBMS and BMS NDS to monitor and report electrical energy usage and instantaneous energy demand. This feature shall also store data for recall via the historical data trend package.

G. Provide run time totalizing software facilities at both the CBMS and BMS NDS that will accumulate the operating times for motors and unitary equipment as selected by the operator using an interactive procedure. Any piece of equipment that has its status monitored by the BMS shall be selectable for inclusion in this feature. It shall be possible to concurrently monitor the accumulated operating time for every item of equipment monitored and/or controlled by the BMS. Historical trend data shall be stored in a non-proprietary database such as Microsoft SQL Server in the BMS NDS.

H. Provide demand limiting and duty cycle programs that will duty cycle equipment usage in a manner that conserves energy. The cycling of equipment shall be initiated by one of the following means:

1. Operator defined schedule.
2. Peak electric demand control software program.
3. Operator manual command.

The proportion of ON time to OFF time in a single cycle shall either be assigned by the operator using an interactive procedure or the operator may elect to have a variable ON/OFF ratio based on other criteria.

I. Provide a scheduling program that will enable the BMS to automatically schedule an item of equipment on and off (occupied) and on and off (unoccupied) based on time to allow, for example, the AHU to operate with the outside air dampers closed during non-occupied time periods, etc. The operator shall be able to assign a minimum of four start and four stop times to each piece of equipment for each day of the week and for holidays. These schedules shall only be in effect for a piece of equipment when it is in the BMS software control mode. Equipment and space time occupancy time schedules shall be available for display and operator adjustable via the CBMS. The scheduling feature shall conform to the CBMS scheduling interface.

J. Provide equipment fail restart software that will restart equipment shut down as the result of a fire alarm system following the return to normal conditions or a power fail condition.

K. Provide a night setback software program that shall:

1. Start HVAC equipment after normal hours of scheduled operation to maintain building after hour setpoints, while reducing energy consumption.
2. Night setback temperatures for heating shall be initially set at 55 Deg. F. to activate the heating equipment and 60 Deg. F. to stop the heating equipment. Once activated, the units involved shall operate as specified in the respective sequence of operation. Coordinate the operation of this program with the requirements for terminal unit controls.

3. Night setup temperatures for cooling shall be initially set at 90 Deg. F. to activate the cooling equipment and 85 Deg. F. to stop the cooling equipment. Once activated, the units involved shall operate as specified in the respective sequence of operation. Coordinate the operation of this program with the requirements for terminal unit controls.
4. This feature shall be provided for all HVAC equipment under control of the BMS. The operator shall be able to enable/disable this function on a unit by unit basis.

L. Provide facilities for alarm notification via both the building BMS NDS and the CBMS via e-mail messaging, wireless text messaging and SNMP.

6. CBMS SOFTWARE, DATABASE AND PROGRAMMING REQUIREMENTS

6.1 INTEGRATION OF STANDALONE BUILDING BMS INTO THE CAMPUS BMS

A. The CBMS Contractor shall provide the mapping, storage, and reporting of the building BMS monitoring and control objects into the CBMS and the preparation of data presentation for the CBMS Management Level Network. The BMS Contractor shall provide to the Owner and to the CBMS Contractor, all necessary documentation, BIBB information, device addressing, etc. as required for the integration of the BMS monitoring and control functions into the CBMS.

B. CBMS installations shall be in compliance with the following requirements and shall provide the following functionality:

1. All BMS and CBMS controllers and operator interface workstations shall be devices that are conformal with the BACnet standardized device types described in Annex L of the ASHRAE Standard 135. BMS devices shall, at minimum, support the BIBB's (defined in Annex K of ASHRAE Standard 135) and the associated functionality that are defined as a functional requirement for the device in Annex L of the ASHRAE Standard 135.
2. All BMS controllers, regardless of their device type, shall communicate on the BMS and CBMS networks and shall be "visible" to the CBMS and BMS networks.
3. BMS data shall comply with the BACnet data object property requirements and, at minimum, shall support the properties defined as "required" in ASHRAE Standard 135.
4. All physical BMS monitored input points (binary and analog type) shall be readable and available for monitoring at the CBMS and by other BMS controllers.
5. All physical BMS controlled output points (binary and analog type) shall be readable and available for monitoring at the CBMS and by other BMS controllers and shall be writeable and shall be capable of being controlled/positioned by the CBMS and by other BMS controllers.
6. All software data points and control system parameters critical to the supervisory monitoring and control of the building systems shall be available for monitoring at the CBMS and by other BMS controllers and/or shall be writeable and shall be capable of being controlled/positioned by the CBMS and by other BMS controllers. Provide the following typical software data points and control parameters with the defined functionality, at minimum. The BMS Specifications shall identify additional points and functionality where required.
   a. System enable virtual points.
   b. Virtual or "logical" software points.
   c. Equipment and System operation Calendar/Time Schedule points and parameters.
   d. Post Fire Alarm System Enable/Disable points.
   e. Post Power Failure System Enable/Disable points.
   f. Control loop setpoints and PID loop values.
   g. Alarm setpoints and alarm limit parameters.
   h. Define and modify alarm states and alarm limit threshold values for any monitored analog and digital input points and for analog output values.
7. BMS data shall be presented in both tabular "report" format and in dynamic graphical display format at the CBMS. Provide the CBMS with the capabilities for the operator to select between report and graphical data display mode.
8. Modification of the controlled output points shall be via operator interface at the CBMS dynamic report and graphical interface facilities and shall not require BMS manufacturer proprietary software or special configuration software files.
9. Performance times shall be as follows:
   a. Data values updated in dynamic report or graphical display reports within maximum interval of 5 seconds.
   b. Defined high priority or critical alarms annunciated within 3 seconds of it's sensed occurrence.

c. CBMS Operator command outputs and data point modifications shall be executed within 5 seconds of the command initiation at the CBMS workstation or other remote BMS device.
d. Failed BMS/CBMS data communications or controller device on the Management Data Communications Level or the Automation Data Communications Level within ten (10) seconds.

12. All BMS standard and proprietary data objects from any BMS connected device shall be available for monitoring on the BMS and CBMS. Values for all BACnet defined required property values, supported optional properties and proprietary properties shall be available to the BMS and CBMS for monitoring and display and control where applicable.

6.2 CBMS DYNAMIC SYSTEM GRAPHIC REQUIREMENTS

A. The work of BMS installation projects in UBC Buildings shall include the integration of the building BMS facilities into the CBMS. The integration of the individual building BMS into the campus BMS shall include the provision of BMS System Graphics representative of all BMS monitoring and control facilities/systems. The BMS Designer shall specify detailed requirements for the BMS Graphic Schematics in the BMS/CBMS Design Documents.

B. The CBMS System Graphics shall be fully dynamic colour graphics. Graphics shall be generated in a non-proprietary format such as .dwg, JPEG, TIFF, etc. One graphic shall be provided for each BMS monitored/controlled system. Miscellaneous HVAC and electrical values monitored by the BMS shall be displayed in graphic displays of logical groups of equipment.

C. Graphics shall be provided by the CBMS Contractor and fully integrated into the campus BMS. CBMS System Graphics shall be capable of being displayed at any OWS simultaneously.

D. CBMS System Graphics shall be developed based on UBC standard graphic symbols and colours. All BMS system graphics shall be coordinated with UBC. The Contractor shall submit copies of proposed graphics in the shop drawings for review and approval by the BMS/CBMS Consultant and UBC.

E. CBMS System Graphics shall include the following requirements:

1. All BMS monitored and controlled points shall be displayed on graphics.
2. Graphics shall clearly indicate the fail state position for all BMS controlled devices.
3. Clearly indicate spring ranges on pneumatic actuated valves and dampers.
4. Graphical representation of controlled device position based on spring/control range.
5. Monitored value units displayed. For BMS monitored temperature values an icon indicating temperature units shall be provided.
6. Spring ranges displayed for all controlled devices.
7. Values/icons for points which are placed in an override state by Operator command shall be displayed in the colour orange.
8. Display System Name and location.

F. Equipment/devices shall be colour coded as follows:

1. Red - Hot Water piping with yellow direction of flow arrows.
2. Blue - Chilled Water piping.
3. Light Blue - Condenser Water piping.
4. Yellow - Steam.
5. Brown - Condensate.

G. BMS analog input and analog output point information shall be displayed as follows:

1. Point Name

2. Expanded Descriptor
3. Automatic Control Priority (Overridden Value, Automatic Control, Disabled, failed, etc.)
4. Actual point monitored input / controlled output value.

H. BMS digital input and digital output point information shall be displayed as follows:

1. Point Name.
2. Expanded Descriptor.
3. Automatic Control Priority (Overridden On/Off, Automatic Control, Disabled, failed, etc.)
4. Point status.

I. Controlled variables shall have the following information displayed:

1. Set point.
2. Actual value.
3. Alarm limit ranges.
4. Facilities shall be provided to override the set point value via a graphical interface in the associated BMS System Graphic.

J. BMS System Graphics shall be provided as follows:

1. Floor Plans for all building project areas. One graphic per floor level. Floor plans shall indicate the associated AHU service domains. AHU Service domains shall be colour coded.
2. Space temperature, relative humidity, static pressure, air quality sensors, etc. mounted throughout the project spaces shall be displayed on the floor plan system graphic.
3. Building areas equipped with BMS zone space temperature control facilities shall have a dynamic link to a separate individual graphic for each terminal unit controller.
4. Floor plans shall reflect normal/alarm status for BMS monitored/controlled points based on the following colour codes:

    a. Green- Device On and operating under “normal” automatic control priority.
    b. Yellow - Critical Alarm Condition.
    c. Blue - Device Off and operating under “normal” automatic control priority.
    d. Orange - General Alarm Condition.
    e. Aqua Blue - Point Trouble Condition.
    f. Red - Immediate Response Alarm Condition.

5. BMS System Graphic shall be provided for each Mechanical and Electrical Equipment Room indicating the BMS monitored/controlled equipment locations.

6. BMS System Graphics shall be provided for all BMS monitored/controlled equipment mounted on building rooftops and exterior building areas.

7. Outside Air Temperature and Relative Humidity shall be displayed on all HVAC System graphic schematics.

6.3 ALARM MANAGEMENT AND ANNUNCIATION

A. Alarms shall be generated by the BMS and shall be annunciated at the CBMS upon the occurrence of one of the following events:

1. Failure of a CCP, DCP, UC, or any other BMS hardware components.
2. Failure of communications or devices on the Automation Level Network.
3. A monitored status indicates a discrepancy between the actual and the required value.
4. A monitored value does not meet criteria established by the operator.
5. The deviation of a variable from setpoint exceeds operator established criteria.

6. The output to a final control element is outside operator established criteria.
7. A digital input is in the state defined by the operator as indicating an alarm condition.
8. Software failures and errors shall be diagnosed and annunciated by the BMS.

Provide configuration of alarming for all monitored and controlled points. BMS Specifications shall detail all required alarm states, values and limits.

B. BMS alarms shall be assigned priority levels as follows:
   1. Priority Level 1 – Critical Alarms:
      a. Sump high level status event
      b. Fire Alarm status event
      c. AHU low temperature detection device event
      d. Main Breaker power fail status event
      e. Generator fault condition
      f. Diesel Tank Storage Tank leak detection event.
      g. ***XXXX UBC Additional Requirements***
   2. Priority Level ? - XXXXXX

C. Defined BMS alarm events shall be communicated by the BMS to the CBMS. Defined alarms shall be annunciated at the CBMS workstation. Alarms shall be retained in the CBMS alarm summary.

6.5 TESTING AND COMMISSIONING REQUIREMENTS

A. Integrated BMS/CBMS joint systems tests shall be undertaken to demonstrate that the interaction between the individual building BMS and the CBMS meets the UBC requirements. The BMS Subcontractor shall participate in joint verification of the integrated systems and cooperate with the Owner in the demonstration of the integrated systems.

B. The BMS Specifications shall specify the requirements for the BMS/CBMS integration joint systems verification in the BMS and CBMS Specifications and/or Contract Documents. The BMS/CBMS Integrated System Verification shall include the following minimum requirements:

   1. Test all BMS monitored and controlled field devices, BMS data points and all BMS input and output points. CBMS monitored data point values shall be verified against actual field device position/state and compared to BMS values to ensure both BMS and CBMS values are the same.
   2. CBMS override control of all BMS output points and control data points shall be verified.
   3. BMS network and controller device status and data communications status are accurately monitored at the CMBS. Alarms for failed controllers and failed data communications are annunciated.
   4. BMS data values displayed on dynamic system graphics or in tabular data format at the CBMS are functional and accurate.
   5. CBMS operator control of BMS control output points and control data points is functional via the dynamic graphic interface.
   6. CBMS facilities for operator adjustment of alarm definition parameters and thresholds, setpoint adjustment, control parameter adjustments, point trend initiation and modification to trends, etc. are fully functional.
   7. The CBMS performance requirements for the monitoring and control of BMS data and field devices meet the UBC requirements.
   8. BMS device addressing and identification definitions are compatible and identical and the addressing scheme meets with UBC requirements.
   9. Point naming used is compatible and conformal with the UBC requirements.

C. Test results shall be documented using test sheets. The test sheets shall be prepared in an appropriate format for the various categories of component and system to be tested. It is the responsibility of the BMS Subcontractor to provide test verification sheets for

each component and system that accurately reflect the sequences of operation and appropriate data for the components and systems.

D. All test documentation shall be maintained in electronic format and in hard copy.

CBMS/BMS ALARM HANDLING ARCHIVING REQUIREMENTS TO BE COMPLETED.

UBC BMS POINT NAMING CONVENTIONS REQUIREMENTS

UBC BMS CONTROLLER AND DEVICE ADDRESSING AND NAMING CONVENTION REQUIREMENTS

7. GUIDELINES FOR APPLICATION OF BMS TO TYPICAL HVAC SYSTEMS

7.1 BMS Sequences of Operation, Field Termination Schedules, and System Schematic Diagrams

A. This section of the UBC BMS Design Guidelines identifies BMS monitoring and control requirements for typical building HVAC Systems and includes “sequences of operation” for typical building systems. BMS design specifications for all UBC BMS projects shall include BMS Sequences of Operation detailing the BMS monitoring and automatic control logic programming requirements. BMS Sequences of Operation to be provided in BMS Design Specifications shall be in the same format as the sequences of operation identified within these guidelines.

B. BMS Design Specifications for UBC BMS projects shall detail BMS monitoring and control requirements in Field Termination Schedules and System Schematic Diagrams. Field Termination Schedules and System Schematic Diagrams shall be provided for all BMS monitored and controlled equipment and systems. The Field Termination Schedules and System Schematics shall be provided for each building system and logical group of monitored and controlled equipment. The Field Termination Schedules and System Schematics shall clearly identify BMS monitoring and control requirements and shall be labelled and cross reference the associated sequences of operation. Examples of Field Termination Schedules and System Schematic Diagrams are included in Appendix A1 of these guidelines. Field Termination Schedules and System Schematic Diagrams provided in UBC project BMS Design Specifications shall be based on the same format as indicated within these documents.

C. Sequences of Operation for typical UBC building HVAC systems are identified within this section. Refer to Appendix A1 of these guidelines for the associated building system Field Termination Schedule and System Schematic Diagrams.

D. BMS automatic control of building systems and equipment shall not override life safety or equipment protection overrides. The BMS Design Consultant shall specify automatic control interface requirements.

7.2 BMS Component and Building Equipment Failure Requirements

A. The BMS Design Specifications shall clearly specify building system/equipment control requirements in the event of failure of BMS components and in the event of failure of building equipment. The following are general minimum component/equipment failure requirements.

1. DCP/UC Controller Failure

a. associated BMS controlled electric motors/equipment off.
b. AHU mixing dampers to full recirculation position.
c. steam control valves closed.
d. hot water control valves open.
e. cooling coil control valves closed.
f. fan/pump speeds set to minimum position.
g. fan/pump volume flow rate control devices (e.g. inlet vanes, etc.) set to no-load position.
h. isolation dampers closed.
i. exhaust dampers and outside air dampers closed.

2. BMS Analog Input Sensor Failure

a. Associated BMS control output retained in last commanded state. If an alternative sensor can be utilized for satisfactory control the BMS shall incorporate automatic control logic to implement the revised control.
b. Failure of information only type BMS input points shall be annunciated as alarms.

3. Controlled Electric Motor/Equipment Failure

   a. Anytime the status of BMS controlled equipment is different than the associated BMS controlled output status the equipment shall be considered as "failed" and shall be shut down by the BMS. The associated BMS controlled system shall also be shut down. Systems and equipment shut down by the BMS as the result of failed components shall require a manual Operator command to acknowledge the failed equipment alarm and shall require a manual Operator command to restart the system/equipment. BMS controlled equipment/systems shut down as the result of a failed component shall not be automatically restarted by the BMS.

   b. Where building systems/equipment are shut down by the by the fire alarm system in an alarm condition or are shut down as the result of a building power failure, the BMS shall restart the failed equipment/systems in an orderly and pre-defined manner following a manual Operator command. The BMS Design Specifications shall specify the post fire alarm equipment restart and the post power failure equipment restart requirements.

   c. All BMS component failures shall be annunciated as an alarm at the defined BMS main central computer facility.

4. If a BMS controlled motor or equipment fails to start as defined in the sequences of operation, the failure shall be annunciated as an alarm and the associated system shut down.

7.3 BMS Automatic Sequenced Control of AHU Mixing Dampers and Valves

A. Designated air handling units require the BMS to control heating and cooling coil control valves and mixing dampers in sequence. BMS facilities shall be provided as follows for air handling units with sequenced control of the heating coil valves, cooling coil valves, and the mixing dampers:

1. The mixing dampers (return air, outside air and exhaust air (where applicable)) shall be modulated in unison to maintain the supply air temperature setpoint. If the supply air temperature setpoint cannot be maintained then the heating coil control valve or the cooling coil control valve shall be modulated in sequence with the mixing dampers to maintain the supply air temperature setpoint. If heating is required the dampers shall be in the minimum outside air position and the heating coil control valve shall be modulated to maintain the supply air temperature setpoint. If cooling is required and the outside air temperature is less than the return air temperature and greater than the supply air temperature setpoint, the outside air dampers shall be fully open and the chilled water cooling coil valve shall be modulated to maintain the supply air temperature. When the outside air temperature is greater than the supply air temperature setpoint and greater than the return air temperature the mixing damper shall be in the minimum outside air position and the chilled water cooling coil control valve shall be modulated to maintain the supply air temperature. When the outside air temperature is less than the supply air temperature setpoint the mixing dampers shall be modulated to maintain the supply air temperature. The intent is that free cooling shall be provided whenever possible. There shall be no simultaneous heating and cooling. Mixing damper control based on supply air temperature setpoint shall be overridden when necessary to satisfy minimum outside air requirements.

7.4 General BMS Monitoring and Control Requirements

A. All BMS alarm limit values and setpoints shall be on-line adjustable by a BMS Operator with the appropriate password access level.

B. All BMS Operator monitoring and control functions shall be provided with the appropriate password access control.

C. A single BMS software control point shall be provided for each BMS controlled system to enable/disable automatic start-up and control of the entire system. BMS controlled systems shall be capable of being started/stopped either by automatic BMS control or via online Operator command.

7.5 Post Fire Alarm Equipment Restart

A. Fire Alarm Systems in buildings will override BMS control of designated equipment in an alarm condition. The BMS shall monitor a set of contacts output from the fire alarm system for status indication of a building fire alarm. The BMS Controls Contractor shall coordinate building equipment that is shut down by the Fire Alarm System.

B. Upon detection of air handling unit shutdown the BMS shall close associated valves and stop associated pumps.

D. Alarms shall be annunciated by the BMS to indicate the equipment failure/shut down and the building fire alarm condition. The BMS shall not annunciate nuisance alarms for monitored input points on systems shut down by the BMS or fire alarm system (e.g. high supply air temperature, low duct static pressure, etc.).

C. Equipment shut down by the fire alarm system shall not be automatically restarted. The BMS shall not restart the equipment until the following:

1. Building fire alarm condition has been cleared.
2. BMS Operator acknowledges the fire alarm.
3. BMS Operator with appropriate access level resets the BMS system shut down software point.
4. BMS Operator with appropriate access level commands a single “Post Fire Alarm Equipment Restart” software command point.

D. Once the above conditions have been satisfied and the BMS receives a Post Fire Alarm Equipment restart command the BMS shall initiate the restart of any equipment shut down by the fire alarm system. The restart sequence shall provide an orderly start-up of the motors for each individual system with time delay between restarts of individual systems. Start of systems shall be according to normal system start up sequences. Only those motors which should be operational in accordance with the Occupancy Schedule or application software programming requirements shall be restarted.

7.6 Post Building Power Failure Equipment Restart

A. Power failures in buildings will result in building equipment shutting down. The BMS shall monitor building electrical distribution equipment status for indication of a building power failure condition. Some building equipment will be serviced with emergency power and UPS power supplies. The BMS Controls Contractor shall coordinate building equipment that is serviced with emergency and UPS power supplies.

B. Post Building Power Failure Equipment Restart facilities shall be provided to ensure the controlled and orderly start up of building equipment following a power failure. The Post Building Power Failure Equipment Restart facilities shall be provided based on the requirements identified above for the Post Fire Alarm Equipment Restart.

7.7 Air Handling Unit Optimum Start and Stop Programs

A. Air handling system shall be started by the BMS according to defined Occupancy Operating Schedules. These schedules exclude the time required for optimum start periods. Heating shall start in order to provide a minimum space temperature in all rooms of 20 Deg. C. by the

beginning of assigned Occupancy Period with the mixing dampers in the "full recirculation" position. Cooling shall start in order to provide a maximum space temperature in all rooms of 22 Deg. C. by the beginning of the assigned Occupancy Period with the mixing dampers in the "full recirculation" position. The system shall stop at the end of the assigned Occupancy Period and return to the state described in B. above.

7.8 After-hours Equipment Operation

A. Designated air handling systems shall be off during Unoccupied Periods if all space temperatures are above 15 Deg. C. If any space temperature falls below 15 Deg. C. the system shall be started and operate with the mixing dampers in the full recirculation position, the heating pump on and the heating coil valve fully open to flow through the coil. The system shall return to the off position as described in B. above when all space temperatures are above 16 Deg. C.

7.9 Air Handling Unit Supply Air Temperature Reset Schedules

A. The BMS typically controls air handling unit equipment to maintain supply air temperature conditions from air handling units. Typical UBC building air handling units may be provided with facilities to automatically reset the supply air temperature setpoint. UBC air handling unit supply air temperature setpoints are reset based on criteria specific to each application. The BMS designer shall specify setpoint reset facilities to suit the specific application and shall coordinate the reset schedules and setpoint values with UBC, the Architect and the associated mechanical engineer.

B. The following are a number of BMS air handling unit control applications and associated supply air temperature reset schedule schemes that may be applied:

1. Constant Volume Air Handling Unit, No BMS secondary controls, adequate BMS space temperature sensors.
   a. BMS to average space temperature values and reset supply air temperature based on an Average space temperature schedule.

Average Space Temperature	Supply Air Temperature Setpoint
20 Deg.C.	?? Deg.C.
24 Deg.C.	?? Deg. C.

2. Constant Volume Air Handling Unit, No BMS secondary controls, insufficient space temperature monitoring.

   a. BMS to reset supply air temperature based on return air temperature reset schedule.

Return Air Temperature	Supply Air Temperature Setpoint
20 Deg.C.	?? Deg.C.
24 Deg.C.	?? Deg. C.

3. Constant or Variable Air Volume Air Handling Unit with BMS secondary controls.

   a. BMS to control to design supply air temperature setpoint. BMS to adjust supply air temperature setpoint to maintain the zone with the greatest demand for cooling as determined by terminal unit damper positions and terminal unit reheat coil control valve positions.

7.10 Dynamic Mixed Air Calculations and Mixing Damper Minimum Outside Air Positioning

A. BMS mixed air calculation facilities shall be provided to dynamically calculate the percentage of outside air flow rate entering air handling units with mixing damper sections (outside air damper, return air damper and exhaust air where applicable). The dynamic mixed air

calculations shall be based on the relationship between BMS monitored values for outside air temperature, mixed air temperature, and return air temperature.

B. The BMS shall override normal BMS minimum outside air damper position control to maintain specified outside air flow requirements based on the dynamic mixed air calculations. The BMS shall implement control strategies to override normal mixing damper control to maintain specified minimum outside air requirements only when the outside air temperature is less than the return air temperature by 10 Deg.C. or more. The BMS shall also limit mixing damper control to prevent the mixed air temperature from falling below 6 Deg.C. Mixing damper settings shall be verified during the Warranty period following a seasonal change.

7.11 Typical Sequence of Operation - Constant Volume Air Handling Unit (AH1)

A. Refer to FTS-0, SD-01.

B. System Off - When the system is off:

1. The return fan shall be off.
2. The supply fan shall be off.
3. The heating coil pump shall be off if outdoor air temperature is above 15 Deg.C. and shall remain on whenever the outside air temperature is below 15 Deg.C.
4. The mixing dampers shall be in the full recirculation position.
5. The cooling coil control valve shall be closed.
6. The heating coil control valve shall be closed to flow through the coil.
7. The steam humidifier control valve shall be closed.
7. System control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. Return fan shall be started with the mixing dampers in the full recirculation position.
2. Following proof of return fan operation and a time delay, initially set at one (1) minute, the supply fan shall be started.
3. Upon proof of supply fan operation and following a time delay initially set at two (2) minutes the mixing dampers shall be positioned in the minimum outside air position and the control loops shall be enabled.

E. System Operation:

1. The mixing dampers (outside air damper, return air damper and exhaust air damper) shall be modulated in unison via single analog output MDC.
2. The mixing dampers shall be modulated in sequence with the heating coil control valve and the cooling coil control valve to maintain the supply air temperature setpoint. The supply air temperature setpoint shall be reset according to (BMS DESIGNER TO IDENTIFY RESET REQUIREMENTS).
3. Override control of the mixing damper positions shall be provided based on dynamic mixed air calculations.
4. The heating coil pump shall be started/stopped by the BMS based on the heating coil control valve position. The pump shall be started on a requirement for heat prior to the heating valve be modulated open and shall be stopped when the valve has been modulated closed. Minimum run times and minimum off times shall be provided to prevent pump cycling.
5. The BMS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BMS shall open the humidifier two-position steam control valve whenever humidification is required, the associated air handling unit supply fan is in operation, and the cooling coil control valve is closed. Upon opening the two-position steam control valve the BMS shall enable automatic modulating

control of the humidifier steam control valve. The BMS shall modulate the humidifier steam control valves to maintain the zone relative humidity setpoint. The zone relative humidity shall be the average of the values of the space relative humidity sensors in a zone. The zone relative humidity setpoint shall be reset according to the following outside air temperature/space relative humidity reset schedule:

Outside Air Temperature	Space Relative Humidity Setpoint
-10 Deg. C	35%
25 Deg. C	50%

The BMS shall monitor the supply air relative humidity. The BMS shall limit the humidifier steam control valve position to maintain the supply air relative humidity to no greater than 80%. An alarm shall be generated and the associated steam control valve shall be closed if the supply air relative humidity remains above 85% for longer than ten minutes.

F. System Shut Down:

1. System shut down shall be initiated by automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.
3. The BMS shall shut down supply fan, position the mixing dampers to the full recirculation position and generate an appropriate alarm message on detection of a supply or mixed air temperature of less than 5 Deg. C. The return fan shall remain on. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. The low temperature detection device shall be hardwire interlocked to shut down the supply fan and position the mixing dampers to the full recirculation position whenever a duct air temperature of 5 Deg. C. or lower is sensed. The return fan shall remain in operation. Device shall be manual reset. The BMS shall monitor the status of the low temperature detection device and shall annunciate an alarm in a low temperature condition.

2. Provide a hardwired supply air relative humidity high limit controller to override BMS control of the humidifier steam valve in a high supply air relative humidity condition initially set at 90% RH. The humidification control valve shall be closed until supply air relative humidity has dropped 20% below alarm value. Provide the hardwired supply air R.H. high limit controller complete with an auxiliary set of dry contacts for alarm monitoring by the BMS.

7.12 Typical Sequence of Operation - Constant Volume Air Handling Unit - hardwire interlocked RF (AH2)

A. Refer to FTS-02, SD-02.

B. System Off - When the system is off:

1. The return fan shall be off.
2. The supply fan shall be off.
3. The heating coil pump shall be off if outdoor air temperature is above 15 Deg.C. and shall remain on whenever the outside air temperature is below 15 Deg.C.
4. The mixing dampers shall be in the full recirculation position.
5. The cooling coil control valve shall be closed.
6. The heating coil control valve shall be closed to flow through the coil.

7. The steam humidifier control valve shall be closed.
7. System control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. Supply fan shall be started with the mixing dampers in the full recirculation position.
2. The return fan shall be hardwire interlocked to start/stop with the associated air handling unit supply fan. The return fan shall be on when the supply fan is on and shall be off when the supply fan is off.
3. Upon proof of supply fan operation and following a time delay initially set at two (2) minutes the mixing dampers shall be positioned in the minimum outside air position and the control loops shall be enabled.

E. System Operation:

1. The mixing dampers (outside air damper, return air damper and exhaust air damper) shall be modulated in unison via single analog output MDC.
2. The mixing dampers shall be modulated in sequence with the heating coil control valve and the cooling coil control valve to maintain the supply air temperature setpoint. The supply air temperature setpoint shall be reset according to (BMS DESIGNER TO IDENTIFY RESET REQUIREMENTS).
3. Override control of the mixing damper positions shall be provided based on dynamic mixed air calculations.
4. The heating coil pump shall be started/stopped by the BMS based on the heating coil control valve position. The pump shall be started on a requirement for heat prior to the heating valve being modulated open and shall be stopped when the valve has been modulated closed. Minimum run times and minimum off times shall be provided to prevent pump cycling.
5. The BMS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BMS shall open the humidifier two-position steam control valve whenever humidification is required, the associated air handling unit supply fan is in operation, and the cooling coil control valve is closed. Upon opening the two-position steam control valve the BMS shall enable automatic modulating control of the humidifier steam valve. The BMS shall modulate the humidifier steam control valve to maintain the zone relative humidity setpoint. The zone relative humidity shall be the average of the values of the space relative humidity sensors in a zone. The zone relative humidity setpoint shall be reset according to the following outside air temperature/space relative humidity reset schedule:

Outside Air Temperature	Space Relative Humidity Setpoint
-10 Deg. C	35%
25 Deg. C	50%

The BMS shall monitor the supply air relative humidity. The BMS shall limit the humidifier steam control valve position to maintain the supply air relative humidity to no greater than 80%. An alarm shall be generated and the associated steam control valve shall be closed if the supply air relative humidity remains above 85% for longer than ten minutes.

F. System Shut Down:

1. System shut down shall be initiated by automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.

3. The BMS shall shut down supply fan, position the mixing dampers to the full recirculation position and generate an appropriate alarm message on detection of a supply or mixed air temperature of less than 5 Deg. C. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. The low temperature detection device shall be hardwire interlocked to shut down the supply fan and position the mixing dampers to the full recirculation position whenever a duct air temperature of 5 Deg. C. or lower is sensed. The return fan shall remain in operation. The BMS shall monitor the status of the low temperature detection device and shall annunciate an alarm in a low temperature condition.

2. Provide a hardwired supply air relative humidity high limit controller to override BMS control of the humidifier steam valve in a high supply air relative humidity condition initially set at 90% RH. The humidification control valve shall be closed until supply air relative humidity has dropped 20% below alarm value. Provide the hardwired supply air R.H. high limit controller complete with an auxiliary set of dry contacts for alarm monitoring by the BMS.

7.13 Typical Sequence of Operation - Variable Volume Air Handling Unit (AH3)

A. Refer to FTS-03, SD-03.

B. System Off - When the system is off:

1. The return fan shall be off.
2. The supply fan shall be off.
3. The heating coil pump shall be off if outdoor air temperature is above 15 Deg.C. and shall remain on whenever the outside air temperature is below 15 Deg.C.
4. The mixing dampers shall be in the full recirculation position.
5. The cooling coil control valve shall be closed.
6. The heating coil control valve shall be closed to flow through the coil.
7. The steam humidifier control valve shall be closed.
8. VSD's shall be set to the minimum speed.
8. System control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. Return fan shall be started at minimum speed with the mixing dampers in the full recirculation position.
2. Following proof of return fan operation and a time delay, initially set at ten seconds, the supply fan shall be started in minimum speed.
3. Upon proof of supply fan operation, and following a time delay, initially set at ten seconds, the supply and return fan speeds shall be ramped to the 40% air volume position and the supply and return fan automatic variable speed controls shall be enabled. The fan variable speed drive outputs shall be ramped up over a 300 second time period from the minimum 40% air volume position until the ramp output equals the associated duct static pressure control loop output at which time the control outputs shall be released to automatic BMS control.
4. Upon proof of supply fan operation and following a time delay, initially set at two (2) minutes, the mixing dampers shall be positioned in the minimum outside air position and the control loops shall be enabled.

E. System Operation:

1. The BMS shall modulate the supply air fan speed to maintain the supply air static pressure setpoint. Supply air static pressure high limit software facilities shall be provided to limit the supply fan speed to prevent excessively high supply air static pressures. The supply air static pressure setpoint shall be Operator adjustable and initially set at ??? Pa. The return fan speed shall be modulated to maintain an Operator definable percentage difference between the supply and return air volume flowrates. Initially the return air volume flowrate shall be maintained at 10% less than the supply air volume flowrate.
2. The mixing dampers (outside air damper, return air damper and exhaust air damper) shall be modulated in unison via single analog output MDC.
3. The mixing dampers shall be modulated in sequence with the heating coil control valve and the cooling coil control valve to maintain the supply air temperature setpoint. The supply air temperature setpoint shall be reset according to (BMS DESIGNER TO IDENTIFY RESET REQUIREMENTS).
4. Override control of the mixing damper positions shall be provided based on dynamic mixed air calculations.
5. The heating coil pump shall be started/stopped by the BMS based on the heating coil control valve position. The pump shall be started on a requirement for heat prior to the heating valve being modulated open and shall be stopped when the valve has been modulated closed. Minimum run times and minimum off times shall be provided to prevent pump cycling.
6. The BMS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BMS shall open the humidifier two-position steam control valve whenever humidification is required, the associated air handling unit supply fan is in operation, and the cooling coil control valve is closed. Upon opening the two-position steam control valve the BMS shall enable automatic modulating control of the humidifier steam control valve. The BMS shall modulate the humidifier steam control valve to maintain the zone relative humidity setpoint. The zone relative humidity shall be the average of the values of the space relative humidity sensors in a zone. The zone relative humidity setpoint shall be reset according to the following outside air temperature/space relative humidity reset schedule:

Outside Air Temperature	Space Relative Humidity Setpoint
-10 Deg. C	35%
25 Deg. C	50%

The BMS shall monitor the supply air relative humidity. The BMS shall limit the humidifier steam control valve position to maintain the supply air relative humidity to no greater than 80%. An alarm shall be generated and the associated steam control valve shall be closed if the supply air relative humidity remains above 85% for longer than ten minutes.

F. System Shut Down:

1. System shut down shall be initiated by automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall ramp down the supply and return fan speeds and return the system to the state described for System Off.
3. The BMS shall shut down supply fan, position the mixing dampers to the full recirculation position and generate an appropriate alarm message on detection of a supply or mixed air temperature of less than 5 Deg. C. The return fan shall remain on and shall be set to a operator adjustable speed, initially set at 65 % air volume. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. The low temperature detection device shall be hardwire interlocked to shut down the supply fan and position the mixing dampers to the full recirculation position whenever a duct air temperature of 5 Deg. C. or lower is sensed. The return fan shall remain in operation and shall be set to a operator adjustable speed, initially set at 65 % air volume. Device shall be manual reset. The BMS shall monitor the status of the low temperature detection device and shall annunciate an alarm in a low temperature condition.

2. Provide a hardwired supply air relative humidity high limit controller to override BMS control of the humidifier steam valve in a high supply air relative humidity condition initially set at 90% RH. The humidification control valve shall be closed until supply air relative humidity has dropped 20% below alarm value. Provide the hardwired supply air R.H. high limit controller complete with an auxiliary set of dry contacts for alarm monitoring by the BMS.

3. Provide duct static pressure high limit devices in the supply and return air ducts to shut down the associated fans and the air handling unit system in a high duct static pressure condition. Devices shall be manually reset.

7.14 Typical Sequence of Operation - VAV Outside Air AHU (AH4)

A. Refer to FTS-04, SD-04.

B. System Off - When the system is off:

1. The exhaust fan shall be off.
2. The supply fan shall be off.
3. The heating coil pump shall be off if outdoor air temperature is above 15 Deg.C. and shall remain on whenever the outside air temperature is below 15 Deg.C.
4. The outside air dampers and the exhaust air dampers shall be fully closed.
5. The cooling coil control valve shall be closed.
6. The heating coil control valve shall be closed to flow through the coil.
7. The steam humidifier control valves shall be closed.
8. VSD's shall be set to the minimum speed.
8. System control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. The BMS shall output a start command to the supply fan variable speed drive motor control circuit. The supply fan shall be started in minimum speed. Provide the damper actuator(s) on the outside air dampers hardwire interlocked with the supply fan such that the dampers are commanded fully open on a start command and are closed when the supply fan is commanded off. Provide damper end switches on the outside air damper sections hardwire interlocked with the supply fan motor control circuit such that the supply fan can not operate unless the dampers are in the fully open position. Provide the end switches hardwire interlocked into both the hand and auto legs of the hand/off/auto motor control circuit to prevent fan operation without the dampers fully open.
2. Following proof of supply fan operation and a time delay, initially set at thirty seconds, the BMS shall output a start command to the exhaust fan variable speed drive motor control circuit. The exhaust fan shall be started in minimum speed. Provide the damper actuator(s) on the exhaust air dampers hardwire interlocked with the exhaust fan such that the dampers are commanded fully open on a start command and are closed when the exhaust fan is commanded off. Provide damper end switches on the exhaust air damper sections hardwire interlocked with the exhaust fan motor control circuit such that the exhaust fan can not operate unless the dampers are in the fully open position. Provide the end switches hardwire interlocked into both the hand and

auto legs of the hand/off/auto motor control circuit to prevent fan operation without the dampers fully open.

3. Upon proof of supply fan operation, and following a time delay initially set at ten seconds, the supply fan speed shall be ramped to the 40% air volume position and the supply fan automatic variable speed controls shall be enabled. The fan variable speed drive outputs shall be ramped up over a 300 second time period from the minimum 40% air volume position until the ramp output equals the associated duct static pressure control loop output at which time the control output shall be released to automatic BMS control.
4. Upon proof of exhaust fan operation, and following a time delay initially set at ten seconds, the exhaust fan speed shall be ramped to the 40% air volume position and the exhaust fan automatic variable speed controls shall be enabled. The fan variable speed drive outputs shall be ramped up over a 300 second time period from the minimum 40% air volume position until the ramp output equals the associated duct static pressure control loop output at which time the control output shall be released to automatic BMS control.
5. Upon proof of supply and exhaust fan operation the remaining automatic control loops shall be enabled.
6. On a system start-up if the outside air temperature is less than 6 Deg.C., the BMS shall position the heating coil control valve to the 30 % open position sixty seconds prior to issuing the supply fan start command. Valve control shall be released when automatic controls are enabled.

E. System Operation:

1. The BMS shall modulate the supply air fan speed to maintain the supply air static pressure setpoint. Supply air static pressure high limit software facilities shall be provided to limit the supply fan speed to prevent excessively high static pressures. The supply air static pressure setpoint shall be Operator adjustable and initially set at ??? Pa.
2. The exhaust fan speed shall be modulated to maintain the exhaust air static pressure setpoint. Exhaust air static pressure low limit software facilities shall be provided to limit the exhaust fan speed to prevent excessively low static pressures. The exhaust air static pressure setpoint shall be Operator adjustable and initially set at ??? Pa.
3. The heating coil control valve and the cooling coil control valve shall be modulated in sequence to maintain the supply air temperature setpoint. The supply air temperature setpoint shall be reset according to (BMS DESIGNER TO IDENTIFY RESET REQUIREMENTS).
4. The heating coil pump shall be started/stopped by the BMS based on the heating coil control valve position. The pump shall be started on a requirement for heat prior to the heating valve being modulated open and shall be stopped when the valve has been modulated closed. Minimum run times and minimum off times shall be provided to prevent pump cycling.
5. The BMS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BMS shall open the humidifier two-position steam control valve whenever humidification is required, the associated air handling unit supply fan is in operation, and the cooling coil control valve is closed. Upon opening the two-position steam control valve the BMS shall enable automatic modulating control of the humidifier steam control valve. The BMS shall modulate the humidifier steam control valve to maintain the zone relative humidity setpoint. The zone relative humidity shall be the average of the values of the space relative humidity sensors in a zone. The zone relative humidity setpoint shall be reset according to the following outside air temperature/space relative humidity reset schedule:

Outside Air Temperature	Space Relative Humidity Setpoint
-10 Deg. C	35%
25 Deg. C	50%

The BMS shall monitor the supply air relative humidity. The BMS shall limit the humidifier steam control valve position to maintain the supply air relative humidity to no greater than 80%. An alarm shall be generated and the associated steam control valve shall be closed if the supply air relative humidity remains above 85% for longer than ten minutes.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall ramp down the supply and exhaust fan speeds and return the system to the state described for System Off.
3. The BMS shall shut down the supply fan and the exhaust fan and generate an appropriate alarm message on detection of a supply air temperature of less than 5 Deg. C. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. The low temperature detection device shall be hardwire interlocked to shut down the supply fan and close the outside air dampers whenever a duct air temperature of 5 Deg. C. or lower is sensed. The BMS shall shut down the exhaust fan and close the exhaust air dampers when a low temperature condition is sensed. Device shall be manual reset. The BMS shall monitor the status of the low temperature detection device and shall annunciate an alarm in a low temperature condition.

2. Provide a hardwired supply air relative humidity high limit controller to override BMS control of the humidifier steam valve in a high supply air relative humidity condition initially set at 90% RH. The humidification control valve shall be closed until supply air relative humidity has dropped 20% below alarm value. Provide the hardwired supply air R.H. high limit controller complete with an auxiliary set of dry contacts for alarm monitoring by the BMS.

3. Provide static pressure high limit devices in the supply air duct hardwire interlocked to shut down the associated fan and the air handling unit system in a high static pressure condition. Provide duct static pressure low limit devices in the exhaust air ducts to shut down the associated fan and the air handling unit system in a low duct static pressure condition. Devices shall be manually reset.

4. Provide outside air and exhaust air damper actuators hardwire interlocked with the associated fan motor control circuit as indicated above.

5. Provide damper end switches on the outside air and exhaust air dampers hardwire interlocked with the associated fan motor control circuit as indicated above.

7.15 Typical Sequence of Operation - Make-up Air AHU (AH5)

A. Refer to FTS-05, SD-05.

B. System Off - When the system is off:

1. The supply fan shall be off.
2. The heating coil pump shall be off if outdoor air temperature is above 15 Deg.C. and shall remain on whenever the outside air temperature is below 15 Deg.C.
3. The outside air dampers shall be fully closed.
4. The heating coil control valve shall be closed to flow through the coil.
5. System control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. The BMS shall output a start command to the supply fan motor control circuit. Provide the damper actuator(s) on the outside air dampers hardwire interlocked with the supply fan such that the dampers are commanded fully open on a start command and are closed when the supply fan is commanded off. Provide damper end switches on the outside air damper sections hardwire interlocked with the supply fan motor control circuit such that the supply fan can not operate unless the dampers are in the fully open position. Provide the end switches hardwire interlocked into both the hand and auto legs of the hand/off/auto motor control circuit to prevent fan operation without the dampers fully open.
2. Upon proof of supply fan operation the automatic controls shall be enabled.
3. On a system start-up if the outside air temperature is less than 6 Deg.C., the BMS shall position the heating coil control valve to the 30 % open position sixty seconds prior to issuing the supply fan start command. Valve control shall be released when automatic controls are enabled.

E. System Operation:

1. The heating coil control valve shall be modulated to maintain the supply air temperature setpoint. The supply air temperature setpoint shall be reset according to (BMS DESIGNER TO IDENTIFY RESET REQUIREMENTS).
4. The heating coil pump shall be started/stopped by the BMS based on the heating coil control valve position. The pump shall be started on a requirement for heat prior to the heating valve being modulated open and shall be stopped when the valve has been modulated closed. Minimum run times and minimum off times shall be provided to prevent pump cycling.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.
3. The BMS shall shut down the supply fan and generate an appropriate alarm message on detection of a supply air temperature of less than 5 Deg. C. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. The low temperature detection device shall be hardwire interlocked to shut down the supply fan and close the outside air dampers whenever a duct air temperature of 5 Deg. C. or lower is sensed. Device shall be manual reset. The BMS shall monitor the status of the low temperature detection device and shall annunciate an alarm in a low temperature condition.

2. Provide outside air damper actuators hardwire interlocked with the associated fan motor control circuit as indicated above.

3. Provide damper end switches on the outside air dampers hardwire interlocked with the associated fan motor control circuit as indicated above.

7.16 Typical Sequence of Operation - Rooftop Self Contained AC Unit (AH6)

A. Refer to FTS-06, SD-06.

B. System Off - When the system is off:

1. The fan shall be off and the unit shut down.

C. The Occupancy operating schedule for this system is:

D. System Start-up: On system start-up:

1. The BMS shall output a system enable command to the self contained ac unit electronic controller. Wire to terminations at the electronic controller.

E. System Operation:

1. Once enabled by the BMS the ac unit shall be controlled by the standalone integral ac unit controller as provided by the ac unit manufacturer.
2. The BMS shall monitor the status of the ac unit and shall monitor an ac unit common fault alarm from the ac unit controller. Wire to terminations at the ac unit controller.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.
3. The BMS shall shut down the supply fan and the exhaust fan and generate an appropriate alarm message on detection of a supply air temperature of less than 5 Deg. C. This BMS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

G. Hardwire Interlocks

1. Hardwire interlocks may be required. BMS Designer to coordinate requirements for any hardwire interlocks, BMS wiring terminations and interfaces, etc..

7.17 Chilled Water (CW) and Condenser Water (CSR) Systems

A. Refer to FTS-10, SD-10.

B. System Off - When the system is off:

1. The chilled water pumps shall be off.
2. The chillers shall be commanded off.
3. The condenser water pumps shall be off.
4. The cooling tower fans shall be off.
4. All control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

1. This system shall be enabled either by an operator manually entered command at the BMCS or automatically by the BMS based on time schedule or demand by the AHU's.
2. Provide two BMS operator modes of control, "BMS Manual" and "BMS Automatic". Selection of operating mode shall be by manual Operator selection. When in the BMS Manual mode start up and shut down of the chilled water and condenser water systems shall be by manual Operator BMS command only. When in the BMS Automatic Mode, start up and shut down of the chilled water and condenser water systems shall be automatically controlled by the BMS as defined in the following sequences of operation.

3. When in the BMS Automatic mode the chilled water and condenser water system shall be on whenever there is a demand for cooling by the associated air handling units as determined by cooling coils control valve positions. System shall be off if all valves

are closed and shall be started when any valve is open more than 10%. Provide minimum run time of four (4) hours and minimum off time of two (2) hours. The system shall be on during occupied periods whenever the outside air temperature is above 20 Deg. C. regardless of cooling coil valve position.

D. System Start-up: On system start-up:

1. BMS shall start the designated "duty" chilled water pump. BMS shall automatically designate "duty" or "standby" status to chilled water pumps based on pump totalized run time. Duty pump designation shall be assigned to the pump with the least accumulated run time at time of system start-up. If duty pump fails to start or is disabled the BMS shall start the standby pump.

2. Upon proof of chilled water pump operation the BMS shall start the designated “duty” condenser water pump. BMS shall automatically designate "duty" or "standby" status to condenser water pumps based on pump totalized run time. Duty pump designation shall be assigned to the pump with the least accumulated run time at time of system start-up. If duty pump fails to start or is disabled the BMS shall start the standby pump.

3. Following proof of chilled water and condenser water pumps, and following an Operator adjustable time delay initially set at thirty seconds, if there is not a condenser water low level alarm the BMS shall output an enable command to the chiller control panel provided by the chiller manufacturer. Once enabled by the BMS, control of the chiller shall be by the chiller control panel. The BMS chiller enable/disable control software shall incorporate minimum chiller run times and minimum times between chiller restarts

4. BMS Controls Contractor shall furnish flow switches for installation by the Mechanical Contractor in the chilled water supply and return as well as the condenser water supply and return lines and shall hardwire interlock these devices to the chiller control panel to prevent chiller operation without flow detected. Flow switches shall be hardwire interlocked into the hand and auto branches of the hand/off/auto control circuit for the chiller.

5. BMS shall monitor chiller status and chiller fault alarms from the integral chiller control panel. Coordinate wiring terminations with the chiller manufacturer. Provide all wiring and auxiliary relays required to monitor multiple chiller fault alarms as a common point on the BMS.

6. Upon proof of condenser water pump operation the BMS shall enable the condenser water system controls. Upon proof of condenser water pump operation the BMS shall control the cooling tower fans to maintain the condenser water supply temperature.

E. System Operation:

1. The BMS shall output a modulating control output to the chiller control panel for chilled water supply temperature setpoint reset control. Provide the chilled water supply temperature setpoint reset signal time averaged to adjust the chilled water supply temperature setpoint over a span of 6 Deg. C. The chilled water supply temperature setpoint shall be adjusted based on air handling unit chilled water control valve positions. Coordinate chilled water supply temperature setpoint reset signal requirements with Chiller Manufacturer.

2. (CENTRIFUGAL CHILLER ONLY) The BMS shall output a chiller current demand signal to the chiller control panel to limit the maximum operating capacity of the chiller based on electrical current demand. The current limiting value shall Operator adjustable and shall be manually set.

3. (If Cooling Tower is Equipped with a By-pass) If the outside air temperature is below an operator defined setpoint, the cooling tower bypass valve shall be positioned to bypass flow to the tower sumps.

4. If the outside air temperature is below an operator defined setpoint, the cell isolation valves for all cells shall open and allow flow over the tower without the fan operating. If the condenser water supply temperature setpoint can not be maintained for an Operator adjustable period of time, initially set at two minutes, then the isolation valves on the operator selected lead tower shall remain open and all other cell isolation valves shall close. The lead fan shall start on low speed. The speed of the operating fan within the cell shall be controlled to maintain the condenser water supply temperature setpoint.

5. If the lead tower cell is operating at low speed and the condenser water supply temperature setpoint can not be maintained for an operator defined period, then the following staging shall occur, with appropriate time delays to prevent excessive fan starting/stopping:

   a. Stage 2 - First cell high speed.
   b. Stage 3 - Second cell low speed.
   c. Stage 4 - Second cell high speed.
   d. Stage 5 - Third cell low speed.
   e. Stage 6 - Third cell high speed.
   f. etc. as determined by the # of cooling tower cells.

   The above sequence shall reverse as required to maintain the condenser water supply temperature setpoint. Provide satisfactory time delays between switching fans to low speed from high speed operation. Coordinate cooling tower control requirements with the cooling tower manufacturer.

6. Provide condenser water supply temperature setpoint reset based on wet bulb temperature approach. Coordinate reset schedule and minimum allowable condenser water temperature with the chiller and cooling tower manufacturers/suppliers.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements and/or air handling unit cooling requirements, by manual Operator command, or via hardwired interlocks.
2. The condenser water system shall be shut down by the BMS if none of the chilling units are operating.
3. On system shut down the BMS shall return the system to the state described for System Off.

G. Hardwire Interlocks

1. Provide flow switches installed in the chilled water supply and return and the condenser water supply and return lines hardwire interlocked with the chiller control panel as identified above.
2. Additional hardwire interlocks may be required associated with the chiller and cooling towers. Provide all required hardwire interlock facilities as identified elsewhere in the Division 15 and Division 16 Specifications.

H. Alarm setpoints - The BMCS shall generate an alarm:

1. If the chilled water supply temperature is outside the operator established low and high alarm limits, which shall be initially set at 38 Deg. F. and 42 Deg. F.
2. If a pump or chiller fails to start or fails in service.

3. If the condenser water supply temperature is outside the operator established low and high alarm limits, which shall be initially set at 4 Deg. F. around the current setpoint.

I. Setpoints - The setpoints for the system shall be determined as follows:

1. The condenser water supply temperature setpoint shall be set initially at 85 Deg. F. during normal operation and 40 Def. F. during economizer operation.

1. The outside air temperature low limit for bypass control shall be 36 Deg. F.
1. The condenser water supply temperature setpoint during after hours operation shall be 85 Deg. F.
2. The time delay for cell staging shall be 10 minutes.
3. The switch over setpoint for staging fans off shall be 5 Deg. F. below setpoint.
4. The plant condenser water supply temperature setpoint shall be 65 Deg. F.

7.18 Supply Hot Water System (SHW)

A. Refer to FTS-15, SD-15.

B. System Off - When the system is off:

1. Hot water circulation pumps shall be off.
2. Steam control valves shall be closed.
3. Three way mixing valve on the secondary hot water system shall be fully closed to flow through from the hot water supply.
4. Control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

1. System shall be started/stopped by the BMS according to the Occupancy Schedule and after hours space temperature control requirements.
2. Additionally the system shall be on if any air handling unit supply fans or Domestic Hot Water pumps are in operation or as required for after hours low space temperature control requirements.
3. This system shall be off if all air handling units and pumps are off and the outside air temperature is greater than 21 Deg. C.

D. System Start-up: On system start-up:

1. BMS shall start the designated "duty" hot water supply pump. BMS shall automatically designate "duty" or "standby" status to the hot water pumps based on pump totalized run time. Duty pump designation shall be assigned to the pump with the least accumulated run time at time of system start-up. If duty pump fails to start or is disabled the BMS shall start the standby pump.
2. Upon proof of hot water supply pump operation and following an Operator adjustable time delay, initially set at one (1) minute, the control loops shall be enabled.
3. Provide pump minimum run and off times. Pump minimum run time and minimum off time shall be Operator adjustable and initially set at thirty (30) minutes.

E. System Operation:

1. The BMS shall modulate the 1/3 - 2/3 steam control valves in sequence to maintain the hot water supply temperature setpoint. The steam control valves shall be sequenced such that the 1/3 capacity valve is modulated fully open first. The 2/3 capacity valve shall be modulated open once the 1/3 valve is fully open and the hot water supply temperature setpoint has not been achieved. The hot water supply temperature setpoint shall be Operator adjustable and shall initially be set at 93 Deg. C.

2. The BMS shall modulate the secondary radiation water three-way mixing valve to maintain the radiation/reheat hot water supply temperature setpoint. The radiation/reheat hot water supply temperature setpoint shall be reset based on an outside air temperature reset schedule as follow:

OUTSIDE AIR TEMPERATURE	HOT WATER SUPPLY TEMPERATURE SETPOINT

-10 Deg. C.	93 Deg. C.
15 Deg. C.	60 Deg. C.

Provide BMS software point for hot water supply temperature setpoint adjustment. Provide facilities to enabled the Operator to adjust the hot water supply temperature setpoint by +/- 10□C. If the hot water supply temperature is 98 Deg.C. or above, the steam valves shall be closed and an alarm generated.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements and/or air handling, space and domestic hot water heating requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.

G. Hardwire Interlocks

1. None identified with this system.

7.19 Domestic Hot Water System

A. Refer to FTS-16, SD-16.

B. System Off - When the system is off:

1. The domestic hot water circulation pump shall be off.
2. Control loops shall be disabled.

C. The Occupancy operating schedule for this system is:

1. The system shall be enabled at an Operator adjustable period of time before the start of the Occupancy Period, initially set at 30 minutes, and shall be disabled at the end of the Occupancy Period.

D. System Start-up: On system start-up:

1. BMS shall start/stop the domestic hot water recirculation pump to maintain the domestic hot water return temperature at setpoint.

E. System Operation:

1. Control of the domestic hot water heater shall be via standalone controls. The domestic hot water temperature controls shall remain operational continuously 24 hours per day.

2. Once enabled to operate by the BMS, the domestic hot water circulation pump shall be cycled on/off to maintain the domestic hot water return temperature at setpoint. The pump shall be started when the domestic hot water return temperature is below setpoint and shall be stopped when below setpoint. Provide deadbands between pump on/off commands. Provide Operator adjustable minimum run and off times initially set at five minutes.

F. System Shut Down:

1. System shut down shall be initiated automatically by the BMS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BMS shall return the system to the state described for System Off.

G. Hardwire Interlocks

1. There are no hardwire interlock requirements associated with this system.

END OF DESIGN GUIDELINES

SCHEDULES AND SYSTEM SCHEMATICS

1. FIELD TERMINATION SCHEDULES AND SYSTEM SCHEMATICS

1.1 BMS Monitoring and Control - Typical HVAC Systems

A. Appendix A1 of the UBC Design Guidelines includes Field Termination Schedules and System Schematic Diagrams for Typical HVAC Systems. The BMS Design Consultant shall apply BMS monitoring and control to UBC HVAC systems using these as guidelines. There will be numerous criteria which will influence the BMS application to each specific building HVAC system including building age, project budgets, system complexity, interaction with other building systems, building use, etc. This section of the UBC Design Guidelines details the points required to undertake the monitoring and control functions of the BMS. The BMS monitoring and control facilities identified are minimum requirements and additional facilities shall be added if needed to for BMS monitoring and control.

B. The following abbreviations are based on the UBC approved standards for building systems as indicated in the UBC Mechanical Systems Guide Specifications and have been used in the BMS Sequences of Operation, Field Termination Schedules and the System Schematic Sheets:

1.	OA	-	Outdoor Air
2.	EA	-	Exhaust Air
3.	SA	-	Supply Air
4.	RA	-	Return Air
5.	MA	-	Mixed Air
6.	CSRS	-	Condenser Water Supply
7.	CSRR	-	Condenser Water Return
8.	CWS	-	Chilled Water Supply
9.	CWR	-	Chilled Water Return
10.	DHW	-	Domestic Hot Water
11.	DHWS	-	Domestic Hot Water Supply
12.	DHWR	-	Domestic Hot Water Return
13.	HWS	-	Hot Water Supply
14.	HWR	-	Hot Water Return
15.	NO	-	Normally Open
16.	NC	-	Normally Closed
17.	STM	-	Steam
18.	CND	-	Condensate

1.2 Field Termination Schedules - General

A. The Field Termination Schedules (FTS) identify BMS monitoring and control requirements to be provided for the associated building systems. Where BMS monitoring and control requirements are identified in the FTS's and System Schematic Diagram's the BMS Contractor shall provide the device and monitor and/or control the device by the BMS.

B. The BMS shall not override any hardwired interlocks including safety interlocks. BMS control of motors shall only be possible when the HOA selector switch is in the Auto position.

C. Unless the BMS Specifications and Contract Documents specifically indicate that components are to be furnished by others the BMS Contractor shall provide (furnish and

install) all of the components necessary to meet the monitoring or control requirements and shall provide cabling, conduit and all other components and work required to connect the point to the PIM at the DCP or ASC and to have the point fully functional on the BMS. The BMS Design Consultant shall fully coordinate all components and facilities to be provided by others with the Owner, Architect, building design team, etc. as required.

1.3 System Schematic Diagrams

A. The schematic diagrams indicate the general configuration of the building systems and the associated BMS monitoring and control requirements. Locations of sensors and devices shall be provided approximately as indicated. All final mounting and sensing locations shall be specifically designed for each application and shall be fully coordinated by the BMS Contractor with the Owner, Architect, BMS Consultant and other Trades.

B. The System Schematic Diagrams are identified on the associated FTS or on the page immediately following the associated FTS. The Field Termination codes identified on the schematic diagrams cross reference the associated FTS.

2. DEFINITION OF THE FIELD TERMINATION SCHEDULES

2.1 BMS Field Termination Schedules

A. The Field Termination Schedules define the minimum monitoring and control functions to be undertaken by the BMS.

B. The column headed **FT** contains the tag that enables cross reference between the Field Termination Sheets and the System Diagrams

C. The column headed **DESCRIPTION** provides an English language description of the point to be monitored or controlled.

D. The column headed **DI** indicates the digital input monitoring requirements. The digital input codes are as follows:

1. Current sensing transformer and relay for motor status.
2. No volt (dry) contacts at equipment or instrumentation on equipment as provided by others.
3. Monitor motor status via contacts provided by others at VSD or motor interface terminal strip.
4. Monitor VSD device common alarm via contacts provided by others at the VSD controller.
5. Air differential pressure switch (Filter Status Indication).
6. Low Temperature Detection Device (Air Plenum Service).
7. Low Temperature Detection Device (Water Service - thermowell installation).
8. Level Switch.
9. Damper end switch.
10. Negative Pressure (Vacuum) Switch (Air Service). Range suitable for application.
11. Pulsed input signal from water meter provided by others. Coordinate pulse signal requirements.
12. Pulsed input signal provided by Division 16. Coordinate pulse signal requirements.
13. Air differential pressure switch (duct static pressure limit switch).
14. Door position switch for BMS status monitoring of field panel door position.
15. Provide and monitor 2 pressure switches sensing the pneumatic controls air main supply for BMS monitoring of high and low pressure alarm conditions. Monitor the two devices as a single point on the BMS.

16. Pressure Switch (Water Service) installed in domestic cold water supply piping for low pressure alarm indication to BMS.

E. The column headed **DO** indicate the digital output control requirements. The digital output codes are as follows:

1. Provide and control a relay across the appropriate terminals at the MCC motor control circuit wiring terminal strip or VSD controller, as applicable, for the stop/start control of a motor.
2. Provide two position damper control.
3. Provide two position valve control.
4. Provide BMS control output to Cooling Tower Fan control circuit terminal strip provided by others for BMS control of cooling tower fan motor.
5. Provide BMS control output to terminal strip at chiller control panel for BMS enable/disable control of chiller machine.
6. Provide on and off control of lighting relays provided by Division 16. Provide grouping of zones as indicated in the Division 16 Drawings. Refer to Division 16 Drawings for locations of each lighting relay panel.
7. Provide BMS control output to terminal strip at rooftop air handling unit for BMS enable/disable control.

F. The column headed **AI** indicates the analog input monitoring requirements. The analog input codes are as follows:

1. Provide and monitor a duct mounted single point temperature sensor - 0 Deg.C. to 50 Deg.C. range.
2. Provide and monitor a duct mounted averaging temperature sensor - 0 Deg.C. to 50 Deg.C. range.
3. Provide and monitor a thermowell mounted temperature sensor - 0 Deg.C. to 100 Deg. C range.
4. Provide and monitor an outside air temperature sensor - (-) 20 Deg.C. to 40 Deg.C. range.
5. Provide and monitor a wall mounted space temperature sensor - 0 Deg.C to 50 Deg.C. range.
6. Provide and monitor a wall mounted button type space temperature sensor- 0 Deg.C to 50 Deg.C. range.
7. Provide and monitor a water differential pressure sensor.
8. Provide and monitor a duct static pressure sensor.
9. Provide and monitor a space static pressure sensor.
10. Provide and monitor an outside air relative humidity sensor.
11. Provide and monitor a duct mounted relative humidity sensor.
12. Provide and monitor fan inlet air flow rate sensor.
13 . Monitor instrumentation on the water chilling unit control panel.
14. Provide and monitor steam pressure sensor and transmitter.
15. Provide and an outside air dewpoint temperature sensor and transmitter.
16. Provide and monitor a Carbon Dioxide (CO_2) sensor and transmitter.
17. Provide and monitor an insertion turbine water flowmeter.
18 . Provide and monitor an ambient light level sensor.
19. Provide and monitor a domestic water pressure sensor and transmitter.
20. Monitor 4-20 mA or 0 - 10 vdc signal provided by others.
21. Provide and monitor an air flow rate station and differential pressure transmitter.
22. Provide and monitor a wall mounted space relative humidity sensor and transmitter.
23. Provide and monitor a thermowell mounted temperature sensor - 0 Deg.C. to 50 Deg.C. range.

G. The column headed **AO** indicates the analog output monitoring requirements. The BMS Contractor shall coordinate the signal ranges with the controlled device. The analog output codes are as follows:

1. Provide modulating BMS control output to valve actuator.
2. Provide modulating BMS control output to damper actuator.
3. Provide modulating BMS control output to electric motor VSD for speed control.
4. Provide modulating BMS control output for chilled water temperature set point reset signal to chiller control panel.
5. Provide modulating BMS control output for chiller kVA demand limiting signal to chiller control panel.

H. The column headed **HI** indicates the hardwired interface requirement. These devices are not monitored by the BMS unless indicated in any of the previous columns. The hardwired interlock codes are as follows:

1. Provide and interlock a water differential pressure switch to prove flow through the chiller bundle to prevent the water chilling unit from operating unless water flow is proven. Provide flow switch in both the condenser water and chilled water lines.
2. Provide and interlock an air differential pressure switch to shut down the associated fan in the event of high duct static pressure condition.
3. Provide return fan hardwire interlocked to start/stop with the supply fan motor. Provide the hardwire interlock wired into the auto leg of the return fan hand/off/auto motor control circuit.
4. Provide damper end switch hardwire interlocked with the associated motor starter/VSD terminal strip to prevent the fan(s) from operating until the damper(s) are completely open. Provide end switches as required.
5. Provide low temperature detection device hardwire interlocked with the supply fan motor control circuit to shut down fan in a low temperature condition. Provide safety device hardwire interlocked into the hand/off/auto motor control circuit to prevent fan operation in either hand or auto position in a low temperature condition.
6. Provide and interlock an air differential pressure switch to shut down the associated fan in the event of low duct static pressure condition.

I. The column headed **CI** indicates the digital communications interface requirements to meters or controllers provided by others. The communications interface codes are as follows:

1. (Not presently Used)

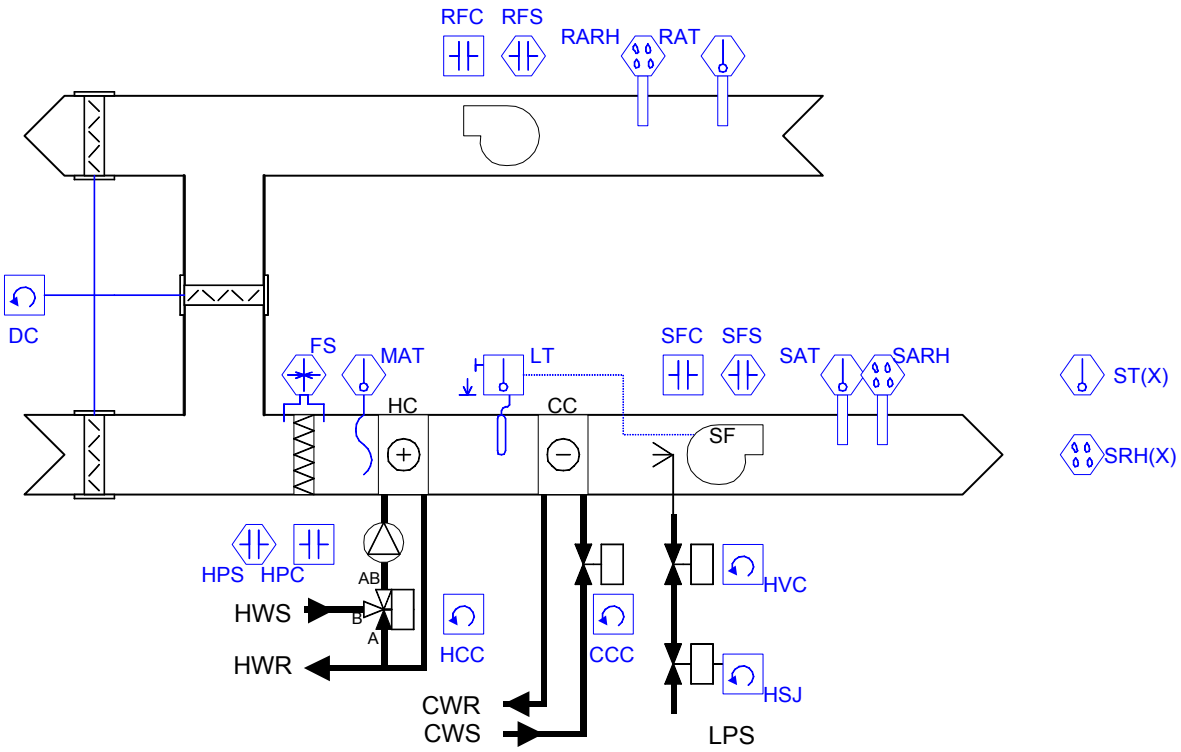
J. The column headed **NOTES** indicates additional information either by description or code. The NOTE codes are:

1. Monitor negative static pressure in exhaust air duct. Coordinate signal range.
2. BMS automatically calculated point. Provide BMS monitoring of the low and high range steam flow rate meters, the steam temperature and the steam gauge pressure as provided by others. The BMS shall automatically identify the meter recording steam flow within its operating range. The BMS shall utilize the signal from the selected meter to calculate steam flow rate and steam energy consumption. The BMS shall monitor/display the steam flow rate and steam energy consumption. The BMS shall utilize the steam temperature and steam pressure values and steam table data within the BMS to calculate the steam energy values. The BMS shall totalize the steam flow and steam energy consumption and shall upload the totalized values to the BMS main computer.
3. Monitor multiple generator fault alarms as a single alarm on the BMS. Wire to terminals provided by others.

FIELD TERMINATION SCHEDULE : 01
SYSTEMS : TYPICAL CONSTANT VOLUME AHU (AH1)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
SFC	SUPPLY FAN CONTROL		1					
SFS	SUPPLY FAN STATUS	1						
RFC	RETURN FAN CONTROL		1					
RFS	RETURN FAN STATUS	1						
HPC	PUMP CONTROL		1					
HPS	PUMP STATUS	1						
DC	DAMPER CONTROL				2			
HCC	HEATING COIL VALVE CONTROL				1			
CCC	COOLING COIL VALVE CONTROL				1			
HVC	HUMIDIFIER STEAM VALVE CONTROL				1			
HSJ	HUMIDIFIER STEAM JACKET VALVE CONTROL		3					
SAT	SUPPLY AIR TEMPERATURE			1				
RAT	RETURN AIR TEMPERATURE			1				
MAT	MIXED AIR TEMPERATURE			2				
SARH	SUPPLY AIR RELATIVE HUMIDITY			11				
RARH	RETURN AIR RELATIVE HUMIDITY			11				
ST(X)	SPACE TEMPERATURE			5				Typical of (x)
SRH(X)	SPACE RELATIVE HUMIDITY			22				Typical of (x)
FS	FILTER STATUS	5						
LT	LOW TEMPERATURE DETECTION DEVICE	6				5		

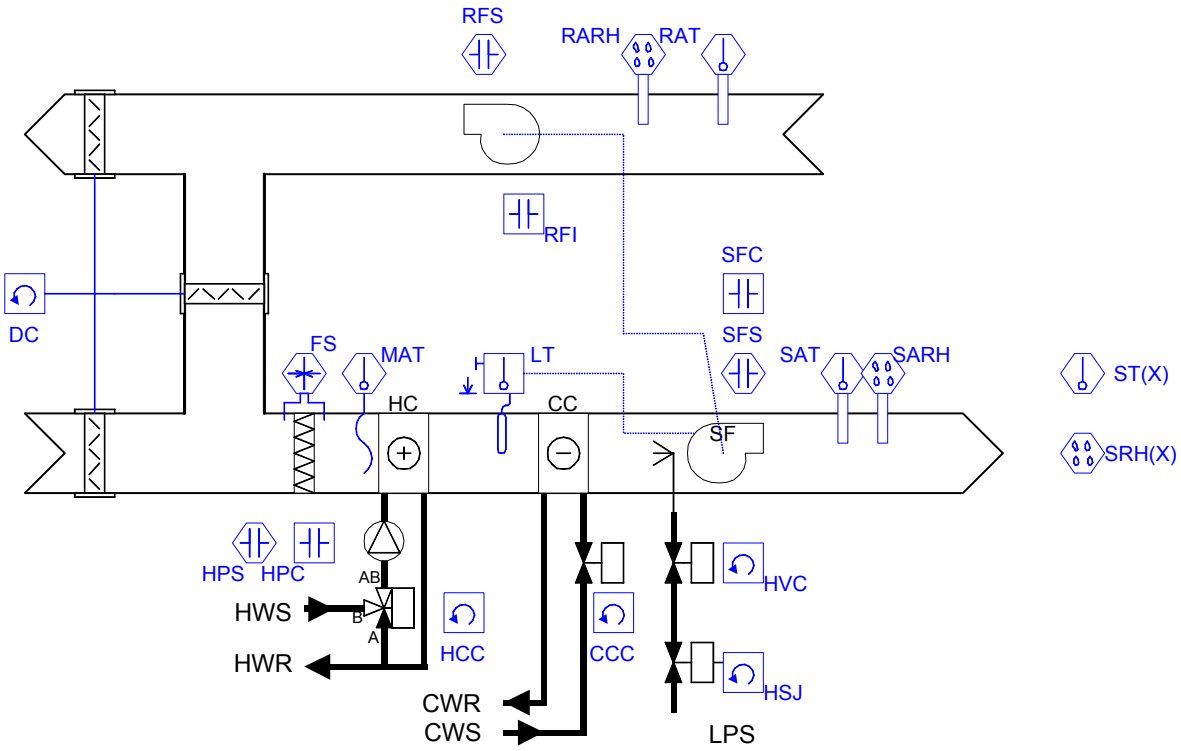
SCHEMATIC DIAGRAM : 01
SYSTEMS : TYPICAL CONSTANT VOLUME AHU (AH1)



FIELD TERMINATION SCHEDULE : 02
SYSTEMS : TYPICAL CONSTANT VOLUME AHU (AH2)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
SFC	SUPPLY FAN CONTROL		1					
SFS	SUPPLY FAN STATUS	1						
RFI	RETURN FAN INTERLOCK					3		
RFS	RETURN FAN STATUS	1						
HPC	PUMP CONTROL		1					
HPS	PUMP STATUS	1						
DC	DAMPER CONTROL				2			
HCC	HEATING COIL VALVE CONTROL				1			
CCC	COOLING COIL VALVE CONTROL				1			
HVC	HUMIDIFIER STEAM VALVE CONTROL				1			
HSJ	HUMIDIFIER STEAM JACKET VALVE CONTROL		3					
SAT	SUPPLY AIR TEMPERATURE			1				
RAT	RETURN AIR TEMPERATURE			1				
MAT	MIXED AIR TEMPERATURE			2				
SARH	SUPPLY AIR RELATIVE HUMIDITY			11				
RARH	RETURN AIR RELATIVE HUMIDITY			11				
ST(X)	SPACE TEMPERATURE			5				Typical of (x)
SRH(X)	SPACE RELATIVE HUMIDITY			22				Typical of (x)
FS	FILTER STATUS	5						
LT	LOW TEMPERATURE DETECTION DEVICE	6				5		

SCHEMATIC DIAGRAM : 02
SYSTEMS : TYPICAL CONSTANT VOLUME AHU (AH2)



FIELD TERMINATION SCHEDULE : 03

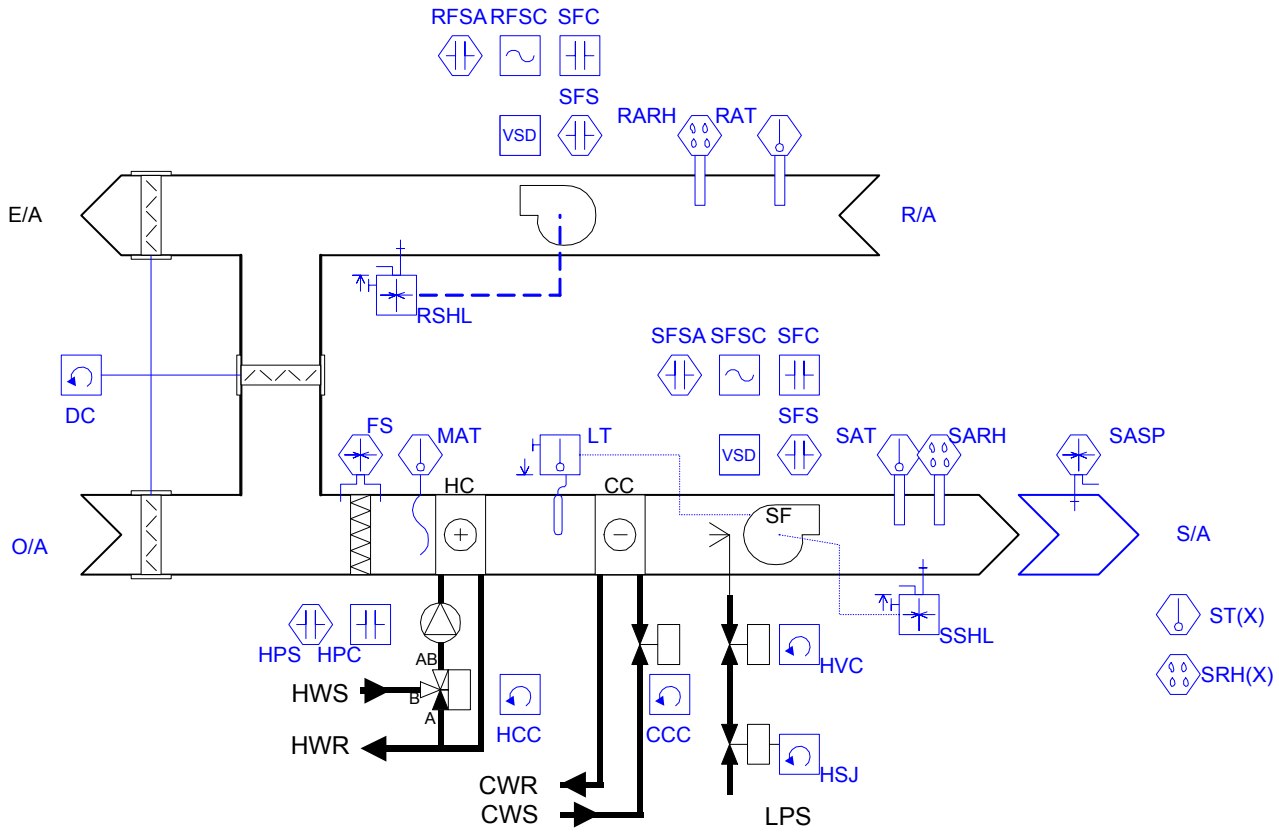
December 14, 2005

SYSTEMS : VAV AHU - AH3

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
SFC	SUPPLY FAN CONTROL		1					
SFS	SUPPLY FAN STATUS	1						
SFSC	SUPPLY FAN SPEED CONTROL				3			
SFSA	SUPPLY FAN SPEED DRIVE FAULT ALARM	4						
RFC	RETURN FAN CONTROL		1					
RFS	RETURN FAN STATUS	1						
RFSC	RETURN FAN SPEED CONTROL				3			
RFSA	RETURN FAN SPEED DRIVE FAULT ALARM	4						
HPC	PUMP CONTROL		1					
HPS	PUMP STATUS	1						
DC	DAMPER CONTROL				2			
HCC	HEATING COIL VALVE CONTROL				1			
CCC	COOLING COIL VALVE CONTROL				1			
HVC	HUMIDIFIER STEAM VALVE CONTROL				1			
HSJ	HUMIDIFIER STEAM JACKET VALVE CONTROL		3					
SAT	SUPPLY AIR TEMPERATURE			1				
RAT	RETURN AIR TEMPERATURE			1				
MAT	MIXED AIR TEMPERATURE			2				
SARH	SUPPLY AIR RELATIVE HUMIDITY			11				
SASP	SUPPLY AIR STATIC PRESSURE			8				MOUNT DEVICE AT LOCATION 2/3 DOWN LONGEST DUCT RUN
RARH	RETURN AIR RELATIVE HUMIDITY			11				
ST(X)	SPACE TEMPERATURE			5				Typical of (x)
SRH(X)	SPACE RELATIVE HUMIDITY			22				Typical of (x)
FS	FILTER STATUS	5						
LT	LOW TEMPERATURE DETECTION DEVICE	6				5		
SSHL	SUPPLY AIR STATIC PRESSURE HIGH LIMIT	13				2		

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
RSHL	RETURN AIR STATIC PRESSURE HIGH LIMIT	13				2		

SCHEMATIC DIAGRAM : 03
SYSTEMS : VAV AHU - AH3

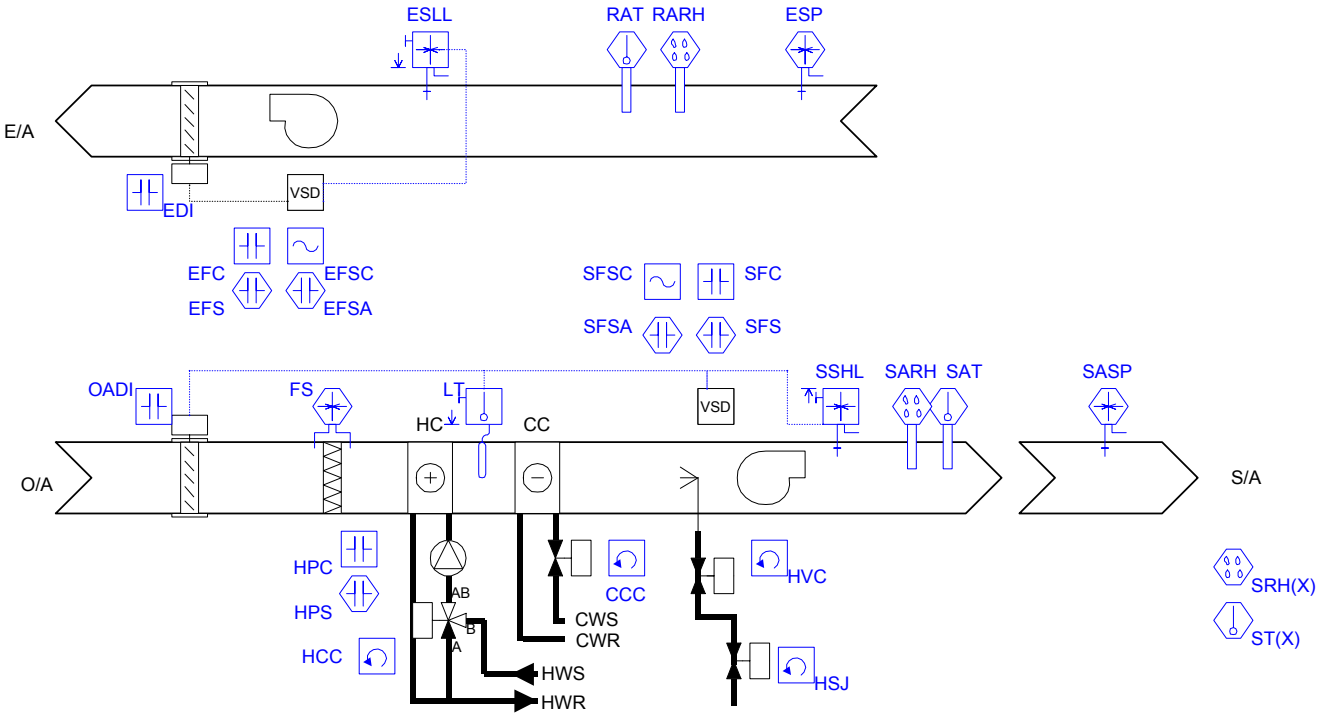


FIELD TERMINATION SCHEDULE : 04
SYSTEMS : VAV OUTSIDE AIR AHU (AH4)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
SFC	SUPPLY FAN CONTROL		1					
SFS	SUPPLY FAN STATUS	1						
SFSC	SUPPLY FAN SPEED CONTROL				3			
SFSA	SUPPLY FAN SPEED DRIVE FAULT ALARM	4						
EFC	EXHAUST FAN CONTROL		1					
EFS	EXHAUST FAN STATUS	1						
EFSC	EXHAUST FAN SPEED CONTROL				3			
EFSA	EXHAUST FAN SPEED DRIVE FAULT ALARM	4						
HPC	PUMP CONTROL		1					
HPS	PUMP STATUS	1						
OADI	OUTSIDE AIR DAMPER INTERLOCK					4		
EDI	EXHAUST AIR DAMPER INTERLOCK					4		
HCC	HEATING COIL VALVE CONTROL				1			
CCC	COOLING COIL VALVE CONTROL				1			
HVC	HUMIDIFIER STEAM VALVE CONTROL				1			
HSJ	HUMIDIFIER STEAM JACKET VALVE CONTROL		3					
SAT	SUPPLY AIR TEMPERATURE			1				
RAT	RETURN AIR TEMPERATURE			1				
MAT	MIXED AIR TEMPERATURE			2				
SARH	SUPPLY AIR RELATIVE HUMIDITY			11				
SASP	SUPPLY AIR STATIC PRESSURE			8				MOUNT DEVICE AT LOCATION 2/3 DOWN LONGEST DUCT RUN
EASP	EXHAUST AIR STATIC PRESSURE			8				1, MOUNT DEVICE AT LOCATION 2/3 DOWN LONGEST DUCT RUN
RARH	RETURN AIR RELATIVE HUMIDITY			11				
ST(X)	SPACE TEMPERATURE			5				Typical of (x)
SRH(X)	SPACE RELATIVE HUMIDITY			22				Typical of (x)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
FS	FILTER STATUS	5						
LT	LOW TEMPERATURE DETECTION DEVICE	6				5		
SSHL	SUPPLY AIR STATIC PRESSURE HIGH LIMIT	13				2		
ESLL	EXHAUST AIR STATIC PRESSURE LOW LIMIT	13				6		

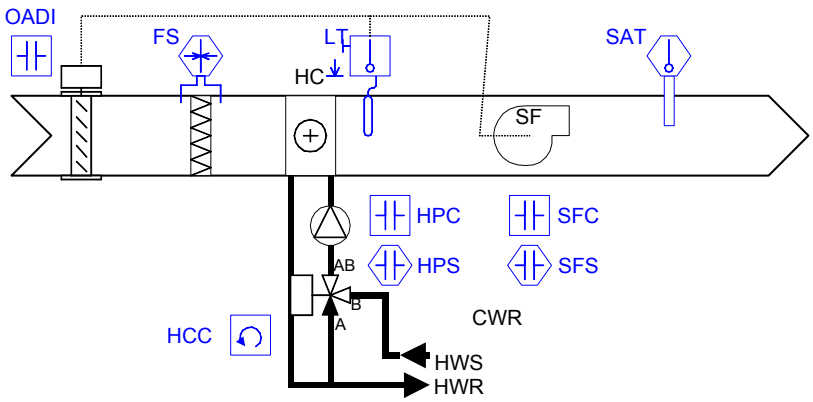
SCHEMATIC DIAGRAM : 04
SYSTEMS : VAV OUTSIDE AIR AHU (AH4)



FIELD TERMINATION SCHEDULE : 05
SYSTEMS : MAKE-UP AIR AHU (AH5)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
SFC	SUPPLY FAN CONTROL		1					
SFS	SUPPLY FAN STATUS	1						
OADI	OUTSIDE AIR DAMPER INTERLOCK					4		
SAT	SUPPLY AIR TEMPERATURE			1				
FS	FILTER STATUS	5						
LT	LOW TEMPERATURE DETECTION DEVICE	6				5		
HPC	HEATING PUMP CONTROL		1					
HPS	HEATING PUMP STATUS	1						
HCC	HEATING COIL CONTROL VALVE				1			

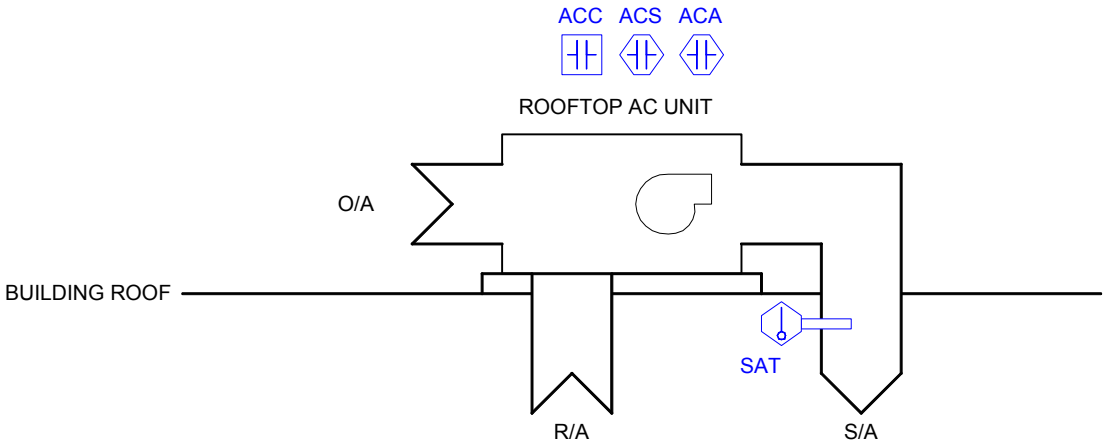
SCHEMATIC DIAGRAM : 05
SYSTEMS : MAKE-UP AIR AHU (AH5)



FIELD TERMINATION SCHEDULE : 06
SYSTEMS : ROOFTOP SELF CONTAINED AC UNIT (AH6)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
ACC	AC UNIT ENABLE/DISABLE CONTROL		7					
ACS	AC UNIT STATUS	1						
ACA	AC UNIT COMMON ALARM	2						
SAT	SUPPLY AIR TEMPERATURE			1				

SCHEMATIC DIAGRAM : 06
SYSTEMS : ROOFTOP SELF CONTAINED AC UNIT (AH6)

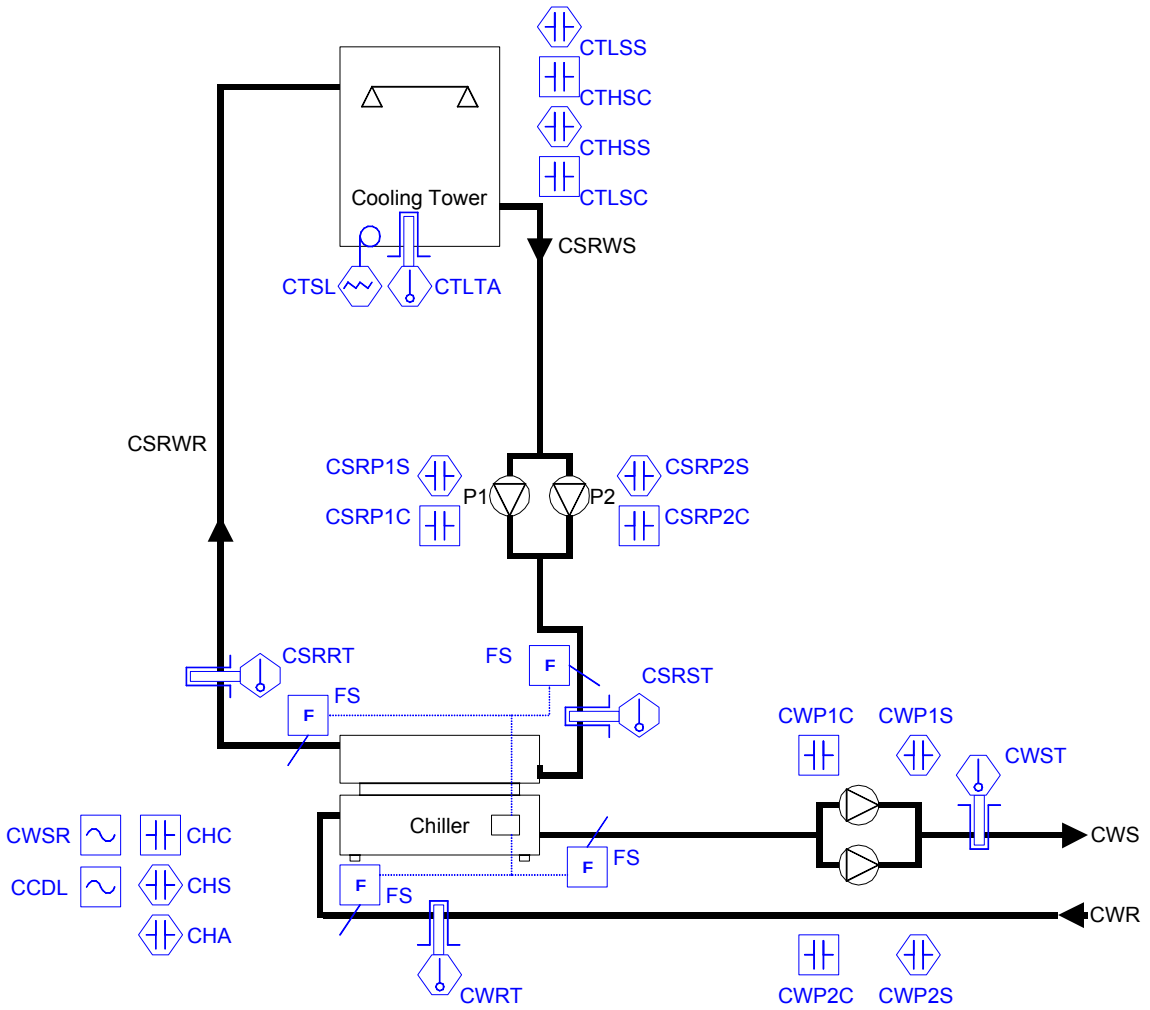


FIELD TERMINATION SCHEDULE : 10
SYSTEMS : CHILLED WATER (CW) AND CONDENSER WATER (CSR) SYSTEMS

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
CHC	CHILLER ENABLE/DISABLE CONTROL		5					
CHS	CHILLER STATUS	2						
CHA	CHILLER COMMON FAULT ALARM	2						
CWSR	CHILLED WATER SETPOINT RESET SIGNAL				4			
CCDL	CHILLER CURRENT DEMAND LIMIT SIGNAL				5			
CWP1C	CHILLED WATER PUMP CONTROL		1					
CWP1S	CHILLED WATER PUMP STATUS	1						
CWP2C	CHILLED WATER PUMP CONTROL		1					
CWP2S	CHILLED WATER PUMP STATUS	1						
CSRP1C	CONDENSER WATER PUMP CONTROL		1					
CSRP1S	CONDENSER WATER PUMP STATUS	1						
CSRP2C	CONDENSER WATER PUMP CONTROL		1					
CSRP2S	CONDENSER WATER PUMP STATUS	1						
CTLSC	COOLING TOWER FAN LOW SPEED CONTROL		4					
CTLSS	COOLING TOWER FAN LOW SPEED STATUS	1						
CTHSC	COOLING TOWER FAN HIGH SPEED CONTROL		4					
CTHSS	COOLING TOWER FAN HIGH SPEED STATUS	1						
CWST	CHILLED WATER SUPPLY TEMPERATURE			23				
CWRT	CHILLED WATER RETURN TEMPERATURE			23				
CSRST	CONDENSER WATER SUPPLY TEMPERATURE			3				
CSRRT	CONDENSER WATER RETURN TEMPERATURE			3				
CTSL	COOLING TOWER SUMP LEVEL ALARM	8						

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
CTLTA	COOLING TOWER SUMP LOW TEMPERATURE ALARM	7						
FS	WATER FLOW SWITCH					1		

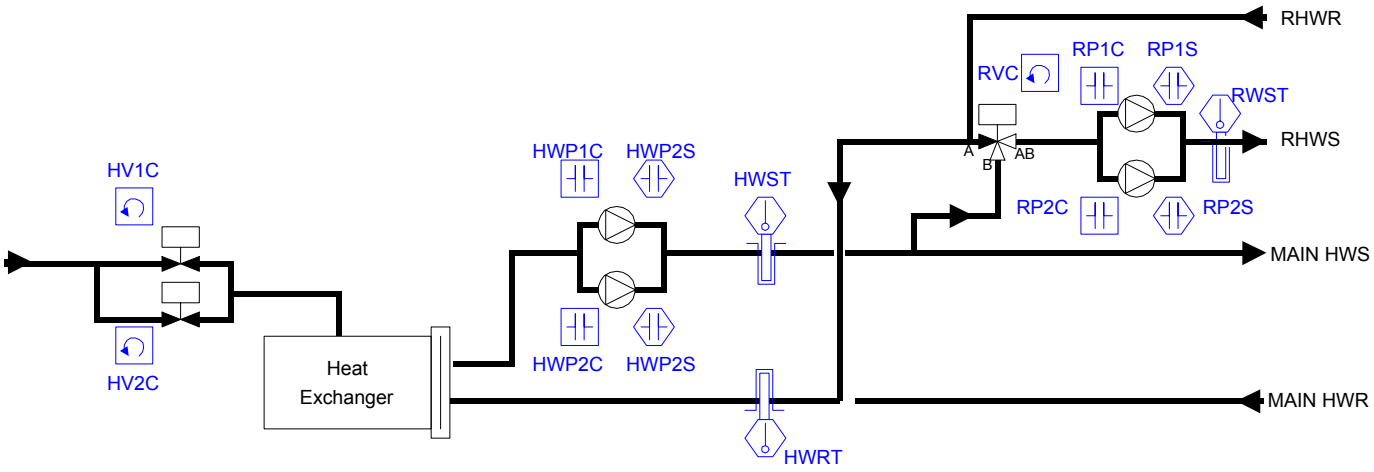
SCHEMATIC DIAGRAM : 10
SYSTEMS : CHILLED WATER (CW) AND CONDENSER WATER (CSR) SYSTEMS



FIELD TERMINATION SCHEDULE : 15
SYSTEMS : SUPPLY HOT WATER SYSTEM (SHW)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
HWP1C	PUMP CONTROL		1					
HWP1S	PUMP STATUS	1						
HWP2C	PUMP CONTROL		1					
HWP2S	PUMP STATUS	1						
RP1C	RADIATION/REHEAT PUMP CONTROL		1					
RP1S	RADIATION/REHEAT PUMP STATUS	1						
RP2C	RADIATION/REHEAT PUMP CONTROL		1					
RP2S	RADIATION/REHEAT PUMP STATUS	1						
HV1C	STEAM CONTROL VALVE				1			
HV2C	STEAM CONTROL VALVE				1			
RVC	RADIATION/REHEAT HOT WATER VALVE CONTROL				1			
HWST	HOT WATER SUPPLY TEMPERATURE			3				
HWRT	HOT WATER RETURN TEMPERATURE			3				
RWST	RADIATION/REHEAT HOT WATER SUPPLY TEMPERATURE			3				

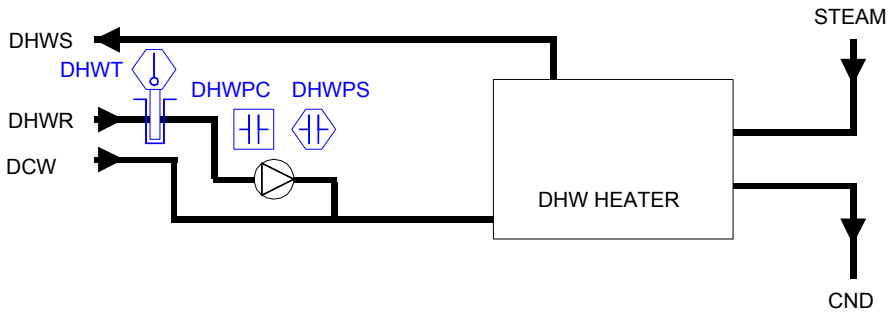
SCHEMATIC DIAGRAM : 15
SYSTEMS : SUPPLY HOT WATER SYSTEM (SHW)



FIELD TERMINATION SCHEDULE : 16
SYSTEMS : DOMESTIC HOT WATER SYSTEM (DHW)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
DHWPC	PUMP CONTROL		1					
DHWPS	PUMP STATUS	1						
DHWT	DOMESTIC HOT WATER RETURN TEMPERATURE			3				

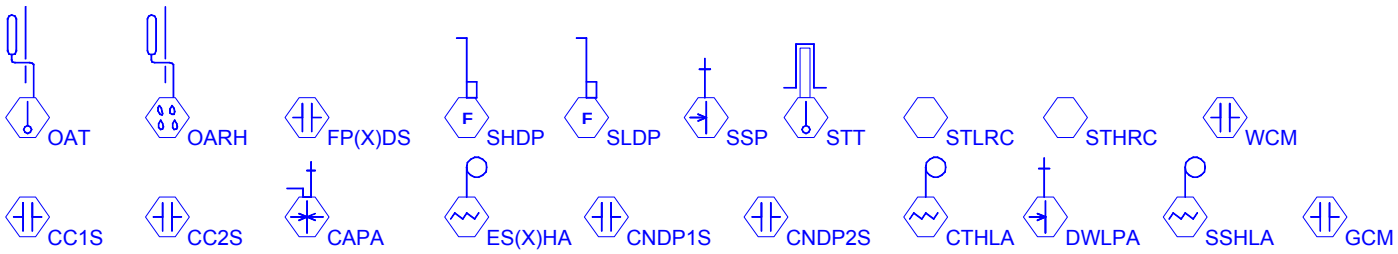
SCHEMATIC DIAGRAM : 16
SYSTEMS : DOMESTIC HOT WATER SYSTEM (DHW)



FIELD TERMINATION SCHEDULE : 17
SYSTEMS : MISCELLANEOUS EQUIPMENT (ME)

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
OAT	OUTSIDE AIR TEMPERATURE			4				
OARH	OUTSIDE AIR RELATIVE HUMIDITY			10				
FP(X)DS	FIELD PANEL #(x) DOOR STATUS	14						
SHDP	STEAM HIGH RANGE DIFFERENTIAL PRESSURE			20				
SLDP	STEAM LOW RANGE DIFFERENTIAL PRESSURE			20				
SSP	STEAM STATIC PRESSURE			20				
STT	STEAM TEMPERATURE			20				
STLRC	STEAM LOW RANGE CONSUMPTION							2
STHRC	STEAM HIGH RANGE CONSUMPTION							2
GCM	GAS CONSUMPTION METER			20				
WCM	DOMESTIC WATER CONSUMPTION METER	11						
CC1S	CONTROLS AIR COMPRESSOR STATUS	1						
CC2S	CONTROLS AIR COMPRESSOR STATUS	1						
CAPA	CONTROL AIR HIGH/LOW PRESSURE ALARM	15						
ES(X)HA	ELEVATOR SUMP #(X) HIGH LEVEL ALARM	8						
SSHLA	STORM SUMP HIGH LEVEL ALARM	8						
SAHLA	SANITARY SUMP HIGH LEVEL ALARM	8						
CNDP1S	CONDENSATE PUMP STATUS	1						
CNDP2S	CONDENSATE PUMP STATUS	1						
CTHLA	CONDENSATE TANK HIGH LEVEL ALARM	8						
DWLPA	DOMESTIC WATER LOW PRESSURE ALARM	16						

SCHEMATIC DIAGRAM : 17
SYSTEMS : MISCELLANEOUS EQUIPMENT (ME)



FIELD TERMINATION SCHEDULE : 18
SYSTEMS : BUILDING ELECTRICAL EQUIPMENT

FT	DESCRIPTION	DI	DO	AI	AO	HI	CI	NOTES
BFA	BUILDING FIRE ALARM	2						
ELD(X)	ELECTRICAL METER #(X) DEMAND			20				
ELC(X)	ELECTRIC METER #(X) CONSUMPTION	12						
MBS	MAIN BREAKER STATUS	2						
THTA	TRANSFORMER HIGH TEMPERATURE ALARM	2						
MTSP	MAIN TRANSFORMER SHUNT POWER	2						
MTTP	MAIN TRANSFORMER TRIP POWER	2						
EGS	EMERGENCY GENERATOR STATUS	2						
EGA	EMERGENCY GENERATOR FAULT ALARM	2						3
DTLLA	DIESEL TANK LOW LEVEL ALARM	2						
TSS	TRANSFER SWITCH STATUS	2						
LBS1	LOAD BREAK SWITCH STATUS	2						
LBS2	LOAD BREAK SWITCH STATUS	2						
DTLDA	DIESEL TANK LEAK DETECTION ALARM	2						

SCHEMATIC DIAGRAM : 18
SYSTEMS : BUILDING ELECTRICAL EQUIPEMENT