Building Automation Systems (BAS)

DESIGN GUIDELINES

Simon Fraser University

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1 OVERVIEW

1.1 General

A. Simon Fraser University 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 SFU Campus on an on-going basis. To assist in the operation and maintenance of campus buildings, SFU Facilities provide centralized monitoring and control of SFU buildings from a central location via microprocessor based DDC controls. To facilitate the centralized BAS monitoring and control standards have been applied to the selection of BAS equipment and for the application of BAS installations in buildings. The SFU BAS Design Guidelines serve to identify typical standards for the application of BAS’s in SFU buildings. These Design Guidelines have also been developed to assist SFU in ensuring that SFU buildings are provided with high quality BAS installations that fully meet their requirements.

1.2 Application of these BAS Design Guidelines

A. This document is intended to serve as a guideline for the Design of Building Automation System (BAS) installations in buildings at Simon Fraser University. The guideline serves to generally identify the existing SFU Campus BAS infrastructure and installed components and to record BAS design requirements specific to SFU installations. The SFU Project Guide Part C may be used by BAS Designers for guidance in the design of SFU BAS installations but shall not be reproduced, in whole, or part, for inclusion in BAS Design Specifications, or Tender or Contract Documents. The SFU Project Guide Part C discussing DDC controls does not include sufficient detail to be used as such. BAS Designers will be required to include additional detailed information in BAS Design Specifications to clearly identify all aspects of the BAS installation.

B. BAS Designs shall be based on sound industry standard practices. BAS Designers shall provide BAS Designs that have been specifically engineered for the application and shall exercise discretion in the application of these guidelines. All new building construction at SFU will utilize DDC BAS 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. BAS Design Documents shall clearly identify the nature of the BAS installation work and shall include the contractual documentation and requirements where applicable.

C. All new BAS installations shall comprise equipment, data and data communications that are fully compliant with ANSI/ASHRAE Standard 135-2001 “BACnet” and Division27.
   1. Legacy equipment manufactured by Schneider Electric or Delta Controls that are not compliant with ANSI/ASHRAE Standard 135-2001 shall NOT be used for NEW BAS installations.
   2. Equipment installed on extensions of a BAS using non-BACnet legacy equipment, manufactured by Schneider Electric and Delta Controls, shall have the capability of directly communicating to the legacy equipment in the proprietary communications protocol as well as communicating with BACnet devices. New equipment that does not have the capability to communicate in both the proprietary protocol and BACnet is placed onto a legacy system; the device shall use the BACnet communications protocol. When equipment capable of communicating only with BACnet is placed onto an existing legacy system, a communication gateway device shall be placed on to the proprietary network. The gateway shall bridge the two disparate communication protocols and act as a translator that allows bilateral communication between the BACnet compliant devices and devices communicating using proprietary communication protocols.
D. Related SFU Technical Requirements:

Division 27

1. It is a requirement that all designs must operate within the University's current Network, Datacentre and I.T. Security infrastructure.

2. Any projects that have components (listed below) that are directly or indirectly providing I.T. control and management features must be reviewed and approved by SFU Network Services.
   a. Affected IT Components:
      Network Ethernet Switches
      Network Ethernet Routers
      Controllers with Ethernet interfaces
      Gateways with Ethernet interfaces
      Servers and P.C. - standalone or virtual
      Storage - Disk drives or SSD
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 SFU relating to Building Automation Systems.

ACC - SFU 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
B-AWS - BACnet Advanced Operator Workstation: The B-AWS is the advanced operator's window into a BACnet system. It is primarily used to monitor the performance of a system and to modify parameters that affect the operation of a system. It may also be used for configuration activities that are beyond the scope of this standard.
B-OWS - BACnet Operator Workstation: The B-OWS is used for monitoring and basic control of a system, but differs from a B-AWS in that it does not support configuration activities, nor does it provide advanced troubleshooting capabilities.
B-OD - BACnet Operator Display: The B-OD is a basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. The B-OD profile could be used for wall-mounted LCD devices, displays affixed to BACnet devices; handheld terminals or other very simple user interfaces.
B-BC - BACnet Building Controller: A B-BC is a general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks.
B-AAC - BACnet Advanced Application Controller: A B-AAC is a control device with limited resources relative to a B-BC. It may be intended for specific applications and supports some degree of programmability.
B-ASC - BACnet Application Specific Controller: A B-ASC is a controller with limited resources relative to a B-AAC. It is intended for use in a specific application and supports limited programmability.
B-SA - BACnet Smart Actuator: A B-SA is a simple control device with limited resources; it is intended for specific applications.
B-SS - BACnet Smart Sensor: A B-SS is a simple sensing device with very limited resources.
BAS - BAS Building Management and Control System
BTL - BACnet Testing Laboratory: A recognized, independent third party laboratory certified to test product for compliance to BACnet standards.
BTL Mark - A seal affixed to product certifying that it has been tested by a recognized BACnet Testing Laboratory and found to conform to BACnet standards.

CBAS - Campus Building Automation System
CCF - BAS Central Computer Facility
CCP - Communications Control Panel
CPU - Central Processing Unit
DAU - Data Archival Unit. A device that sits on the Automation Network Level and automatically collects data to be sent up to the central data archive server that resides on the Management Level network and is located in the MACC.
DCP - Distributed Control Panel
DDC - Direct Digital Control
DELTA - Delta Controls Inc.
ESC - ESC Automation Inc. is the installing contractor and local representative for DELTA Controls.
FAS - Fire Detection, Alarm and Communication System
FTS - Field Termination Schedule
H/O/A - Hand/Off/Auto Motor Control Switch/Circuit
HDAS - Historical Data Archiving Server
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
MACC - BAS 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
PICS - Protocol implementation conformance statement: All devices conforming to the BACnet protocol shall have a documented statement (PICS) that identifies all of the portions of BACnet that are implemented in the device.
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
SBT - Siemens Building Technologies Ltd.
1.4. **Existing BAS Facilities**

A. Informational Note: SFU existing facilities BAS consists primarily of Delta Controls and Andover systems.

1.5. **Existing BAS Communication Network Facilities at SFU**

A. There are two separate and autonomous BAS’s installed and operating on the SFU Campus, with individual central alarm monitoring and control facilities, interconnecting network communications facilities and BAS monitoring and control facilities installed within campus buildings. BAS installations within individual buildings are configured as stand-alone BAS installations capable of real-time monitoring and control. Each of the stand-alone building BAS installations communicates with a centralized Campus BAS System (either Delta or Andover). CBAS work stations are located in pairs (one for Delta and one for Andover), strategically around the campus in locations such as the Energy Management Office and the boiler house.

B. All controls additions or modifications involved in a building renovation and/or addition shall be an extension of the existing BAS located in the building being renovated. An exception to this clause may be made if a vendor, other than the vendor of the existing BAS, makes an acceptable bid to replace the entire existing BAS system as well as satisfying the requirements of the building renovation or addition specifications.

1. SFU retains the right to define what an acceptable bid is.
2. SFU retains the right to define the extent of work required to be completed before an existing BAS can be deemed to be replaced.
3. The vendor seeking to replace an existing BAS shall submit a comprehensive engineering proposal to SFU Facilities detailing the proposed replacement BAS. SFU Facilities will approve of the replacement BAS system design and scope before the system can be approved as an acceptable replacement.
2 BAS INSTALLATION GUIDELINES

2.1 General BAS Installation Requirements

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

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

C. All BACnet equipment and software supplied for the projects shall be supported by manufacturer supplied PICS (Protocol Implementation Conformance Statement) certifying that the device complies with the specified BACnet requirements.

1. At a minimum, a BACnet PICS shall convey the following information:
   a. Basic information identifying the vendor and describing the BACnet device.
   b. The BACnet Interoperability Building Blocks supported by the device.
   c. The standardized BACnet device profile to which the device conforms.
   d. All non-standard application services that are supported along with an indication for each service of whether the device can initiate the service request, respond to a service request, or both.
   e. A list of all standard and proprietary object types that are supported.
   f. For each object type supported:
      I any optional properties that are supported,
      II which properties can be written-to using BACnet services,
      III if the objects can be dynamically created or deleted using BACnet services, IV any restrictions on the range of data values for properties.
   g. The data link layer option options, both real and virtual, supported.
   h. Whether segmented requests are supported.
   i. Whether segmented responses are supported.

2. All products have a BTL Mark certifying that the product was independently tested by a third party testing facility and complied with BACnet conformance requirements.

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

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

F. All new BAS Installations shall be integrated into existing DDC Andover and/or Delta Controls System.

G. The following are general installation guidelines for BAS 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 BAS 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 BAS 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 SFU 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 BAS Consultant and shall be identified on project design drawings. For new construction projects the BAS panel locations shall be identified in the project mechanical design drawings. For retrofit applications the BAS panel locations shall be identified on building floor plan drawings to be included in the project BAS Specifications/Contract Documents.

7. All components of the BAS shall be Identification tagged. Identification tags shall be 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. BAS controlled valve and damper actuators.
d. End-Devices.
e. Distributed ControlPanels (DCP)’s.
f. BACnet Advanced Application Controller (B-AACS)
g. BACnet Application Specific Controllers (B-ASC)’s.
h. Field panels.

8. Warning notices shall be provided at all equipment controlled by the BAS and at all associated motor starters. The warning notices shall state that the equipment is under the control of the BAS 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. SFU Building Operations shall furnish the warning notices to the BAS Contractor for use on each project. BAS Contractors shall be instructed to obtain the warning labels from SFU 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 BAS wire and cable 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 BAS field panel and DCP mounting locations. All control panels will be on emergency power and integral UPS except for non-critical control panels.
equipment. The BAS 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 BAS 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 BAS data point value engineering units shall be the International System of Units (SI).

H. Facilities shall be provided for the mounting of SFU Plant Operation Telephone and Data Communications facilities. The BAS Contractor shall provide the following “blue board” mounting facilities at all BAS 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 SFU 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 BAS record documentation for BAS Operator interface work.

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

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

2.2. BAS Electrical Installation Requirements

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

B. The BAS 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 coding of conduit is not required.

C. BAS 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. BAS data communication and network cable shall be installed in dedicated conduit and shall not share conduit with any other wire/cable.
D. The following are minimum requirements related to BAS 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.
   a. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 28 requirements.
   b. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be sub-fused.
2. With the specific exception identified within this document, all BAS 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 BAS Consultant and SFU.

E. Conduit:

1. Conduit shall be run in all exposed areas,
2. Conduit must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Conduit sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
3. Secure conduit with conduit clamps fastened to the structure and spaced according to code requirements. Conduit and pull boxes shall not be hung on flexible duct strap or tie rods. Conduit, junction boxes, pull boxes, and control panels shall not be run on or attached to ductwork.
4. Conduit fill:
   a. Shall meet the requirements of the Electrical Specifications for line voltage or AC power runs.
   b. Shall not exceed 60% of the cross-sectional area of the conduit for low voltage signal carrying conductors.
   c. Signal wiring, data wiring, and power wiring shall not be run in the same conduit.
   d. Communication network wiring shall be run in a conduit dedicated to network communications.
   e. Line voltage AC carrying conductors shall NOT be mixed in with DC carrying conductors.
      i. Low voltage AC (≤ 24 VAC) signal wiring with DC signal wiring may be combined in the same conduit.
   f. Sensor wiring shall be run in conduits dedicated to sensor wiring.
5. Junction or pull boxes shall be installed:
   a. Every 25 meters for 12mm conduit runs,
   b. Every 30 meters for conduit greater than 12mm,
   c. After the equivalent of four (4) 90° bends have been made. Every offset counts as ½ of a 90°, and each saddle counts as one 90° bend,
   d. All junction boxes shall be installed in accessible locations,
6. Use of flexible or BX (or equivalent) shall be limited to a maximum length of one (1) meter, and shall be supported on each end.
7. Exposed conduit ends shall have bushings installed to protect wiring running through the end of the conduit.
8. Flexible conduit shall have anti-short inters installed at each end to protect the wire or cable running through the end,
9. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
10. 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.
   a. Wire/cable installed in ceiling spaces without conduit shall be suitably rated and labelled.
   b. Wire/cable shall be securely supported and installed in a neat and workmanlike manner following building lines.
   c. Sleeves shall be provided for all wire/cable that penetrates wall partitions, concrete slabs, or rated partitions.
F. BAS low voltage monitoring and control wiring shall meet the following minimum requirements:

1. Minimum #20 AWG stranded copper conductors (larger gauge wire/cable shall be provided where required by BAS equipment and where applications warrant (e.g. long runs, etc.).
2. Twisted pair conductors.
3. All BAS input/output point wire/cable and communication cable shall be shielded.
   a. Non-shielded cables may be approved for BAS input and output field point wiring following certification from the BAS 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.
   b. The manufacturers certification shall guarantee to SFU that should it be determined that BAS system performance is negatively affected or another building system or equipment is negatively affected due to the non-shielded cable, the BAS manufacturer shall replace the cable at no cost to SFU.
4. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
5. Free air cabling installed in non-combustible rated buildings shall be fire rated cable with a minimum rating of FT-6.
6. Wiring located in combustible rated buildings above T-bar ceiling shall be run in free air using fire rated cable with a minimum rating of FT-4.
   a. Note: all free air cabling used in combustible rated buildings to interface to security or fire alarm systems shall be FT-6 rated.
   b. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
7. Cables shall follow building lines and be installed in bundles resting in a cabling support system (J-hooks).
8. Cable supports shall be attached to the wall or ceiling of the area they are running through. Cable supports shall not be attached to:
   a. Electrical raceways,
   b. Duct work,
   c. Ceiling suspension systems,
   d. Piping,
   e. Wilson joists.
9. Cabling bundles shall be held in the cable support system using Velcro straps.
10. Cable bundles shall be identified every ten (10) meters. The following nomenclature shall be used:
    a. “CONTROLS POWER” for bundles carrying EMCS or final control elements' control power wiring,
    b. “CONTROLS I/O” for bundles carrying EMCS input and output wiring.

G. Data Communication Cabling shall meet the following minimum requirements;

1. Unless otherwise specifically called for in the specifications, uniformity of manufacture to be maintained throughout the building for any particular item or type of equipment.
2. All data cabling shall use stranded conductors. Solid core conductors shall not be accepted.
3. Data cabling shall be run separately from power and signal wiring,
4. Data cabling shall be clearly labeled as “CONTROLS DATA HIGHWAY” at the beginning, the end, every twenty (20) meters of the run,
5. Communication runs be one continuous run from end to end without splices or connections,
6. Cabling shall be colour coded with different colours for each conductor,
7. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:
   a. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter.
   b. The maximum length of an MS/TP segment is 900 meters (with AWG 22 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
   c. The maximum number of nodes per segment shall be 32, as specified in the
EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.

d. An MS/TP EIA-485 network shall have no T connections.

e. Controls Contractor shall produce a test report based on their installed cable schedules. The report should indicate for each cable the values of all measured parameters, when it was tested successfully and the signature of the technician that performed the test; location, cable type, cable number, and tester make and model. A copy of the test report must be submitted to the Consultant for approval. The entire report must be signed by an authorized person for the Controls Contractor at the end of the project.

H. BACnet Ethernet communications cabling shall meet the following minimum requirements
1. Data cable shall Category 6E Ethernet cable.
2. Data cable shall be four twisted pair 24 AWG solid copper, Plenum Rated FT-6 / CMP or Riser Rated FT-4 / CMR (as required by local codes) unshielded twisted cable meeting EIA / TIA 568B.1 Category 5e classification.
3. The maximum cable length for each run shall be limited to 90 meters.
4. All Category 6e cables must be Power Sum accepted and recognized by the manufacturer.
5. Cable Skew must be specified as 20Ns or less per 100 meters.
6. Cables must display the manufacturer’s stamp stating that the cable is included in the latest UL verified publication for Category 6e standards.
7. All cables must be included in the System / Applications Certification Warranty.
8. All cabling installed inaccessible areas, (above drywall ceilings, and crawl spaces), must be installed in conduit or cable tray. Conduit fill must not exceed 40%.
9. Ethernet Cable Testing:
   a. The Controls Contractor is to use a Level III tester that is capable of testing the specified cable to the performance level(s) indicated in this document. The tester is to use the latest version of firmware and software to test the unshielded twisted pair (UTP) cabling system.
   b. The nominal velocity of propagation (NVP) must be set specific to each cable manufacturer before testing. Portable tester is to be calibrated on a minimum annual basis.
   c. The Consultant before the commencement of all field-testing may perform a visual inspection. The installation will be validated for compliance with the Industry Standards with particular attention given to the following criteria:
      I. Cable jacket removal and connector termination.
      II. Routing and pathway supports.
      III. Cable bend radius and cable tie slack.
      IV. Neatness, clamping, and harnessing of cabling and wiring.
      V. Wire and cable identification and labeling.
      VI. Nameplates, identification, plates, and markings.
   d. Provide two copies of testing and commissioning documentation for all items and their related components to the Project Manager and Owner’s Designated Representative before the designation of substantial completion for the project. Include maintenance manuals and operating instructions for Customer’s staff use. Substantial completion will not be granted until all documentation has been submitted and accepted by the Consultant.
   e. The permanent link performance of the installed cabling Data system must comply with EIA / TIA 568B-1 specifications for testing Category 5e systems. All horizontal channel testing shall be performed end to end for each port, (Dual NEXT). No conditional passes will be accepted.
   f. Testing of all 4 pairs of the horizontal cable (as specified in this document) is to include but not be limited to the following:
      I. Wire Map including; end to end continuity, open and shorts, pair polarity
      II. Cable length
      III. Attenuation
      IV. NEXT/FEXT
V. ACR
VI. Return Loss
VII. ELFEXT, PSELFEXT
VIII. Propagation Delay, Delay skew
IX. PSNEXT, PSACR.
g. All of the above parameters must be recorded and included in the test results.
h. Correct all cable faults. Splicing of any cables will not be permitted, for any reason, unless prior authorization is received in writing from the Consultant.
i. The Controls Contractor shall supply the Consultant with test results for approval and system acceptance. An additional copy of the test results is to be included for the maintenance manuals.

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

J. All BAS equipment and components shall be grounded to building ground facilities.

K. BAS shall only be capable of controlling electric motors when the associated hand/off/auto (HOA) motor control switches are in the “auto” position. BAS 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 BAS Controls Contractor.

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

M. Existing interlocks and override control facilities should typically not be removed or overridden by the application of new BAS control facilities without the specific instruction of the BAS Design Consultant and the approval of SFU Building Operations.

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

2.3. **BAS Communication Provisions**

A. The following minimum requirements shall be provided for SFU data communication interfaces:

1. The BAS data communication facilities shall be provided complete with suitable back boxes, blank cover plates and connection jacks, etc. mounted immediately adjacent to the BAS panel. Connection jacks are to be located inside the junction box.

2. In a SFU new construction project the BAS 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 BAS Controls Contractor shall provide an empty 27 mm (1”) conduit and back boxes complete with pull tapes for the future installation of wire and terminations by others. **Division 27, Section 27 0508** – 1.4.8. and drawing ITSTD – 20 &21.

2.4. **BAS Installation Training Requirements**

A. The BAS Specifications shall specify requirements for CBAS/BAS training to be provided as part of the work of all CBAS/BAS projects. CBAS/BAS 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 BAS Contractor 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 BAS 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 BAS Contractor shall provide initial basic monitoring and control training to the Owners personnel to provide them with sufficient knowledge of the BAS installations such that they can use the BAS for the day-by-day monitoring and control of the BAS.

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

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

1. BAS 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 BAS.
6. Trouble shooting and replacement of faulty components at CCP, DCP and UC's.

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

H. 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 BAS without any on-going assistance from any outside party.

I. The CBAS Contractor shall provide Owner Training on the CBAS monitoring and control facilities provided for each project. CBAS 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 BAS.
2. Details related to the point mapping, database development, programming, BACnet BAS device and object identification, point naming, integration, etc.
3. VDU graphics set up and modification.
4. Alarm monitoring, display, annunciation and modification facilities.
J. The BAS Contractor may provide computer based, self-directed training accomplish the portions of the SFU training requirements. Provide onsite training for details specific to the particular BAS 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.

2.5. **BAS Documentation Requirements**

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

B. A complete draft set of engineered system graphics shall be submitted prior to the start of commissioning for review and approval of the BAS manager. The submittal shall clearly identify:

1. All building floor plans,
2. All mechanical system graphics,
3. A schematic graphic detailing an overview of the hydronic systems and air systems contained within the building,
4. All individual mechanical equipment graphics (E.G.: VAV boxes, fan terminal units, etc.),
5. All system operating parameter tables, tables shall include:
   a. All unitary equipment (e.g.: heat pumps, etc.),
   b. All terminal equipment (e.g.: VAV boxes, radiation zones, etc.),
   c. All third party BACnet interface device object values (chillers, boilers, VFD BACnet object variables that may need to be referenced rarely).
      i. BACnet object values that are pertinent to daily operating requirements shall be displayed on the mechanical system graphic as well as in the object table.
6. All interlinking between the graphics, and third party documents, (PDF files, spreadsheets, etc.) referenced through graphical links.
7. All third party documents that will be graphically linked to the graphics package.

C. 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 BAS Contractor.
7. Name and address of supplier or vendor if appropriate.
8. Name of manufacturer.

D. Shop drawings shall be CAD generated, minimum plot size of 11 x 17 inches; refer to SFU Facilities Services Record Submission Requirements for details. 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. BAS topology/network architecture schematic(s).
2. Installation drawings and schedules.
4. CCP, DCP, UC and other panel layouts, including floor plan location and interconnection drawings.
5. Field instrumentation locations on floor plan drawings.
6. Schematic of systems indicating instrumentation locations.
7. Installation details.
8. Schedule of cabling including details of proposed cable types.
9. Composite drawings of all motor starter terminal strips and damper terminal strips indicating all wiring by all contractors on the motor terminal strip.

E. 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 CBAS. 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.

F. 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
5. Maintenance Manuals.
6. Control Drawings.
7. Other supporting documentation.

G. BAS O&M manuals will exist in Mechanical O&M, no separate standalone copies will be accepted.

H. 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 database 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.

I. 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.
J. 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 BAS 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.

K. 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 BAS 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 BAS point database for all installed and calculated points.
8. Other relevant software information.

L. 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 Contract.
2. Maintenance instructions for all BAS hardware equipment including but not limited to CCP, DCP, UC, distributed DDC controllers, modems, printers, ROW, etc.

M. 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 SFU project number and SFU drawing number.
N. 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.

O. 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-built drawings 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.

P. 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.

Q. Manuals shall be updated whenever the Contractor makes changes to the Work.

R. Comply with and additional project requirements for documentation.

S. 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.

T. 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.

U. All BAS and CBAS Record Documentation shall be provided in electronic .pdf file format on a CD or DVD.

2.6. BAS Installation Commissioning and Testing

A. BAS specifications shall clearly specify the requirements for Contractor testing and commissioning of the BAS including test documentation and requirements for testing and demonstration with other project commissioning personnel and the BAS design consultant.

B. All commissioning shall be completed using the graphics generated for the user interface, and the graphics shall be verified at the same time that point end-to-end checks and programmed sequences of operation verifications are completed.

1. Hardware and graphics commissioning shall take place simultaneously.
2. Should the initial end-to-end checks be completed without the use of the graphics, the end-to-end checks must be completed again to confirm the point layout indicated on the graphics is consistent with the point locations in the field.

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

D. The BAS Contractor shall undertake joint testing of the BAS integration with the CBAS with the CBAS Integration Contractor. The BAS Specifications shall specify requirements for the joint BAS/CBAS Contractor Testing and Commissioning.
E. The BAS Contractor shall perform a complete and detailed operational check of each BAS 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.

F. 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.

G. 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 BAS output.
6. Calibration of the control device.
7. Labels provided on the control devices and mechanical equipment is correct.

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

I. System testing shall be undertaken by the BAS Contractor and the BAS Contractor shall complete and submit the BAS Contractor Commission Record Sheets. The following shall be demonstrated as a minimum with the presence of the commissioning authority:

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.

J. The Consultant's verification tests shall be performed by the BAS Contractor 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. Additionally, the commissioning authority shall be present for testing. The BAS Contractor 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.

K. Integrated BAS/CBAS joint systems tests shall be undertaken to demonstrate that the interaction between the individual building BAS and the CBAS meets the SFU requirements. The BAS Contractor shall participate in joint verification of the integrated systems and cooperate with the Owner in the demonstration of the integrated systems.
L. The BAS Specifications shall specify the requirements for the BAS/CBAS integration joint systems verification. The BAS/CBAS Integrated System Verification shall include the following minimum requirements:

1. Test all BAS monitored and controlled field devices, BAS data points and all BAS input and output points. CBAS monitored data point values shall be verified against actual field device position/state and compared to BAS values to ensure both BAS and CBAS values are the same.
2. CBAS override control of all BAS output points and control data points shall be verified.
3. BAS 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. BAS data values displayed on dynamic system graphics or in tabular data format at the CBAS are functional and accurate.
5. CBAS operator control of BAS control output points and control data points are functional via the dynamic graphic interface.
6. CBAS 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 CBAS performance requirements for the monitoring and control of BAS data and field devices meet the SFU requirements.
8. BAS device addressing and identification definitions are compatible and identical and the addressing scheme meets with SFU requirements.
9. All BACnet controllers addressing shall conform to the SFU schedule for BACnet device addressing.
10. Point naming used is compatible and conformal with the SFU requirements.

M. 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 BAS Contractor 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.

N. All test documentation shall be maintained in electronic format and in hard copy.
3  BAS DESIGN GUIDELINES

3.1.  General BAS Design Requirements

A. BAS installations at SFU buildings shall be turnkey installations operating fully standalone.

B. All BAS 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 BAS devices shall be native BACnet compliant at the Automation data communication network level.

C. The CBAS shall be compliant with the requirements defined for a BACnet Operator Workstation Device (B-OWS). The CBAS shall provide centralized operator interface for monitoring and supervisory control of the individual building BAS.

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

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

F. All BAS installations shall have a network data server computer with associated BAS manufacturer application software installed and running located in the BAS 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 BAS Contractor complete with all manufacture specific BAS 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 SFU. The NDS shall be provided with functionality detailed in these documents. The dedicated NDS shall communicate with the individual building BAS’s over the SFU Management Level WAN. Data communications shall be BACnet/IP. Any BAS installation provided for a SFU building shall have a NDS dedicated to BAS 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 BAS manufacturer.

G. SFU building BAS 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 BAS. The individual building BAS installation

Contractor work shall include coordination and documentation work for the integration of the BAS into the CBAS via BACnet data interface by other contract. Installations shall in no way negatively affect existing BAS installations and existing campus BAS performance.
H. BAS installations shall be provided which incorporate BAS equipment and network facilities in compliance with the requirements identified in these guidelines. The BAS designer shall specify detailed BAS equipment requirements and BAS network architecture requirements in the BAS Design Specifications. BAS equipment and data communication network specifications shall incorporate good BAS engineering, design, and application practices and shall incorporate the SFU BAS Design Guideline requirements.

I. BAS online editing is necessary for all controllers that serve critical equipment (to be determined by project team) which cannot be shut down without a maintenance shutdown notice.

J. BAS installations in SFU buildings shall incorporate the following minimum requirements:

1. Equipment shall be approved components as manufactured by one of the SFU approved BAS Manufacturers and shall be in compliance with the SFU BAS Design Guidelines.
2. Management and Automation Level communication LAN’s shall be provided to ensure the following:
3. 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. The failure of an UC shall not affect the operation of other operating UC or DCP.
5. All BAS 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 BAS 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 BAS 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.
6. 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. BAS Contractor and System Qualifications

A. BAS’s to be provided for any SFU building installations shall be products as manufactured by one of the following manufacturers:

1. Schneider Electric
2. Delta Controls

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

1. Houle Electric Ltd.
2. ESC Automation
C. BAS installations shall be provided by BAS Contractors who meet the following requirements:

1. Must have been in operation in the BAS industry in the City of Burnaby area for a minimum of 10 years.
2. Employ qualified staff in the Burnaby area capable of undertaking a complete BAS installation project and to provide routine and emergency maintenance on all elements of the BAS.
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 BAS. BAS Contractor shall have service and support facilities available to SFU 24 hours per day, 7 days per week.
5. Have local, or access to, supplies of BAS components with a maximum delivery period of 24 hours.

D. All new control points shall be connected to the closest existing or new Infinity Andover or Delta Control panel, and are to be fully compatible with the existing installed central monitoring and control facilities, network communications facilities, and with other SFU building BAS installations.

E. All BAS DCP’s, UC’s, OIW’s where applicable, and other BAS 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 BAS facilities from one of the approved SFU BAS manufacturers. In applications where HVAC system controls within an existing building are being retrofitted and BAS facilities of any of the approved BAS manufacturers exist within the building, BAS facilities shall be provided by the manufacturer of the BAS equipment already installed. The retrofitted BAS installation shall be provided to interconnect the new renovation work into the existing building and campus BAS facilities.

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

G. All BAS products proposed for installation on a SFU project shall have been previously demonstrated to SFU Building Operations satisfaction and approved by SFU Building Operations prior to being listed as an approved bidder. Any BAS 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 CBAS shall be fully demonstrated to SFU’s satisfaction and approved by SFU Building Operations prior to being considered as an approved product.

3.3. **BAS Network Architecture and Communications Requirements**

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

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

C. The CBAS/BAS architecture shall comprise the following network layers:
1. Management Level (by CBAS and BAS Contracts):
   a. A Wide Area Network (the SFU Campus WAN) shall provide a means of interoperable communication between the CBAS and the individual building BAS 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 SFU 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 BAS buildings.

   b. It shall be the responsibility of each BAS building contractor, to ensure that all BAS system data is available at the Management Level Network. The intent is that the CBAS shall be able to automatically read this data from the network using the BACnet automatic “find new objects” features. Each BAS 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 CBAS contractor. BAS Specifications shall specify the inform

   c. Each BAS system shall have a dedicated NDS installed at the SFU MACC. The NDS shall be dedicated to campus building BAS’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 BAS’s over the BAS 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 BAS 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 SFU 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 SBT Apogee with BACnet Option server computer and application software shall be the operator interface for supervisory monitoring and control of the building BAS systems. The SBT Apogee Server computer, application software and associated management level WAN facilities shall be the Campus Building Automation System (CBAS).

   f. The CBAS shall be in conformance with the requirements and functionality detailed in ANSI/ASHRAE Standard 135 (BACnet) for a BACnet Operator Workstation (B-AWS). The CBAS shall have terminal service capabilities with “Thin Client” operator interface. The CBAS shall communicate with the individual building BAS’s over the BAS Management Level via BACnet/IP. CBAS applications software shall run on the existing SBT Apogee NDS server computer installed at the SFU MACC. The CBAS 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 CBAS and BAS shall be resident on the Management Level Network, not the BAS Automation Level. If an OIW is required within a remote building, the CBAS 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 BAS and the Management Level Network (SFU WAN). If multiple
CCP are required in a building due to Automation Level node quantities or limitations of CCP capabilities, the BAS Contractor shall add the additional CCP as an extension of the Management Level Network within the school. The BAS Contractor shall provide Management Level network facilities within individual buildings.

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

2. Automation Level (by the BAS Contract):
   a. The Communication Control Panels (CCP) shall be part of the BAS. 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 CBAS 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 BAS standardized devices where testing protocols and certification requirements are not yet finalized, the BAS 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 BAS controllers shall be tested and certified within a reasonable period of time of the testing and certification process being available.
   f. The BAS Automation Level Networks shall be BACnet MS/TP protocol. 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 accomplished through a point-for-point, hardwired interface.

3. Field Level (by BAS 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 BAS 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 CBAS 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 SFU Campus WAN.

B. OPERATOR INTERFACE WORKSTATION (OIW)

1. The OIW shall conform to the BACnet device profile B-AWS.
2. The B-AWS is the advanced operator's window into a BACnet system. It is primarily used to monitor the performance of a system and to modify parameters that affect the operation of a system. It will also be used for BAS system configuration activities that are beyond the scope of the BACnet standard.
3. At minimum the workstation shall be capable of meeting the following requirements of the BACnet standard:
   a. Data Sharing,
      i. Presentation of data (i.e., reports and graphics),
      ii. Ability to monitor the value of all BACnet object types, including all required and optional properties,
      iii. Ability to modify setpoints and parameters,
   b. Alarm and Event Management
      i. Operator notification and presentation of event information
      ii. Alarm acknowledgment by operators
      iii. Alarm summarization
      iv. Adjustment of alarm limits
      v. Adjustment of alarm routing
      vi. Creation of new Event Enrollment and Notification Class objects
      vii. Presentation of Event Logs
   c. Scheduling
      i. Modification of calendars and schedules
      ii. Display of the start and stop times (schedule) of scheduled devices
      iii. Display of calendars
      iv. Creation of new calendars and schedules
   d. Trending
      i. Modification of the parameters of a trend log
      ii. Display of trend data
      iii. Creation of new Trend Log objects
   e. Device and Network Management
      i. Ability to find other BACnet devices
      ii. Ability to find all objects in BACnet devices
      iii. Ability to silence a device on the network that is transmitting erroneous data
      iv. Ability to synchronize the time in devices across the BACnet internetwork at the request of the operator
      v. Ability to cause a remote device to reinitialize itself
      vi. Ability to backup and restore the configuration of other devices
      vii. Ability to command half-routers to establish and terminate connections
4. At minimum the workstation shall be capable of meeting the following requirements that fall outside of the BACnet standard:
   a. Operating third party drawing packages such as AUTODESK AutoCad, MICROGRAPHIX Draw, ADOBE Illustrator, or COREL Draw,
   b. Operating third party office suites such as MICROSOFT Office Professional,
   c. Operating database analysis tool such as SAP Crystal Reports.
   d. Capability to transmit detailed documents, screen captures, reports, trend graphs, alarms, and notifications via email.
      i. Email should be capable of being sent to individuals, and or groups.
      ii. The system shall have the capability to generate emails automatically based upon BAS calendar dates and times, system events, or system alarm events.
      iii. Emails generated by the BAS systems shall have the capability to send to different people, departments or groups based upon the type of alarm, alarm priority, and the building system generating the email.
   e. Capability to transmit critical alarms to cellular phones via SMS text messaging.
      i. Text messages generated by the BAS systems shall have the capability to send to different people, departments or groups based upon the type of alarm, alarm priority, and the building system generating the text messages.

C. WEB SERVER OPERATOR INTERFACE (WOI)

1. The WIO, at minimum, shall conform to the BACnet device profile B-OWS.
2. ‘The B-OWS is an operator interface with limited capabilities relative to a B-AWS. The B-OWS is used for monitoring and basic control of a system, but differs from a B-AWS in that it does not support configuration activities, nor does it provide advanced troubleshooting capabilities.
3. The B-OWS profile is targeted at the daily operator who needs the ability to monitor basic system status and to perform simple modifications to the operation of the system.
4. At minimum the workstation shall be capable of meeting the following requirements of the BACnet standard:
   a. Data Sharing
      i. Presentation of data (i.e., reports and graphics)
      ii. Ability to modify setpoints and parameters
   b. Alarm and Event Management
      i. Operator notification and presentation of event information
      ii. Alarm acknowledgment by operators
      iii. Alarmsummarization
      iv. Adjustment of analog alarm limits
   c. Scheduling
      i. Modification of calendars and schedules
      ii. Display of the start and stop times (schedule) of scheduled devices
      iii. Display of calendars
   d. Trending
      i. Display of trend data
   e. Device and Network Management
      i. Ability to find other BACnet devices
      ii. Ability to synchronize the time in devices across the BACnet internetwork at the request of the operator
5. At minimum the workstation shall be capable of meeting the following requirements that fall outside of the BACnet standard:
   a. Web Server Capabilities
      i. Automatically generate WEB pages from graphics that are resident in the Operator Interface Workstation (OIW).
      ii. Serve up universally compatible web pages to the World Wide Web (internet, intranet, extranet) or cloud.
         i. Web pages shall be compatible with web browsers operating on remote computers, laptops, tablets, or smartphones.
         ii. Web pages shall be compatible with web browsers such as Internet Explorer operating on MICROSOFT platforms (Windows, Windows Server, Windows CE), Safari operating on APPLE platforms (OSX and IOS), Dolphin operating on the ANDROID platform, or any universal browsers that are platform independent (Chrome, Firefox, Mozilla).
            • Web pages are to use HTML5 encoding for animation and **not** ADOBE Flash.
      III. Any changes made to the graphics residing in the OIW will be automatically updated at the web page level.
   
D. BMS Historian

1. Historian must be able to trend log every point for a 2-year period at an interval of 15 minutes.

2. Data must be CSV exportable.

E. BACnet Operator Display (BOD)

1. The TOI shall conform to the BACnet device profile B-OD.
2. The B-OD is a basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. The B-OD profile could be used for wall-mounted LCD devices, displays affixed to BACnet devices; handheld terminals or other very simple user interfaces.
3. At minimum the workstation shall be capable of meeting the following requirements of the BACnet standard:
   a. Data Sharing
      i. Presentation of basic data
      II. Ability to modify setpoints and parameters
   b. Alarm and Event Management
      i. Operator notification and presentation of event information
   c. Scheduling
      i. No minimum requirements
   d. Trending
      i. No minimum requirements
   e. Device and Network Management
      i. Ability to find other BACnet devices
4.2. **BAS Automation Level Network**

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

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

2. BACnet IP protocol implemented via Ethernet.
   a. 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 BAS 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 CBAS.

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 BAS.

F. CCP shall record and store device change of state data, BAS event/transaction and alarm data, and trend data in memory within the CCP and shall automatically upload the data to the CBAS and NDS. In the event that the CBAS and/or NDS is not available, the CCP shall store the data in memory within the controller and automatically upload the data once the CBAS/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.

G. CCP panels shall comply with the BACnet Building Control (B-BC) device profile. A B-BC is a general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks. The panel shall have the following capabilities:

1. Data Sharing
   a. Ability to provide the values of any of its BACnet objects,
   b. Ability to retrieve the values of BACnet objects from other devices,
   c. Ability to allow modification of some or all of its BACnet objects by another device,
   d. Ability to modify some BACnet objects in other devices.

2. Alarm and Event Management
   a. Generation of alarm / event notifications and the ability to direct them to recipients,
   b. Maintain a list of unacknowledged alarms / events,
   c. Notifying other recipients that the acknowledgment has been received,
   d. Adjustment of alarm / event parameters.

3. Scheduling
   a. Ability to schedule output actions, both in the local device and in other devices, both binary and analog, based on date and time.

4. Trending
   a. Collection and delivery of (time, value) pairs.

5. Device and Network Management
   a. Ability to respond to queries about its status,
   b. Ability to respond to requests for information about any of its objects,
   c. Ability to respond to communication control messages,
   d. Ability to synchronize its internal clock upon request,
   e. Ability to perform re-initialization upon request,
   f. Ability to upload its configuration and allow it to be subsequently restored,
   g. Ability to command half-routers to establish and terminate connections.
4.4. Distributed Control Panels (DCP)

A. The BAS 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 BAS. 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. DCP panels shall comply with the BACnet Building Control (B-BC) device profile. A B-BC is a general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks. The panel shall have the following capabilities:

1. Data Sharing
   a. Ability to provide the values of any of its BACnet objects,
   b. Ability to retrieve the values of BACnet objects from other devices,
   c. Ability to allow modification of some or all of its BACnet objects by another device,
   d. Ability to modify some BACnet objects in other devices.

2. Alarm and Event Management
   a. Generation of alarm/event notifications and the ability to direct them to recipients,
   b. Maintain a list of unacknowledged alarms/events,
   c. Notifying other recipients that the acknowledgment has been received,
   d. Adjustment of alarm/event parameters.

3. Scheduling
   a. Ability to schedule output actions, both in the local device and in other devices, both binary and analog, based on date and time.

4. Trending
   a. Collection and delivery of (time, value) pairs.

5. Device and Network Management
   a. Ability to respond to queries about its status,
   b. Ability to respond to requests for information about any of its objects,
   c. Ability to respond to communication control messages,
   d. Ability to synchronize its internal clock upon request,
   e. Ability to perform re-initialization upon request,
   f. Ability to upload its configuration and allow it to be subsequently restored,
   g. Ability to command half-routers to establish and terminate connections.

6. Data Sharing
   a. Ability to provide the values of any of its BACnet objects,
   b. Ability to retrieve the values of BACnet objects from other devices,
   c. Ability to allow modification of some or all of its BACnet objects by another device,
   d. Ability to modify some BACnet objects in other devices.
7. Alarm and Event Management
   a. Generation of alarm / event notifications and the ability to direct them to recipients,
   b. Maintain a list of unacknowledged alarms / events,
   c. Notifying other recipients that the acknowledgment has been received,
   d. Adjustment of alarm / event parameters.

8. Scheduling
   a. Ability to schedule output actions, both in the local device and in other
      devices, both binary and analog, based on date and time.

9. Trending
   a. Collection and delivery of (time, value) pairs.

10. Device and Network Management
    a. Ability to respond to queries about its status,
    b. Ability to respond to requests for information about any of its objects,
    c. Ability to respond to communication control messages,
    d. Ability to synchronize its internal clock upon request,
    e. Ability to perform re-initialization upon request,
    f. Ability to upload its configuration and allow it to be subsequently restored,
    g. Ability to command half-routers to establish and terminate connections.

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

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

H. 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.

I. 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.

J. 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.

K. 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.

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

M. 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 BAS 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 CBAS.

I. UC’s that serve equipment, (such as a unit ventilator), that requires a degree of custom programming to achieve the specified sequence of operation shall be a BACnet Advanced Application Controller (B-AAC). The B-AAC shall have the following capabilities:

1. **Data Sharing**
   a. Ability to provide values for any of its BACnet objects upon request,
   b. Ability to allow modification of some or all of its BACnet objects by another BACnet device.

2. **Alarm and Event Management**
   a. Generation of limited alarm and event notifications and the ability to direct them to recipients,
   b. Tracking acknowledgments of alarms from human operators,
   c. Adjustment of alarm parameters.

3. **Scheduling**
   a. Ability to schedule actions in the local device based on date and time.

4. **Trending**
   a. No requirement.

5. **Device and Network Management**
   a. Ability to respond to queries about its status,
   b. Ability to respond to requests for information about any of its objects,
   c. Ability to respond to communication control messages.
J. UC’s that serve equipment, (such as a VAV box, heat pump, or fan coil), that does not require a degree of custom programming to achieve the specified sequence of operation shall be a BACnet Application Specific Controller (B-ASC). The B-ASC shall have the following capabilities:

1. Data Sharing
   a. Ability to provide values for any of its BACnet objects upon request,
   b. Ability to allow modification of some or all of its BACnet objects by another BACnet device.

2. Alarm and Event Management
   a. No requirement.

3. Scheduling
   a. No requirement.

4. Trending
   a. No requirement.

5. Device and Network Management
   a. Ability to respond to queries about its status,
   b. Ability to respond to requests for information about any of its objects,
   c. Ability to respond to communication control messages.

K. Any trending requirements required for data located at the B-AAC or B-ASC level shall be completed at the CCP level.

L. Any alarming functions that may be required for data located at the B-ASC level shall be completed at the CCP level.

M. A dedicated UC shall be provided for the BAS 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 BAS monitoring and control or operation of other unitary equipment or BAS devices.

4.6. Valves and Dampers

A. Automatic Control Valve General Requirements:

1. The BAS Contractor shall furnish all valves controlled by the BAS as detailed in the mechanical trade documents and as indicated on control drawings. The BAS Contractor shall furnish all shut-off valves for instrumentation. The Mechanical Contractor 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 Contractor. The BAS Contractor shall provide details of the manufacturer's installation requirements to the Mechanical Contractor. The BAS Contractor shall coordinate the valve body type and pipe connections with the mechanical trade.

B. The BAS Contractor 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

I. 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.
   1. Valve configuration (e.g. two way, three way, butterfly).
   2. Leakage rate.
   3. Maximum pressure shut-off capability.
   4. Actuator manufacturer and model number.
   5. Valve body pressure and temperature rating.

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

K. 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.

L. 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.

M. The BAS Contractor 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.

N. Two-Way Control Valves
   1. The BAS Contractor 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:
         \[ N = \frac{P_1}{P_1 + P_2} \]
      b. where \( P_1 \) = pressure drop across the fully open valve, and
         \( P_2 \) = 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. BAS Consultant to specify requirements.

O. Three-way Control Valves
1. The BAS Contractor 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: 
      \[ N = \frac{P_1}{P_1 + P_2} \]
   b. where \( P_1 \) = pressure drop across the fully open valve
   c. \( P_2 \) = 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.

P. 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 BAS Contractor 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 than the system working pressure, whichever is the greater.
   f. Rated for a minimum of 50 °C (90 °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 BAS SFU contractor 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.

Q. Valve Actuators - Electric

1. The BAS Contractor shall provide electric actuators for valves that are furnished by the BAS Contractor. Pneumatic type actuators are not acceptable.
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 BAS 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.
R. DAMPERS - GENERAL

1. The BAS Contractor shall furnish automatic dampers (CD) as indicated in the Mechanical trade documents and in the Field Termination Schedules for installation by the Division 23 Mechanical Contractor.

2. The BAS Contractor shall provide actuators for all automatic dampers furnished as part of the BAS contract and for all dampers provided by the air handling unit manufacturers, unless otherwise specified. The BAS Contractor shall provide all required actuator mountings, installation, drive arms, linkages and damper end switches. The BAS Contractor shall provide electric damper actuators as specified within the BAS 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 BAS 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 23 Mechanical Drawings and Specifications.

8. The BAS Contractor shall provide actuators sized in accordance with manufacturers recommendations and industry standards for accurate and stable control of airflow in each application.

9. The BAS Contractor 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 BAS Contractor shall furnish manufacturers’ installation details to the Division 23 Mechanical Contractor. 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 BAS Contractor 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.

S. CONTROL DAMPERS (CD)

1. The BAS Contractor 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 BAS Contractor 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 aluminum 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.
V. DAMPER ACTUATORS FOR Control Dampers (CD)

1. Unless otherwise specified the BAS Contractor 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. BAS 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 BAS analog output subsystem. BAS controlled actuators for two position dampers shall be controlled by 24Vac, 24Vdc or single-phase 120 Vac power switched by the BAS.

   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:

<table>
<thead>
<tr>
<th>Service</th>
<th>Timing Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two position normal service</td>
<td>75 seconds</td>
</tr>
<tr>
<td>Modulating normal service</td>
<td>120 seconds</td>
</tr>
<tr>
<td>Emergency service (stair pressurization,</td>
<td>15 seconds</td>
</tr>
</tbody>
</table>

   i. Rated for operation at ambient temperatures of minus 40 °C. to 50 °C. (-40 ° F. to 122 ° 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.

4. Motorized controls shall have a 5 year warranty.
W. DAMPER HARDWIRED INTERLOCKS

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

2. The BAS Contractor shall provide all wiring as required for the control and interlocking of automatic dampers. The BAS Contractor shall provide control signal and power supply wiring between any damper monitored and/or controlled by the BAS regardless of whether the BAS Contractor has furnished the damper/actuator assembly. The BAS Contractor 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 BAS Contractor 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 BAS Contractor 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 BAS specifications, and as indicated in the Division 23 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. **BAS Field Devices And Instrumentation**

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

B. The BAS specifications shall instruct the BAS 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 BAS monitoring and control of the device.

C. BAS field device requirements shall be identified in the BAS project specifications. The BAS Consultant shall identify BAS monitoring and control requirements in the specifications via BAS Field Termination Schedules and BAS Systems Schematics. Individual BAS points identified in the Field Termination Schedules shall cross reference corresponding devices indicated on the associated BAS System Schematic. The BAS 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 BAS System Schematics.

D. All BAS 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 BAS component shall be provided which contains asbestos, PBC’s, or other hazardous materials.

E. BAS 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 °C. (Coefficient of resistivity of 0.00385 ohms/ohm/°C.).
   
   II. 1000 ohm Platinum at 0 °C. (Coefficient of resistivity of 0.00385 ohms/ohm/°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 BAS 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 BAS monitored temperature sensors shall be ± 0.5 °C.
   
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 °C. to +50 °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 °C. to 65 °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 °C. to 50 °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 have displays which at minimum display current temperature and setpoint. Room temperature sensor shall also have an occupancy button which will allow the room to be placed in occupied mode for an adjustable time period.
   c. Mounted at locations approved by SFU and the BAS 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 °C. to 50 °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 °C.
   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.
   d. Setpoint shall be adjustable in the range of, at minimum, 0 °C. to 7 °C. (32 °F. to 45 °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 auxiliary contacts for monitoring by the BAS.

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 °C. to 80 °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 BAS. Sensor to be fully compatible with BAS.
   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 0 °C. to 50 °C. (32 °F to 122 °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 SFU and the BAS 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 BAS 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 °C. to +63 °C.
d. Two wire, 4-20 mA output proportional to minimum dry bulb temperature range of -23 °C. to +79 °C.
e. Probe shall be a minimum of 200mm for duct application.
f. BAS shall report the monitored dry bulb temperature with an accuracy of ± 0.5 °C.

15. BAS shall report the monitored dewpoint temperature with an accuracy of ± °C. at 50% RH and dry bulb temperature of -25 °C. to +65 °C.

a. If it meets the above requirements, provide Honeywell HyCal model HYD840, Honeywell HyCal HYDMP2 Moisture Pro or approved equal.

16. 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 BAS digital output.
d. Located in the DCP, UC or other local enclosures.
e. Malfunction of an BAS component shall cause the controlled output to fail to the positions identified in the failure procedure.
17. 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 BAS 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.

18. 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 °C to 49 °C (20 °F to 120 °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.
   h. 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.

19. 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 °C to 38 °C (32 °F to 100 °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.

20. 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 23 Contractor.
   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 °C to 60 °C (0 °F to 140 °F).
   i. ± 5% accuracy of measured value.
j. Transducer to be provided complete with easily accessible, integral non-interacting zero and span adjustment.

21. 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 23 Contractor.
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 °C. to 60 °C. (0 °F. to 140 °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.

22. 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 °C. to 60 °C. (5 °F. to 140 °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.

23. 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 23 Contractor. Furnish the valves to the Division 23 Contractor. 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.

24. **Differential Pressure Switch - Air Service - Duct Static Pressure Limit Devices**
   - UL, cUL, CSA listed and approved.
   - SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
   - Adjustable setpoint with a setpoint range to suit the application.
   - 1/4 inch compression fittings suitable for copper sensing tubing.
   - Temperature range of -18 ° C. to 71 ° C. (0 ° F. to 160 ° F.).
   - Manual reset.
   - Provide sensing inputs complete with signal dampening facilities to prevent nuisance tripping where required.
   - If it meets the above requirements, provide Kele Model AFS-460, Dwyer, or approved equal.

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

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

27. **Water Pressure Sensor**
   - Input range of 0 to 200 psi.
   - Complete with transducer with 4-20 mA output signal proportional to water pressure.
   - 0.5% accuracy over entire sensing range.
   - Temperature range of 0 ° C. to 38 ° C. (32 ° F to 100 ° F.).
   - Transducer with easily accessible, integral non-interacting zero and span adjustment.
   - Over pressure input protection of two times rated input.
   - NEMA-4 rated fittings.
   - Stainless steel wetted parts.
   - Burst pressure of 5 times rated input.
   - Long-term stability of .25 percent of full scale.
k. If it meets the above requirements, provide Precise Sensor, Fisher/Rosemount, or approved equal.

l. Stainless Steel wetted parts suitable for continuous contact with the sensed medium.

28. 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 ° C. to 71 ° C. (32 ° F. to 160 ° 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.

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

30. 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 ° F. to 125 ° F.
   e. Pressure range of 0 to 500 psia.
   f. If it meets the above requirements, provide MagneTek, 7025 Series, product or approved equal.

31. 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 ° C. to 60 ° C. (32 ° F. to 140 ° F.).
   f. Mounting and enclosure suitable for duct air or space air monitoring as
32. 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 CO₂ 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 °C to 32 °C temperature range. Accuracy of ±/− 5 % or 100ppm of reading whichever is the more stringent requirement over 0 °C to 50 °C temperature range.
f. Annual Drift not to exceed ±/− 10 ppm.
g. Operating temperature of 0 °C to 50 °C.
h. Complete with auxiliary 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.
l. Nondispersive Infrared technology based sensor.

33. 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.

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 BAS SOFTWARE, DATABASE AND PROGRAMMING REQUIREMENTS

5.1. General

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

5.2. System Requirements

A. 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 BAS data, etc.

B. The NDS and associated application specific BAS Software shall be provided with programming and configuration facilities to allow BAS operators to undertake BAS 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 BAS controllers.

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

D. The BAS Contractor shall include, at minimum, two days of work in the BAS installation to work with the CBAS Contractor for the integration of the BAS into the CBAS beyond any time required to make all system data available at the CCP connection to the WAN. The building BAS designer shall assess each installation and specify additional scope of work and time requirements for the BAS Contractor integration work required based on project size and complexity.

E. BAS installations shall be in compliance with the following requirements and shall provide the following functionality:

1. All BAS and CBAS controllers and operator interface workstations shall be devices that are conformal with the BACnet standardized device types described in Annex L of the current ASHRAE Standard 135. BAS 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 BAS controllers, regardless of their device type, shall communicate on the BAS and CBAS networks and shall be “visible” to the CBAS and BAS networks.
3. BAS 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 BAS monitored input points (binary and analog type) shall be readable and available for monitoring at the CBAS and by other BAS controllers.
5. All physical BAS controlled output points (binary and analog type) shall be readable and available for monitoring at the CBAS and by other BAS controllers and shall be capable of being controlled/positioned by the CBAS and by other BAS 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 CBAS and by other BAS controllers and/or shall be writeable and shall be capable of being controlled/positioned by the CBAS and by other BAS controllers. Provide the following typical software data points and control parameters with the defined functionality, at minimum.

F. The BAS Specifications shall identify additional points and functionality where required.

1. System enable virtual points.
2. Virtual or “logical” software points.
3. Equipment and System operation Calendar/Time Schedule points and parameters.
5. Post Power Failure System Enable/Disable points.
6. Control loop setpoints and PID loop values.
7. Alarm setpoints and alarm limit parameters.
8. Define and modify alarm states and alarm limit threshold values for any monitored analog and digital input points and for analog output values.

G. Modification of the controlled output points shall be via operator interface at the CBAS dynamic graphical interface facilities and shall not require BAS manufacturer proprietary software or special configuration software files.

H. Performance times shall be as follows:

1. Data values updated in dynamic report or graphical display reports within maximum interval of 5 seconds.
2. Defined high priority or critical alarms annunciated within 3 seconds of its sensed occurrence.
3. CBAS Operator command outputs and data point modifications shall be executed within 5 seconds of the command initiation at the CBAS workstation or other remote BAS device.
4. Failed BAS/CBAS data communications or controller device on the Management Data Communications Level or the Automation Data Communications Level within ten (10) seconds.

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

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

K. Trending: The BAS contractor shall setup and configure system trending as follows:

1. In general, all DDC system points shall be trended and each trend log point shall be minimum 200 samples. Trend logs shall be set up to meet the following requirements:
a. Storage:
   I. Trend log sample frequency shall be setup to have the trend log information display meaningful data that can be used to Trend logs must reside in the controller of the points being trended.
   II. All trend logs shall be archived to the trend archival system.

b. Sample Frequency:
   I. Sample frequencies shall be configured to gather meaningful data required to analyze system performance, confirm loop tuning, and aid system troubleshooting.
   II. Control points and loops that have a slow dynamic response shall have lower sample frequencies (E.g.: outdoor air temperature, radiant slab heating, etc.).
   III. Control points and loops that have a faster dynamic response shall have higher sample frequencies (E.g.: mixed air temperature, water differential pressure, etc.).
   IV. Trend logs used to verify loop tuning shall be set at the fastest possible sample frequency for the duration of the loop tuning interval.
   V. Loop tuning trend logs shall have a high enough sample frequency to accurately describe the loop response to rapid changes in set point or input variables.
   VI. The trend logs shall be archived and the trend sample frequency set to an interval used for day-to-day operation.

2. Trended Points:
   a. All physical input and out points.
   b. All setpoint values (this is to include loop setpoints, high and low limit setpoints, and all room setpoints).

3. Trend Log Grouping:
   a. Trend logs shall be grouped to display the performance of the various control loops required to control the system.
   b. Trend groups shall be accessible directly from the graphics.
   c. Trend logs shall contain all input variable, all controlled variables, and all setpoint for the system being trended. For example:
      I. A terminal reheat room temperature control trend would contain the following points:
         i. Room Temperature
         ii. Active Room Setpoint
         iii. Occupancy Status
         iv. Heating Valve Output
      II. Where a system is too complex to display all of the required trend variables in one trend log, the system will be broken down to its functional components and each component shall be trended. For example, a zone being controlled by variable air volume boxes with terminal reheat, CO2, and occupancy would need more than one trend log.
         i. Trend Log A would contain the variable associated with the heating component:
            ♦ Room Temperature
            ♦ Active Room Setpoint
            ♦ Occupancy Status
            ♦ Heating Valve Output
            ♦ Primary Air Supply Temperature
            ♦ VAV supply air temperature (downstream of the reheat coil)
            ♦ VAV Supply Air Volume
            ♦ VAV Damper Position
         ii. Trend Log B would contain variables associated with the ventilation component:
            ♦ CO2 Level
            ♦ Active CO2 setpoint
4. Where variable trends are repeated in each functional component of the system, repeat the trending in each trend log to ensure that the trend log is clear and complete. (E.g.: occupancy status, VAV Supply Air Volume, VAV Damper Position are repeated in the above example).

L. Data Archiving: The BAS contractor shall install, configure and program the DAU. The DAU shall be configured as follows:
   1. Every physical point shall be archived,
   2. Every software variable that is used for day to day operations shall be archived,
   3. The archival time period shall be set for five (5) years.
      a. The DUA device or system shall automatically prune all data that has aged beyond the five year time limit.
   4. All alarms shall be archived. Alarms shall be archived to include the following information:
      a. All alarms shall include the following identification;
         DCC Network Descriptor acronym
      b. Expanded DDC Network Descriptor,
      c. Date
      d. Time
      e. Point Name
      f. Expanded Point Descriptor
      g. Alarm Type (e.g.: Operating, Maintenance, Critical, Emergency, etc.)
      h. Alarm Status
         i. Automatic Control Priority (Overridden Value, Automatic Control, Disabled, failed, etc.)
      j. Actual point monitored input / controlled output value.
      k. Alarm Setpoint
      l. Alarm Message.

5.3 SOFTWARE

A. An operator with BAS 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 BAS 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 BAS software control mode and for motors in the BAS manual control mode.

C. The BAS 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 BAS output control mode.

D. Unless stated to the contrary, the modulation of final control elements by the BAS in the BAS 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 BAS manual control to BAS 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 CBAS 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 CBAS and BAS 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 CBAS and BAS 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 BAS 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 BAS. Historical trend data shall be stored in a non-proprietary database such as Microsoft SQL Server in the BAS 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.

I. 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.

J. Provide a scheduling program that will enable the BAS 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 BAS software control mode. Equipment and space time occupancy time schedules shall be available for display and operator adjustable via the CBAS. The scheduling feature shall conform to the CBAS scheduling interface.

K. 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.

L. 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 13 °C to activate the heating equipment and 15.5 °C to stop the heating equipment. Once activated, the units involved shall operate as specified in the respective sequence of operation.

M. Coordinate the operation of this program with the requirements for terminal unit controls.
   1. Night setup temperatures for cooling shall be initially set at 32 °C to activate the cooling equipment and 29 °C 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.
   2. This feature shall be provided for all HVAC equipment under control of the BAS. The operator shall be able to enable/disable this function on a unit by unit basis.

N. Provide facilities for alarm notification via both the building BAS NDS and the CBAS via e-mail messaging, wireless text messaging and SNMP.
5.4. **SFU BAS POINT NAMING CONVENTIONS REQUIREMENTS**

A. All point naming conventions shall be reviewed and accepted by the SFU Facilities prior to be implemented.

B. Each point name shall consist of the following components:
   1. Abbreviated building name
   2. Equipment type as per table below.

<table>
<thead>
<tr>
<th>System</th>
<th>Point</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV</td>
<td></td>
<td>Variable Air Volume System</td>
<td></td>
</tr>
<tr>
<td>AHU</td>
<td></td>
<td>Air Handling Unit</td>
<td></td>
</tr>
<tr>
<td>BLR</td>
<td></td>
<td>Boiler System</td>
<td></td>
</tr>
<tr>
<td>HTG</td>
<td></td>
<td>Heating System</td>
<td></td>
</tr>
<tr>
<td>CHSYS</td>
<td></td>
<td>Chiller System</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td></td>
<td>Heat Pump System</td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td></td>
<td>Supply Fan</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td></td>
<td>Return Fan</td>
<td></td>
</tr>
<tr>
<td>EF</td>
<td></td>
<td>Exhaust Fan</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>Pump</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>Boiler</td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td></td>
<td>Chiller</td>
<td></td>
</tr>
<tr>
<td>VSD</td>
<td></td>
<td>Variable Speed Drive</td>
<td></td>
</tr>
<tr>
<td>HEX</td>
<td></td>
<td>Heat Exchanger</td>
<td></td>
</tr>
<tr>
<td>SAT</td>
<td></td>
<td>Supply Air Temperature</td>
<td></td>
</tr>
<tr>
<td>RAT</td>
<td></td>
<td>Return Air Temperature</td>
<td></td>
</tr>
<tr>
<td>MAT</td>
<td></td>
<td>Mixed Air Temperature</td>
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</tr>
<tr>
<td>OAT</td>
<td></td>
<td>Outside Air Temperature</td>
<td></td>
</tr>
<tr>
<td>CDT</td>
<td></td>
<td>Cold Deck Temperature</td>
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</tr>
<tr>
<td>HDT</td>
<td></td>
<td>Hot Deck temperature</td>
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</tr>
<tr>
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<td></td>
<td>Supply Air Humidity</td>
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</tr>
<tr>
<td>RAH</td>
<td></td>
<td>Return Air Humidity</td>
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<tr>
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<td>Mixed Air Dampers</td>
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<td>EAD</td>
<td></td>
<td>Exhaust Air Dampers</td>
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</tr>
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<td>Cooling Tower</td>
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</tr>
<tr>
<td>CCP</td>
<td></td>
<td>Cooling Coil Valve</td>
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</tr>
<tr>
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<td>Heating Coil Valve</td>
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</tr>
<tr>
<td>PCV</td>
<td></td>
<td>Preheat Coil Valve</td>
<td></td>
</tr>
<tr>
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<td>Direct Expansion Valve</td>
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</tr>
<tr>
<td>CCP</td>
<td></td>
<td>Cooling Coil Pump</td>
<td></td>
</tr>
<tr>
<td>HCP</td>
<td></td>
<td>Heating Coil Pump</td>
<td></td>
</tr>
<tr>
<td>PCP</td>
<td></td>
<td>Preheat Coil Pump</td>
<td></td>
</tr>
<tr>
<td>ECP</td>
<td></td>
<td>Evaporative Cooling Pump</td>
<td></td>
</tr>
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</table>
### System

<table>
<thead>
<tr>
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<th>Point</th>
<th>Function</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FRZ</td>
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<td>Freeze Detection</td>
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<tr>
<td>RT</td>
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<td>Room Temperature</td>
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</tr>
<tr>
<td>VAV</td>
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<td>Variable Air Volume</td>
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</tr>
<tr>
<td>S</td>
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<td>Status</td>
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<tr>
<td>SP</td>
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<td>Setpoint</td>
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<tr>
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<tr>
<td>PG</td>
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<td></td>
</tr>
<tr>
<td>AL</td>
<td></td>
<td>Alarm</td>
<td></td>
</tr>
</tbody>
</table>

3. Number of instance.

5.5. **SFU BAS CONTROLLER AND DEVICE ADDRESSING AND NAMING CONVENTION REQUIREMENTS**

A. All IP addresses are to be provided by SFU personnel once the necessary IT infrastructure is in place.
   1. In the event of new building construction this infrastructure will not be in place until the building is near completion.

B. BACnet device addressing is to be managed by the controls contractor and should be coordinated with SFU Facilities.

C. SFU personnel are to provide BACnet device addresses for devices outside of the assigned vendor address ranges.

D. SFU personnel must be provided any necessary tools to change the BACnet device address on any devices installed.
6 CBAS SOFTWARE, DATABASE AND PROGRAMMING REQUIREMENTS

6.1. INTEGRATION OF STANDALONE BUILDING BAS INTO THE CAMPUS BAS

A. The CBAS Contractor shall provide the mapping, storage, and reporting of the building BAS monitoring and control objects into the CBAS and the preparation of data presentation for the CBAS Management Level Network. Two separate CBAS system are currently in place, Delta Controls System and Andover system. The BAS Contractor shall provide to the Owner and to the CBAS Contractor, all necessary documentation, BIBB information, device addressing, etc. as required for the integration of the BAS monitoring and control functions into the corresponding CBAS.

B. The CBAS Contractor shall integrate all trend logging and trend log archiving set up in the building BAS into the CBAS.

6.2. ALARM MANAGEMENT AND ANNUNCIATION

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

1. Failure of a CCP, DCP, UC, or any other BAS 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 BAS.

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

C. BAS alarms shall be assigned priority levels as follows:

1. Critical Alarms:
   These alarms are assigned by 2 criteria: 1) alarm leads to dangers and/or life threatening conditions. 2) occupants specify they want to be notified immediately when a certain alarm condition occurs. The following list is not all inclusive but lists the typical critical alarms.

   a. Natural gas alarm
   b. Freon gas alarm
   c. Carbon monoxide alarm
   d. Hydrogen sulfide alarm
   e. Exhaust fan pressure failure
   f. Fume hood exhaust fan failure
   g. Cooling unit failure serving critical area (server room, refrigeration etc.)
   h. High temperature water in mechanical systems
   i. Freezing of water lines

2. Non-critical alarms
   Remaining alarms are non-critical alarms.

D. Defined BAS alarm events shall be communicated by the BAS to the CBAS. Defined alarms shall be annunciated at the CBAS workstation. Alarms shall be retained in the CBAS alarm summary.
E. All alarms shall include the following identification:

1. DCC Network Descriptor acronym
2. Expanded DDC Network Descriptor,
3. Date
4. Time
5. Point Name
6. Expanded Point Descriptor
7. Alarm Type (e.g.: Operating, Maintenance, Critical, Emergency, etc.)
8. Alarm Status
9. Automatic Control Priority (Overridden Value, Automatic Control, Disabled, failed, etc.)
10. Actual point monitored input / controlled output value.
11. Alarm Setpoint

F. The alarm log shall have the capability to be sorted or filtered on any or all of the following values:

1. DCC Network Descriptor acronym
2. Alarm Message.
3. Time
4. Date
5. Point Name
6. Alarm Type (e.g.: Operating, Maintenance, Critical, Emergency, etc.)
7. Automatic Control Priority (Overridden Value, Automatic Control, Disabled, failed, etc.)
8. Alarm Status

6.3. CBAS/BAS ALARM HANDLING ARCHIVING REQUIREMENTS

A. The CBAS shall allow access of BAS alarms related to each system (Delta or Andover).

B. The CBAS shall maintain a historical alarm log that encompasses all alarms for a predefined period.

C. The historical alarm log shall be searchable and have the capability to be sorted or filtered on any or all of the following values:

1. DCC Network Descriptor acronym
2. Alarm Message.
3. Time
4. Date
5. Point Name
6. Alarm Type (e.g.: Operating, Maintenance, Critical, Emergency, etc.)
7. Automatic Control Priority (Overridden Value, Automatic Control, Disabled, failed, etc.)
8. Alarm Status

D. The database sorting and filtering keys shall be a minimum of three levels deep.

6.4. TESTING AND COMMISSIONING REQUIREMENTS

A. Integrated BAS/CBAS joint systems tests shall be undertaken to demonstrate that the interaction between the individual building BAS and the CBAS meets the SFU requirements. The BAS Contractor shall participate in joint verification of the integrated systems and cooperate with the Owner in the demonstration of the integrated systems.

B. The BAS Specifications shall specify the requirements for the BAS/CBAS integration joint systems verification in the BAS and CBAS Specifications and/or Contract Documents. The BAS/CBAS Integrated System Verification shall include the following minimum requirements:
1. Test all BAS monitored and controlled field devices, BAS data points and all BAS input and output points. CBAS monitored data point values shall be verified against actual field device position/state and compared to BAS values to ensure both BAS and CBAS values are the same.

2. CBAS override control of all BAS output points and control data points shall be verified.

3. BAS 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. BAS data values displayed on dynamic system graphics or in tabular data format at the CBAS are functional and accurate.

5. CBAS operator control of BAS control output points and control data points is functional via the dynamic graphic interface.

6. CBAS 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 CBAS performance requirements for the monitoring and control of BAS data and field devices meet the SFU requirements.

8. BAS device addressing and identification definitions are compatible and identical and the addressing scheme meets with SFU requirements.

9. Point naming used is compatible and conformal with the SFU 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 BAS Contractor 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.
7 GUIDELINES FOR APPLICATION OF BAS TO TYPICAL HVAC SYSTEMS

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

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

B. BAS Design Specifications for SFU BAS projects shall detail BAS monitoring and control requirements in Field Termination Schedules and System Schematic Diagrams. Field Termination Schedules and System Schematic Diagrams shall be provided for all BAS 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 BAS 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 SFU project BAS Design Specifications shall be based on the same format as indicated within these documents.

C. Sequences of Operation for typical SFU 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. BAS automatic control of building systems and equipment shall not override life safety or equipment protection overrides. The BAS Design Consultant shall specify automatic control interface requirements.

7.2. BAS Component and Building Equipment Failure Requirements

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

B. DCP/UC Controller Failure
   a. associated BAS 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.

1. BAS Analog Input Sensor Failure
   a. Associated BAS control output retained in last commanded state. If an alternative sensor can be utilized for satisfactory control the BAS shall incorporate automatic control logic to implement the revised control.
   b. Failure of information only type BAS input points shall be annunciacted alarms.
2. Controlled Electric Motor/ Equipment Failure
   
a. Anytime the status of BAS controlled equipment is different than the associated BAS controlled output status the equipment shall be considered as “failed” and shall be shut down by the BAS. The associated BAS controlled system shall also be shut down. **Project Design Specifications shall specify the post failure equipment restart requirements.**

   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 BAS shall restart the failed equipment/systems in an orderly and pre-defined manner following **the cleaning of the Fire Alarm or return to normal power.** The BAS Design Specifications shall specify the post fire alarm equipment restart and the post power failure equipment restart requirements.

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

3. If a BAS 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. **BAS Automatic Sequenced Control of AHU Mixing Dampers and Valves**

   A. Designated air handling units require the BAS to control heating and cooling coil control valves and mixing dampers in sequence. BAS 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 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. 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 BAS Monitoring and Control Requirements**

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

   B. All BAS Operator monitoring and control functions shall be provided with the appropriate password access control.
C. A single BAS software control point shall be provided for each BAS controlled system to enable/disable automatic start-up and control of the entire system. BAS controlled systems shall be capable of being started/stopped either by automatic BAS control or via online Operator command.

7.5. Post Fire Alarm Equipment Restart

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

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

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

D. Equipment shut down by the fire alarm system will be completed through hardwired connections. The BAS will automatically start equipment once fire alarm is cleared – all buildings monitor status of fire alarm signal sent to BAS.

E. 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 BAS 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 BAS 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 startup 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 BAS 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 °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 °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 °C. If any space temperature falls below 15 °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 °C.

7.9. **Air Handling Unit Supply Air Temperature Reset Schedules**

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

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

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

<table>
<thead>
<tr>
<th>Average Space Temperature</th>
<th>Supply Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C.</td>
<td>?? °C.</td>
</tr>
<tr>
<td>24 °C.</td>
<td>?? °C.</td>
</tr>
</tbody>
</table>

2. **Constant Volume Air Handling Unit, No BAS secondary controls, insufficient space temperature monitoring.**
   a. BAS to reset supply air temperature based on return air temperature reset schedule.

<table>
<thead>
<tr>
<th>Return Air Temperature</th>
<th>Supply Air Temperature Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C.</td>
<td>?? °C.</td>
</tr>
<tr>
<td>24 °C.</td>
<td>?? °C.</td>
</tr>
</tbody>
</table>

3. **Constant or Variable Air Volume Air Handling Unit with BAS secondary controls.**
   a. BAS to control to design supply air temperature setpoint. BAS 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. Mixed Air Calculations and Mixing Damper Minimum Outside Air Positioning

A. BAS 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 BAS monitored values for outside air temperature, mixed air temperature, and return air temperature.

B. The BAS shall override normal BAS minimum outside air damper position control to maintain specified outside air flow requirements based on the dynamic mixed air calculations. The BAS 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 °C or more. The BAS shall also limit mixing damper control to prevent the mixed air temperature from falling below 6 °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. 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 °C. and shall remain on whenever the outside air temperature is below 15 °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. System control loops shall be disabled.

B. The Occupancy operating schedule for this system is:

C. 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.

D. 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 (BAS DESIGNER TO IDENTIFYRESET 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 BAS 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 BAS shall enable the steam humidifier control on a requirement for humidification if
cooling is not required. The BAS 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 BAS shall enable automatic modulating control of the humidifier steam control valve. The BAS 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:

<table>
<thead>
<tr>
<th>Outside Air Temperature</th>
<th>Space Relative Humidity Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 ° C</td>
<td>35%</td>
</tr>
<tr>
<td>25 ° C</td>
<td>50%</td>
</tr>
</tbody>
</table>

E. The BAS shall monitor the supply air relative humidity. The BAS 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 BAS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BAS shall return the system to the state described for System Off.
3. The BAS 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 ° C. The return fan shall remain on. This BAS 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 ° C or lower is sensed. The return fan shall remain in operation. Device shall be manual reset. The BAS 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 BAS 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 BAS.
7.12. Typical Sequence of Operation - Constant Volume Air Handling Unit - hardwire interlocked RF

A. 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 °C. and shall remain on whenever the outside air temperature is below 15 °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. System control loops shall be disabled.

B. The Occupancy operating schedule for this system is:

C. 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.

D. 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 (BAS DESIGNER TO IDENTIFYRESET 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 BAS 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 BAS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BAS 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 BAS shall enable automatic modulating control of the humidifier steam valve. The BAS 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:

<table>
<thead>
<tr>
<th>Outside Air Temperature</th>
<th>Space Relative Humidity Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 ° C</td>
<td>35%</td>
</tr>
<tr>
<td>25 ° C</td>
<td>50%</td>
</tr>
</tbody>
</table>

E. The BAS shall monitor the supply air relative humidity. The BAS 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 BAS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BAS shall return the system to the state described for System Off.
3. The BAS 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 °C. This BAS 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 °C or lower is sensed. The return fan shall remain in operation. The BAS 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 BAS 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 BAS.
7.13. **Typical Sequence of Operation - Variable Volume Air Handling Unit**

A. 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 °C. and shall remain on whenever the outside air temperature is below 15 °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.
9. System control loops shall be disabled.

B. The Occupancy operating schedule for this system is:

C. 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 BAS 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.

D. System Operation:

1. The BAS 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 by the mechanical engineer. 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 (BAS 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 BAS 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 BAS shall enable the steam humidifier control on a requirement for humidification if cooling is not required. The BAS 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 BAS shall enable automatic modulating control of the humidifier steam control valve. The BAS 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:

<table>
<thead>
<tr>
<th>Outside Air Temperature</th>
<th>Space Relative Humidity Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 °C</td>
<td>35%</td>
</tr>
<tr>
<td>25 °C</td>
<td>50%</td>
</tr>
</tbody>
</table>

E. The BAS shall monitor the supply air relative humidity. The BAS 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 BAS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BAS shall ramp down the supply and return fan speeds and return the system to the state described for System Off.
3. The BAS 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 °C. The return fan shall remain on and shall be set to an operator adjustable speed, initially set at 65% air volume. This BAS 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 °C or lower is sensed. The return fan shall remain in operation and shall be set to an operator adjustable speed, initially set at 65% air volume. Device shall be manual reset. The BAS 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 BAS 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 BAS.
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

A. 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 °C. and shall remain on whenever the outside air temperature is below 15 °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.
9. System control loops shall be disabled.

B. The Occupancy operating schedule for this system is:

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

1. The BAS 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 hardware 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 command OFF. Provide damper end switches on the outside air damper sections hardware interlocked with the supply fan motor control circuit such that the supply fan cannot operate unless the dampers are in the fully open position. Provide the end switches hardware 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 BAS 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 hardware 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 hardware interlocked with the exhaust fan motor control circuit such that the exhaust fan cannot operate unless the dampers are in the fully open position. Provide the end switches hardware 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 BAS 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 BAS 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 °C., the BAS 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.

D. System Operation:

1. The BAS 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 by
the mechanical engineer.
   a. 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 by the mechanical engineer.
   b. 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 (BAS DESIGNER TO IDENTIFY
RESET REQUIREMENTS).
   c. The heating coil pump shall be started/stopped by the BAS 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.
   d. The BAS shall enable the steam humidifier control on a requirement for
humidification if cooling is not required. The BAS 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 BAS shall enable automatic
modulating control of the humidifier steam control valve. The BAS shall modulate the
humidifier

E. 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:

1. | Outside Air Temperature | Space Relative Humidity Setpoint |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. -10 ° C</td>
<td>35%</td>
</tr>
<tr>
<td>b. 25 ° C</td>
<td>50%</td>
</tr>
</tbody>
</table>

F. The BAS shall monitor the supply air relative humidity. The BAS 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.
G. System Shut Down:

1. System shut down shall be initiated automatically by the BAS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
2. On system shut down the BAS shall ramp down the supply and exhaust fan speeds and return the system to the state described for System Off.
3. The BAS 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 °C. This BAS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

H. 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 °C. or lower is sensed. The BAS 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 BAS 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 BAS 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 BAS.

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**

A. 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 °C. and shall remain on whenever the outside air temperature is below 15 °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.

B. The Occupancy operating schedule for this system is:

C. System Start-up: On system start-up:
   1. The BAS 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 cannot operate unless the dampers are in the fully open position. Provide the end switches hardware 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 °C., the BAS 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.

D. 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 (BAS DESIGNER TO IDENTIFYRESET REQUIREMENTS).
   2. The heating coil pump shall be started/stopped by the BAS 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.

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

A. System Off - When the system is off:
   1. The fan shall be off and the unit shut down.

B. The Occupancy operating schedule for this system is:

C. System Start-up: On system start-up:
   2. The BAS shall output a system enable command to the self-contained ac unit electronic controller. Wire to terminations at the electronic controller.

D. System Operation:
   1. Once enabled by the BAS the ac unit shall be controlled by the standalone integral ac unit controller as provided by the ac unit manufacturer.
   2. The BAS 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.

E. System Shut Down:
   1. System shut down shall be initiated automatically by the BAS according to Occupancy Schedule requirements, by manual Operator command, or via hardwired interlocks.
   2. On system shut down the BAS shall return the system to the state described for System Off.
   3. The BAS 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 °C.
      C. This BAS software shutdown sequence shall be disabled during the first ten (10) minutes following system start-up.

F. Hardwire Interlocks
   1. Hardwire interlocks may be required. BAS Designer to coordinate requirements for any hardwire interlocks, BAS wiring terminations and interfaces, etc..
7.17. **Chilled Water (CW) and Condenser Water (CSR) Systems**

A. **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.
   5. All control loops shall be disabled.

B. **The Occupancy operating schedule for this system is:**
   1. This system shall be enabled either by an operator manually entered command at the BAS or automatically by the BAS based on time schedule or demand by the AHU's.
   2. Provide two BAS operator modes of control, "BAS Manual" and "BAS Automatic". Selection of operating mode shall be by manual Operator selection. When in the BAS Manual mode start up and shut down of the chilled water and condenser water systems shall be by manual Operator BAS command only. When in the BAS Automatic Mode, start up and shut down of the chilled water and condenser water systems shall be automatically controlled by the BAS as defined in the following sequences of operation.
   3. When in the BAS 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 °C. regardless of cooling coil valve position.

C. **System Start-up: On system start-up:**
   1. BAS shall start the designated "duty" chilled water pump. BAS 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 BAS shall start the standby pump.
   2. Upon proof of chilled water pump operation the BAS shall start the designated "duty" condenser water pump. BAS 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 BAS 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 BAS shall output an enable command to the chiller control panel provided by the chiller manufacturer. Once enabled by the BAS, control of the chiller shall be by the chiller control panel. The BAS chiller enable/disable control software shall incorporate minimum chiller run times and minimum times between chiller restarts.
   4. BAS 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. BAS 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 BAS.
6. Upon proof of condenser water pump operation the BAS shall enable the condenser water system controls. Upon proof of condenser water pump operation the BAS shall control the cooling tower fans to maintain the condenser water supply temperature.

D. System Operation:

1. The BAS 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 °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 BAS 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 cannot 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 cannot be maintained for an operator defined period, then the following staging shall occur, with appropriate time delays to prevent excessive fan starting/stoping:
   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.

E. 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.

1. 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 BAS 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 BAS if none of the chilling units are operating.
   3. On system shut down the BAS 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 23 and Division 26 Specifications.

H. Alarm setpoints - The BAS 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 ° F. and 42 ° 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 ° 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 ° F. during normal operation and 40 Def. F. during economizer operation.
   2. The outside air temperature low limit for bypass control shall be 36 ° F.
   3. The condenser water supply temperature setpoint during after hours operation shall be 85 ° F.
   4. The time delay for cell staging shall be 10 minutes.
   5. The switch over setpoint for staging fans off shall be 5 ° F. below setpoint.
   6. The plant condenser water supply temperature setpoint shall be 65 ° F.

7.18. Supply Hot Water System (SHW)

A. 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.

B. The Occupancy operating schedule for this system is:
   1. System shall be started/stopped by the BAS 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 afterhours 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 °C.

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

1. BAS shall start the designated "duty" hot water supply pump. BAS 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 BAS 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.

D. System Operation:

1. The BAS 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 °C.

2. The BAS 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:

<table>
<thead>
<tr>
<th>OUTSIDE AIR TEMPERATURE</th>
<th>HOT WATER SUPPLY SETPOINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 °C.</td>
<td>93 °C.</td>
</tr>
<tr>
<td>15 °C.</td>
<td>60 °C.</td>
</tr>
</tbody>
</table>

E. Provide BAS 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 °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 BAS 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 BAS 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. System Off - When the system is off:
   1. The domestic hot water circulation pump shall be off.
   2. Control loops shall be disabled.

B. 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.

C. System Start-up: On system start-up:
   1. BAS shall start/stop the domestic hot water recirculation pump to maintain the domestic hot water return temperature at setpoint.

D. 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 BAS, 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.

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

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

***END OF SECTION***