UNIVERSITY OF TORONTO | Facilities & Services

Building automation systems design standard

Last updated: August 14, 2025
Revision 9

Table of contents

Table of figures

List of tables

1 Introduction

1.1 Intent

1.1.1 This building automation systems (BAS) design standard specifies all BAS and associated components for all the new construction, retrofit, renovation and upgrades at the University of Toronto's St. George campus.

1.1.2 The purpose of this standard is to convey the University of Toronto's (the University) requirements for the BAS, mechanical control systems, direct digital controls components, process instrumentation components, and the integration with the Energy Management and Reporting System (EMRS).

1.1.3 This standard outlines the expectations and the bases of design (BOD) for all products, installations, and the workmanship quality related to BAS. It also outlines the University's requirement of the Design Team and the Commissioning Agent (CxA).

1.1.4 It is the responsibility of the Design Team to ensure that the information in this standard is incorporated in the project's specification documents. The requirements presented in section 3.17 - EMRS integration with non-BACnet compliant components, Appendix A - Diagrams, Appendix B - Typical control wire and cable schedule, and Appendix D - Terminal equipment controller (TEC) submittal package shall be included as attachments in the project's specification.

1.1.5 All BAS on St. George campus shall be fully interoperable as per the ANSI/ASHRAE standard-135 2020 (ASHRAE-135). Non-BACnet Testing Laboratories (BTL) listed or legacy BAS shall not be extended or installed. The reasoning behind specifying interoperable systems based on BACnet is to:

1.1.5.1 Specify the desired building automation and control system functionality.

1.1.5.2 Specify the desired workstation functionality and relationship to the EMRS.

1.1.5.3 Specify the network technologies, relationships, and responsibilities.

1.1.5.4 Ensure that all networks use the BACnet protocol (ASHRAE-135), and all supplied devices implement the BACnet functionality as required in the approved device profiles (2.2.3 BACnet building controller (B-BC), 2.2.4 BACnet advanced application controller (B-AAC) and application specific controller (B-ASC)).

1.1.5.5 Ensure consistent and current BAS designs and installations across the St. George campus portfolio.

1.1.5.6 Engage and expand a centralized enterprise management system for the campus-wide building performance optimization, verification, and reporting system.

1.1.5.7 Provide the management, operations, and maintenance teams with the necessary tools to fully manage, operate, expand, and maintain the campus BAS without using off-campus or software as a service (SaaS) platform.

1.1.6 Any references to the contractor's obligations in this standard shall be incorporated in the project specification that is provided by the Design Team.

1.1.7 The Design Team shall submit variance request form as per the University's deliverable standard when designing products that utilize alternative means, methods, and configurations.

1.1.8 In this standard, "shall" expresses a mandatory requirement, supplier, or criteria.

1.1.9 The University welcomes state of the art solutions for BAS on campus. It will not however, allow products or solutions to be tested, or beta level equipment to be installed without prior approval from the University.

1.1.10 A centralized EMRS exists on the St. George campus from which all buildings' BAS can be controlled and monitored. All BAS require integration with EMRS.

1.1.11 The use and procurement of any equipment covered under the U.S. National Defense Authorization Act (NDAA), 889(1)(B) is prohibited. Architect shall follow the most current list and make updates throughout the project's design process.

1.2 Overview

1.2.1 The University's intent is to competitively procure BAS solutions that offer complete and cost-effective direct digital control (DDC) building automation system. These systems should automatically control the operation of the heating, ventilating, air conditioning and lighting (HVAC&L) systems, and monitor and/or control project specific auxiliary systems as required.

1.2.2 The campus's architecture features building level controls known as BAS (including controllers, field level devices, actuators, sensors, etc.) and a campus wide EMRS. Any new or migrated BAS shall be fully integrated into the EMRS. The integration involves creating and installing custom interactive color graphics and compiling and displaying all devices and objects from integrated BAS across the campus. All new EMRS graphic displays shall reside on the existing EMRS and developed and modified by F&S IT to fit each project's need. Integration of all campus BAS into EMRS shall be through BACnet/IP communication protocols.

1.2.3 The BAS system shall employ object-oriented technology (OOT) to represent all data and control devices within the system.

1.2.4 A campus wide ethernet physical layer is supplied and maintained by F&S IT to which all approved IP based devices and systems shall be connected. This connection shall be made through network switches via University-specified and provided color coded patch panels and switches. The process shall follow the University's Communications Infrastructure

Specifications, standards, and practices. The Project Manager/Design Team shall coordinate with the University for the integration and installation of IT components.

1.2.5 The Design Team shall coordinate the proposed location of all the network switches with the University. The Design Team shall coordinate the location and installation of all IP switches for any given project during the design stage.

1.3 Definitions

Accuracy	Accuracy includes combined effects of nonlinearity, non-repeatability, and hysteresis.
Advanced application controller (AAC)	A device with limited resources relative to the building controller (BC). It may support a level of programming and may also be intended for specific applications. Typically serviced on the serial field bus network.
Application specific controller (ASC)	A device with limited resources relative to the advanced application controller (AAC). It may support a level of programming and may also be intended for specific applications. Typically serviced on the serial field bus network.
Approvals	Where the term “approvals” or similar is used it means the reference issue shall be approved by the university in writing before the issue can be incorporated.
BACnet standard	BACnet communication requirements as defined by the latest ASHRAE/ANSI 135 at the time of the receipt of the bid.
BACnet interoperability building blocks (BIBB)	A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
Building automation system (BAS)	A set of integrated control devices in a building that is used to access, control, and monitor all interfaced building systems from a central interface - EMRS.
BACnet building controller (B-BC)	A fully IP programmable device capable of performing multiple tasks, including control and monitoring via direct digital control (DDC) of specific systems, acting as a communications router between the F&S VLAN and serial field buses, and storing trend information, time schedules, and alarm data. Similar to other BTL Listed controller types (B-AAC, B-ASC etc.), a B-BC device is required to support the server ("B") side of the Read

	Property and Write Property services. However, unlike the other controller types, it is also required to support the client ("A") side of these services. Communication between controllers requires that one of them supports the client side and the other supports the server side, so a B-BC is often used when communication between controllers is needed.
BACnet advanced application controller (B-AAC)	A control device which contains BIBBs to support scheduling and alarming but otherwise has limited resources compared to a B-BC. It may be intended for specific applications and supports some degree of programmability.
BACnet application specific controller (B-ASC)	A controller with limited resources relative to a B-AAC. It is intended for use in a specific application and supports limited programmability.
BACnet instance numbers	The BACnet instance number is a unique number associated with each BACnet object.
BACnet metafile definitions	The precise definition of the constructs and rules needed for creating BACnet objects.
BACnet object list	A list of BACnet objects associated with a project building controls implementation, completed with a description of their physical representation, and system association.
Basis of design (BOD)	A “living document” that is updated at each phase of design to the appropriate level of detail required for that phase. It is the document that conveys the understanding of the project and how the design solution will address the user requirements. It is also a record of the assumptions and decision-making process driving the design.
BAS controller	A fully programmable device capable of capable of performing multiple tasks, including control and monitoring via direct digital control (DDC) of specific systems, acting as a communications router between the F&S VLAN and serial field buses, and storing trend information, time schedules, and alarm data.
Calibration tolerance (CTL)	The acceptable variation in instrument indication for a given input, for which no adjustment is required. The CTL is derived from the instrument manufacturers limits. The CTL is within the process calibration tolerance limit of an instrument.

Change	Any addition to, deletion from, or modification to an aspect material, facility, utility, equipment, logic, or practice within the scope of the building automation systems. This differs from a deviation due to unplanned events requiring temporary actions to be remediated to the initial conditions prior to the unplanned event.
Commissioning Agent (CxA)	An individual or company identified by the University to lead, plan, schedule, and coordinate the Commissioning Team in the implementation of the commissioning process (refer to ASHRAE Standard 202-2018).
Design Team	A group of consultants responsible for the design of the project in its entirety. Depending on the project, the design team shall include all core disciplines such as, architectural, mechanical, electrical, structural, and civil. For most projects, the architect is the prime consultant that manages the deliverables for the design team.
Device object identifier	An address used to uniquely identify managed devices and their statuses (the University will assign device object identifier properties).
Direct digital control (DDC)	Microprocessor-based control including analog/digital conversion and program logic.
Embedded controllers	Specific equipment containing packaged OEM controllers. Examples of such equipment are variable speed drives, chillers, boilers, pump sets, etc. In all cases, the controllers shall be accessible and readable/writable to the BAS and EMRS. Proprietary communication protocols are not allowed.
Energy management and reporting system (EMRS)	EMRS is a campus wide administration application-level system, provided and maintained by F&S IT. BACnet interoperability areas data sharing, alarm and event management, scheduling, trending, and network management can all be performed at this level. All BAS shall be capable of integration with the EMRS.
Functional performance testing	A range of tests conducted under actual load to verify the specific systems, subsystems, components, and interfaces between systems conform to specified criteria.

Facilities & Services Automation and Control group (F&S ACG)	Representative of the University's F&S Automation and Control department, responsible for oversight of the project's Building Automation System (BAS) design, who reviews and comments on the related deliverables of the University's BAS Design Standard.
Facilities & Services secured network	Network with security measures in place that helps protect it from outside attackers. F&S secured network is a private network with no internet access by default, the inbound and outbound traffic is overseen by F&S IT.
Facilities & Services VLAN (F&S VLAN)	1BA dedicated and secured CAT 6 fiber Ethernet intranet spans throughout the campus that connects buildings to a Main Distribution Switch located inside the buildings with a common IP network. The University oversees the specification, implementation, and maintenance of this campus F&S VLAN. All BAS shall connect to this F&S VLAN data link layer, forming a single campus backbone. Any expansion from this F&S VLAN shall be coordinated with the University's Central IT department and F&S IT.
Facility & Services IT (F&S IT)	Representative of the University's F&S Information Technology department, responsible for providing and maintaining all F&S LANs, switches, EMRS points migration, IP addresses and access. The local IT department is responsible for providing and maintaining all operator interface, hardware, and network connections within the campus.
Facility & Services server	Server located on campus premises that is administered and maintained by F&S IT.
Gateway	A device, which contains two or more dissimilar networks/protocols, permitting information exchange between them (ASHRAE/ANSI 135). Gateways are not to be included in the basis for design and must be justified and approved by the University's Project Team before consideration in a final design.
Graphical user interface (GUI)	A system of interactive visual components for computer software. A GUI displays objects that convey information and represent actions that can be taken by the user.

Human machine interface (HMI)	A device designed to enable humans to access the BAS and/or the EMRS by using a set of custom-built graphics.
LAN interface device	Device or function used to facilitate communication and data sharing through the BAS. Includes the University switches, routers, gateways (if allowed). They are typically located in IT rooms, electrical closets, and mechanical rooms. Design Team shall verify locations, describe, justify, and attain approval from the University before including them in tender documents and BAS design.
BACnet MSTP	Data link protocol as defined by the BACnet ASHRAE standard. Operates over the serial field bus network (RS485).
Network numbering	BACnet allows for up to 65,535 interconnected networks. The University's Project Team will assign all network numbers.
Network switch	Networking hardware that connects devices on a computer network by using packet switching to receive and forward data to the destination.
Operations and maintenance manual	A document that describes, in layman's terms, the operation of all systems and equipment in a facility. An operations manual details mode of operation with associated diagrams to illustrate the sequence of operation for each system and interaction between systems. The maintenance manual describes maintenance requirements and sequences, including the required bill of materials.
Operation training	Training for the individuals who use (owner), operate (facility personnel), or maintain (skilled trades, technicians, and engineers) using the most current versions of the commissioning documents including operations and maintenance manual. The training shall be designed specifically for each group and delivered both in the classroom and on-site.
Operator interface (OI)	A device used by the operator to manage the BAS including OWSs, POTs, Service Tools. Interchangeable with HMI.

Operator workstation (OWS)	The user's interface with the BAS. Functionality defined as a B-OWS in ASHRAE-135. F&S IT specifies and supplies the OWS.
Owner's project requirement (OPR)	A document that details the requirements of a project and the expectations for how it will be used and operated, including project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, training requirements, documentation requirements, and supporting information (refer to ASHRAE Standard 202-2018).
Patch panel	A device with ports between field environments and network switches.
Portable operators' terminal (POT)	A device that can be a PC, tablet or mobile device that must run a standard operating system like, Windows, Android or equivalent that is approved by F&S IT. If the device is a standard PC or tablet, this will be supplied by F&S IT. Required application licenses and service level software are to be supplied by the contractor, typically for the University building operators and controls service technicians. Also referred to as a Service Tool.
Project Team (University's Project Team)	The Project Team consists of all or part of the following groups: F&S-IT, Sustainability, Automation and Control Group, Area Managers, integrators, and any others assigned by the University.
Protocol implementation conformance statement (PICS)	A written document, created by the manufacturer of a device, which identifies the options specified by BACnet that are implemented in the device (ASHRAE-135).
Router	A device that connects two or more networks at the network layer.
Secondary controlling LAN (Serial field bus)	RS-485 LAN connecting AACs and ASCs.
Smart device/smart actuator (SD/SA)	A control I/O device such as a sensor or actuator that can directly communicate with the controller network to which it is connected. This differs from an ASC in that it typically deals only with one variable.

Static verification	The verification and documentation that all system elements are in accordance with the design requirements, correctly installed, connected, and labeled with consideration for accessibility.
Startup verification	The verification that documentation is complete, sensors are calibrated, control wiring integrity checked, correct response of all points in the system verified with the correct response from all end devices.
System graphics screens	Graphic User Interface that provides information on the BAS and/or EMRS related to all BAS data object points.
Switch	A device that filters and forwards packets between LAN segments, in this case, between the field level network and the F&S VLAN. F&S - IT specifies and supplies the switches and associated patch panels in coordination with the F&S IT.
University of Toronto (The University)	Owner representative representing the University.
University's Project Manager	The Project Manager shall be the main point of contact and coordinate the University's staff for the approvals of the BAS design and implementation.

1.4 Codes and standards

1.4.1 The design shall comply with rules and regulations of codes and ordinances of local, provincial, and federal.

1.4.2 It is the intention that all BAS designs and installations provide for optimum operations, monitoring, verification, and energy performance. Codes and standards with a basis of design that encourage optimum long term, low energy performance is preferred.

1.4.2.1 American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) - 90.1 Energy standards and 62.1 Ventilation standards (latest version)

1.4.2.2 National Electrical and Local Codes

1.4.2.3 ASHRAE - 135: BACnet - A Data Communication Protocol for Building Automation and Control Networks. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 2004 including Addendums A through E

1.4.2.4 Underwriters Laboratories

A. UL 916: Energy Management Systems

1.4.2.5 NEMA Compliance

A. NEMA 250: Enclosure for Electrical Equipment
B. NEMA ICS 1: General standards for Industrial Controls

1.4.2.6 Institute of Electrical and Electronics Engineers (IEEE)

A. IEEE 802.3: CSMA/CD (Ethernet - Based) LAN

1.4.2.7 Refer to all related design standards for coordination at the link below:

Design standards and project forms - Facilities & Services - University of Toronto (utoronto.ca)

1.4.2.8 Refer to University of Toronto Communication Infrastructure Specifications, standards and Practices: Specifications standards Practices 2.6 (utoronto.ca)

1.4.2.9 Refer to University of Toronto Lighting and Lighting Control Design Standard

1.5 Design guidelines

1.5.1 The campus as a “single building”

1.5.1.1 For further clarification of the campus BAS architecture, the BAS basis of design for all the new construction, renovations, additions, and upgrades projects shall treat the whole campus as a “single building with multiple mechanical rooms” connected by an existing, F&S VLAN through a secure enterprise server where all enterprise management interoperability processes reside, communicating with all the “mechanical rooms” (i.e. buildings, HVAC systems, etc.) BAS connected to the F&S VLAN, across the campus. This “single building” BAS architecture can be imagined as a horizontal version of a 120-storey vertical commercial property with a building wide LAN, central host and floor by floor controller BAS network. The EMRS is the equivalent of a typical tower application layer front end with oversight and access to the complete “building” BAS; the “floors” are similar to the campus buildings with distributed intelligence DDC devices and access for operators and service. No BAS shall be considered as a “stand-alone” property or project.

1.5.2 EMRS/BAS architecture

1.5.2.1 The Design Team is responsible for specifying all necessary equipment and resources to implement, maintain, and operate the systems in compliance with BOD and the University’s design standards. The design of the system shall be operable in a standalone basis.

1.5.2.2 A system architecture document shall be developed by the design engineer in collaboration with F&S IT, F&S ACG, and shall graphically describe the extent of controls installed and their communication hierarchy, from the physical to application (EMRS) layer. All control devices shall be indicated on the floor plans and identified by a room number provided and approved by the University.

a. F&S network components, including the University's IP switches, shall be shown on the system architecture to indicate which equipment is communicating over the F&S network, with their respective designated static IP addresses. This document shall be updated by contractor throughout the project to track modifications made during design, construction, commissioning, and closeout.

1.5.2.3 The system shall be configured as a distributed processing network(s) capable of expansion using the same network technology and ASHRAE-135 protocols.

1.5.2.4 The system architecture consists of a secure F&S maintained CAT 6 ethernet-based, F&S VLAN connected to all buildings, a single building level or multi-leveled sub-networks (serial field bus, MS/TP, MODBUS) that support BCs, AACs, ASCs, operator workstations (OWS), smart devices (SD), and portable operator's stations (POTs) as applicable.

1.5.2.5 All connections by IP enabled devices shall be to the F&S network through F&S approved switches. The Design Team shall confirm with F&S IT about the location and capacity of all existing switches and collaborate with F&S IT on the placement of any new switches, if required, to design the necessary sub-networks.

1.5.2.6 Rapid Spanning Tree Protocol (RSTP) shall not be utilized within the building automation network. Network topologies can be considered with explicit approval from F&S IT and F&S ACG.

1.5.2.7 All requests for connections shall be made to Project Manager by contractor at least 5 business days before the connection is required. Any BACnet/IP device shall be specifically configured to use only designated static IP addresses. IP addresses will be issued to contractor for the purposes of BAS installation and commissioning with end dates that will be extended, if requested, through a formal request to F&S IT.

1.5.2.8 The contractor is responsible for supply and installation of all networks from field devices through controllers to the patch panel(s).

1.5.2.9 Remote data access: design to include remote access connectivity and coordination with F&S IT. The system shall support the following methods of remote access to the building data through smart phones & portable devices via one or more of the current following common standards: Apple iOS (iPhone, iPad), Android Open-Source Project (Android devices), and Windows Mobile Devices. Request for Access Form shall be submitted to F&S IT. The form is available here: https://www.fs.utoronto.ca/wp-content/uploads/2021/06/12_BuildingAutomationSystems_AccessRequestForm.pdf

1.5.2.10 Browser-based access: a remote user using a standard browser shall be able access all control system facilities and graphics with unique access credential. F&S IT shall provide the required internet connection.

1.5.2.11 The following paradigms are acceptable for browser-based access: native internet-based user interfaces (HTML, Java, XML, etc.) that do not require a plug-in. The user interface must be compatible with the most current stable version of the supporting software (Java, etc.) without requiring the user to downgrade to a lesser version.

1.5.2.12 The communication speed between the controllers, LAN interface devices, and operator interface devices shall be sufficient to ensure fast system response time under any loading condition. In no case shall delay times between an event, request, or command initiation and completion be greater than those listed herein. The serial field bus, ASC/AAC layout and BC to switch layout is to be planned as necessary to accomplish these performance requirements (maximum values):

A. 3 seconds between a Level 1 (critical) alarm occurrence and enunciation at operator workstation.
B. 8 seconds between a Level 2 alarm occurrence and enunciation at operator workstation.
C. 10 seconds between and a Level 3-5 alarm occurrence and enunciation at operator workstation.
D. 8 seconds between an operator command via the operator interface to change a setpoint and the subsequent change in the controller.
E. 3 seconds between an operator command via the operator interface to start/stop a device and the subsequent command to be received at the controller.
F. 8 seconds between a change of value or state of an input and it being updated on the operator interface.
G. 8 seconds between an operator selection of a graphic and it completely painting the screen and updating at least 10 points.

1.5.2.13 The EMRS operator interface, typically an OWS, shall provide the overall system supervision, graphical user interface, management report generation, alarm annunciation, and remote monitoring. The operator interface is the access point to a collection of dynamic displays at the EMRS.

1.5.2.14 EMRS interface type and location to be defined with the University. Unless specifically defined otherwise, F&S IT will supply the operator interface(s) in the compliance with the project schedules and timelines.

1.5.2.15 Enterprise management level: the main F&S server hosts and maintains the EMRS. The EMRS is at the application layer and provides data sharing, alarm and event management, scheduling, trending, and device and network management to the approved B-OWS locations. F&S IT defines and manages the architecture and location of the point/object and enterprise databases in the EMRS. The EMRS Control Systems Server shall hold the backup and point data files of the information downloaded into the individual controllers and as such support uploading and downloading that information directly to/from the controllers. It shall also act as a control information server to non-control system-based programs. It shall allow secure multiple access to the BAS control information.

1.5.2.16 Access to the F&S VLAN: all access to the F&S VLAN shall be coordinated and approved with F&S IT who will also control and distribute any required IP addresses and their access timelines. The F&S IT will specify and supply any switches, patch panels, racks, and connection devices to the F&S VLAN. The Design Team shall not design to install any gateways, Java Application Control Engine (JACE) type of the devices or equivalent, routers, bridges, or repeaters without prior approval from the University's Project Team. Once the standalone functionalities of B-BC controllers are verified by CxA, the access to the F&S VLAN will be provided to the contractor. Refer to the Section 3.20.4.3.6 for more details on the acceptance procedures.

1.5.2.17 Building level controls: all BAS control devices will connect to the F&S VLAN with approved sub-networks. All new or replacement BAS devices shall be BACnet Testing Laboratories (BTL) listed with current Protocol Implementation and Conformance Statements (PICS). These include BACnet device profiles as identified by ASHRAE 135, B-OWS, B-BC, B-AAC, B-ASC, B-SS and B-SA. The BAS control strategies will reside at the controllers and will communicate with the F&S VLAN using MS/TP or IP data link protocols. Other field level network types must be approved by the University Project Team. BAS technologies that require dedicated servers or gateways in the project will not be allowed without written approval from the University's Project Team.

1.5.2.18 The BCs, AACs, ASCs, and SDs shall monitor, control, and provide the field interface for all points specified. Each BC, AAC, or ASC shall be capable of performing all specified energy management functions, and all DDC functions, independent of other BCs, AACs, or ASCs and operator interface devices.

1.5.2.19 The system will be designed to ensure that not more than 27 MS/TP devices shall be connected to a single B-BC controller. The resource of the B-BC shall be selected to have an additional 15% spare capacities (15% more connection points and 15% more storage).

1.5.2.20 Interruptions or fault at any point on the F&S VLAN shall not interrupt communications between other nodes on the network. If a F&S VLAN is severed, two separate networks shall be formed and communications within each network shall continue uninterrupted.

1.5.2.21 Monitoring only interface for the purpose of alarming can be made between fire, life safety, access control systems and the BAS/EMRS.

1.5.2.22 All signal boosters, signal conditioners, etc. shall only be used if approved by the University and will be included for proper data communication if needed. The intent of design is not to use drivers or boosters but to use proper network architecture and layout.

1.5.2.23 The contractor must supply its own dedicated temporary communication gateway and/or a modem device for the internet connectivity along with the SMTP service that is properly and securely configured and functional by the contractor. This is to ensure that all the alarms notifications for the predefined and approved critical control objects/points are being sent to the predefined list of the alarm recipients from the temporary operator interface workstation (temporary GUI).

1.5.2.24 Field level devices: include actuators, sensors, valves, etc., that control the space conditions through interaction with the BAS controllers. The specifications for these devices are found in Section 2.3 Instrumentation.

1.5.2.25 Controlled & monitored equipment interface:

A. Variable frequency drives (VFD): all VFDs that are controlled by the BAS shall have a minimum of the following points hardwired (Table 1). All other points shall be interfaced to the BAS through soft points using BACnet or Modbus protocols on an Ethernet or RS485 medium. Points shall comprise a minimum of required parameters (i.e. KW, KWh, voltage, current, frequency, alarm codes) along with all other points accessible through the communication interface.

	Description	Type	Signal
1	Start stop Command	Digital Output	Dry contact
2	Alarm	Digital Input	Dry contact
3	Control signal	Analog Output	4-20 mA
4	Feedback signal	Analog Output	4-20 mA
5	Status	Digital Input	Dry contact from a current switch

Table 1 - Points connection of BAS controlled VFDs

B. Chillers: all chillers that are controlled by the BAS shall have a minimum of the following points hardwired (Table 2). All other points shall be interfaced to the BAS through soft points using BACnet or Modbus protocols on an Ethernet or RS485 medium. Points shall comprise a minimum of required parameters (i.e. KW, KWh, voltage, current, each compressor status and loads) along with all other available points accessible through the communication interface.

	Description	Type	Signal
1	Enable Command	Digital Output	Dry contact
2	Chiller Status	Digital Input	Dry contact
3	Chiller general Alarm	Digital Input	Dry contact
4	Setpoint	Analog Output	4-20 mA
5	Load	Analog Input	4-20 mA
6	Chiller capacity	Analog Input	4-20 mA

Table 2 - Points connection of BAS controlled chillers

C. Packaged AC units: packaged units that are being monitored can be integrated through BACnet IP or MS/TP to the BAS. Units that need control are listed below:

	Description	Type	Signal
1	Space temperature	Analog input	BACnet
2	Status	Digital Input	BACnet
3	Alarm	Digital Input	BACnet

Table 3 - Points connection of packaged AC units

D. Boilers: all boilers controlled by the BAS shall have a minimum of the following points hardwired (Table 4). All other points shall be interfaced to the BAS system through soft points using BACnet or Modbus protocols on an Ethernet or RS485 medium. Points shall comprise of a minimum required parameters (i.e., KW, KWh, voltage, current, each compressor status, and loads) along with all other available points accessible through the communication interface.

	Description	Type	Signal
1	Enable Command	Digital Output	Dry contact
2	Boiler Status	Digital Input	Dry contact
3	Boiler general Alarm	Digital Input	Dry contact
4	Setpoint temperature	Analog Output	4-20 mA
5	Load	Analog Input	4-20 mA

Table 4 - Points connection of BAS controlled boilers

1.5.2.26 BACnet object list is a critical component of the handover material required for the building controls implementation and integration to the EMRS. During BAS design process, a list of BACnet objects at minimum which includes all the binary, analog, calculated and virtual points associated with the design and sequences must be identified, reviewed, and accepted by the University's Project Team prior to implementation. This list shall include objects required from embedded controls such as variable speed drives, chillers, heat pumps and other application specific controllers.

1.5.2.27 Unless otherwise stipulated, the line of demarcation for the contractor is at the patch panel(s) within the building. All control sub network cabling, controllers, end devices and components specified as a part of the BAS shall be supplied and installed by the contractor. F&S IT shall coordinate the supply and installation of all network switches, racks, patch panels, operator workstations and portable service terminals as required with the BAS contractor.

1.5.2.28 All new, retrofit, and renovated BAS devices shall meet the ASHRAE - 135 standards and be approved by BTL. Approved products can be found in the BTL Product Listing: BTL Listing of Tested Products – BACnet Testing Laboratories (bacnetinternational.net)

1.5.2.29 Approved manufacturers are Honeywell, Johnson Controls, Siemens, Automated Logic, and Schneider Electric. The approved product lines for the BAS implementations are listed below:

Manufacturer	Product line	Controller series
Johnson Controls	Metasys	Supervisory Network Controller
Honeywell	Comfort Point Open	CP-O, CP-IPC, CP400
Siemens	Apogee	PXC series
Automated Logic	OptiFlex	PSM, OF, ZN series

Schneider Electric	EcoStruxure	AS, MP-C

Table 5 - Approved manufacturers and product lines

Note: JCI Controllers model NAE 55XX are not acceptable.

1.5.2.30 All field level mounted or embedded controllers must be supplied by an approved controller manufacturer. Any factory level mounted controllers for products such as rooftop units, boilers, chillers, etc., must follow and meet this standard in its entirely including open point accessibility, device discoverability, readability, and write-ability. Proprietary and non-open or otherwise locked systems are not allowed.

1.5.2.31 All equipment/devices of the same type serving the same function shall be identical and from the same manufacturer.

1.5.2.32 All naming conventions and graphics shall be consistent for all projects according to this standard.

1.5.2.33 The contractor or its subcontractor must be specialized and experienced in control system installations with more than five years of experience with proposed DDC technology installation. The experience should be with similar point counts, complexity, and scale as those of the specified project. The contractor is also responsible to ensure that more than three years of experience shall be associated with the acceptable manufacturers' product line.

1.5.2.34 The contractor is responsible to ensure that installer's Field Coordinator and Sequence Programmer shall be specialized and trained in proposed control system installation for more that five years. Contractor will be required to provide documented certificates form the manufacturer of the product for the Field Coordinator and Sequence Programmer assigned to execute the project, confirming that they have the required product line training and programming training respectively.

A. Product line training: advanced training offered by the manufacturer on that product line for installation and configuration.
B. Programming training: advanced programming training offered by the vendor of the programming application offered by the manufacturer.

1.5.2.35 Contractor's response time and proximity

A. Installer must maintain a fully capable service capacity within a 70 km radius of the project site. Service facility shall manage the emergency service dispatches and maintain the inventory of spare parts.
B. Emergency response times should be within 48 hours. Installer must demonstrate the ability to meet the response times in the submittal.

1.5.3 Temporary workstation

1.5.3.1 The temporary operator interface workstation (temporary GUI): all graphical representations of systems shall be provided on the temporary vendor specific standalone BAS workstation with the contractor’s temporary installed GUI in the building. Provisions of all required alarms, trends, monitoring, and control points (physical & virtual) shall be provided and verified by the CxA on the HMI provided by the contractor. Screenshots of the HMI pages shall be included as a part of the field Cx documentation to aid the development of EMRS.

1.5.3.2 The temporary workstation shall be provided with a reporting package that allows the operator to select, modify, or create reports. Each report shall be definable as to data content, format, interval, and date. Report data shall be archivable on the hard disk for historical reporting. Ensure that the operator can obtain real-time logs of all objects categorized by type or status (i.e., alarm, lockout, normal). Reports and logs shall be stored on the PC hard disk in a format that is readily accessible by other standard software applications, including spreadsheets and word processing. Reports and logs shall be readily printed to the system printer and shall be set to be printed either on operator command or at a specific time each day.

1.5.4 Trending requirements

The temporary workstation and the EMRS shall be set up with data acquisition parameters as below for troubleshooting and optimization. The temporary workstation shall store data for a minimum of 3 years.

1.5.4.1 All physical digital inputs and outputs, including setpoints and effective setpoints, shall be trended.

1.5.4.2. Data acquisition shall adhere to the specified frequency of sampling as minimum. If higher frequencies are needed, the Design Team shall provide a rationale for the requirement. Refer to the following table.

Parameter	Point type	Data acquisition
Temperature	Analog Input	60 seconds
Pressure	Analog Input	60 seconds
Flow	Analog Input/ Analog Value	60 seconds
Thermal energy, thermal energy flow	Analog Input/ Analog Value	60 seconds
PH/CO/CO2/O2	Analog Input	COV *
Voltage/current/KWH	Analog Input	60 seconds
Setpoints	Analog Value	COV *
Effective setpoints	Analog Value	COV *

Table 6 - Data acquisition frequency requirements

*Change of Values (COV) above shall follow settings as per section 2.2.3.24 in this standard.

1.5.5 Demand Control Ventilation (DCV)

1.5.5.1. All binary inputs /outputs and values data shall be logged with every change of state.

1.5.5.2. Demand Control Ventilation (DCV) systems shall provide real-time ventilation control based on measured indoor environmental quality (IEQ) parameters. The system shall serve applicable spaces including laboratories.

1.5.5.3. Approved manufacturers for DCV platforms:

- Antrum
- Aircuity

1.5.5.4. The mechanical consultant shall review the selected vendor with F&S Utilities representative and shall receive formal sign-off on the DCV shop drawings.

1.5.5.5. DCV system shall:

A. Continuously monitor and report the following minimum parameters:

a. Carbon Dioxide (CO_2)

b. Total Volatile Organic Compounds (TVOCs) (PID and MOS/EChem)

c. Particulate Matter PM2.5

d. Relative Humidity (%RH) or Dew Point

e. Temperature (°C)

f. Carbon Monoxide (CO)

g. Formaldehyde

h. Ammonia

B. Interface with the EMRS/BAS controller via BACnet/IP, using standard object types and property mappings.

C. Not have control logic to adjust ventilation setpoints or air change rates in real-time based on measured values.

1.5.5.4. Sensor installation

A. Sensor sampling shall be configured as per the approved manufacturer’s design.

B. Locations shall be coordinated to represent actual occupied zone conditions and reviewed by the Client (University of Toronto Facilities & Services).

C. Sampling points, tubing, and enclosures shall be clearly labeled and easily accessible for maintenance.

1.5.5.5. Integration requirements

A. All sensor data shall be mapped to the BAS with unique device IDs and meaningful point naming consistent with the building automation system point naming convention.

B. Trends shall be configured for each parameter at an interval not exceeding 5 minutes.

C. Alarm thresholds shall be settable via the BAS. Sensor faults, disconnections, or calibration drift shall generate BAS alarms.

1.5.5.6. Provide full commissioning of the DCV system, including:

A. Verification of communication with the BAS.

B. Functional testing of ventilation responses to sensor input limit changes.

C. Calibration certification for all sensing devices. Include a written DCV Calibration and Maintenance Schedule in the final commissioning manual. Calibration frequency shall follow manufacturer recommendations but not exceed annual intervals.

1.6 Submittals – documents, shop drawings, and sequence of operations

1.6.1 Design Team shall provide the complete project documentation as listed in the deliverable standard (Appendix A).

1.6.2 The DDC and equipment power coordination schedule shall include the information required from the table: https://www.fs.utoronto.ca/wp-content/uploads/2024/04/1.6.2-DDC-andequipment-power-coordination-schedule.xlsx

1.6.3 Electronic submittals: a copy of the control submittals and O&M information shall be provided in an unlocked, searchable, and editable Adobe PDF format. Any documents scanned as images must be converted to a searchable text format using OCR (Optical Character Recognition) and reduced in size prior to submission.

1.6.4 Qualifications: manufacturer, installer, and key personnel qualifications as mentioned in section 1.5.2.29. This shall include QA/QC plan for all phases (design, install, Cx, warranty, training) along with documentation of industry standard QA/QC practices.

1.6.5 Product data: submit a copy of the manufacturer's technical product data or each control device, panel, and accessory furnished. The technical product data shall indicate dimensions, capacities, performance and electrical characteristics, material finishes, and installation, start-up, and maintenance instructions.

1.6.6 Shop drawings: submit a copy of the shop drawings for each control system, including a complete drawing for each air handling unit system, pump device, etc. with all point descriptors, addresses and point names indicated. Shop drawing shall contain the following information:

1.6.6.1 One line diagram indicating schematic locations of all control units, workstations, LAN interface devices, etc. Indicate network number, device ID, address, device instance, MAC address, drawing reference number, and controller type for each control unit. Indicate media, protocol, baud rate, and type of each network. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the diagram.

1.6.6.2 Indicate device instance and IP address for each controller. Indicate media, protocol, baud rate, and type of each LAN.

1.6.6.3 Provide floor plans on PDF locating all control units, LAN interface devices, etc. Include all LAN communication wiring routing, power wiring, power originating sources, and low voltage power wiring. Wiring routing as-built conditions shall be maintained accurately throughout the construction period. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the floor plans.

1.6.6.4 Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and all control devices. Include all interfaces (wiring) between control devices, and electrical equipment.

1.6.6.5 All physical points on the schematic flow diagram shall be indicated with names, descriptors, and point addresses identified as listed in the point summary table.

1.6.6.6 For each schematic flow diagram, list building number and abbreviation, system type, equipment type, full point name, point description, ethernet backbone network number, network number, device ID, object ID (object type, instance number).

1.6.6.7 Submitted drawings shall include labels for each control device with setting and adjustable range of control with respective units.

1.6.6.8 Submitted panel wiring drawings shall include labels for each input and output terminal with the appropriate range and units.

1.6.7 Provide a bill of materials with each schematic. Indicate device identification to match schematic and actual field labeling, quantity, actual product ordering number, manufacturer, description, size, voltage range, pressure range, temperature range, etc. as applicable.

1.6.8 Provide a control valve schedule listing valve and actuator information including size, Cv (valve flow coefficient), design flow, design pressure drop, manufacturer, model number, close off rating, control signal, etc. Indicate normal positions of spring return valves.

1.6.9 Provide a control damper schedule listing damper and actuator information including size, material, blade arrangement, manufacturer, model number, control signal, etc. Indicate normal positions of spring return dampers.

1.6.10 Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified, connections between control devices, controllers and equipment; connections to sources of power and grounds; control device designations, control device terminal designations, control device location; equipment terminal designations; cabinet terminal strip designations; wire designations. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring which are existing, factory-installed and portions to be field-installed. For control devices shown on multiple drawings, indicate the control device with the same designation on all drawings. Differentiate between manufacturer installed wire and field installed wire.

1.6.11 Provide details of control panels, including controls, instruments, and labeling shown in plan or elevation indicating the installed locations. Provide panel layout drawing including power supply, control unit(s) and wiring terminals.

1.6.11.1 Sheets shall be consecutively numbered.

1.6.11.2 Each sheet shall have a title indicating the type of information included and the HVAC&L system controlled.

1.6.11.3 Table of contents listing sheet titles and sheet numbers.

1.6.11.4 Provide a symbol legend and list of abbreviations.

1.6.11.5 All field labeling of devices shall match the device identifications listed in the schematic flow diagrams. Submit a sample of labeling to be used.

1.6.12 Control logic documentation and software

1.6.12.1 Submit control logic program listings to document the control software of all control units to the University.

1.6.12.2 Include written description of each control sequence.

1.6.12.3 Include test plan for each unique control program.

1.6.12.4 Include control response, settings, setpoints, throttling ranges, gains, reset schedules, adjustable parameters, and limits.

1.6.13 Operation and maintenance materials

1.6.13.1 Documents shall be provided electronically.

1.6.13.2 Submit maintenance instructions and spare parts lists for each type of control device, control unit, and accessories.

1.6.13.3 Include all submittals (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) in maintenance manual, in accordance with requirements of Commissioning Standard. Only include sections for equipment and software used on this project. Do not provide entire catalog of product data with extraneous information.

1.6.13.4 Submit BAS User's Guides (Operating and Service Manuals) for each controller type to the University.

1.6.13.5 Submit BAS Advanced Programming Manuals for each controller type to the University.

1.6.13.6 The contractor shall provide the University with all product line technical manuals and technical bulletins, to include new and upgraded products, by the same distribution channel to dealers or branches throughout the warranty period of the project.

1.6.13.7 Manufacturers certificates: for all listed and/or labeled products, provide certificate of conformance to the University.

1.6.13.8 Product warranty certificates: the University shall approve all warranty start dates.

1.6.13.9 Coordinate and submit manufacturers product warranty certificates covering the hardware provided once approved by the University.

1.6.14 BAS sequence of operations - context and format

1.6.14.1 It is the responsibility of the Design Team to ensure that the project design specifications include the requirements listed in this standard.

1.6.14.2 Intent: clear, detailed control sequence of operation is necessary to provide proper operation of the building. It shall be described in a simple and understandable language and include how the control system and associated building systems and equipment shall operate.

1.6.14.3 Details of methodology to calculate/measure energy consumption, savings, and demands as well as system performance is required, and shall be part of the building operation and BAS.

1.6.14.4 The sequence of operation shall describe the design intent for the building operation with set values (set points) to what the building shall be operated to. It shall identify the parameters that shall be determined and/or adjusted during initial start-up, balancing, and commissioning. It shall also identify the parameters that are user adjustable. It shall provide information on safety features (hardwired/soft points), integration with life safety systems (fire alarm, smoke exhaust, stair pressurization, and similar). It shall describe system operation during power failure, scheduled start/stop and integration with any other building systems/equipment.

1.6.14.5 The BAS shop drawings shall include the sequence of operation and all the required details to allow the F&S to operate and maintain the buildings. The shop drawings shall include all relevant information associated with packaged units and lab controls, and/or be referenced and affixed as an appendix. These requirements are mandatory and are applicable to all the projects listed in section 1.2 of this standard.

1.6.14.6 Application: this standard is applicable to BAS controls and any other control systems that may be provided by the separate control vendors/equipment packages for integration with/through BAS. Examples are lab control, fume hood control, VRF systems, packaged AHUs, chillers, boilers, etc.

1.6.14.7 Content: the sequence of operation shall consist of the following sections. The Design Team shall provide as many sections and details as required to meet the intent of this standard. The following list outlines the minimum required information:

A. General description of the system (what is it serving, components, locations, integration with any other systems/equipment)
B. Schedule
C. Start/stop
D. Safeties (hardwired connections, integration with life safety systems fire alarm and similar) if applicable
E. Modes of operation (occupied/unoccupied) and control (temperature control, etc.)
F. List of all points that shall be alarmed
G. List of all points that shall be monitored
H. List of all points that shall be historically gathered for trend creation, and any pre-set trends that can be created to help in troubleshooting or monitoring system operation
I. List of all setpoints that shall be adjusted (design specification shall indicate on the controls as-builts drawings the list of adjustable setpoints that need to be set, adjusted, or modified during the commissioning and verification process)
J. Any special requirements for GUI
K. Identify points that shall be historically gathered and trended, GUI will be done during EMRS integration phase by the University. These points shall be included in the Shop Drawings Sequence of Operation document for reference. The Design Team shall propose pre-set trends used for troubleshooting purposes that can be determined during commissioning process and added to the “as-built” controls shop drawings
L. Details for sequence of operation as listed in the above sections (A to E), points and graphical representation as listed in F to I, and instruments associated with maintenance and operations for packaged units/controls shall be included in BAS control package
M. Indication and definition of the integration between BAS and packaged unit, the scope of the integration and the scope of the autonomous control

1.6.14.8 General description: the overview of the system or purpose of the equipment; what equipment is controlled and where the equipment is located; any interactions with other systems; overview of how each component will work together as a system.

1.6.14.9 Schedule: scheduled run conditions during occupied and unoccupied modes.

1.6.14.10 System start/stop shall consist of the following requirements:

A. Description of how each component on the system will operate, including start-up and shutdown, enable/disabled.

B. Sequence of events in case the equipment fails to start and/or in emergency.
C. Sequence of events in case of loss of normal power; operation during normal power outage and/or start upon restoring of normal power.

1.6.14.11 Safeties: the list of failure modes and safety devices or subsystems, safety hardwires/soft points, and monitoring and alarming only with fire/life safety system.

1.6.14.12 Demand reduction: provide a control strategy to reset setpoints for equipment operation to predefined values to limit the energy consumption as a demand reduction strategy. This sequence, for all equipment or systems shall be executed manually through BAS - via single demand control event virtual on/off button. On all other GUIs there will be indication if the equipment or system in in the demand control mode. The sequence shall be written as such to allow for future automatic execution of demand control strategy inn the event a site wide global BACnet object is triggered automatically.

1.6.14.13 Mode of operation and control strategies/sequences shall consist of the following:

A. System/equipment specific sequence description detailing process, sequence of events and parameters with all set point based on the time-of-day schedule and/or season (heating, cooling, economizer mode).
B. Detail description of the process and sequence of events with breakdown per component/equipment when multiple components/equipment are required to operate to control/maintain one parameter. For example: temperature control in VAV system where terminal units have reheat coils, or in central VAV system where one VAV air handling unit is serving one space.
C. Control strategies for controlling various parameters (such as temperature, air flow, pressurization, etc.) shall be itemized per control parameter. These strategies shall be detailed out in the following programming logic. For example, where trim and response programming logic are to be used for reset control, it shall be detailed out as per ASHRAE 36 guideline 2021, edition section 5.14.1, selected for the specific project application.
D. Parameters that will be used for:
    a. Setback control (e.g., temperature set point for unoccupied/occupied mode)
    b. Reset control (e.g., hot water heating temperature reset based on outside temperature)
    c. Low limit/high limit control (e.g., low limit for mix air damper control or high limit for maximum temperature or relative humidity)
    d. Lead (duty)/stand-by control (e.g., run time to alternate between two pumps in a system where one pump is duty, and the one is in stand-by)
    e. Lead/lag control (e.g., staging up/down pumps to meet load and alternating them based on the runtime),

f. High/low signal select control (e.g., when a space has multiple sensors and one control)
g. Return fan control (e.g., modulating the speed of the return fan to maintain pressurization) based on the volumetric offset, detailed in either written or tabulated form, specifying the exact value

E. The setpoints shall be defined with the ranges that can be adjusted without adversely affecting system operation. The setpoints tolerances shall also be included.
   a. If the values are to be adjusted by operator through the EMRS (BAS) interface, it shall be stated as “operator adjustable”.
   b. If the values are to be adjusted during commissioning, it shall be stated as “adjustable”.
   c. If the values are to be adjusted by the building occupants via a user interface (such as adjustable room thermostats or similar), it shall be stated as “user adjustable”.

F. The expected priority and the set point adjustment arbitration between “operator” and “occupant” shall be clearly defined and stated.

1.6.14.14 Data collections and historical trends shall include the following:

A. List all points that shall be collected, indicating the duration and pre-set trends.
B. Energy monitoring: outline energy savings and consumption monitoring features.
C. Provide calculations for output values used by BAS controls vendors, including:
D. Flow consumption
E. Supply and return temperature
F. Differential, supply, and return pressure
G. Energy flow calculation
H. Troubleshooting: list out possible troubleshooting processes and provide pre-set trends. Additional sensors, flow switches, and/or similar devices shall be provided to accommodate Fault Detection and Diagnostic (FDD) algorithms (sequences of operation) programmed in the controller to meet the requirements of this standard.
   a. There shall be sensors and sequences of operation programmed to generate alerts (energy alarms) to prevent prolonged energy waste from incomplete execution of control sequences while maintaining thermal comfort of the building. At minimum:
      i. Alert for simultaneous heating and cooling
      ii. Alert when economizer and any other energy recovery/waste reduction feature is not functioning as designed
      iii. Alert for passing or leaky control valves or dampers resulting in wasting energy

b. There shall be sequences of operation for troubleshooting alarms. including:
    i. Using temperature sensors on the inlet and outlet of all coils in air handling units, fan coils units (especially 4 pipe), and supply from the VAV with reheat coils. The BAS shall be capable of identifying problems with passing valves or malfunctioning controls.
    ii. Using fan coil unit fan speed and status to identify issues with fan performance.

I. BAS dashboards shall be developed to display additional information beyond the standard control schematic. This information shall include energy use, utility consumptions of the building, and system troubleshooting capabilities.

1.6.15 Alarms shall list all the mandatory process values that are included in the DDC alarm notifications, clearly identifying low and high alarm limits to aid fault detection and diagnostic.

1.6.16 Provide the list of all necessary documentation (e.g., floor plans, zoning diagrams, equipment dashboards, etc.) to create the graphical interface with the visual indication of the alarm state for each process value and help in troubleshooting.

1.6.17 Layout all the alarms in the table format to include the following:

A. Description of the alarm event
B. Required action
C. Alarm classification
D. Possible reasons for the alarms and recommended actions

1.6.18 Below is an example of an alarm table for the heating loop for reference:

Alarm description	Action	Alarm	Possible reasons/recommended action
Lead pump commanded on and pump does not start (5 min delay)	Start second pump	High	• Check if pump is operating in Auto mode on local panel • Mechanical problem with pump
Both pumps fail to start	Shut down	Critical	• Check if pump is operating in Auto mode on local panel • Mechanical problem with pump
Low supply water temperature (10°C below SP for 10 min)	Continue to run	Critical	• Mechanical problem with boilers • Primary flow is higher than the design flow of the boilers in operation • Deviation between the internal

			boiler hot water supply temperature sensor and the plant hot water supply temperature is too high (i.e., boiler sensor is out of calibration)
Pump status ON/ Commanded OFF	Pump to remain off	Low	• Check if pump is operating in Auto mode on local panel • Mechanical problem with pump
System switch to manual	Indicate on graphic	Low	• Maintenance mode

Table 7 - Example of alarm table for heating loop

1.6.18.1 Summary checklists shall be populated by the Design Team during the design stage. Refer to the following tables:

Sequence of operation/shop drawings	Included in BAS specification (YES / NO / N/A)
a) general description of the system (what is it serving, components, locations, integration with any other systems/equipment)	
b) schedule	
c) start/stop	
d) safeties (hardwired connections, integration with life safety systems fire alarm and similar) if applicable	
e) modes of operation (occupied / uncopied) and control (temperature control, etc.)	
f) list of all alarm points	
g) list of all the monitored points	
h) list of all points that shall be historically gathered for trend creation, and any pre-set trends that can be created to help in troubleshooting/monitoring system operation	
i) list of all adjustable setpoints	
j) any special requirements for graphical user interface	

k) Details for sequence of operation as listed in the points a) to e), points and graphical representation as listed in f) to j); instruments (details associated with maintenance and operations) for packaged units/controls (such as lab and fume hood controllers) also need to be included in BAS control package. The integration between BAS and packaged unit, what can be done via BAS (control and/or monitor) and what controls will be done via packaged unit has to be clear indicated and delineated	-
Documents	**Included in the BAS specification (YES /NO / N/A)**
a) Zoning Diagrams	
b) Schematic Flow Diagrams	
c) Air Pressurization Diagrams	

Table 8 - Sequence of operation/shop drawing summary checklist

List of packaged units/control systems shall be integrated with EMRS via BAS (Design Team to populate)	Included in the BAS specification (YES /NO / N/A)	Local controls with display provided (YES/NO/N/A)
1		
2		
3		
4		
5		

Table 9 - Format for list of packaged units and systems to be integrated via BAS into EMRS

1.7 As-built documents

1.7.1 Documentation shall be submitted electronically.

1.7.2 Update as-built documents including product data and control shop drawings to reflect the final installed condition. Accurately record actual setpoints and settings of controls, final sequence of operation, including changes to programs made after submission and approval of shop drawings, and changes to programs made during specified testing.

1.7.3 As-built copies of approved control logic programming and database shall be stored on USB key or the University's SharePoint if applicable.

1.7.4 As-built drawings that represent the final system architecture, configuration input/output points and device locations shall be in the AutoCAD editable format.

1.7.5 I/O points list shall include the name/description, display units, alarm limit(s)/definitions and BACnet object description, including Object ID and Device ID, for each I/O point.

1.7.6 As-built copies of approved project specific graphic software shall be stored on USB key or the University's SharePoint if applicable.

1.7.7 As-built documents shall include individual floor plans with controller locations with all interconnecting wiring routing including space sensors, LAN wiring, power wiring, low voltage power wiring.

1.7.8 Documentation for any non-standard BACnet objects, properties, or enumerations used detailing their structure, data types and any associated lists of enumerated values.

1.7.9 Integration details with any BACnet based control systems (i.e. lighting, chemical treatment, thermal occupancy counting sensors, and wireless controls).

1.7.10 Provide as-built riser diagram showing the location of all controllers, connection to F&S VLAN, routers, wireless and repeaters.

1.7.11 As-built drawings shall be reviewed, approved, and stamped by the Design Team as record drawings before submission to the University.

1.8 Warranty maintenance

1.8.1 The contractor shall warrant all products, software, and labor for specified control system free from defects for a period of two years after the final acceptance by the University.

1.8.2 The University reserves the right to make changes to the BAS during the warranty period. Such changes do not constitute a waiver of warranty. The contractor shall warrant parts and installation work regardless of any such changes made by the University unless the contractor provides clear and convincing evidence that a specific problem is the result of such changes to the BAS. Any disagreement between the University and the contractor on such matters shall be subject to resolution through the contract 'dispute' clause.

1.8.3 At no cost to the University, during the warranty period, the Contractor shall provide maintenance services for software and hardware components as specified below:

1.8.3.1 Maintenance services: shall be provided for all devices and hardware specified for the project. Service all equipment per the manufacture's recommendations. All devices shall be calibrated within the last month of the warranty period.

1.8.3.2 Emergency service: any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following notification by the University to the Contractor.

A. Response by telephone to any request for service shall be provided within one hour of the University's initial telephone request for service.
B. If the malfunction, failure, or defect is not corrected through the telephonic communication, at least one hardware and software technician, trained in the system to be serviced, shall be dispatched to the University's site within two hours of the University's initial telephone request for such services, as specified.

1.8.3.3 Normal service: any malfunction, failure, or defect in any hardware component or failure of any control programming that would not result in property damage or loss of comfort control shall be corrected and repaired following telephonic notification by the University to the Contractor.

A. Response by telephone to any request for service shall be provided within two working hours (contractor specified 40 hours per week normal working period) of the University's initial telephone request for service.
B. If the malfunction, failure, or defect is not corrected through the telephonic communication, at least one hardware and software technician, trained in the system to be serviced, shall be dispatched to the University's site within three working days of the University's initial telephone request for such services, as specified.

1.8.3.4 Request for service: the Contractor shall specify a maximum of three telephone numbers for the University to call in the event of a need for service. At least one of the lines shall be 24/7. Once contacted a technician shall respond to within 15 minutes.

1.8.3.5 Technical support: Contractor shall provide technical support to the University throughout the warranty period.

1.8.3.6 Preventive maintenance: shall be provided throughout the warranty period in accordance with the hardware component manufacturer's requirements.

1.8.3.7 All warranty work to be performed by original manufacturer’s trained staff.

1.8.3.8 Provide updates to controller firmware that resolve Contractor identified deficiencies at no charge during warranty period.

1.8.3.9 Installation labor and materials shall be covered under warranty. Demonstrate operable condition of reused devices at time of Project Team’s acceptance (see section 3.6 for more details).

1.8.3.10 Factory mounted controllers shall be warranted by the manufacturer.

1.9 Delivery, storage, and handling

1.9.1 Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons during shipping, storage and handling as required and as per manufacturer’s recommendation. Prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials indoors and protect from construction work and weather.

2 Products

2.1 Materials and equipment

Materials shall be new and of the highest quality available in the market, free from defects or blemishes and shall not be damaged in any way. Used equipment shall not be used in any way for the permanent installation except where drawings or specifications allow existing materials to remain in place. Equipment that is planned for a phase out within the next 5 years shall not be used.

2.2 BAS field devices and instrumentation

2.2.1 Stand-alone functionality

2.2.1.1 General: these requirements are for the stand-alone functionality relative to packaging I/O devices with a controller. Stand-alone functionality is specified with the controller and for each application category. The requirement below refers to acceptable paradigms for associating the points with the controller(s).

2.2.1.2 Functional boundary: provide controllers so that all points associated with and common to one unit or other complete system/equipment reside within a single control unit. When referring to the controller pertaining to the standalone functionality, a reference is made explicitly to the processor. One processor shall execute all the related I/O control logic via one operating system that uses a common programming and configuration tool.

2.2.1.3 The following configurations are considered acceptable with reference to a controller's standalone functionality:

A. Points packaged as integral to the controller such that the point configuration is listed as an essential piece of information for ordering the controller (having a unique ordering number).
B. Controllers with processors and modular back planes that allow plug in point modules as an integral part of the controller.
C. I/O point expander boards plugged directly into the main controller board to expand the point capacity of the controller.
D. I/O point expansion devices connected to the main controller board via wiring and as such may be remote from the controller and that communicate via an approved subnet protocol. These arrangements to be considered standalone shall have a subnet LAN that is dedicated to that controller and include no other controller devices (AACs or ASCs). All wiring to interconnect the I/O expander board shall be contained in the control panel enclosure or run-in conduit. Wiring shall only be accessible at the terminations.
E. Controller shall have an integrated or remote HMI/display that is connected to the standalone controller to monitor, override, and annunciate I/O points.
F. HMI shall have security features to limit the access and prevent users from overriding or altering the operation of the equipment.

2.2.2 This section intentionally left blank.

2.2.3 BACnet building controller (B-BC)

2.2.3.1 The BC(s) shall provide fully distributed control independent of the operational status of the EMRS. All necessary calculations to achieve control shall be executed within the BC, independent of any other device. All control strategies performed by the BC(s) shall be definable and modifiable through the operator interfaces.

2.2.3.2 BCs shall perform overall system coordination, accept control programs, perform automated HVAC functions, control peripheral devices, and perform all necessary mathematical and logical functions. BCs shall share information with the entire network of BCs and AACs/ASCs for complete global control. Each controller shall permit multi-user operation from multiple workstations and portable operator terminals connected locally or over the F&S VLAN. Each unit shall have its internal RAM, non-volatile memory, microprocessor, battery backup, regulated power supply, power conditioning equipment, ports for connection of operating interface devices, and control enclosure. BC shall contain sufficient memory for all specified global control strategies, user-defined reports and trends, communication programs, and central alarming.

2.2.3.3 BCs will be used in each equipment room where major or more than two pieces of equipment are controlled. ASC or AAC devices for critical and main system equipment will not be permitted.

2.2.3.4 All BCs that are configured as the BBMD shall be labeled as “BAS Broadcast Device”. Any BC set up as a BBMD shall be installed in a separate locked and labeled NEMA 4 enclosure and be powered through a lockable circuit breaker.

2.2.3.5 For broadcast distribution, BBMD’s shall be provided, or appropriate arrangements shall be made for the use of IP multicasting.

2.2.3.6 BCs shall be programmable from the Service Tool.

2.2.3.7 BCs shall be connected to the F&S VLAN through color-coded patch panels and switches specified and supplied by F&S IT. All BCs shall be protected from any memory caused by a loss of power, by one or a combination of the following:

A. Volatile RAM shall have a battery backup using a lithium battery with a rated service life of fifty hours, and a rated shelf life of at least five years. Self-diagnostic routine shall report an alarm for a low battery condition.
B. EEPROM, EPROM, or NOVROM non-volatile memory
C. Dedicated UPS

2.2.3.8 In addition, BCs can provide intelligent, standalone control of HVAC functions. Each BC may be capable of standalone direct digital operation utilizing its own processor, non-volatile memory, input/output, wiring terminal strips, A/D converters, real-time clock/calendar, and voltage transient and lightning protection devices.

2.2.3.9 The BC shall provide for point mix flexibility and expandability. This requirement may be met via either a family of expander boards, modular input/output configuration, or a combination thereof. The BC shall have a minimum of 10% spare (panel real estate) capacity for future point connection and no less than two spares of each implemented I/O type.

2.2.3.10 All BC point data, algorithms and application software shall be modifiable from the Service Tool.

2.2.3.11 Each BC shall execute application programs, calculations, and commands via a microprocessor resident in the BC. The database and all application programs for each BC shall be stored in non-volatile or battery backed volatile memory within the BC and will be able to upload/download to/from the Service Tool.

2.2.3.12 BC shall provide buffer for holding alarms, messages, trends etc.

2.2.3.13 Each BC shall include self-test diagnostics, which allow the BC to automatically alarm any malfunctions, or alarm conditions that exceed desired parameters as determined by programming input.

2.2.3.14 The following is the list of the mandatory BACnet Interoperability Building Blocks (BIBBs) for the B-BC:

A. Alarm and event services:
   a. Alarm and event notification acknowledgement: AE-ACK-A; AE-ACK-B
   b. Alarm and event alarm summary: AE-ASUM-A; AE-ASUM-B
   c. Alarm and event notification: AE-N-A
   d. Subscribe COV: DS-COV-A; DS-COV-B
B. Data sharing:
   a. Read property: DS-RP-A; DS-RP-B
   b. Read property multiple: DS-RPM-A; DS-RPM-B
   c. Write property: DS-WP-A; DS-WP-B
   d. Write property multiple: DS-WPM-A; DS-WPM-B
C. Device and network management:
   a. Dynamic device binding: DM-DDB-A; DM-DDB-B 2.3.2.14.3.2
   b. Dynamic object binding: DM-DOB-A; DM-DOB-B 2.3.2.14.3.3
   c. Time synchronization: DM-TS-A; DM-TS-B 2.3.2.14.3.4
   d. UTC time synchronization: DM-UTC-A; DM-UTC-B

2.2.3.15 The following is the list of the mandatory BACnet object types for the B-BC:

A. Analog Input
B. Analog Output
C. Analog Value
D. Binary Input
E. Binary Output
F. Binary Value

G. Multistate Value
H. Notification Class
I. Calendar
J. Schedule

2.2.3.16 Three mandatory BACnet alarm notification classes shall be created in every B-BC with the following definitions:

A. Notification class URGENT - BACnet priority 80
B. Notification class HIGH - BACnet priority 160
C. Notification class LOW - BACnet priority 240

All the notification classes shall allow to modify the priorities through EMRS. The notification class object name must comply with the following naming convention:

xxx_DDCyy_NCz_URGENT	for urgent priority
xxx_DDCyy_NCz_HIGH	for high priority
xxx_DDCyy_NCz_LOW	for low priority

where:
xxx building number index
yy controller number index
z notification class index (80 - URGENT, 160 - HIGH, 240 - LOW)

All process values shall be assigned to the notification class LOW priority by default. The University's Project Team will reassign the priorities for the process values based on the internal process.

2.2.3.17 B-BC functionality and compliance with BIBB and object types shall be presented to the University's Project Team before shop drawing submission. Functionality shall be approved by the University's Project Team.

2.2.3.18 B-BC shall be BTL listed.

2.2.3.19 Each BC shall contain software to perform full DDC/PID control loops.

2.2.3.20 Input-Output processing:

A. Digital Outputs (DO): outputs shall be rated for a minimum of 24 VAC or VDC, 1 amp maximum current. Each output shall be configurable as normally open or normally closed and shall have an LED to indicate the operating mode with a manual hand-off -auto switch to allow for an override. If these HOA switches are not provided on the mainboard, they shall be provided via isolation relays within the control enclosure. Each DO shall be discrete outputs from the BC's board (multiplexing to a separate manufacturer s board is unacceptable). Provide suppression to limit transients to acceptable levels.
B. Analog Inputs (AI): AI shall be 0-5 VDC, 0-10 VDC, and 4-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the BC s board (multiplexing to a separate

manufacturer's board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 12 bits.

C. Digital Inputs (DI): monitor dry contact closures. Accept pulsed inputs of at minimum one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board.

D. Universal Inputs (UI-AI or DI): to serve as either AI or DI as specified above.

E. Electronic Analog Outputs (AO): voltage mode: 0-5 VDC and 0-10 VDC; current mode: 4-20 mA. Provide zero and span calibration and circuit protection.

F. Pulsed Inputs: capable of counting up to 10 pulses per second with buffer to accumulate pulse count. Pulses shall be counted at all times.

2.2.3.21 A communication port for Service Tool shall be provided in each BC. All program and database back-up, system monitoring, control functions, and BC diagnostics shall be performed through this port.

2.2.3.22 Each BC shall be equipped with loop tuning algorithm for precise proportional, integral, derivative (PID) control. Loop tuning tools provided with the Service Tool software is acceptable. Tools to support loop tuning shall be provided such that P, I, and D gains are automatically calculated.

2.2.3.23 All analog output points shall have a selectable failure setpoint. The BC shall be capable of maintaining this failure setpoint in the event of a system malfunction, which causes loss of BC control, or loss of output signal, as long as power is available at the BC. The failure setpoint shall be selectable on a per point basis.

2.2.3.24 Every Analog Input and Analog Output point must have the BACnet Change of Value Increment (COV) parameters configured as per the following table:

	Space	Return air	Discharge air	Mixed air	Outside air	Chilled water	Hot water	Cond. water
Temperature								
°C	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5
Pressure								
Inch H2O		0.1	0.1					
PSI						0.5	0.5	
PA	5	5	5					
Humidity	2%	2%	2%	5%	2%			
Volumetric flow	5% of range	2% of range	2% of range			2% of range	2% of range	2% of range
All types								

Other Parameters	5% of range
Outputs	5% of range

Table 10 - Change of value increment (COV) parameters

2.2.3.25 Reporting accuracy

A. System shall report values with a minimum end-to-end accuracy as listed in the table below. The accuracy level of each project shall be reviewed by the University based on the specific user or program requirements.

Measured variable	Reported accuracy
Space temperature	±0.2°C
Ducted air	±0.2°C
Outside air	±1.0°C
Dew point	±1.5°C
Water temperature	±0.1°C
Delta-T	±0.15°C
Relative humidity	±5% RH
Water flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air pressure (space)	±3 Pa
Water pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, power factor)	±1% of reading (see Note 3)
Carbon monoxide (CO)	±5% of reading
Carbon dioxide (CO2)	±50 ppm

Table 11 - Reporting accuracy requirements

Note 1: accuracy applies to 10%–100% of scale.

Note 2: for both absolute and differential pressure.

Note 3: not include utility-supplied meters.

B. Control stability and accuracy

Controlled variable	Control accuracy	Range of medium
Air pressure	±50 Pa (±0.2 in. w.g.)	0-1.5 kPa (0-6 in. w.g.)

Controlled variable	Control accuracy	Range of medium
	±3 Pa (±0.01 in. w.g.)	-25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space temperature	±1.0ºC (±2.0ºF)	
Duct temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	0-1 MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

Table 12 - Control accuracy requirements

2.2.3.26 BC power loss:

A. Upon a loss of power to any BC, the other units on the F&S VLAN shall not in any way be affected.
B. Upon a loss of power to any BC, the battery backup shall ensure that the energy management control software, the DDC software, the database parameters, and all other programs and data stored in the RAM are retained for a minimum of fifty hours. An alarm diagnostic message shall indicate that the BC is under battery power.
C. Upon restoration of power within the specified battery backup period, the BC shall resume full operation without operator intervention. The BC shall automatically reset its clock such that proper operation of any time dependent function is possible without manual reset of the clock. All monitored functions shall be updated.
D. Should the duration of a loss of power exceed the specified battery back-up period or BC panel memory be lost for any reason, the panel shall automatically report the condition (upon resumption of power) and be capable of receiving a download via Service Tool. In addition, the University shall be able to upload the most current versions of all energy management control programs, DDC programs, database parameters, and all other data and programs in the memory of each BC via the Service Tool.

2.2.3.27 BC failure:

A. F&S VLAN data transmission failure: BC shall continue to operate in stand-alone mode. BC shall store loss of communication alarm along with the time of the event. All control functions shall continue with the global values programmable to either last value or a specified value. Peer BCs shall recognize the loss and report a critical level alarm.
B. BC hardware failure: BC shall cease operation and terminate communication with other devices. All outputs shall go to their specified failure position.

2.2.3.28 Each BC shall be equipped with firmware resident self-diagnostics for sensors and be capable of assessing an open or shorted sensor circuit and taking an appropriate control action (close valve, damper, etc.).

2.2.3.29 BCs may include LAN communications interface functions for controlling serial field bus sub-networks.

2.2.4 BACnet advanced application controller (B-AAC) and application specific controller (B-ASC)

2.2.4.1 Where these devices are included with HVAC&L equipment such as boilers, chillers, variable speed drives, lighting, pump sets, air handling units, etc., they shall meet these standards. They shall be able to be connected to the EMRS using BACnet communication and interoperability protocols with complete accessibility to objects/points in the controller.

2.2.4.2 AACs and ASCs shall provide intelligent, standalone control of HVAC&L equipment. Each unit shall have its own internal RAM, non-volatile memory and will continue to operate all local control functions in the event of a loss of communications on the ASC sub-network. It shall be able to share information with every other BC and AAC/ASC on the entire network.

2.2.4.3 Each AAC and ASC shall include self-test diagnostics that allow the AAC and ASC to automatically relay to the related BC, any malfunctions or abnormal conditions within the AAC/ASC or alarm conditions of inputs that exceed desired parameters as determined by programming input.

2.2.4.4 AACs and ASCs shall include sufficient memory to perform the specific control functions required for its application and to communicate with other devices.

2.2.4.5 Each AAC and ASC must be capable of stand-alone direct digital operation utilizing its own processor, non-volatile memory, input/output, minimum 8-bit A to D conversion, voltage transient and lightning protection devices. All volatile memory shall have a battery backup of at least fifty hrs with a minimum battery life of five (5) years.

2.2.4.6 All point data, algorithms and application software within an AAC/ASC shall be modifiable from the Service Tool.

2.2.4.7 The following is the list of the mandatory BACnet Interoperability Building Blocks (BIBBs) for the B-AAC and B-ASC:

A. Alarm and event services:
   a. Alarm and Event Notification - Acknowledgement: AE-ACK-A; AE-ACK-B
   b. Alarm and Event - Alarm Summary: AE-ASUM-A; AE-ASUM-B
   c. Alarm and Event Notification: AE-N-A

B. Data sharing:
   Read property DS-RP-A; DS-RP-B

Read property multiple	DS-RPM-A; DS-RPM-B
Write property	DS-WP-A; DS-WP-B
Write property multiple	DS-WPM-A; DS-WPM-B

C. Device and network management:

Dynamic device binding	DM-DDB-A; DM-DDB-B
Dynamic object binding	DM-DOB-A; DM-DOB-B
Time synchronization	DM-TS-A; DM-TS-B
UTC time synchronization	DM-UTC-A; DM-UTC-B

2.2.4.8 The following is the list of the mandatory BACnet object types for the B- AAC and B-ASC:

A. Analog Input
B. Analog Output
C. Analog Value
D. Binary Input
E. Binary Output
F. Binary Value
G. Multistate Value
H. Notification Class

2.2.4.9 Three mandatory BACnet alarm notification classes must be created in the B-AAC and B-ASC with the following definitions:

Notification class	URGENT - BACnet Priority 80
Notification class	HIGH - BACnet Priority 160
Notification class	LOW - BACnet Priority 240

All the notification classes shall allow to modify the priorities through EMRS. The notification class object name must comply with the following naming convention:

xxx_DDCyy_NCz_URGENT	for Urgent priority
xxx_DDCyy_NCz_ HIGH	for High priority
xxx_DDCyy_NCz_ LOW	for Low priority

where:

xxx	building number index
yy	controller number index
z	notification class index (80 - URGENT, 160 - HIGH, 240 - LOW)

All process values shall be assigned to the notification class LOW priority by default. The University's Project Team will reassign the priorities for the process values based on the internal process.

2.2.4.10 B-ASC and B-AAC functionality and compliance with BIBB and object types shall be presented to the University's Project Team before shop drawing submission. Functionality must be approved by the University's Project Team.

2.2.4.11 All AACs and ASCs shall be BTL listed.

2.2.4.12 AAC(s) and ASC(s) shall communicate to the BACnet Building Controller (B-BC) on the RS485 MSTP field bus.

2.2.4.13 AAC and ASC input-output processing

A. Digital Outputs (DO): outputs shall be rated for a minimum 24 VAC or 24 VDC, 1-amp maximum current. Each shall be configurable as normally open or normally closed. Each output shall have an LED to indicate the operating mode of the output and a manual hand off or auto switch to allow for override. If these HOA switches are not provided on the main board, they shall be provided via isolation relays within the control enclosure. Each DO shall be discrete outputs from the AAC/ASC s board (multiplexing to a separate manufacturer's board is unacceptable). Provide suppression to limit transients to acceptable levels.
B. Analog Inputs (AI): AI shall be 0-5 Vdc, 0-10Vdc, and 4-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the ASC/AAC s board (multiplexing to a separate manufacturers board is unacceptable). A/D converters shall have a minimum resolution of 12 bits.
C. Digital Inputs (DI): monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the ASC/AAC and shall be isolated from the main board.
D. Universal Inputs (UI-AI or DI): to serve as either AI or DI as specified.
E. Electronic Analog Outputs (AO): voltage mode, 0-5VDC and 0-10VDC; current mode (4-20 mA). Provide zero and span calibration and circuit protection. D/A converters shall have a minimum resolution of 12 bits.
F. Analog Output Pneumatic (AOP), 0-20 psi: pneumatic outputs via an I/P transducer or 0-10vdc to pneumatic transducer are acceptable. Multiplexed pneumatic outputs of a separate manufacturer are unacceptable.

2.2.4.14 Mandatory ASC/AAC as-built submittals must be provided for all the MSTP controllers, to determine the point mapping and the point description that is associated with every ASC/AAC application. In cases where the vendor is using any variations of the ASC/AAC application (sometimes referred to as TEC Application Number), the detailed specification document must be provided as part of the as-built package.

A. Please refer to the F&S standard website for the Project point list energy management reporting system (EMRS) submittal form(Design standards and project forms - Facilities & Services - University of Toronto (utoronto.ca)).

2.2.5 Service Tool

2.2.5.1 Service Tool is supplied by F&S - IT when required. The BAS contractor is responsible for software that allows complete configuration of the BAS.

2.2.5.2 Control manufacturers software

A. Provide all licensed software associated with the project to the University's Project Team.
B. The software must include the following:
   a. All licenses and operating keys.
   b. Most recent Service/Technicians Tools software as used by the manufacturers' Service Technicians.
   c. Capable of programming and servicing all the DDC devices.
   d. Backup and restore controller databases.
   e. Add, modify, and delete any existing or new system points.
   f. The software must include a help file and a fully open library of the manufacturers' installed control devices.
   g. The latest controller global library.
   h. If controller databases exist for any given project, the latest version must be provided.
C. Warranty and licenses:
   a. Include all software updates during the warranty.
   b. Unlimited license without annual fees.
D. Provide all necessary interface cables for servicing the project controllers.

2.3 Instrumentation

2.3.1 General notes

2.3.1.1 All instrumentation is to be compatible with the BAS/EMRS for data access, control, and monitoring. Systems with BACnet protocol compatibility shall be the basis for all BAS instrumentation where applicable.

2.3.1.2 All sensor, devices and instrumentation locations shall be shown on the mechanical drawings and approved by the University's Project Team.

2.3.1.3 The Contractor shall provide and install all instrumentation required to satisfy the sequence of operation.

2.3.1.4 The following list of instrumentation describes minimum specifications.

2.3.1.5 The Design Team may enhance these minimum specifications to achieve the project requirements. The Contractor is encouraged to suggest alternates that are more advanced in design for review and approvals by the Design Team.

2.3.1.6 Contractor is responsible for coordinating with the Mechanical and Electrical contractor for the supply of BAS components that may over-lap such as metering, valves, line voltage devices. When in doubt, Design Team shall contact the University's Project Team for clarity.

2.3.1.7 The Design Team shall indicate location of all sensors on the floor plans and air flow schematics.

2.3.2 Temperature sensors

A. Platinum or Nickel RTD type sensors, either 100-ohm 3-wire Platinum at 0˚C. Class B, or 1000-ohm Platinum at 0˚C (both with coefficient of resistivity of 0.00385 ohms/ohm/˚C).
B. For temperature sensors used in controlling the operation of chilled water or hot water systems, only 1k ohm platinum, 3-wire Class A sensors with an accuracy of ±0.1˚C shall be used.
C. If the RTD is 1000-ohm Platinum or Nickel, provide a transmitter at the RTD when the I/O subsystem at the controller cannot interface directly to an RTD or if the distance between the RTD and the associated controller exceeds 50m.
D. The end-to-end accuracy for all BAS monitored temperature sensors shall be ± 0.2˚C or better (see 2.3.11 for temperature sensors used in metering).
E. Positive temperature coefficient thermistor type sensors are acceptable **only** for space temperature sensing associated with terminal units.

2.3.3 Outside air temperature sensor

A. Ventilated white PVC or metal sun shield.
B. Wall mounted weatherproof enclosure with conduit fitting, accessible for maintenance.
C. If not installed at a northern exposure, determine location with University's Project Team.
D. Operating temperature range of -50˚C to +50˚C.
E. Not installed near any exhaust vents or other sources of heat or cold.

2.3.4 Duct temperature sensors

A. Single point type sensor probe. Sensor probe length shall be no less than 1/3 of duct width or diameter.
B. Complete with duct mounting facilities and conduit fittings.
C. Operating temperature range of 0˚C to 65˚C.
D. Sensor shall be mounted in accessible locations for maintenance and quick replacement.

2.3.5 Duct averaging temperature sensors.

A. Duct averaging probe materials may be stainless steel, copper, or aluminum. The probe length must be 3.7m minimum or 3.25m per sqm. of duct cross- sectional area, whichever is greater.
B. Duct mounted moisture/waterproof housing with conduit fitting.
C. Suitable supports at all bends and at intermediate points to prevent movement in the air stream using capillary clips and protection where capillary goes through fan casing.

D. Sensor shall be installed and secured using factory provided clips or metal clips that allow for quick removal and replacement. **Cable ties are not accepted.**
E. Operating temperature range of -5˚C to 50˚C.

2.3.6 Space thermostats

A. All thermostats must be capable of temperature monitoring, temperature indication, set point adjustment, set point limiting, occupied/unoccupied mode selection, override, and reporting to the BAS/EMRS.
B. The actual space thermostat configuration shall be confirmed in written by the University's Project Team otherwise the options listed in the section above (section 2.3.6 A) shall be provided.
C. The accuracy of the temperature sensor must be ± 0.2°C.
D. All non-common area space thermostats shall have exposed temperature set point adjustment. Set points are limited from 18°C to 23°C and shall be capable of remote reset by the BAS/EMRS.
E. Space thermostats must have a programmable timed override request push button with LED status.
F. All space thermostats in public/common areas, such as, corridors, lobbies, cafeterias, gyms, auditoriums, classrooms, etc. will have no setpoint adjustment with blank covers or lockable protective enclosures. Blank covers or enclosures to be ventilated.
G. Insulated mounting bases must be installed when thermostats are located on exterior walls.

2.3.7 Electric line thermostat (only to be used for replacement purposes)

A. Provide heating/cooling type thermostat with dead-band where sequencing of heating and cooling/ventilation is required.
B. Line-voltage thermostats shall be UL-listed, SPDT, SPST, or DPST with contact rating suitable for application, maximum 1.5°C differential.
C. Provide heavy duty type. Include back plate and bracket for mounting on standard size outlet box where required.
D. Standalone line thermostats are not considered a component of the BAS/EMRS.
E. Provide isolation switch or list thermostats power source and label it at thermostat.

2.3.8 Electric low voltage thermostat

A. Provide complete with heat anticipator, and back plate and bracket for mounting on standard size outlet box where required. Include sub-base with fan On-Off-Auto switch with each thermostat where summer ventilation is required. Include modulating heating or cooling stage where used in conjunction with control valves; step controllers; SCR's; or similar equipment requiring modulation, and switches where On-Off control is required.
B. Standalone thermostats are not considered a component of the BAS/EMRS.

2.3.9 Standalone space thermostats

A. Low-voltage thermostats shall be single or multi-stage heating and/or type as required by application.
B. Combination heating/cooling thermostats shall have independent adjustments for heating and cooling set points and shall not allow set point crossover.
C. Provide individual heat or cooling anticipator for each control stage. Anticipator shall be matched to connected load or shall be adjustable.
D. Suitable switch sub-bases shall be provided when required by application, with switch functions clearly identified by permanent labels. Field- applied "stick-on" labels are not acceptable.
E. Microprocessor-based programmable type thermostats, when used, shall not lose time or program upon power failures of 12 hours or less and must have password protection capability.
F. All space thermostats in non-common areas shall have exposed temperature setpoint adjustment. The temperature setpoint is limited to 18°C and 23°C.
G. All space thermostats in public areas, such as, corridors, lobbies, cafeterias, gyms, auditoriums, classrooms or as specified will have no setpoint adjustment. Blank covers and enclosures shall be ventilated.
H. Insulated mounting bases shall be installed when thermostats are located on exterior walls and at locations approved by the University's Project Team.

2.3.10 Space temperature sensors

A. The accuracy of the temperature sensor must be ± 0.2°C or better.
B. Blank covers or enclosures shall be ventilated.

2.3.11 High precision temperature sensors: used in energy metering applications

A. Tip-sensitive RTD sensors complete with 316 drilled stainless steel thermo-wells.
B. 1000-ohm Platinum Class A (100 ohm ± 0.06 ohm @ 0°C.) stainless steel sheathed element.
C. Three-wire RTD's compensate for resistance.
D. The sensors must be a matched pair sensors while measuring temperature differentials.
E. Strap on Sensors **will not be allowed**. Insertion thermowells must be used and can be hot tapped for filled lines.

2.3.12 Thermowells

A. Stainless steel (316 SST ¾ inch) probe. Probe length shall be at minimum 30% of the pipe width.
B. Moisture/waterproof housing with conduit fitting.
C. Provide complete with drilled stainless steel thermowells.
D. Provide complete with thermal transfer compound inside thermowell.

2.3.13 Low temperature detection device

A. Duct mounted freeze protection is a dedicated equipment protection system and is not required to be incorporated into the BAS/EMRS unless specifically requested by the University's Project Team.
B. Minimum 6.1 m vapour tension element, which shall serpentine on the inlet face on all coils. Provide additional sensors, wired in series, to ensure 3.25 m per sqm. of coil surface area.
C. Provide freeze stat for each 3.25 m² of duct area where necessary, wired in series with safety circuit.
D. Hardwire interlock device to shut down fans and position mixing dampers to the full recirculation position. Refer to sequences of operation.
E. Provide device hardwire interlocked such that AHU fan will shut down when HOA switch in Hand or Auto position.
F. Manual reset.
G. Set-point shall be adjustable in the range of, minimum, 0°C to 7°C. Provide a scale with temperature setting clearly displayed.
H. DPDT switch contacts. Switch contacts shall be rated for duty.
I. Provide suitable supports.
J. Provide complete with auxiliary contacts for monitoring by the BAS.
K. Must be mounted horizontally across the coil using capillary clips.
L. Where capillary enters through fan cabinet to have protective sleeve around capillary.

2.3.14 Relative humidity sensors

A. Overall accuracy of ±3% reading from 0 to 95% RH unless the University's Project Team specifies higher accuracy for the application.
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 2-10 VDC 0r 4-20 mA output proportional to RH. Humidity sensor shall be replaceable.

2.3.15 Outdoor air relative humidity sensors

A. Non-corroding outdoor shield to minimize wind effects and solar heating.
B. Wall mount weatherproof enclosure with conduit fitting. Must be mounted in location that is accessible for repair or replacement.

2.3.16 Duct mount relative humidity sensors

A. Duct mount moisture resistant enclosure with conduit fitting.
B. 20 cm probe length.
C. Operating temperature range of 0°C to 50°C.
D. Sensor shall be suitable for operation in moving air streams.
E. When mounting sensors in the supply duct, sensors shall be placed at least 3 metres downstream from the nearest fan and/or coil, and maintain a minimum distance of 5 times the humidification distance from a humidifier.

2.3.17 Space relative humidity sensors

A. Suitably finished wall mounted enclosure with discrete manufacturer logos markings only. Enclosure shall not have temperature or RH indication devices.
B. Provide protective ventilated enclosures for all sensors mounted in mechanical and electrical rooms, janitor closets, any public spaces.

2.3.18 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 shall provide separate sensors meeting the specification stated. The individual sensors must each meet the specifications detailed above.

2.3.19 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 200 mm for duct application.
F. BAS/EMRS shall report the monitored dry bulb temperature with an accuracy of ± 0.2°C.
G. BAS shall report the monitored dewpoint temperature with an accuracy of ±1.0°C at 50% RH and dry bulb temperature of 25°C to +65°C.

2.3.20 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 BC, ASC, AAC or other local enclosures.
E. Malfunction of a BAS component shall cause the controlled output to fail to the positions identified in the failure procedure.
F. 10-amp contact rating.
G. Pin type terminals complete with mounting bases.

2.3.21 Momentary

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 BC, ASC, AAC or other local enclosures.

D. 10-amp contact rating.
E. LED status indication
F. 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. ±2.5% accuracy.
    d. Operating temperature range of -7°C to 50°C.
    e. Easily accessible, integral non-interacting zero and span adjustment.
    f. Minimum over pressure input protection of five times rated input.
    g. Basis of design, Setra or Greystone

2.3.22 Space static pressure transmitter

A. Input range to suit application.
B. 4-20 mA output proportional to pressure input range.
C. ±2.5% accuracy of range.
D. Temperature range of 0°C to 38°C.
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 with the University's Project Team.
H. Basis of design, Setra or Greystone.

2.3.23 Air flow rate sensor

A. Duct mounted multipoint flow cross or grid measuring device. Complete with transducer and range appropriate for application.
B. Bulkhead fittings to allow sensor tubing to be connected or removed without removing ductwork.
C. Internal materials of the transducer suitable for continuous contact with air.
D. Sensing grid shall be constructed of stainless steel.
E. Integral signal integrator to minimize primary signal noise from the output signal.
F. Output signal of 4-20 mA proportional to input pressure.
G. Temperature range of -18°C to 60°C, ± 2.5% accuracy of measured value.
H. Transducer to be provided complete with easily accessible, integral non- interacting zero and span adjustment.
I. The air flow sensor shall be installed in straight section of the duct, away from any bends or obstructions that could affect the accuracy of the readings.
J. The sensor shall also be installed perpendicular to the airflow and at a distance from any disturbances that could cause turbulence.
K. Air flow and velocity monitoring stations shall be installed at least 10 duct diameters upstream of the sensor and 5 duct diameters downstream of the sensor.

2.3.24 Air flow rate 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.
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.
I. Combined sensor and transducer accuracy of ±2.5% of measured value.
J. Meter should have local indication of Flow.
K. Transducer to be provided complete with accessible, integral non- interacting zero and span adjustment.

2.3.25 Current sensing transformer and relay combination

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 2.5% of full range per 6 months.
D. Current transformer and relay shall have over current and over voltage protection.
E. Transformer and relay may be combined into a single unit or can be separate units.
F. Transformer core shall be sized for the application.
G. Accuracy ±2% of reading from 10% to 100% of full-scale range, ±2% full scale from 0 to 10% of full-scale range.
H. Temperature range of -15°C to 60°C.
I. For new installations, solid core shall be used.
J. Split core, when used, shall be complete with LED indication and have a zero and span adjustments.
K. Relay portion shall not be installed in within the MCC tubs. Relay portion shall be installed in local field panel enclosure, in the BC, ASC, AAC enclosure, or in the wiring channel between MCC tubs. Provide device securely mounted with screw type wire terminations.
L. Device shall be mounted for easy access.

2.3.26 Water differential pressure sensor (not to be used in flow metering)

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. Valve taps shall be installed by the Mechanical Subcontractor.
H. Basis of design, Setra, or Greystone.

2.3.27 Differential pressure switch - duct static pressure limit

A. UL, CSA listed and approved.
B. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
C. Adjustable set-point with a setpoint range to suit the application.
D. 1/4-inch compression fittings suitable for copper sensing tubing.
E. Temperature range of -18°C to 71°C.
F. Manual reset switch based in application.
G. Provide sensing inputs complete with signal dampening facilities to prevent nuisance tripping where required.

2.3.28 Differential pressure switch - filter status indication

A. UL, CSA listed and approved.
B. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
C. Adjustable set-point with a setpoint range to suit the application.
D. 1/4-inch compression fittings suitable for copper sensing tubing.
E. Operating range to suit application.
F. Automatic reset.
G. Basis of design as manufactured by Dwyer or approved equal.

2.3.29 Differential pressure switch - water service (not used in flow metering)

A. UL, CSA listed and approved.
B. SPDT or two SPST switches rated for 10 amps minimum at 120 Vac.
C. Adjustable set-point with a setpoint range to suit the application.
D. 1/4-inch compression fittings suitable for copper sensing tubing.
E. Operating temperature and pressure range to suit application.
F. Durable NEMA-4 rated enclosure.
G. Provide sensing inputs complete with signal dampening facilities to prevent nuisance tripping where required.
H. Suitable for continuous contact with the sensed fluid and rated for operating temperature.
I. Repeatability of ±1 % of span.
J. Over pressure input protection to a minimum of five (5) times rated input.
K. Basis of design, Dwyer or Penn.

2.3.30 Water pressure sensor

A. Input range of 0 to 200 psi or as per the University's Project Team.
B. Complete with transducer with 4-20 mA output signal proportional to water pressure.
C. 0.5% accuracy over entire sensing range.
D. Temperature range of 0°C to 38°C.
E. Transducer with easily accessible, integral non-interacting zero and span adjustment.
F. Over pressure input protection of two times rated input.
G. NEMA-4 rated fittings.

H. Stainless steel wetted parts.
I. Burst pressure of 5 times rated input.
J. Long-term stability of .25 percent of full scale.
K. Shall be ANSI 300 rated or as per the University's Project Team.
L. Stainless steel wetted parts suitable for continuous contact with the sensed medium.
M. Basis of design, Dwyer.

2.3.31 Air quality sensor

A. Measurement of volatile organic compounds (VOC) containing, at minimum, the following gases: Methane, Ethylene, Hydrogen, Carbon Monoxide, Carbon Dioxide, Ammonia.
B. Ventilated cover, circuit board covered by polycarbonate housing.
C. 135 mA max current, 4 K OHMS min. load resistance, 24 VAC + 10%, - 50% or 24DC. (Min. 12 V, Max 24 V) power supply.
D. Rate of rise circuit to filter out short term disturbances and provide a stable output.
E. Temperature range of 0°C to 60°C.
F. Mounting and enclosure suitable for duct air or space air monitoring as specified.
G. Monitoring system shall be manufactured by Arjay Engineering Ltd or CET.

2.3.32 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 blank, white enclosure with no manufacturer Logo or LED indication.
J. For duct sensing applications provide sensor complete with aspiration box and air stream sensor.
K. Non-dispersive Infrared technology-based sensor.
L. Basis of design, Vaisala.

2.3.33 Occupancy sensor

A. The occupancy sensor system shall sense the presence of human activity within the desired space and fully control the on/off function of the loads automatically. Sensors shall turn on the load within 0.6 m of entrance.
B. Sensing technologies shall be completely passive in nature, in that the occupancy sensor system shall not emit or interfere with any other electronic device, or human

characteristic. Acceptable known technologies are Passive Infrared (PIR) or Thermal Imaging.

C. Upon detection of human activity by the detector, a Time Delay shall be initiated to maintain the “ON” state as specified and be field adjustable from 30 seconds to 20 minutes.
D. All sensors shall have non-adjustable factory calibrated sensitivity for maximum performance. Time Delay and field adjustments shall be provided as needed.
E. The installing contractor shall be responsible for a complete and functional system. Proper coverage of the area for all types of human activity, and any necessary relays or miscellaneous devices is the responsibility of the contractor.
F. Occupancy sensors may be connected to the BAS or stand alone and direct to load (i.e., lighting). Application and control functionality to be defined in the sequences of operation.

2.3.34 Occupancy demand control sensor

A. A thermal array-based sensor that counts occupants entering and leaving the monitored space shall be the basis of design for demand control of HVAC equipment where possible.
B. Design Team is responsible for coordinating the locations of the sensors and any related equipment such as repeaters, nodes, masters/slaves, and power as required to furnish an operating system.
C. All data shall be communicated to the EMRS. Design Team will coordinate with University’s Project Team for required integration with EMRS.
D. Counter has self-contained imaging optics, IR sensor, signal processing and interfacing electronics in an ABS package capable of ceiling mounting with twist off front piece for service.
E. Unit uses the infra-red signature of people only no other identifying features are to be captured.
F. Up to 8 units can be connected in series to allow for large zone entrance areas.
G. People are counted at “net” remaining in the controlled zone with multiple and user programmable count increment modes (crossing the line, leaving the field of view, U-turns, direction).
H. Data output and configuration can be via IP connection or direct serial connection to the master unit.
I. The University shall be able to completely configure the system and access all the data without requiring third party service teams. All firmware upgrades shall be possible remotely via IP.
J. Can be powered over CAT5.
K. Sensors can operate indoors between 0°C and 40°C.
L. Basis of design is using InfraRed Integrated Systems, IRC 3000 series.

2.3.35 Refrigeration alarm/monitoring system

A. Refrigeration Alarm/Monitoring system must be installed according to B52 standards and follow all TSSA requirements.

B. Must have a local LCD display complete with membrane keypad for user interface.
C. Alarm/Monitoring system must have Password protection.
D. The ventilation starter system should have HAND and AUTO switch only (no OFF position).
E. Alarm/Monitoring system must have local audible, visual alarm and remote alarm capabilities.
F. Communication capabilities to the EMRS via Modbus TCP/IP, BACnet/IP, and relay contacts for alarming.
G. Refrigeration Alarm/Monitoring system shall be manufactured by either Honeywell Vulcain or Arjay Engineering Ltd Refrigerant Gas Monitor.

2.3.36 Chiller vent pipe refrigerant leak monitoring

A. Refrigerant monitoring sensor must be installed in vent pipe on each chiller.
B. The sensor will be added to the Chiller Mechanical Room leak monitoring system panel.
C. Refrigerant alarm/monitoring system shall be manufactured by either Honeywell Vulcain or Arjay Engineering Ltd.

2.3.37 Parking garage carbon monoxide (co) alarm/monitoring system

A. Carbon Monoxide (CO) alarm/monitoring system must comply with the Ontario Building Code 2012- 6.2.2.3 Garage Ventilation.
B. Shall have a local LCD display complete with membrane keypad for user interface unless otherwise specified by the University's Project Team.
C. Alarm/monitoring system shall have password protection.
D. Alarm/monitoring system shall have local audible, visual alarm and remote alarm capabilities.
E. Communication capabilities to the EMRS via Modbus RTU, Modbus TCP/IP, BACnet/IP, and relay contacts for alarming.
F. Carbon Monoxide (CO) alarm/monitoring system shall be manufactured Arjay Engineering Ltd.

2.3.38 Damper position switch

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

2.3.39 Electronic to pneumatic transducers

A. Provide current-to-pneumatic (I/P) transducers for BAS DDC control of pneumatically actuated devices.
B. Output range shall be as required for the control device.

C. Provide device mounted within the associated BC/ASC/AAC controller panel or remote field panel enclosure mounted adjacent to the associated BC/ASC/AAC.
D. Operable temperature range of, at minimum, -10°C to 50°C with 5% to 90% RH (non-condensing).
E. Internal materials suitable for continuous contact with commercial standard controls air supply.
F. Combined non-linearity, hysteresis and repeatability effects not to exceed ±2% of span over the entire range.
G. Integral and accessible zero and span adjustments.
H. Complete with pressure gauge on the pneumatic control output.

2.3.40 Fluid flow measurement thermal energy

A. Flow metering installations shall be provided for the measurement of steam, high temperature hot water (supply and return), hot water heating (supply and return), chilled water (supply and return), condenser water (supply and return), domestic city water and condensate.

2.3.41 Metering devices: steam, heating/cooling water and condensate.

A. Flow metering used for measuring energy consumption.
B. Flow metering installations shall in compliance with governing body regulations such as ISO, API, AGA, and ANSI 2530/ASME Fluid Meters standards.

2.3.42 Mass flow density compensation and thermal energy devices - requirements for temperature compensation

A. High precision temperature sensors used in metering (i.e., thermal energy flow meter) applications must comply with the following requirements listed below.
B. Tip-sensitive RTD sensors complete with 316 drilled stainless steel thermo-wells.
C. The RTD is 100-ohm Platinum Class A (100 ohm ±0.06 ohm @ 0°C) stainless steel sheathed element.
D. Four-wire RTD's compensate for resistance resulting from length.
E. The sensors must be a matched pair.
F. Provide thermowells for temperature sensors in compliance with the following requirements:
    a. Stainless steel probe length shall be at minimum 30% of the pipe width.
    b. Moisture/waterproof housing with conduit fitting.
    c. Provide complete with thermal transfer compound inside thermal well.

2.3.43 Requirements for pressure compensation

A. Gauge pressure transmitter used in metering applications shall comply with the following requirements:
    a. 0.035 percent span accuracy, 150:1 range turndown, 15-year stability.
    b. Output 4-20 mA and HART protocol.

c. Provide a two-valve manifold (316SST) for instrument isolation and a drain/vent valve rain/vent valve allows venting, draining, or calibration.

B. Provide devices as manufactured by Rosemount MVP Series.

2.3.44 Steam flow and thermal energy measurement

A. For steam flow measurement provide Inline Linear Variable Area (ILVA) meter device complete with a smart differential pressure transmitter. The smart transmitter shall have the following:
   a. Density compensation via pressure and/or temperature.
   b. Password protected security access.
   c. A lithium battery for backup.
   d. USB communication adaptors complete with blanking plug and a universal serial bus A/B cable for a PC, or with the ability to manually configure the transmitter without taking the meter out of service. All tools required to execute configuration and calibration must be provided with the supply of the device.
   e. An external 24VDC power supply, mounted in a panel that protects the device from its environment.
   f. Capable of 4-20 ma analog, pulse, and RS 485 using Modbus and/or BACnet protocols
   g. Accuracy ±0.05% for Spans >10% of the URL.
   h. Accuracy ±0.005 (URL/SPAN) for Spans <10% of the sensor.

B. Must have a local LCD display and flow computer which can be configured for various display, for example, flow, totalizing, thermal energy, etc. unless otherwise approved by the University’s Project Team.

C. All convertors required to integrate with Modbus IP or BACnet IP for interfacing with the EMRS must be provided as part of the supply.

D. The primary measuring element shall be a spring-loaded variable area orifice with high turndown capability (100:1). Unit to be sized by Mechanical Design Team.

E. The following points shall be interfaced with the EMRS:

Thermal energy flow rate	MJ/hr
Thermal energy total	KJ or J
Pressure (air)	Pa
Pressure (water/steam)	KPa
Pressure (compressed air)	KPa
Temperature	Deg C
Mass flow rate (steam)	Kg/hr
Total mass (steam)	Kg
Volumetric flow rate (water)	Litre/minute
Volumetric total (water)	Litre
Volumetric flow rate (air)	Litre/second

Table 13 - Points required to be interfaced to EMRS

2.3.45 Water flow & thermal energy measurement (heating & chilled)

A. Design Team shall verify and confirm all meter locations with the U of T Project Team.
B. The minimum turndown capability of 40:1.
C. For monitoring purposes, communication shall be restricted to the EMRS Modbus TCP/IP and BACnet/IP. BACnet MS/TP and Modbus RTU will only be considered if distance to F&S switch locations exceed 91 meters.
D. For monitoring and control, in addition to point C, the device shall interface with the DDC controller using a 4-20 mA analog signal for the measured variable being controlled.
E. Capable of 4-20 mA analog, pulse, and RS 485 outputs.
F. High precision temperature sensors that are matched pair 3 or 4 wire type, Class A, 1k ohm RTD shall be used.
G. This display or flow computer unit shall operate in an environment from 0°C to 50°C, include a keypad for data input and retrieval, and an LCD display.
H. The accumulated data shall be stored in a battery backed data logger in continuous and periodic modes. The unit shall have a real time clock and shall date stamp logged data for a minimum period of 1 week with 1 minute data intervals.
I. Must have a local LCD display & flow computer which can be configured for various energy and configuration displays.
J. Accuracy: factory calibrated: 1.2% of reading, ± 0.01m/s; field calibrated: 0.5% of reading, ±0.01m/s. or better.
K. Flow/thermal energy meters to be sized by Mechanical Design Team.
L. Provide all configuration software, licenses and required interface cables as determined by the University's Project Team.
M. The thermal energy display/flow computer supplier shall set up, commission, and verify thermal energy measurement and shall train the University's Project Team in all aspects of thermal energy computer setup and operation.
N. Thermal energy meter installation shall include sensor wiring, power wiring, coordination of flow meter installation in a pipeline, setup for operation, labeling, commissioning with commissioning reports.
O. Final commissioned report to be included in OEM manual.
P. Verification of flow through a 3-point check by a water balancer shall be provided after installation.
Q. Basis of design shall be:
    a. Ultrasonic flow meter
        i. Siemens
        ii. Flexim Fluxus or Katronics
        iii. Approved by University's Project Team
    b. Magnetic flow meter
        i. E+H
        ii. Rosemount
        iii. ABB
        iv. McCrometer **(FPI only)**

R. The following minimum points shall be interfaced to the EMRS:

1	Thermal energy flow rate	MJ/hr
2	Thermal energy total	KJ or J
3	Supply temperature	Deg C
4	Return temperature	Deg C
5	Volumetric flow rate	Litre per minute
6	Volumetric total flow	Litre

Table 14 - Points required to be interfaced to EMRS

2.3.46 Condensate metering

A. A condensate flow meter shall be installed on the line leaving the condensate tank returning to the Central Steam Plant. The flow meter must have a working pressure of 230 psi (16 bar) and 130°C operating temperature. Flow meter shall have a minimum resolution of 1 cubic meter and a capacity register of minimum 100 cubic meter. Complete with remote reading capability.
B. For monitoring purposes, communication shall be restricted to the EMRS Modbus TCP/IP and BACnet/IP. BACnet MS/TP and Modbus RTU will only be considered if distance to F&S switch locations exceed 91 meters.
C. Provide a GWF (Super static Series) Kent/AMCO/Neptune Hot Water Meter (to be sized by Mechanical Design Team).

2.3.47 Electrical metering

A. It is the intention to sub meter electrical loads that are under the jurisdiction of the F&S Utilities. Electrical metering is to follow the electrical standards for application and installation. See electrical standards (metering).
B. Submetering refers to meters that are installed after the main utility meter and within the building.
C. All sub meters shall communicate with the EMRS using approved protocols with Modbus IP (BACnet IP will be considered as per project basis) the basis for design. Minimum data set to be available is watts, amps, volts, (all phases), kWh, time of day.
D. Single or multiple point metering applications shall be determined with the University's Project Team.
E. The University's Project Team shall approve all metering applications.
F. Approved electrical sub meter: Schneider PowerLogic or Triacta.

2.3.48 Automatic control valves

A. Valve schedules shall be submitted for review and approval by the University's Project Team and shall clearly show the following for each valve:
   a. Associated system
   b. Manufacturer and model number with the indication of the medium

c. Valve size and line size
d. Flowrate, flow coefficient (CV) and pressure drop at design conditions or valve authority, flowrate and pressure drop across the valve at design conditions and pressure drop across the associated mechanical equipment, i.e., coil, heat exchanger, etc., at design conditions.
e. Valve configuration (i.e., two-way, three-way, butterfly)
f. Leakage rate
g. Maximum pressure shut-off capability
h. Actuator manufacturer and model number
i. Valve body pressure and temperature rating
j. Normally open/closed and failure positions

B. Valves shall "fail safe" in a normally open or closed position or as dictated by the University’s Project Team and shall be easily accessible for servicing. Design Team and BAS contractor shall verify “fail safe” operation requirements before submitting shop drawings. Default operation is “fail safe”.
C. All screwed control valves from 13 mm up shall have replaceable stem plug and seat ring.
D. Control valve shall be provided with an actuator, sized to allow the control valve to shut off against normal inlet operating pressures.
E. Pneumatic valve actuators used to sequence multiple valves shall be provided with pilot positioners to ensure proper sequence of each valve and to allow for an adjustable dead band between heating and cooling valves.
F. 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 diameter stainless steel tag that shall be attached to the valve by a chain in such a manner that it cannot be unintentionally removed.
G. Valves 13mm to 50mm shall have screwed ends with union fittings to allow easy removal for servicing. Valves 63mm and larger shall have flanged ends. All valves shall meet the appropriate ANSI requirements.
H. The Design Team shall certify that the materials of construction are appropriate for the application. Valves used for the control of glycol solutions shall have a trim that is suitable for a glycol solution.

2.3.49 Two-way automatic control valves

A. Shall have equal percentage characteristics.
B. 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.

2.3.50 Three-way automatic control valves

A. Shall have linear characteristics, sized for maximum 3 psi drop.
B. 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 linear plug and stainless-

steel trim. Valves shall have metal-to-metal stainless steel seats to assure tight seating.

C. 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.

2.3.51 Water service automatic control valves

A. Valves for water service shall be provided with stainless steel stems.
B. Valves supplied for water service at 1034 kPa (150 psig) or less shall be provided with brass plugs and elastomer U-cup or Teflon packing; valves shall be provided with removable brass seat rings.
C. Valves supplied for water service over 1034 kPa (150 psig) shall be provided with stainless steel plugs and Teflon packing; all valve sizes shall be provided with removable stainless steel seat rings.

2.3.52 Steam service automatic control valves

A. Valves for steam service shall be provided with stainless steel stems.
B. Valves supplied for steam service at 241 kPa (35 psig) or less shall be provided with brass plugs and removable brass seat ring and Teflon packing.
C. Valves supplied for steam service over 241 kPa (35 psig) shall be provided with stainless steel plugs and Teflon packing.
D. For steam capacities with modulating steam valves greater than 907 kg/hr, two valves shall be supplied and sequenced, one sized for 2/3 and the other for 1/3 capacity.

2.3.53 High temperature hot water service automatic control valves

A. Flanged - bolts to ANSI Class 300 rated flanges (DN 25-300)
B. Carbon steel body materials
C. Trim, Self-aligning eccentrically rotating plug
D. (DN 80-300) 316L stainless steel with hard faced seating surface
E. Seat Ring, solid clamped
F. Upper & Lower Bearings seals must be for slurry/viscous service
G. Operating fluid temperature range, 250°C
H. Flow characteristic, standard trim - linear
I. Actuator, spring-opposed rolling diaphragm
J. Actuator bench test spring range, 7-24 psi on supply
K. Failsafe normally closed on supply valve and normally open on the by- pass valve
L. Shall be Masoneilan valve 35002 Series Camflex® II Complete with SVI-II smart positioner sized by Mechanical Design Team.

2.3.54 Valve actuators: electric/electronic

A. The Design Team shall design electric/electronic actuators for all valves except as noted in design documents.

B. Pneumatic type actuators may be acceptable for steam control valves where required to meet the shut-off and torque requirements. Design Team shall request permission from the University's Project Team for the proposed application of pneumatically actuated valves.
C. Pneumatic type actuators are required for high temperature hot water service.
D. BAS contractor is responsible for connecting to existing pneumatic system or supplying and installing pneumatic system where required to operate valves.
E. Actuator shall be motor driven type. Valve stem position shall be adjustable in increments of one (1%) percent or less of full stem travel.
F. Actuator shall have an integral self-locking gear train, mechanical travel stops, and adjustable travel limit switches with electrically isolated contacts.
G. Actuator gear assembly shall be made of hard-anodized aluminum or steel or material of equivalent durability. No plastic components shall be acceptable.
H. Actuator shall be rated for continuous duty and have an operating voltage of 24 VAC, an input of 0-10 VDC or 4-20 mA control signal and provide a 0-10 VDC feedback.
I. Note: no floating-point actuators will be accepted.
J. Actuators on valves located in the outdoors shall have NEMA 4 enclosures.
K. Actuator motor shall be fully accessible for ease of maintenance.
L. 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.
M. Actuator shall control against system maximum working pressures.
N. Actuator shall fail safe as indicated on the control drawings that form part of these contract documents. Provide spring return to de-energized position on loss of power and loss of control signal if required by the sequences of operation. Note: no fail last position actuators will be accepted.
O. Actuator shall accept control signals compatible with the BAS analog or digital output subsystem as appropriate. The valve stem position shall be linearly related to the control signal.
P. Actuator shall have visual mechanical position indication, showing valve position.
Q. Actuator shall operate the valve from the fully closed to the fully open position and vice versa in less than two minutes.
R. Actuator shall be constructed to withstand high shock and vibration without operations failure. Materials of construction shall be non- corroding.
S. All valve actuators for service of control valves larger than ¾ ” or as approved by the University's Project Team, shall be equipped with an integral position potentiometer or 0-10 VDC feedback to indicate the stem position of the valve. All valve actuators shall have integral end position indicators.
T. Actuators shall have manual over-ride capability. The operator will be able to manually modulate valves located in mechanical rooms in the event of loss of power.
U. Actuator motor shall be fully accessible for ease of maintenance.
V. Approved Manufacturers: Belimo, Siemens Building Technologies, Johnson Controls Inc., Honeywell, Automated Logic, and Schneider Electric.

2.3.55 Damper actuators: electric/electronic

A. Unless otherwise specified the Design Team shall design electric/electronic actuators for all dampers and shall meet, at minimum, the following requirements:
B. Damper actuators shall be selected as per manufacturer's recommendations with sufficient close-off to effectively seal the damper.
C. Modulating actuators shall provide smooth modulating control under design flow and pressure conditions.
D. Provide one actuator for each damper section. Damper actuators shall not be stacked.
E. Damper actuators 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 and loss of control signal if so required by the sequences of operation. Note: no fail-to-last position actuators will be accepted.
F. Actuator for modulating automatic dampers shall be rated for continuous duty and have an operating voltage of 24 VAC, an input of 0 -10 VDC or 4- 20 mA control signal and provide a 0-10 VDC feedback.
G. Note: no floating-point actuators will be accepted.
H. Actuators for two position dampers shall be controlled by 24 VAC, 24 VDC power.
I. Actuators shall be designed for mounting directly to the damper shaft without the need for connecting linkages.
J. All actuators shall accept a 25 mm diameter shaft directly, without the need for auxiliary adapters.
K. All actuators shall have self-centering damper shaft clamp that guarantees concentric alignment of the actuator's output coupling with the damper shaft. The self-centring lamp shall have a pair of opposed "V" shaped toothed cradles; each having two rows of teeth to maximize holding strength. A single clamping bolt shall simultaneously drive both cradles into contact with the damper shaft.
L. All actuators shall have an all-metal housing made from die-cast aluminum.
M. All actuators shall provide overload protection through the full range of rotation, enabling the actuator to detect a blockage in the damper and withstand a continuous stall condition without premature failure in performance.
N. All spring return actuators shall be capable of either clockwise or counterclockwise spring return fail-safe operation.
O. Stroke dampers from fully closed to fully open in accordance with the following table:

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

Table 15 - Timing requirements of stroke dampers from fully closed to fully open

P. All actuators shall be equipped with a manual drive release mechanism and manual positioning mechanism in the absence of power.
Q. Rated for operation at ambient temperatures of minus 40˚C to 50˚C.
R. All actuators shall provide an easily readable damper/actuator position indicator.
S. Actuators shall be quiet in operation such that noise from actuator operation is not detectable in any occupied spaces.
T. Approved manufacturers: Belimo, Siemens Building Technologies, Johnson Controls, and Honeywell.

3 Execution

3.1 Inspection

3.1.1 For retrofits or new installation projects on existing equipment, Design Team shall review area and equipment conditions to verify the feasibility of installing the BAS equipment. Any unsatisfactory conditions shall be reported to the University.

3.1.2 The Design Team shall ensure that all BAS equipment required to fulfill the full intent of these standards is included in their design. Any exceptions, including all cabling, patch panels, connections to the F&S secured network, and any required BAS devices, shall be clearly identified to the University's Project Team during design phase.

3.1.3 Arrange for Electrical Authority inspection of all electrical work. Arrange for a separate inspection of any field assembled electrical panels or systems that have not been preapproved by CSA/ULC. Submit the Certificate of Inspection and Product Approval Certificate with the record documentation.

3.2 Installation of control system

3.2.1 Contractor shall install sensor(s), meters, and devices strictly in accordance with manufacturer's instructions. Any deviation shall be documented on the variance request form and submitted to the University.

3.2.2 Contractor shall install all related controllers, cabinets, control devices and power supplies in readily accessible locations, providing adequate ambient conditions for their specified application and complying with the Canadian Electrical Code.

3.2.3 Contractor shall check installation in field to verify the installation has been built to the issued for construction document including accepted Change Orders as per the Design Team.

3.2.4 Contractor shall verify and document completed signed calibration report of all sensors and instruments installed. They should cross-reference this documentation with the construction documents to verify process range capability.

3.2.5 Contractor shall verify the wiring integrity for each end device output to BAS controller using a service tool to confirm its existence and correctness as per construction document. They should also verify all communication settings, such as IP addresses and BACnet instance numbers, ensuring a 100% verification.

3.2.6 Contractor shall verify all connections between BAS Controller and patch panels by using a cable test management tool (Fluke testing) with integrated recording and reporting capabilities.

3.2.7 F&S IT shall manually verify all connections between patch panel and F&S VLAN switch, documenting 100% of the connections.

3.2.8 Contractor shall verify 100% of connections from the controller to end devices using a Service Tool, performing loop tests to ensure the integrity of the signal, response to commands, and range of process control tolerance. This process requires visual confirmation at the end device and the Service Tool network switch simultaneously.

3.2.9 Contractor shall verify and document the operation of the UPS powering the panel by simulating a power loss to the UPS.

3.2.10 Using existing EMRS, CxA shall verify 100% acquisition of data to "System Graphic Screen" from end devices for specified functionality. This verification shall occur simultaneously at both EMRS station and end device locations, ensuring compliance with the BAS object naming convention as outlined in the project's BACnet Metamodel File Definitions document provided by the University after the approval of the BAS architecture.

3.2.11 CxA shall use existing EMRS to verify the integrity of graphics as specified in the system design.

3.2.12 Contractor shall verify meter readings on the local meter/display panel and the EMRS for accuracy in value and displayed units.

3.2.13 Contractor shall verify that all electrical power supplies to the control devices and auxiliary components must have current protection such as circuit breakers (fuse are not acceptable for this purpose).

3.2.14 Contractor shall install and verify all external fast-blow fuses are be installed to all powered input/output devices (such as actuators for valves and dampers, transmitters etc.) with a rating slightly lower than the maximum recommended current rating provided by the manufacturer.

3.2.15 Contractor must mount sensors securely. Mountings shall be suitable for the sensor's operational environment.

3.3 Control panels, controller quantity and location

3.3.1 Control panels shall consist of one or multiple controllers to meet the project's requirements and the University's design standards. Control panels shall be wall mounted within mechanical equipment rooms. In no case shall panels other than terminal unit controllers be located above ceilings. The Contractor shall extend power to the control panel from the designated panel upon submission of the power request through the RES online platform. Furthermore, the Design Team is responsible for ensuring that panel locations are adequate, avoiding interference with other project requirements, and maintaining sufficient clearance for maintenance access.

3.3.2 It is the Contractor's responsibility to provide enough controllers to ensure a completely functioning system, according to BAS architecture, point list and sequence of operations.

3.3.3 For rooftop AHUs, ERUs, exhaust fans, etc., controllers rated for use outside the building envelope shall be mounted inside the unit's casing. If adequate space is not available for installation of the controllers per the manufacturer's recommendations, they shall be installed in NEMA-4X enclosures adjacent to the unit that they serve. For all other controllers serving rooftop equipment coordinate with the University's Project Team for control panel location. Typically, within the building envelope, preferably in the near vicinity of the equipment in an accessible location for maintenance.

3.4 Controllers for terminal equipment

3.4.1 For equipment located in the conditioned space, controllers shall be mounted inside the unit enclosure. Where sufficient mounting space is not available inside the unit enclosure, a control panel shall be installed above the drop ceiling, inside the room, as close to the equipment as possible. Coordinate with the University's Project Team to clarify acceptable mounting locations.

3.4.2 For equipment located above the drop ceiling, controllers shall be unit mounted (notify the University's Project Team if 1 meter clearance in front of control panel has not or cannot be provided).

3.4.3 Provide adhesive backed labels identifying power source, including DB and circuit breaker number and room number.

3.4.4 Provide adhesive backed ceiling labels, affixed to ceiling grid below all ceiling concealed controllers, affix to ceiling panel access door for solid ceilings for ease in locating panels.

3.4.5 Laminated control drawings, including system schematic flow diagrams, sequences of operation and panel termination drawings, shall be provided in panels for major pieces of equipment. Terminal unit drawings in standardized letter size shall be located in the central plant equipment panel or mechanical room panel.

3.4.6 All points from terminal devices that are communicating through MS/TP or Modbus shall be mapped to the respective B-BC controller according to this standard's nomenclature, with required BACnet alarming enabled.

3.4.7 The BAS contractor shall submit the TEC BACnet Point Matrix and the TEC Field Layer Network Schedule before BACnet compliance testing phase (refer to Appendix D) .

3.5 Uninterruptible power supply and surge protection

3.5.1 Design Team shall design power supply surge protection, filters, etc. for proper operation and protection of all BCs, AAC/ASCs operator interfaces, printers, routers and other hardware and interface devices. All equipment shall be capable of handling voltage variations above or below measured nominal value, with no effect on hardware, software, communications, and data storage, as per the Electrical standards.

3.5.2 If failure occurs from surges and transients during the warranty period, the Contractor shall repair surge protection equipment and other equipment damaged by the failure at no cost to the University.

3.5.3 Isolation shall be provided at all peer-to-peer network terminations, as well as all field point terminations to suppress induced voltage transients.

3.5.4 UPS shall supply power for the BC(s), repeater(s) and/or ASC(s)/AAC(s) that monitor or serve emergency and/or critical equipment, locations, or points. The intent of UPS is to primarily reduce power interruptions caused due to power blips and transience.

3.5.5 The dry contacts for monitoring the UPS(s) status shall be monitored by the BAS.

3.5.6 The UPS shall be equipped with a cord and plug and shall be plugged into a secure outlet. The outlet shall be connected via a dedicated BAS circuit to the building Normal/Emergency, Standby-Optional electrical panel, which may be the same outlet specified above, if applicable. The UPS is not to be hardwired.

3.5.7 Signage at the UPS plug-in location shall include the Electrical Panel Name and breaker # with “this outlet for UPS only”.

3.5.8 The UPS and the related plug shall be enclosed where public access is possible.

3.6 Installation of meters and related devices

3.6.1 Install sensor(s), meters, and devices strictly in accordance with the manufacturer’s recommendations to accurately sense the specified variables. Any deviation shall be documented on the variance request form and submitted to the University prior to installation.

3.6.2 Contractor is responsible for the supply and the installation of all devices, software, communication devices and power supplies to bring metered data to the EMRS.

3.6.3 Contractor shall verify the communication of all metered data from the field level meter point to the EMRS is consistent, reliable and matches actual field measured data.

3.6.4 Mount sensors securely. Mountings shall be suitable for the sensor’s operational environment.

3.6.5 Sensor locations shall be such that the instruments can be accessed for service and removal.

3.6.6 Sensors mounted on water lines shall have isolation valves (for pressure and flow monitoring) to facilitate easy removal of the sensor without the need to drain any lines or portions of lines.

3.6.7 When installed on steam service the DP transmitter must be installed below the flow sensing device.

3.6.8 Contractor shall verify the DP transmitter is equipped with a five-way manifold.

3.6.9 Where supplied, the meter local display to be installed at a height that allows it to be read while standing on floor.

3.6.10 The display must have back light display capabilities.

3.6.11 On steam flow measurement, the Design Team may recommend a remote display, subject to approvals by University's Project Team.

3.6.12 Contractor to verify the remote output reading matches the local display.

3.6.13 Differential pressure transmitter lead sensing lines shall be ½ inch OD x 0.035 316 stainless steel and Swagelok fittings or equivalent (equivalent fitting shall be interchangeable with Swagelok).

3.6.14 Contractor shall verify the lead sensing lines are sloped downward toward the transmitter at a minimum slope of 1 inch per foot. The length of the lead sensing lines shall be minimized. Isolation valves must be installed at the flow sensing device for the lead sensing lines.

3.6.15 The lead sensing lines must have filling Tee's installed at the isolation valves. These Tee's should be installed in a bull-nose fashion.

3.6.16 When installed on steam service a blow-down must be added to the Lead sensing lines.

3.6.17 Display or flow computer units shall operate in an environment of 0˚C to 50˚C.

3.6.18 The meter must be installed in a clean pipeline, free from any foreign materials.

3.6.19 Condensate flow meters must have 10 pipe diameters upstream of the unit and 5 downstream to ensure proper flow through the meter (Installation details to be shown in approved construction drawings).

3.6.20 A condensate flow meter shall be installed on the line leaving the condensate tank back to the Central Steam Plant.

3.7 Demolition and reuse of existing materials and equipment

3.7.1 Design Team shall assume that existing equipment intended for reuse is in good condition and operational. They should coordinate with University's Project Team for clarification on the status of reusable equipment. Design Team shall perform a comprehensive investigation of these devices to determine if any require replacement or repair. Design Team shall prepare an itemized list of suggested repairs and replacements.

3.7.2 The Design Team shall document any deviations or irregularities in the installation and add them to the list of suggested repairs and replacements.

3.7.3 Existing wire, conduit, and control panel cabinets may be reused at the University's Project Team discretion, but only if such materials or equipment comply with the applicable specification for new materials and equipment. Such materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service.

3.7.4 Where such materials are reused, the contractor's shop drawings shall reflect the existing wiring designation. If existing labeling is illegible or does not comply with the applicable specification for labeling, wiring runs shall be relabeled in accordance with the requirements specified by the Design Team.

3.7.5 Existing pneumatic tubing and tubing conduit located between the existing BAS panels and the pneumatic operators may be reused if such materials comply with the applicable specification for new materials. Materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service.

3.7.6 All pneumatic tubing to be reused shall be pressure tested and all leaks shall be repaired. All reused pneumatic tubing shall be purged with dry air or nitrogen.

3.7.7 The existing pneumatic main air supply system shall be modified as required and reused to serve existing pneumatic controls that are to remain and shall be extended as necessary to serve new pneumatic controls. Where existing pneumatic controls are removed, main air piping shall be removed back to the point of connection to the main air supply which remains in use and shall be capped or plugged.

3.7.8 Existing valves and dampers and their operators may be reused with prior approval of the University's Project Team. Contractor shall lubricate all damper linkages that are used for their project.

3.7.9 Other materials and equipment not addressed here may be reused only if they are indicated on the drawings and approved by the University's Project Team.

3.7.10 For HVAC systems which are indicated to receive a new BAS, all existing materials and equipment associated with the existing pneumatic controls and BAS shall be removed unless otherwise specified or indicated to remain, or unless reused in accordance with the above requirements, except for the following:

3.7.10.1 Conduit and electrical boxes (but not wiring within conduit) may remain in place if not reused (leave a pull line).

3.7.10.2 Inaccessible pneumatic tubing may remain in place if not reused. Tubing must be sealed and permanently labeled as "Abandoned in Place" and approved by University's Project Team.

3.8 Sequence of work for pneumatic systems conversion

3.8.1 All work involving a change of control functions from the existing pneumatic control system to the new DDC BAS, shall be performed per the following sequence to minimize the duration of equipment outages. The following requirements outline the sequence in which the work shall be performed and do not define the full scope of the work.

3.8.2 All conversions from pneumatic controls to DDC shall be completed with products and procedures per the University's design standards.

3.8.3 Install operator's terminal, peripherals, graphic software, and LAN before placing any equipment under the control of the new BAS.

3.8.4 Work that requires shutting down a pump motor, fan motor, or chiller shall be considered a utility shutdown and subject to the restrictions specified in the University's electrical design standard.

3.8.5 The following sequence applies to an individually controlled HVAC subsystem, such as an air handling unit. Only one system shall be placed under manual control at any given time. Contractor's responsibilities are listed below:

- 3.8.5.1 Install controllers adjacent to (or within if possible) the existing control panel. Programming shall be completed (except for loading and debugging) before installation. Install all field devices, which do not require interruption of the existing control system.
- 3.8.5.2 Install all conduit, wiring, and pneumatic tubing, which does not require interruption of the existing control system.
- 3.8.5.3 Remove existing controls, including wiring, conduit, and tubing (except materials to be reused per provisions specified elsewhere), which shall be removed to facilitate the installation of new BAS materials and equipment.
- 3.8.5.4 Remove existing digital control system points (if applicable). Install and calibrate the remainder of this subsystem's new BAS materials and equipment. Load controller software. Connect controller(s) to F&S VLAN.

3.8.6 Contractor shall perform all field testing and calibration that do not require the connection of permanent pneumatic outputs.

3.8.7 Contractor shall remove remaining existing pneumatic and digital control system materials and equipment (except materials to be reused per provisions specified elsewhere). All existing digital controls equipment for those subsystems that have not yet been converted shall remain intact, online, and fully functional.

3.8.8 Contractor shall schedule work in university occupied spaces at least ten working days in advance, coordinating with the University's Project Manager and obtaining approval. Scheduling is not required for work in equipment rooms, electrical closets, and similar service areas, unless it involves disruption of services.

3.9 Integrated automation control of laboratory systems

3.9.1 Terminal devices such as supply, general exhaust, and fume hood exhaust air valves (venturi type and/or damper type), shall be one of the following manufacturers: Phoenix, Siemens, EH Price or AccuValve.

3.9.2 All measured and calculated variables shall be available and interfaced through BACnet using controllers from JCI (Metasys), Honeywell (CPO), Siemens (PXC Series), Automated Logic (OptiFelx), or Schneider Electric (EcoStruxure). Jace controllers are not permitted.

3.9.3 All alarming points shall have local and remote alarming capabilities.

3.9.4 Devices controlling the lab operation, such as fume hood controllers, air valves, sensors, control elements, and lab control units (LCUs), shall be fully functional and integrated with their corresponding LCUs, regardless of the communication bus status between the labs.

3.9.5 Actuators shall be electronic and operate at speeds suitable for specific lab operations and infrastructure capabilities.

3.9.6 All devices within the lab, including fume hood controller, air valves, sensors, control elements, and LCUs shall be sourced from a single manufacturer and be compatible with a B-BC controller from JCI (Metasys), Honeywell (CPO), Siemens (PXC Series), Automated Logic (OptiFelx), or Schneider Electric (EcoStruxure).

3.9.7 The lab display unit shall display all parameters specific to the lab.

3.9.8 Lab pressurisation shall be based on the volumetric flow offset.

3.9.9 The following lab BAS architecture shall be used as the framework for the BOD.

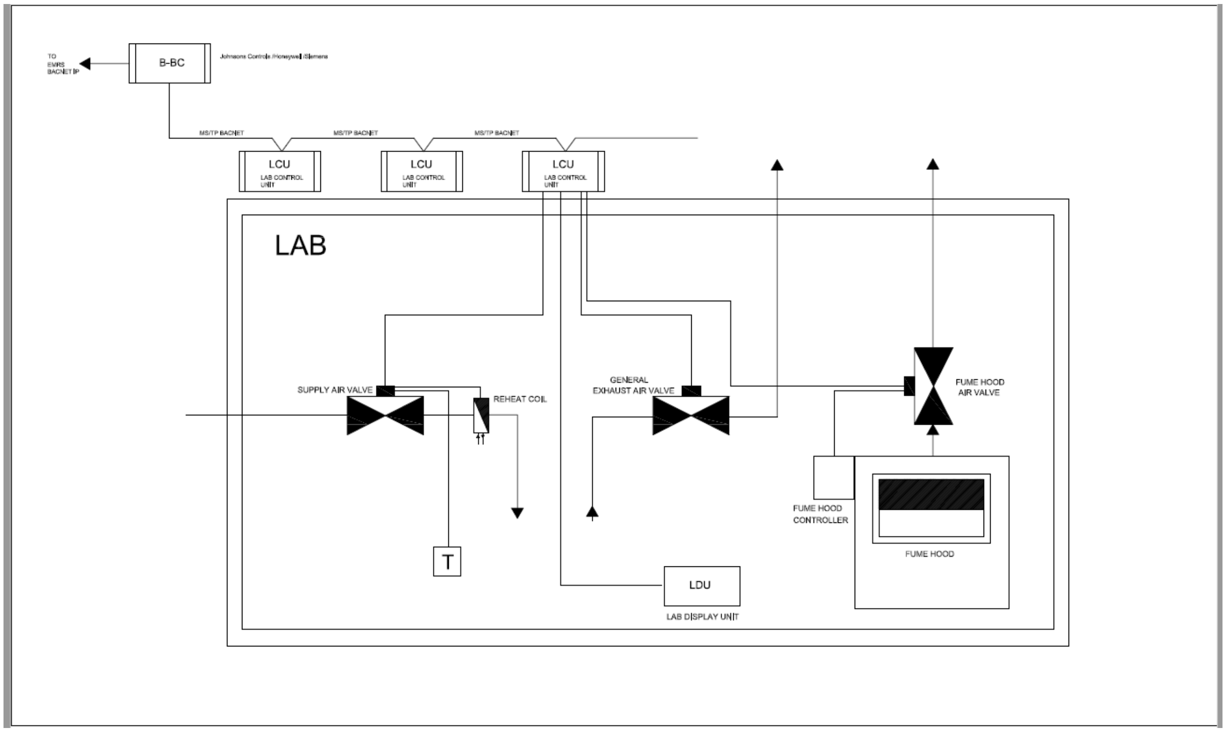


Figure 1 - Sample of lab control BAS architecture

3.10 Control power source and supply

3.10.1 Design Team shall design the extensions of all power source wiring required for the operation of all equipment and devices provided in the BAS project.

3.10.2 Control panels shall be fed from motor control centers panel or power panel, and not be derived from any lighting panel or receptacle panel.

3.10.3 B-BC control panels shall be provided with an external UPS power. The UPS capacity must provide a minimum of two hours of backup power.

3.10.4 Control panels shall be labeled with their respective electrical panel and circuit source.

3.10.5 When a device controls multiple pieces of equipment fed from different sources, the control load shall be powered from an emergency supply via a UPS.

3.10.6 All mechanical control loads shall be fed from the same source of supply as the equipment it is controlling. Where equipment is powered from a 600V source, power shall be obtained from the nearest 120V source available from a shared power feed.

3.10.7 Where control equipment is located inside a new equipment enclosure, coordinate with the equipment manufacturer, and feed the controls panel with the same source as the equipment. If the equipment's control transformer is large enough and of the correct voltage to supply the controls, it may be used. If the equipment's control transformer is not large enough or of the correct voltage to supply the controls, provide a separate transformer with the required protection and isolation circuits.

3.10.8 All device power sources and supplies must be labeled with information detailing the source of power, including the location of the breaker and panel from which the power source is fed.

3.11 Password protection

3.11.1 Programming and setup of multiple-level password access protection groups shall be implemented at the smart device, controller, and workstation to ensure appropriate access levels for control, display, and database manipulation capabilities.

3.11.2 All passwords for the BAS, including the manufacturer-level passwords for the systems provided under this project, shall be provided to the F&S IT and F&S ACG by the contractor during the training session Module C.

3.11.3 Passwords shall restrict access to all control units.

3.11.4 Each username shall be assigned to a discrete access level. A minimum of five levels of access shall be supported. Alternately, a comprehensive list of accessibility and functionality items shall be provided, to be enabled or disabled for each user.

3.11.5 A minimum of one username per area shall be supported and programmed as directed by F&S ACG.

3.11.6 User-definable, automatic log-off timers from 1 to 60 minutes shall be provided to prevent Operators , BAS Analysts and Control Technicians from inadvertently leaving interface device software online.

3.12 Password setup

3.12.1 Set up the following password levels to include the specified capabilities:

A. Level 1 (F&S IT, EMRS Administrator, BAS analysts and University's Control Technicians):
   a. Modify graphic software
   b. Manage usernames, passwords, and password levels, including addition, modification, and deletion
   c. Use all unrestricted system capabilities, including all supervisory devices
   d. Configure system software
   e. Modify control unit programs
   f. Any modifications to control units
   g. All Administrator rights

B. Level 2 (University's Control Technicians):
   a. Access to all campus Areas
   b. All unrestricted system capabilities including all supervisory devices

c. Configure system software
d. Modify control unit programs
e. Any modifications to control units programing must be requested in writing through the University's change request process

C. Level 3 (Building Operator Lead Hand):
a. Access only to their assigned Area
b. Override output points
c. Change setpoints
d. Change equipment schedules
e. Acknowledge alarms
f. Unrestricted access for viewing or modifying Building Operators usernames & passwords
g. Exit BAS software to use third party programs

D. Level 4 (Building Operator):
a. Access only to their assigned Area
b. Override output points
c. Change setpoints
d. Change equipment schedules
e. Acknowledge alarms

E. Level 5 (Read Only, Guest):
a. Display all graphic data
b. Trends point data

3.13 Point nomenclature

3.13.1 Point nomenclature shall be consistent and approved by The University's Project Team. Contractor shall adhere to this nomenclature for all points to be interfaced with the GUI. The point name shall uniquely identify the point within the EMRS and describe the point function. The name will include point location, category, equipment type, space type and point type. Sample naming as follows:

BUILDINGNUMBER_SYSTEMNAME_ DEVICENAME_ENGUNITS

For example:

042_AHU1_SASPT1_TTT degC

3.13.2 The University building and point naming convention list

3.13.2.1 See Appendix C – Point naming convention (building numbers, system, and device name list).

3.14 Point override

3.14.1 Each displayed point shall be individually enabled and disabled to allow mouse-driven override of digital points or changing of analog points.

Note: these override points will have a programmable time-out function. Such overrides shall occur in the control unit, as well as the EMRS system. The graphic point override feature shall be subject to password-level protection. The overridden points shall be reported as an alarm and displayed in a coded PINK color. See Appendix A.

3.14.2 The alarm message shall include the operator's user ID. A list of points that are currently in an override state shall be available through menu selection.

3.14.3 All override points shall be limited to a selectable allowable time up to a maximum of 24 hrs. When the overridden point has timed out, the point shall reset back to a default setting and generate an alarm.

3.14.4 Only the BACnet Manual Operator Override function is allowed with the BACnet Priority 8. Any vendor-specific override functionalities that use non BACnet compliant functions are not acceptable.

3.15 Graphic screens

3.15.1 Refer to Appendix A - Diagrams for samples of interactive graphic designs. All graphics will be configured for the EMRS by F&S IT and approved by the U of T Project Team.

3.15.2 The contract document drawings shall be made available to the UofT Project Team. These drawings will be used for developing backgrounds for specified graphic screens.

3.15.3 Each programmed alarm shall appear on at least one graphic screen.

3.15.4 Alarms shall be displayed on the graphic system schematic screen for the system that the alarm is associated with (for example, chiller alarm shall be shown on the graphic cooling system schematic screen).

3.15.5 For all graphic screens, display analog and digital values that are in an 'alarm' condition in red colour. See Appendix A, Figure 4 for alarm symbols.

A. Building floor plans:
   a. Provide a graphic site plan with links to and from each building plan.
   b. Provide the main page graphic that will have links to all other provided graphic pages.
   c. Provide graphic floor plan screens for each floor of the building, including the roof. Indicate the location of all equipment on the floor plan, including equipment that may be displayed on the detailed equipment system graphic pages/screens.
   d. Use a distinct line symbol to demarcate each terminal unit zone boundary. Use distinct colors to demarcate each air handling unit zone. Upon request, mechanical floor plan drawings will be made available to the contractor to determine zone boundaries. Provide a drawing link from each space temperature sensor symbol and equipment symbol shown on the graphic floor plan screens to each corresponding equipment schematic graphic screen.

e. Provide graphic floor plan screens for each mechanical equipment room. Indicate the location of every mechanical equipment on the floor plan. Provide a drawing link from each equipment symbol shown on the graphic plan view screen to each corresponding mechanical system schematic graphic screen.
f. If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views and plan views as necessary to graphically indicate the location of all the larger-scale floor plans. Link graphic building key plan to larger-scale partial floor plans. Provide links from each larger-scale graphic floor plan screen to the building key plan and each of the other graphic floor plan screens.
g. Provide a plan screen that connects to the building key plan and each of the other graphic floor plan screens.

B. System schematic screens:
a. Each controlled HVAC subsystem shall have a system schematic screen displaying all input/output and virtual points in a graphic format at least once.
b. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc., as applicable by projects.
c. Input/output devices shall be shown in their schematically correct locations. Include appropriate engineering units for each displayed point value. English language descriptors shall be included for each point on all graphics; this may be accomplished by using a pop-up window accessed by selecting the displayed point with the mouse. Indicate all adjustable setpoints on the applicable system schematic graphic screen or, if space does not allow, on a supplemental linked-setpoint screen.
d. Link screens for air handlers to the heating and cooling system graphics. If they are not combined onto one screen, link screens for supply and exhaust systems.
e. Provide a graphic screen for each zone. Provide links to graphic system schematic screens of air handling units that serve the corresponding zone.
f. Provide a cooling system graphic screen showing all points associated with the chillers, cooling towers, and pumps. Indicate outside air dry-bulb temperature and calculated wet-bulb temperature. Link screens for chilled water and condenser water systems if they cannot fit one cooling plant graphic screen.
g. Link screens for heating and cooling system graphics to utility history reports showing current and monthly electric uses, demands, peak values, and other pertinent values.
h. For any equipment shown on the screen, a maximum of five variables indicating the status or command of that equipment may be provided. If the number of variables exceeds five, use pop-up windows containing the required variables. Each pop-up window should include a close function.
i. Include a page outlining the sequence of operation for that system.

C. Equipment details screens:
   a. Provide a separate page for each piece of equipment as required.
   b. Each equipment page shall display nameplate details along with all relevant variables.
   c. Pop-ups for higher volume variables can be considered.

D. Equipment summary dashboard:
   a. Provide a tabular page listing all major equipment for the building.
   b. The tabular page shall display the statuses of terminal equipment, such as VAVs, VFDs, split units, radiant panels etc., based on their quantity.
   c. This page(s) should include a list of the equipment using their technical descriptors with colour code statuses (Run/Stop/Alarm)/(ON/OFF/ALARM).
   d. Each equipment entry should have links to their respective detailed system screens.

E. Operational energy efficiency dashboards:
   a. GUI shall identify any special parameters such as energy savings on the equipment with heat recovery components and/or free cooling, waste heat, and pressurization diagrams. Refer to the section 3.15 Graphic screens and Appendices for more details.
   b. The Design Team shall provide drawings indicating BAS dashboards that will display additional information beyond the standard schematic flow diagram, related to energy use and utility consumptions of the buildings/systems.
   c. There shall be one page that presenting the overall scope of the project, illustrating how different systems impact the key performance indicator (KPI) for the energy efficiency dashboard – referred to as the “KPI tree”. This tree shall start with the systems used for KPI creation, followed by a list of specific KPIs (such as chiller efficiency, CHW pump effectiveness, normalized CH use), and the potential steps to be taken if the KPIs are not met (such as review setpoint changes, investigate overrides, etc.)
   d. BAS dashboards shall include related information for operators to execute basic and advanced troubleshooting of the systems.
   e. The baseline or benchmark for the energy use/energy saved and utility consumption/savings shall be based on the energy modeling data, while the actuals shall be either per actual metered value or actual calculated.
      i. This shall be done for general energy loads (lights, plug loads, service/process water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, pumps, on-site energy generation) and systems/equipment (such as chillers, pumps, cooling towers, energy recovery, etc.).
      ii. The dashboards may be project specific, depending on the project they are designed for. An example of how dashboards should display information for each system is presented below:

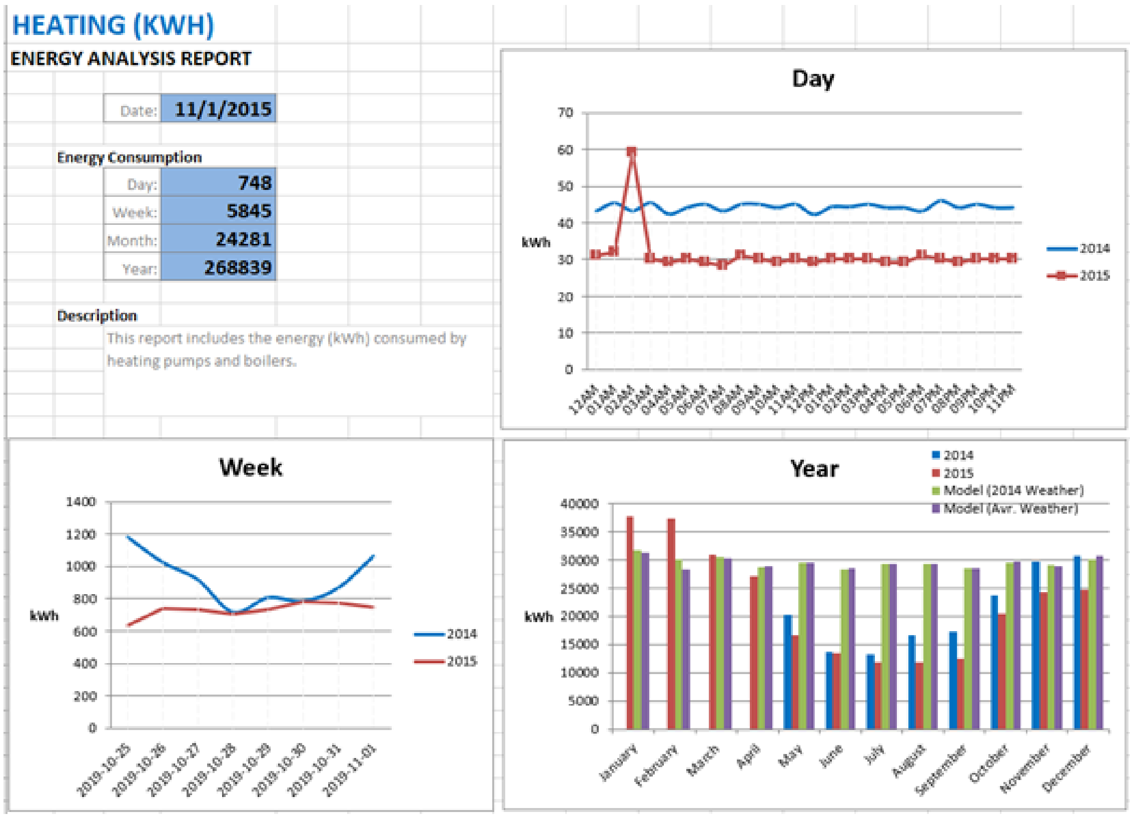


Figure 2 - GUI example for heating system

Note: for heat recovery equipment or similar, the same guidelines above shall apply.

3.16 Dynamic symbols:

3.16.1 Provide a selection of standard symbols that change in appearance based on the value of an associated point. See Appendix A.

A. **Point status color:** graphic presentations shall indicate different colors for different point statuses (i.e., for ALARM and OVERRIDE STATUS: green = Normal, red = Critical Alarm, yellow = Non-Critical Alarm and pink = Operator Override)
B. **Analog symbol:** provide a symbol that represents the value of an analog point as an engineering unit and linear bar graph.
C. **Digital symbol:** provide symbols such as switches, pilot lights, rotating fan wheels, etc., to represent the value of digital input and output points.

3.17 EMRS integration with non-BACnet compliant components

3.17.1 Purpose and definitions: to describe the functional requirements for the BACnet protocol data acquisition (DAQ) and data sharing between the EMRS, BAS Direct Digital Controllers (B-BC, B-AAC), and the embedded non-compliant BACnet controls components. These may include equipment such as variable refrigerant flow (VRF) devices, chillers, boilers, humidifiers, variable speed drives, meters interfaces, lighting controls, weather stations, flow stations, gas monitors, fume hoods and lab controls, etc.

3.17.1.1 In this standard, a BACnet compliance component is a BACnet device that has the following minimum requirements:

A. Ability to modify BACnet object names to comply with this standard and its naming conventions.
B. Ability to support BACnet intrinsic alarming.
C. Ability to support the BACnet notification classes with the read and write ability to modify the ranges for urgent, high, and low priorities.
D. Ability to support the BACnet share functions with reading and writing capabilities as a minimum.

3.17.1.2 Devices that do not possess all the above capabilities are categorized as non-BACnet compliant components.

3.17.2 Implementation

3.17.2.1 Direct integration between EMRS and embedded non-compliant BACnet controls components is not allowed.

3.17.2.2 For such devices the standard implementation requires one of the approved BAS Controls vendors (Siemens, Honeywell, Johnson Controls, Automated Logic, or Schneider Electric) to implement the solution where the integration with the embedded non-compliant BACnet component is done directly through a BACnet compliant B-BC/B-AAC.

3.17.2.3 All the BACnet object mapping, BACnet alarm management, and BACnet DAQ algorithms are solely created within the vendor’s approved B-BC or B-AAC controllers.

3.17.2.4 It is the responsibility of the BAS vendor to identify the devices and compliance level of the embedded non-compliant BACnet controls components. The interface shall be identified in the network architecture and approved by F&S IT and F&S ACG.

3.17.2.5 The non-compliant BACnet controls component serving critical mechanical system(s) shall implement the fully functional and alarmed Device Status heartbeat and watchdog algorithm. This will allow monitoring of the status of the non-compliant BACnet controls component. The fully functional and alarmed Device Status heartbeat and watchdog algorithm shall be implemented for the critical BAS applications like chillers, fume hoods, critical labs, and refrigerant alarming systems.

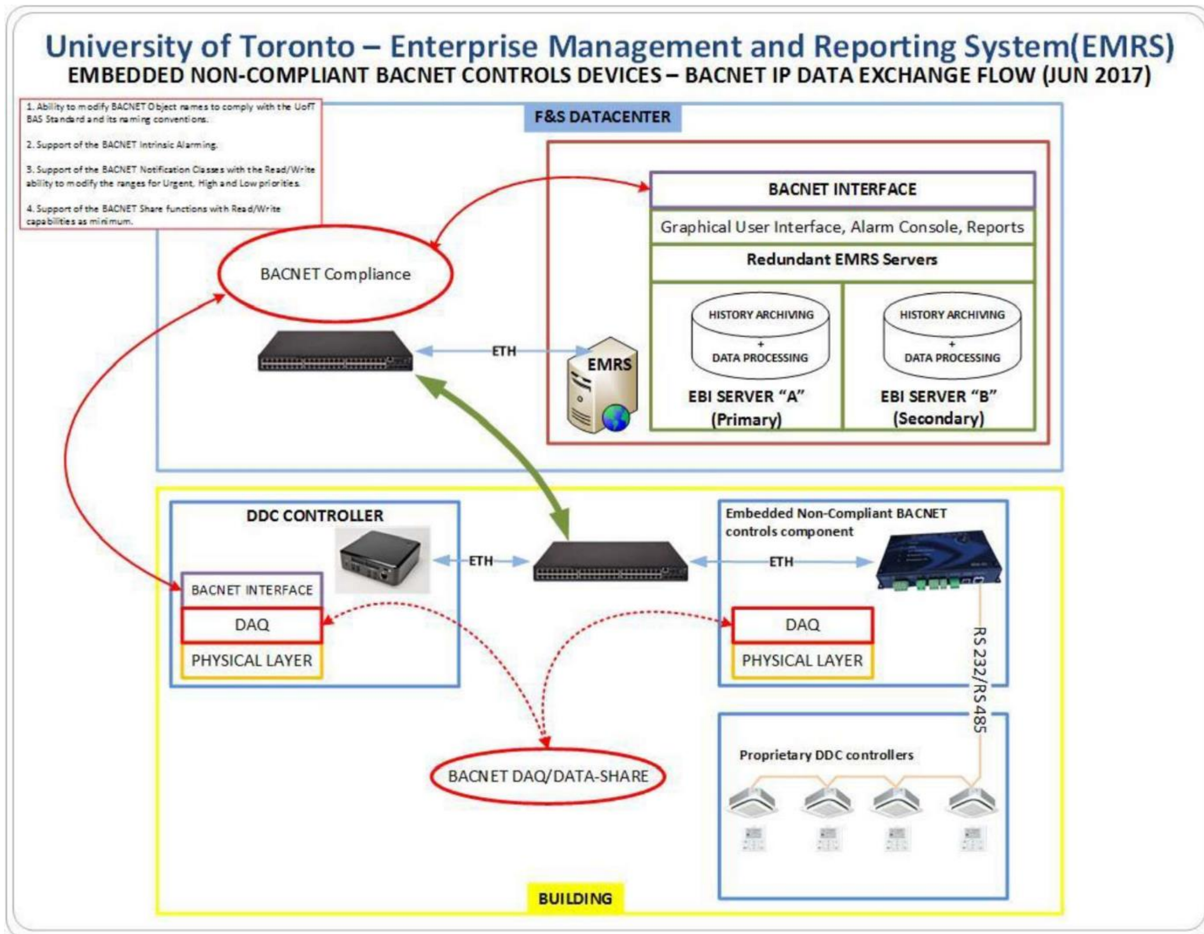


Figure 3 - Integration diagram

3.18 EMRS integration commissioning process

3.18.1 The commissioning process for EMRS integration is intended to direct the commissioning activity for integrating a building level BAS to the EMRS for all new, expanded, or renovated systems. The following is a guideline to establish the stages of the EMRS integration process and prerequisites to ensure the following requirements.

3.18.2 During the project's ready-for-takeover phase, the University's Project Team shall operate and monitor the interfaced equipment through the temporary standalone BAS workstation, which has the capabilities to provide remote alarm notifications. Refer to section 1.5.3 Temporary workstation.

3.18.3 Upon the project completion, the University's Project Team shall have the ability to operate and monitor interfaced BAS equipment remotely.

3.18.4 The process is described in stages and define required deliverables and responsibilities throughout the project development and implementation.

3.18.5 To ensure a smooth transition between project stages, each stage's deliverables should be submitted and accepted before entering the next stage.

3.18.6 The CxA is responsible for the coordination between all stakeholders to develop the Cx schedule that will incorporate following milestones and establish timelines as agreed by all stakeholders.

3.18.7 Design/pre-tender stage:

F&S IT/F&S ACG shall provide the Cx team with estimates of time and cost to execute the integration of the BAS systems to the EMRS. The estimate is intended to provide the Cx team with approximate timelines required for F&S IT to complete various tasks regarding EMRS integration.

3.18.8 Construction stage

A. The Contractor shall provide the BAS shop drawings to the Design Team and CxA for review.
B. BAS shop drawings must be reviewed by both the Design Team and CxA.
C. Refer to the U of T's Deliverable Standard for shop drawings review.
D. The University's Project Manager may arrange a shop drawing review meeting with members of the Project Team to expedite responses.
E. The CxA shall review the documents from the commission ability standpoint and verify that it is in line with this standard. Their review should clearly state that the shop drawings have all required information for commissioning of the BAS including testing all sequences of operation.
F. The CxA shall submit their comments in editable document to the Design Team.
G. The Design Team shall respond to all the CxA comments in the editable document. This document shall be provided to the University's Project Team with reviewed shop drawings for their record.
H. The CxA shall provide functional performance test scripts/BAS acceptance procedures to the Cx Team for review through an updated Cx Plan.
I. The CxA shall conduct regular site inspections to review the installation of BAS devices and equipment from functionality, operational and maintainability perspectives, and document any concerns in the issues log.

3.18.9 Commissioning

The Design Team should ensure that the following requirements are included in the commissioning specifications. The CxA shall:

A. Perform all functional performance tests as per Cx Plan and report any discrepancies or issues through an issues log, including details of concerns, corrective measures, and responsibilities. Submit the issues log to the University's Project Team.
B. Ensure that all field devices, including sensors and final control elements are installed as per approved schematic flow diagrams. Any discrepancies shall be marked up and submitted as part of the Field Cx documentation. Ensure that

changes are accepted by the Design Team and reflected in the as-built documentation.

C. Ensure all controllers, such as B-BC, B-ASC, B-AAC are installed, powered up and commissioned as per the approved BAS shop drawings. Any discrepancies shall be marked up and submitted as part of the field Cx documentation.

D. Verify and document all individual wiring connections between the end devices and the BAS controller, identifying terminal numbers.

E. Verify and document the operation and capacity of all UPS.

F. Verify and document individual IP address and BACnet instance numbers for existence and accuracy, tabulating them and obtaining individual sign-offs from the Contractor for each controller.

G. Ensure all required physical networking comply with sections 3.18.10 EMRS BACnet compliance testing stage and 3.19.3 Wiring installation qualification document of this standard. Review and verify all networking cable checklists and fluke test reports submitted by the contractor. Any discrepancies shall be marked up and submitted as part of the field Cx documentation.

H. Ensure all graphical representations of systems are provided on the temporary vendor specific standalone BAS Workstation with the contractor's temporary installed GUI in the building. Confirm that all required alarms, trends, monitoring, and control points (physical and virtual) are provided and verified by the CxA on the GUI provided by the Contractor. Screenshots of the GUI pages shall be included as a part of the field Cx documentation to aid in the development of EMRS graphics.

I. Ensure that the alarms notifications for the critical control objects/points are sent from the temporary BAS workstation to a list of the alarm recipients. The BAS vendor shall supply own dedicated temporary communication gateway and a modem device for the internet connectivity along with the SMTP service that is properly and securely configured and functional.

J. Ensure that all the BACnet Analog Inputs and Outputs have properly configured Change of Value (COV) properties as defined in this standard.

K. Ensure all systems functional test forms after completion are submitted as part of the field Cx documentation.

L. Field Cx documentation package shall include, at minimum:
   a. A table identifying "Detailed Design Requirement" and corresponding "As-built" found in the field, signed off by the CxA.
   b. Verification and signing-off of all (100%) system functionalities.
   c. Calibration certificate of end devices requiring calibration that identifies the device.
   d. CTL and the comparison of the CTL to the Process Calibration Tolerance Limits (PCTL) tabulated and signed off by the CxA.
   e. Verification and signing-off of all (100%) functional test forms.
   f. Verification and signing-off of marked up schematic flow diagrams, identifying any accepted changes.
   g. Verification and signing-off of all (100%) controllers commissioning sign-off sheets.

h. Networking cable checklists and fluke test verified and signed off.
i. Screenshots of the GUI pages verified and signed off.
j. Alarms list shall be completed with BACnet notification classes and limits and shall be verified and signed off.

M. Upon receipt of the Field Commissioning documentation, F&S IT will conduct an on-site visit to perform the following tasks:
a. Verification of the installation checklist prior the site visit.
b. Site visit with the visual verification of the installation checklist.
c. Installation qualification of the BACnet compliance of the BAS DDC components. Read/write access, naming convention, alarm notifications.

N. The CxA shall coordinate with the contractor for the training of Building Engineers and Control and Automation staff. The training shall align with the requirements outlined in section 3.18.13 Training. It is mandatory to deliver training modules, A, B and C on a functional system prior to the project reaches the mechanical building systems handover.

3.18.10 EMRS BACnet compliance testing stage

A. This phase can be initiated only after field commissioning documentation is submitted and F&S IT has completed their verifications.
B. Ensure that the EMRS BACnet Compliance Test Readiness Form is submitted based on the following template: https://www.fs.utoronto.ca/wp-content/uploads/2025/08/3.18.10-EMRS-BACnet-Compliance-Test-Readiness-Form.docx
C. Partial submissions and/or incomplete documentation sets are not acceptable. The intent is to reduce the modification of tag references for points populated on the EMRS in the following phase.
D. This phase includes multiple testing procedures performed by F&S to ensure that the physical installation and the DDC software configuration complies with the University's BAS standard.
E. This phase includes the EMRS database design to create the real-time data acquisition. This phase includes the following:
a. Auto-discovery of all the BACnet objects between the DDC field controllers and EMRS. This will create the actual licensing cost model that is mentioned in the Design/pre-tender stage, section 3.18.7 of this document.
b. Verification of the naming convention and BACnet compliance.
c. Download all compliant BACnet objects to the online database and the initial start of the historical data collection and the ability of EMRS to send out the alarm notifications to the existing list of recipients.
F. Upon completion of this phase, a fully programmed EMRS for real-time data acquisition will be established. The EMRS operators will have the capability to collect historical data for trending and receive alarm notifications.

3.18.11 EMRS graphical user interface programming stage

A. This phase includes the programming of the EMRS graphical user interface with dynamic data.
B. Subsequently, the operators and the CxA can use the developed programmed set of the EMRS GUI.
C. Upon completion of EMRS GUI, CxA will complete necessary GUI functional verifications on the EMRS and provide review report to the University's Project Team. These verifications shall include, at minimum:
   a. Ensure all graphic pages on the vendor's temporary GUI have been replicated on the EMRS.
   b. Ensure that all commands required for operator are accessible to execute necessary operations according to the documented sequence of operations.
   c. Ensure all alarms have been setup on the EMRS with required limits (training will be provided if required by F&S IT).
   d. Ensure that all standard trends are set up and accessible for operators.
   e. Ensure that the updated sequence of operation is accessible on the EMRS.
   f. Verify the units for each displayed parameter.

D. CxA shall document their verifications and update the issues log as necessary.
E. CxA shall collect the required information to develop a Systems Manual for the University's Project Team's review.
F. The contractor's temporary GUI database backup shall be provided to the University's Project Team and related hardware will be decommissioned from the network.

3.18.12 Final tune up stage

A. Upon completion and availability of the final set of the as-built drawings, final tuning of the EMRS GUI can commence by F&S IT.
B. Updated as-built drawings due to final tune-up shall be submitted by the Contractor to CxA and Design Team for review.
C. The final Operation and Maintenance Manual shall be developed in accordance with section 1.6.13 of this standard.
D. CxA will provide an assimilated Cx report, which includes all field Cx documentation and certificate of completion and handover as per building commissioning standard.

3.18.13 Training

3.18.13.1 A qualified instructor (or instructors) shall have a minimum of five years of field experience in installing and programming the project's BAS DDC systems and shall be factory-trained and experienced in presenting this material.

3.18.13.2 Contractor shall provide a course outline and training manual for each training session at least six weeks before the first training session. Engineer and CxA will modify course outlines and manuals if necessary to meet F&S's needs. The Design Team will review and approve course outlines and training manuals at least three weeks before the first training session. Training sessions shall cover the complete operation of the equipment using the building automation system, and the software procedures to allow the F&S ACG to add and modify points, DDC loops, or energy management programs.

3.18.13.3 Contractor shall account for a minimum of six on-site and classroom training sessions. These sessions shall occur on four different days, throughout the contract period, and be conducted for the University's designated personnel. Additionally, the contractor shall provide two additional training sessions at the 6th and 12th month following the building's turnover. Each training session shall not exceed three hours.

3.18.13.4 The training shall be conducted in the building and video recorded on digital media with the time stamps of each section.

3.18.13.5 During each training session, CxA shall take formal minutes, including attendees and discussed subjects. No informal discussions or troubleshooting will be counted against training time.

3.18.13.6 Classroom training shall be conducted using working controllers representative of the installed hardware.

3.18.13.7 This section describes the structure of the training requirements for the University's operations staff. It consists of four modules to be conducted at two stages of the EMRS integration process. The training plan structure below shall be followed, and training dates shall be included in Cx schedule.

A. Stage 1, which includes Modules A, B, and C, is a prerequisite for occupancy and/or the mechanical building systems handover.
B. Stage 2, which include Modules D, can be conducted after the EMRS GUI programming stage.

3.18.13.8 Training plan

Module A: Operation training part I
Attendees: Building Engineers, Building Shift Engineers, BAS Analysts, Control technicians Trainer: BAS vendor's specialist Witness: Commissioning Agent
A. Review the as-built control drawings to understand the system drawings and proficiently operate the system with the provided BAS. B. Review the list of control system components to understand the installed DDC system, the layout, location, and accessibility of BAS components (controllers, sensors, gateways, and switches). C. Conduct a walk-through of the mechanical system and installed DDC components (panels, controllers, valves, dampers, sensors, etc.). D. Review the list of points and objects and their abilities to operate the system in the intended sequence of operation. E. Review the device and Network Communication Architecture to understand potential failures in operations attributed to the failure of the communication network.

F. Discuss the components and functions at each DDC panel. G. Demonstrate the operational use of portable operator's terminal (wherever applicable) and hand over licensed devices as per contract to Automation and Control Representative of UofT.

Module B: Operation training part II (via temporary workstation)
Attendees: Building Engineers, Building Shift Engineers, BAS Analysts, Control Technicians Trainer: BAS vendor's specialist Witness: Commissioning Agent
A. Create required Logins as required by Area Manager/Lead hands and/or Control Technicians. B. Review the sequence of operations, control functions and alarm functions. C. Review logging in and navigating the system graphics. D. Review methodology to adjust and change system setpoints, time schedules, and holiday schedules to ensure system runs as per the sequence of operations in Auto. E. Recognize malfunctions of the system by observing the printed copies and graphics visual signals. F. Address event management and scheduling. G. Discuss override control devices capabilities. Review points that should not be overridden H. Review alarm capabilities and acknowledge protocols. I. Troubleshooting strategies. J. Trends setup.

Module C: Servicing and programming DDC training
Attendees: Control Technicians Trainer: BAS vendor's specialist Witness: Commissioning Agent
A. Review the as-built control drawings to understand the system drawings and various DDC components, and the abilities and limitations of BAS equipment. B. Review the device and network communication architecture to understand potential operational failures attributed to communication network issues. C. Review of application programs for B-ASC controllers, including sequences, available points, download strategies, and modifications to vendor specific applications. D. Review the sequence of operations and its programming as it pertains to the methodology used to program controllers for equipment operation. E. Modify and download control program changes procedures. F. Create, edit, and view alarms (for Newer Applications). G. Backup and restore programming and database modifications.

H. Add, replace, and remove network devices. (for Newer systems)
I. Diagnose malfunctions and perform maintenance on the BAS and its devices.
J. Review potential hardware troubleshooting errors.
K. Custom application programming software.
L. Custom reporting (if applicable).
M. Perform DDC system field checkout procedures. (Carry out systems check)
N. Perform DDC controller unit operation and maintenance procedures.
O. Create and change graphics on the temporary workstation.
P. Maintain software and device firmware.
Q. Interface with job specific, third-party operator software.
R. Establish user access credentials as per standard. Section 3.12
S. Perform database backups.
T. Hand over software licenses to U of T (F&S ACG).

3.19 Building automation wiring requirements

3.19.1 Building automation - low voltage cables

A. Refer to the University's electrical design standard section 26 05 33.13.
B. Control and interlock wiring and installation shall comply with national and local electrical codes, and manufacturer's recommendations.
C. Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by OESC.
D. Low-voltage wiring shall meet OESC Class 2 requirements. Sub-fuse low-voltage power circuits as required to meet Class 2 current limit.
E. Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed and plenum rated for the intended application.
F. Install wiring in raceway where subject to mechanical damage in mechanical, electrical, or service rooms and shall be threaded galvanized rigid conduit (GRC).
G. Install Class 1 and Class 2 wiring in separate raceways.
H. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.
I. Do not install wiring in raceway containing pneumatic or hydronic tubing.
J. Conduits exposed to the exterior climate/weather shall be rated for UV exposure and be sealed against water ingress. When penetrating buildings, the conduit shall be filled to prevent water ingress.
K. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly and securely at 3 m (10 ft) intervals.
L. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

M. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.
N. Size raceway and select wire size and type in accordance with manufacturer's recommendations and OESC requirements.
O. Include one pull string/fish wire in each raceway 2.5 cm (1 in.) or larger.
P. Use color-coded conductors throughout.
Q. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.
R. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment such as steam pipes or flues.
S. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.
T. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.
U. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.
V. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.
W. All equipment and systems installed shall be grounded, isolated, or conditioned as required to permit equipment to continue to function normally, without interruption, in the event of radio frequency interference (RFI), electromagnetic interference (EMI), power surges/dips or other electrical anomalies.
X. All cables installed in conduit shall be identified with permanent orange markings on the conduit. Cables that are plenum rated not installed in conduits but tray will also be identified with permanent orange markings,
Y. All Junction boxes will also have cover plates painted with permanent orange paint.

3.19.2 Building automation - data cables

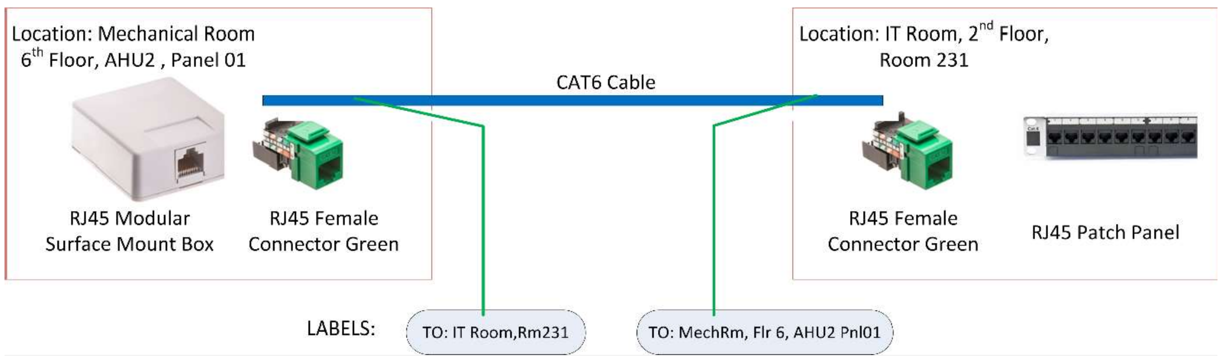
3.19.2.1 This section shall be read in conjunction with the University’s communications infrastructure specifications, standards, and practice. All communication ethernet data cabling for building automation shall follow this standard: Specifications standards Practices 2.6 (utoronto.ca). All Data cables (IP/MS/TP) installed in conduit shall be identified with permanent orange markings on the conduit

3.19.2.2 Contractor shall also follow the requirements below:

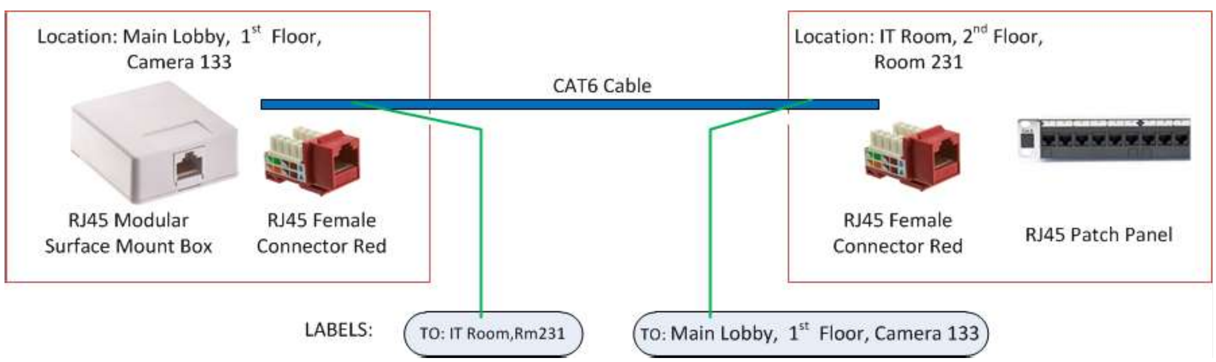
A. The CAT6 cable must be labeled on both ends with the following label syntax: TO [name of the location].

B. The RJ45 connector must be fully compliant with the patch panel. Installer shall use the RJ45 connector that properly fits the patch panel.

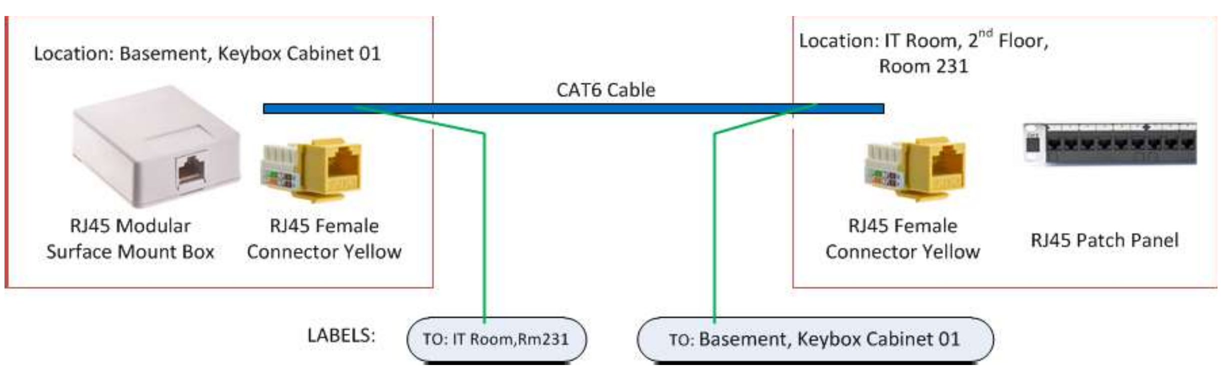
Building automation end devices



Building security end devices-SALTO



Building auxiliary end devices



C. The CAT6 cable must be terminated on both ends with RJ45 female modular connector, as shown in the pictures below.

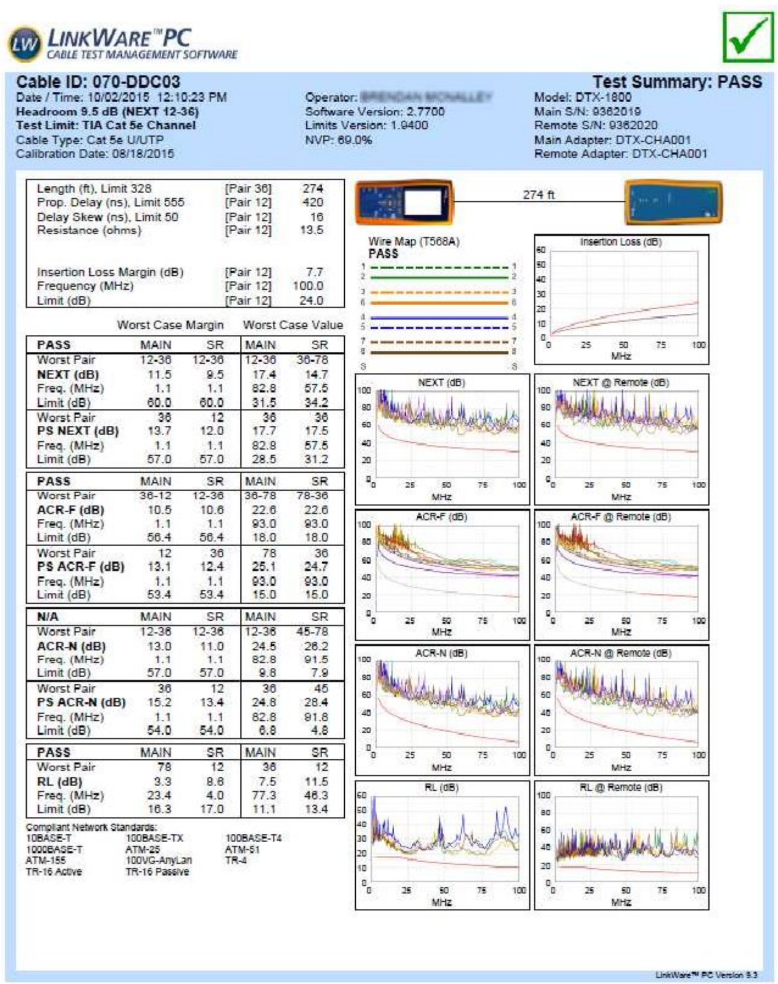
		

D. The Contractor must provide Cat6 cable of minimum 0.91 metre in length to patch between the RJ45 female modular connector and the F&S switch. The contractor shall leave this cable disconnected. F&S IT will use this cable to patch into the F&S switch.

3.19.3 Wiring installation qualification document

It is the responsibility of the submitter that the pictures are in high resolution, properly formatted and fully readable. The form is available in editable format with a sample: https://www.fs.utoronto.ca/wp-content/uploads/2025/08/3.19.3-Wiring-installation-qualification-form.docx

3.19.4 **Fluke reports requirements:** the LINKWARE Fluke report must be provided as per the following template. Cable ID must correspond with the Cable ID record from the installation checklist.



LINKWARE™PC
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: 070-DDC03 — **Test Summary: PASS**

Date / Time: 10/02/2015 12:10:23 PM
Headroom 9.5 dB (NEXT 12-36)
Test Limit: TIA Cat 5e Channel
Cable Type: Cat 5e U/UTP
Calibration Date: 08/18/2015

Operator: [illegible]
Software Version: 2.7700
Limits Version: 1.9400
NVP: 69.0%

Model: DTX-1800
Main S/N: 9362019
Remote S/N: 9362020
Main Adapter: DTX-CHA001
Remote Adapter: DTX-CHA001

Length (ft), Limit 328	[Pair 36]	274
Prop. Delay (ns), Limit 555	[Pair 12]	420
Delay Skew (ns), Limit 50	[Pair 12]	16
Resistance (ohms)	[Pair 12]	13.5
Insertion Loss Margin (dB)	[Pair 12]	7.7
Frequency (MHz)	[Pair 12]	100.0
Limit (dB)	[Pair 12]	24.0

	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	12-36	36-78
NEXT (dB)	11.5	9.5	17.4	14.7
Freq. (MHz)	1.1	1.1	82.8	57.5
Limit (dB)	60.0	60.0	31.5	34.2
Worst Pair	36	12	36	36
PS NEXT (dB)	13.7	12.0	17.7	17.5
Freq. (MHz)	1.1	1.1	82.8	57.5
Limit (dB)	57.0	57.0	28.5	31.2
PASS	MAIN	SR	MAIN	SR
Worst Pair	36-12	12-36	36-78	78-36
ACR-F (dB)	10.5	10.6	22.6	22.6
Freq. (MHz)	1.1	1.1	93.0	93.0
Limit (dB)	56.4	56.4	18.0	18.0
Worst Pair	12	36	78	36
PS ACR-F (dB)	13.1	12.4	25.1	24.7
Freq. (MHz)	1.1	1.1	93.0	93.0
Limit (dB)	53.4	53.4	15.0	15.0
N/A	MAIN	SR	MAIN	SR
Worst Pair	12-36	12-36	12-36	45-78
ACR-N (dB)	13.0	11.0	24.5	26.2
Freq. (MHz)	1.1	1.1	82.8	91.5
Limit (dB)	57.0	57.0	9.8	7.9
Worst Pair	36	12	36	45
PS ACR-N (dB)	15.2	13.4	24.8	28.4
Freq. (MHz)	1.1	1.1	82.8	91.8
Limit (dB)	54.0	54.0	6.8	4.8
PASS	MAIN	SR	MAIN	SR
Worst Pair	78	12	36	12
RL (dB)	3.3	8.8	7.5	11.5
Freq. (MHz)	23.4	4.0	77.3	46.3
Limit (dB)	16.3	17.0	11.1	13.4

Compliant Network Standards:
10BASE-T, 100BASE-TX, 100BASE-T4, 1000BASE-T, ATM-25, ATM-51, ATM-155, 100VG-AnyLan, TR-4, TR-16 Active, TR-16 Passive

LinkWare™ PC Version 9.3

Appendices

Appendix A – Diagrams

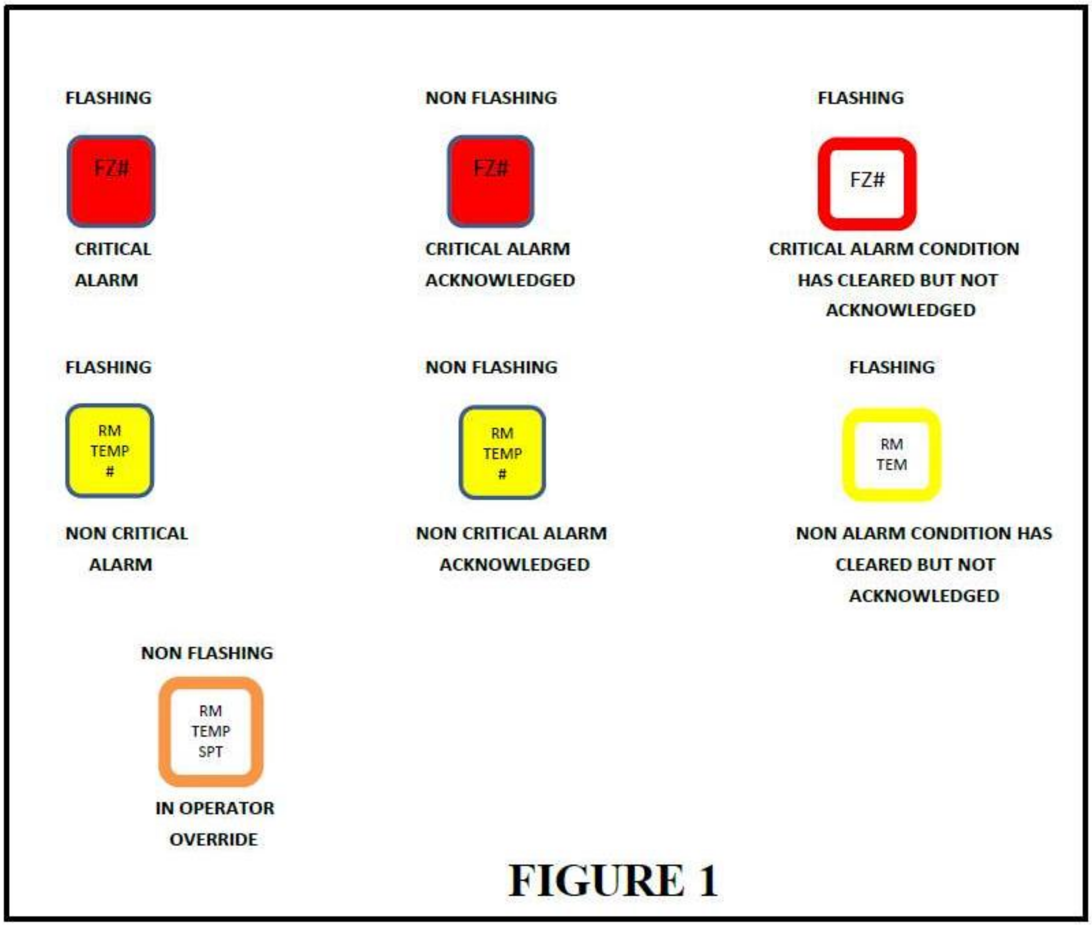


Figure 4 - Typical dynamic symbols for alarming and operator override

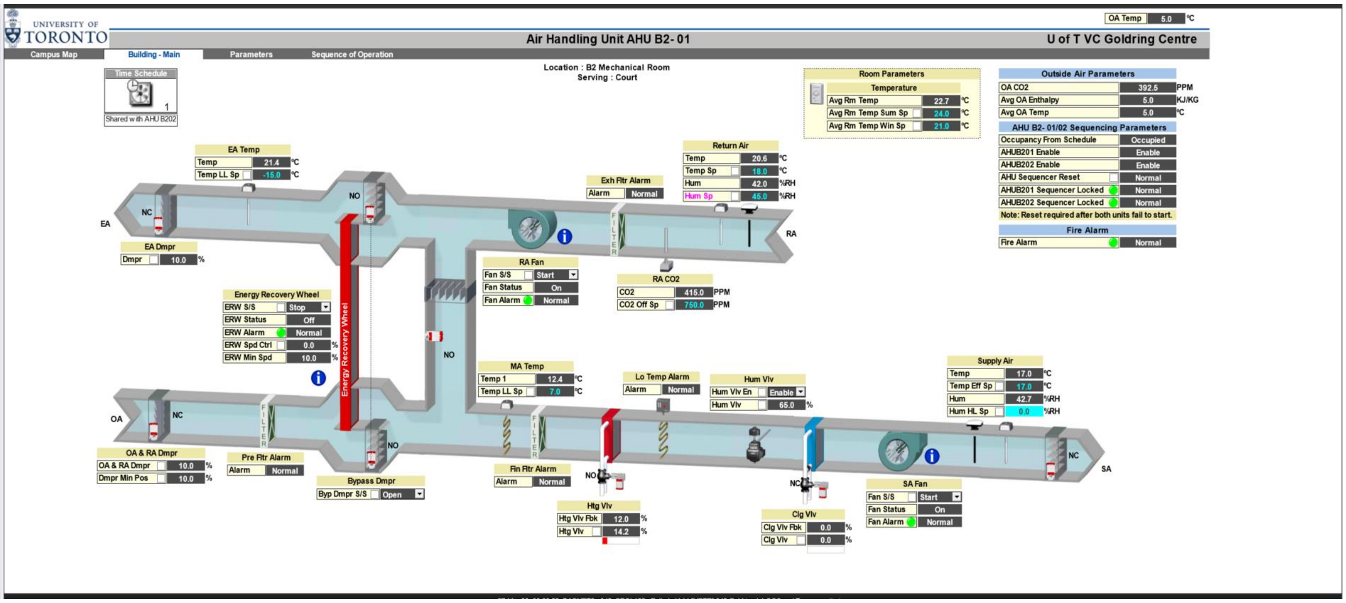


Figure 5 - Sample of AHU system graphic

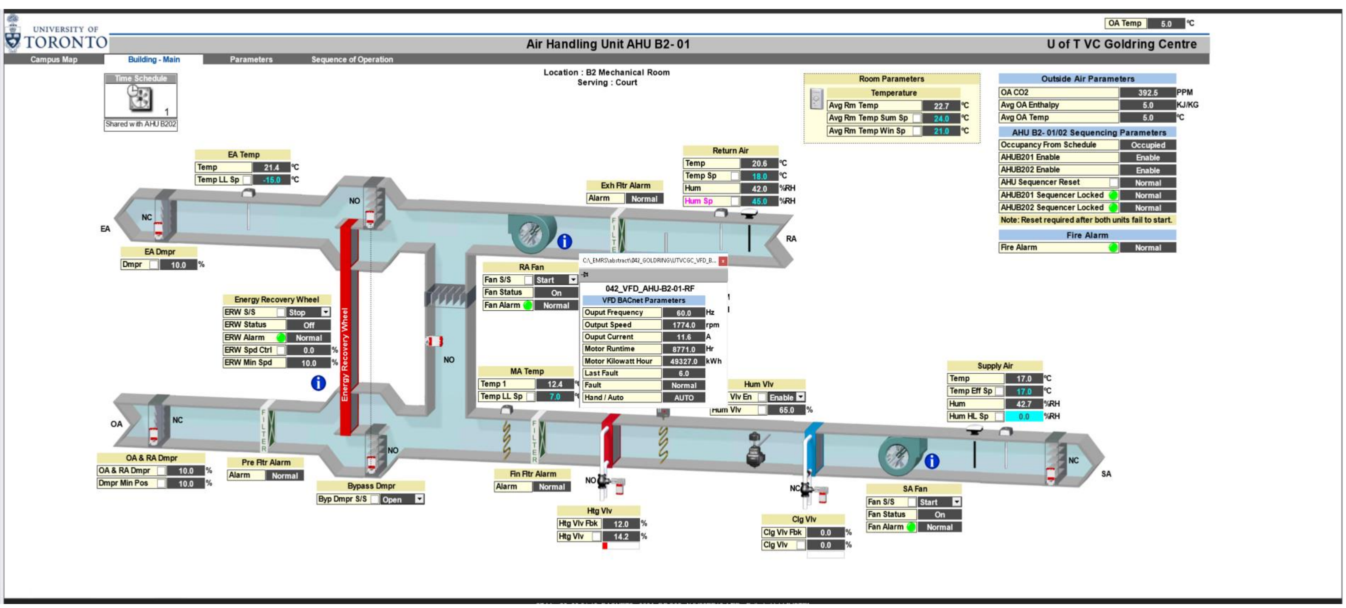


Figure 6 - Sample of AHU system graphic

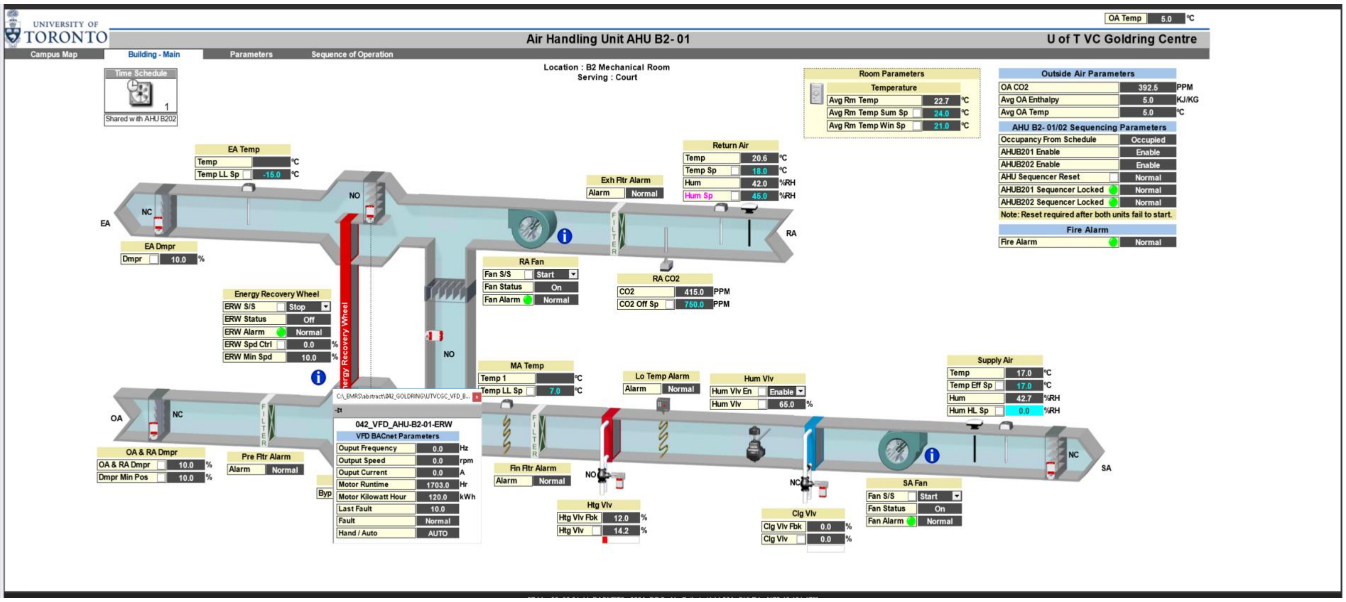


Figure 7 - Sample of AHU system graphic

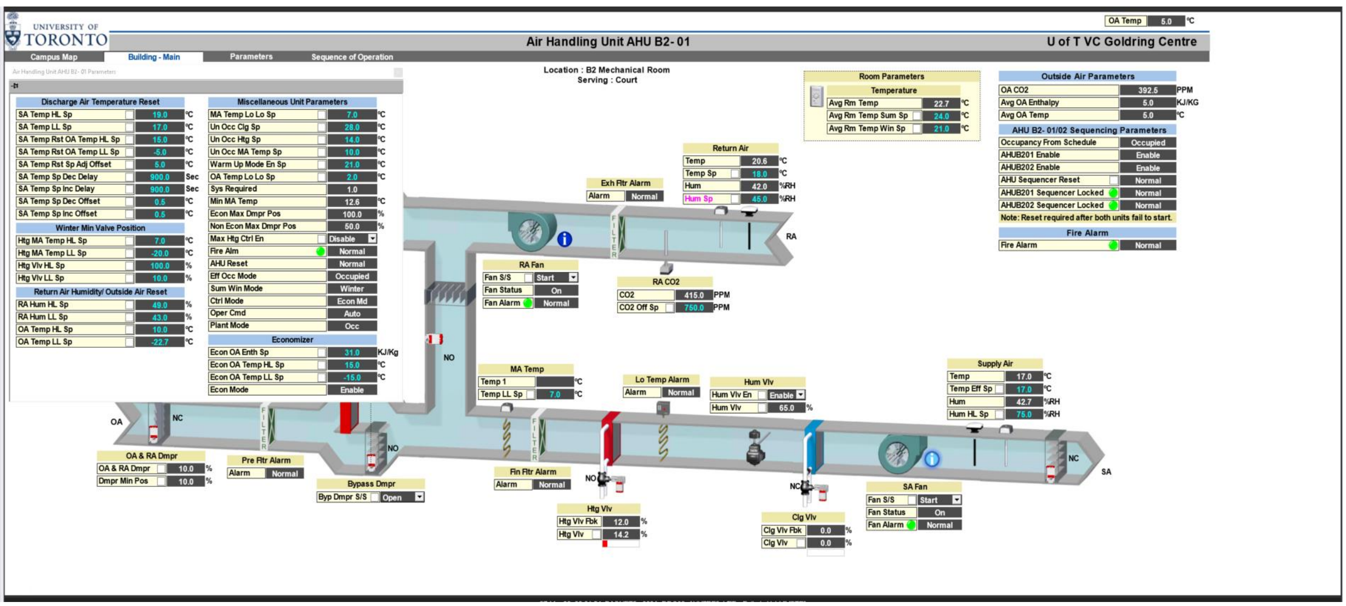


Figure 8 - Sample of AHU system graphic

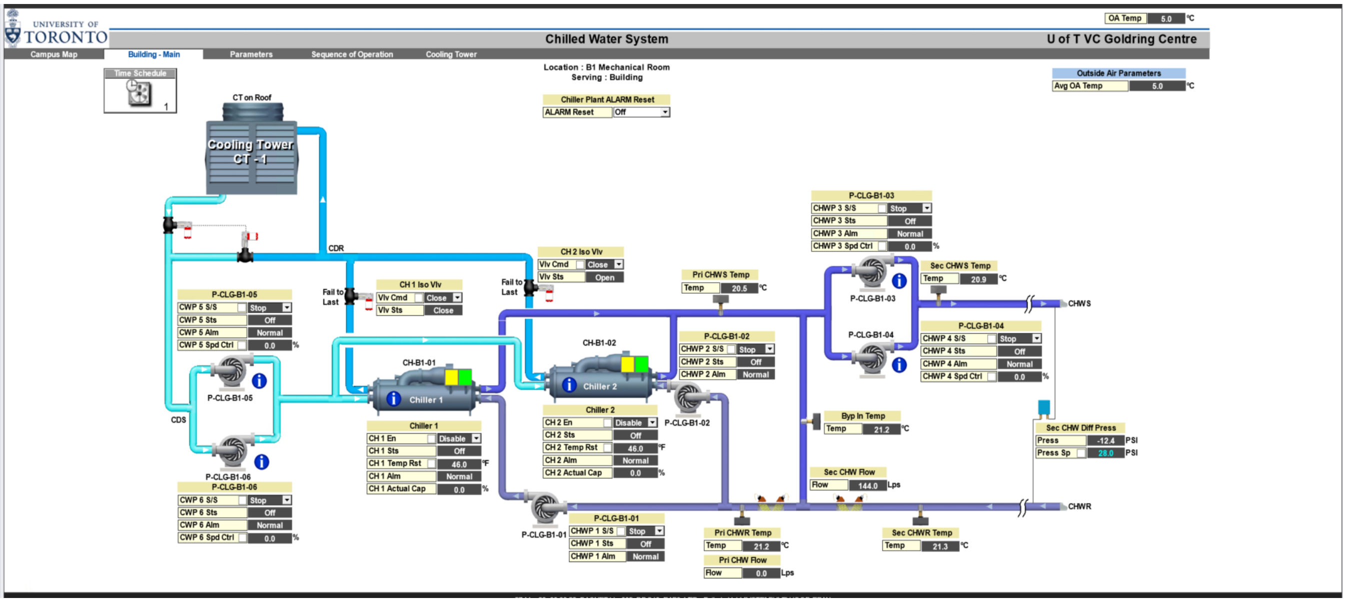


Figure 9 - Sample of chilled water loop system graphic

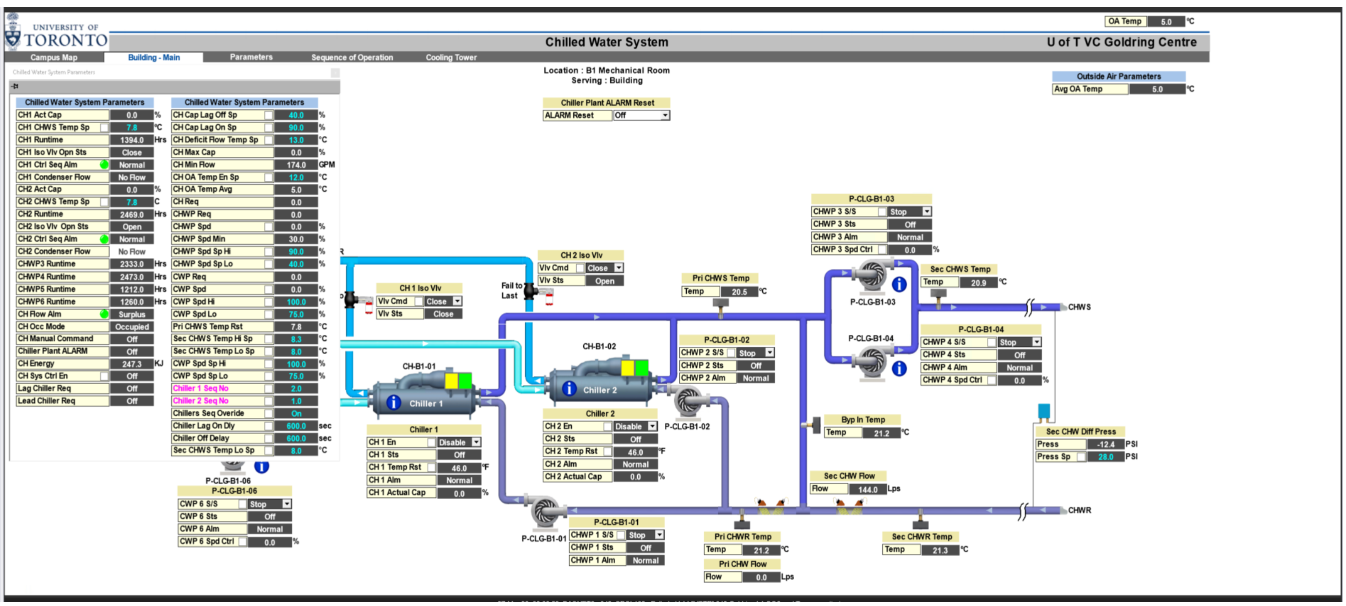


Figure 10 - Sample of chilled water loop system graphic indicating popup for chilled water system parameters

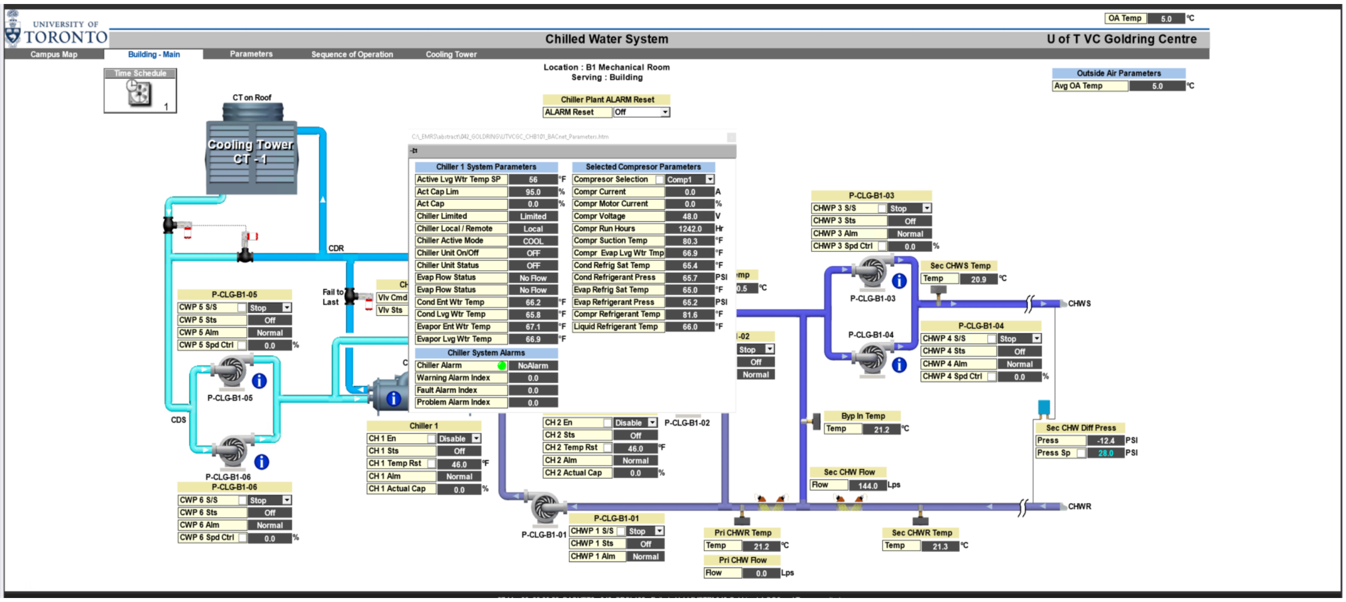


Figure 11 - Sample of chilled water loop system graphic indicating popup for chiller details

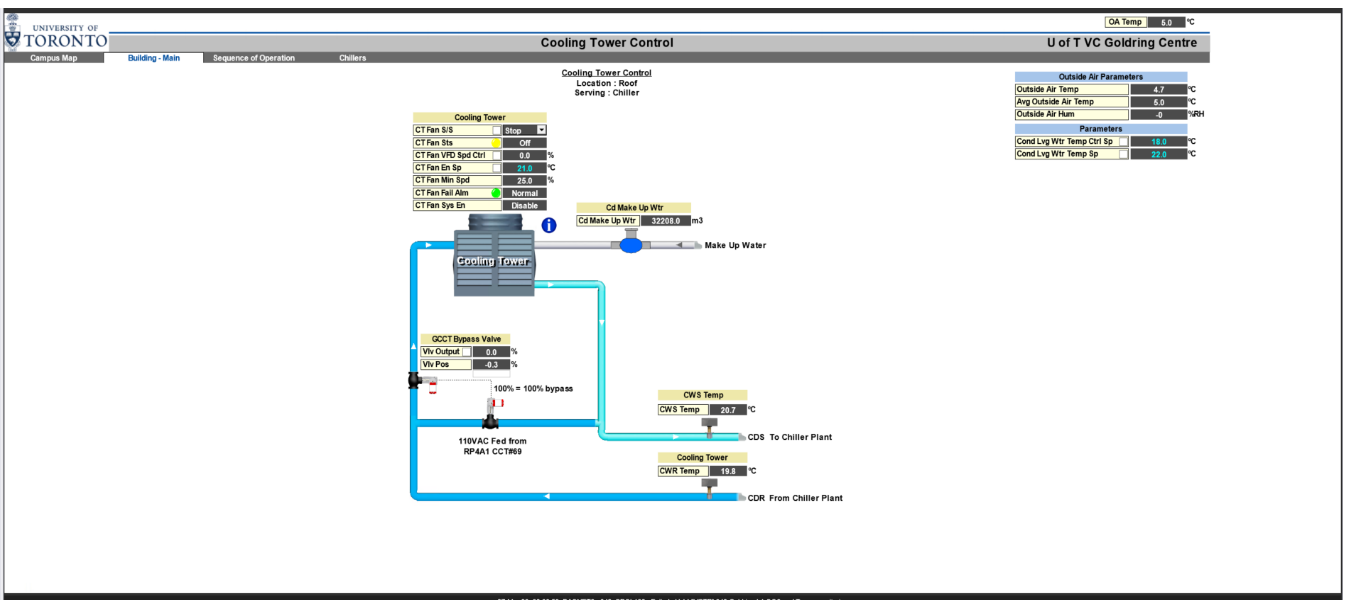


Figure 12 - Sample of detailed schematic with cooling tower

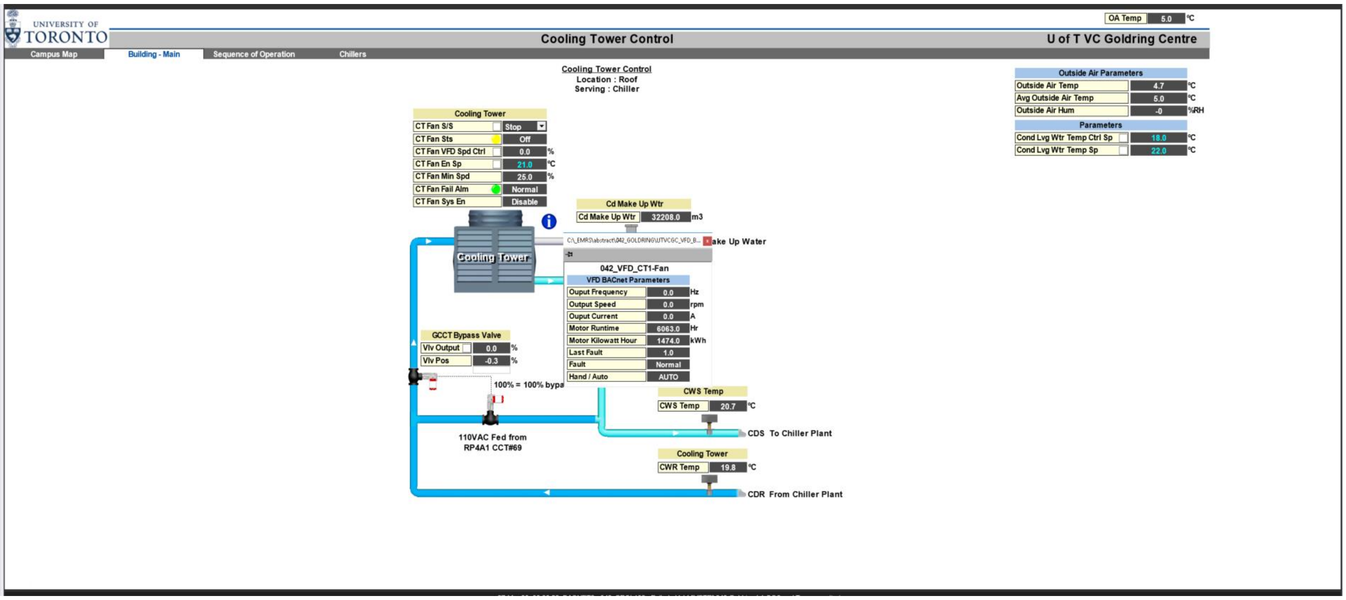


Figure 13 - Sample of detailed schematic with cooling tower

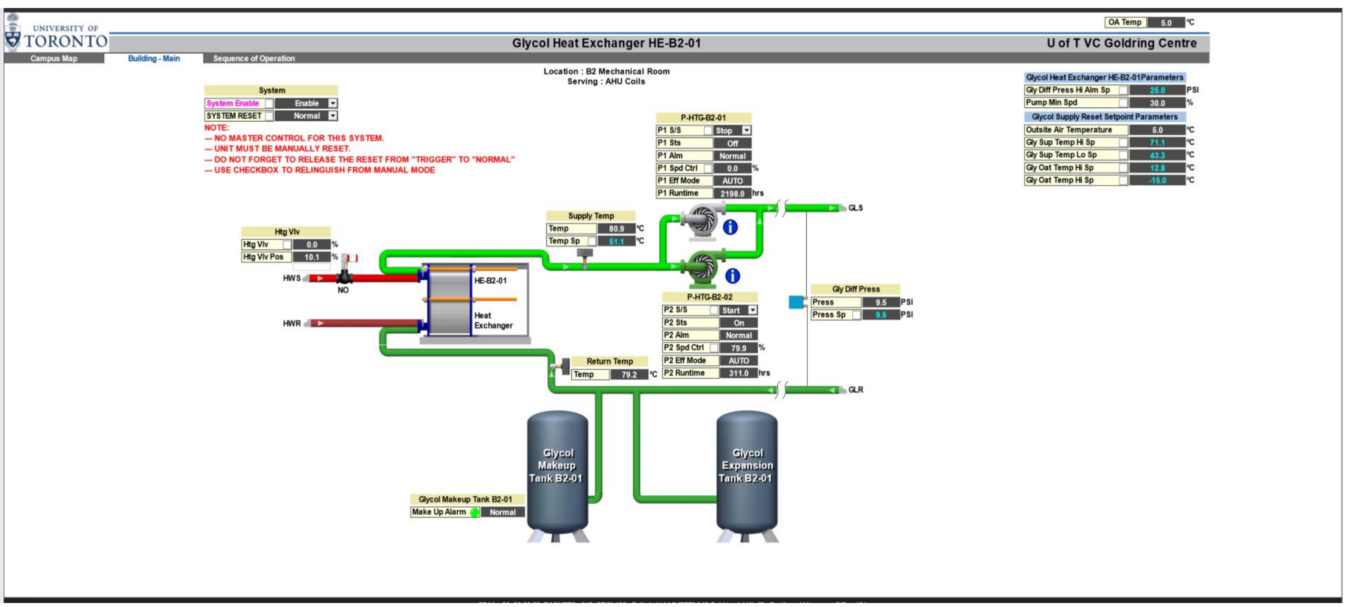


Figure 14 - Sample of glycol heating loop system graphic

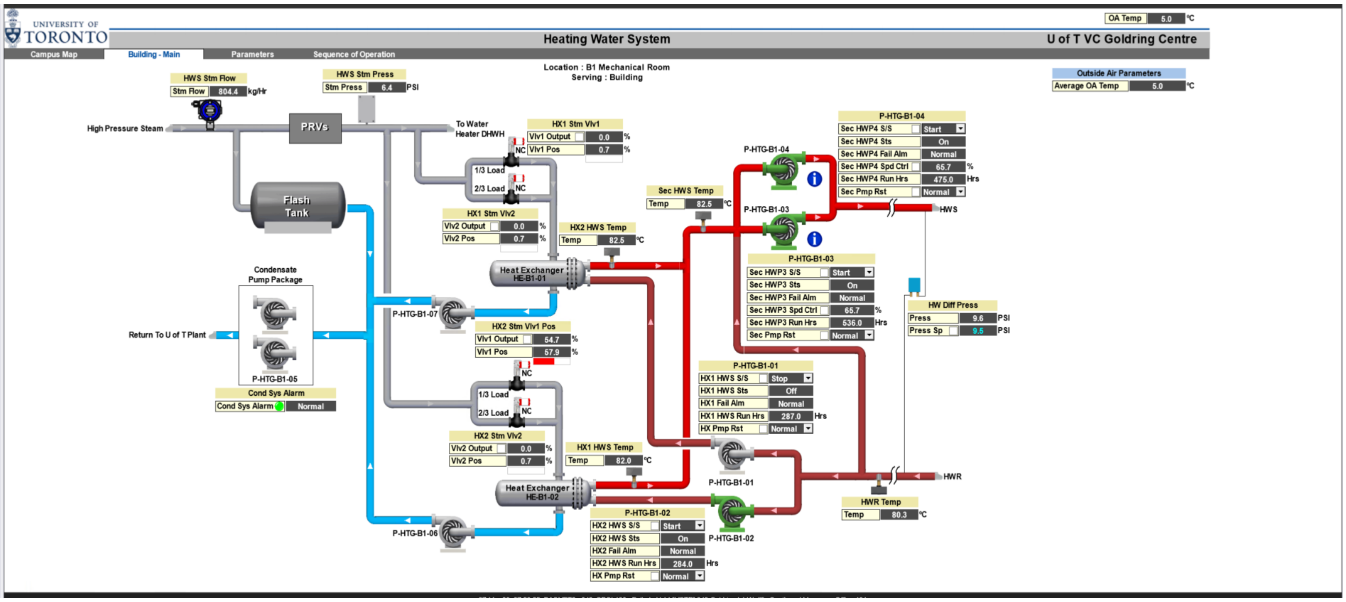


Figure 15 - Sample of heating water system graphic

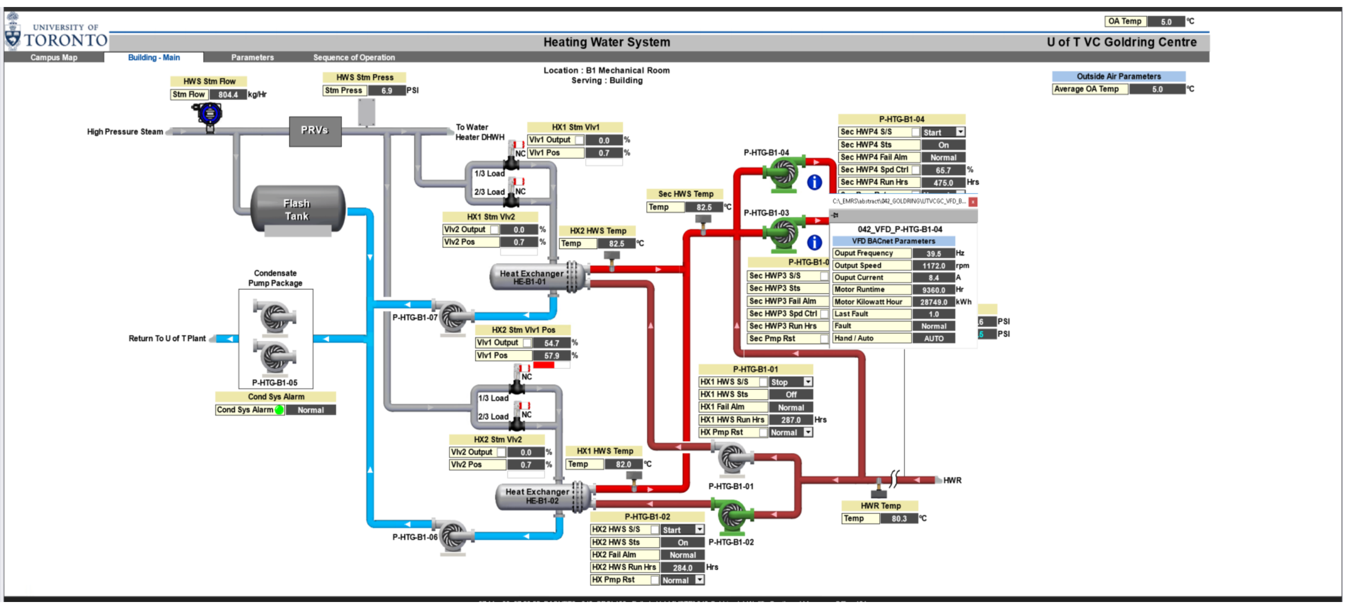


Figure 16 - Sample of heating water system graphic

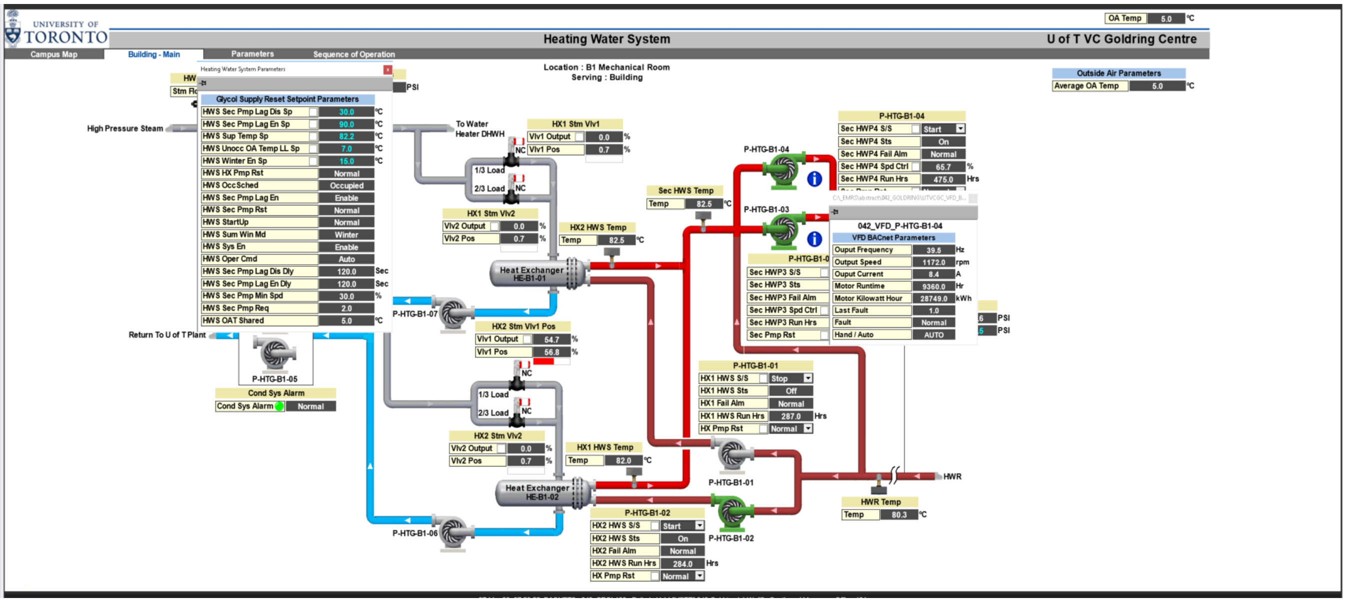


Figure 17 - Sample of heating water system graphic

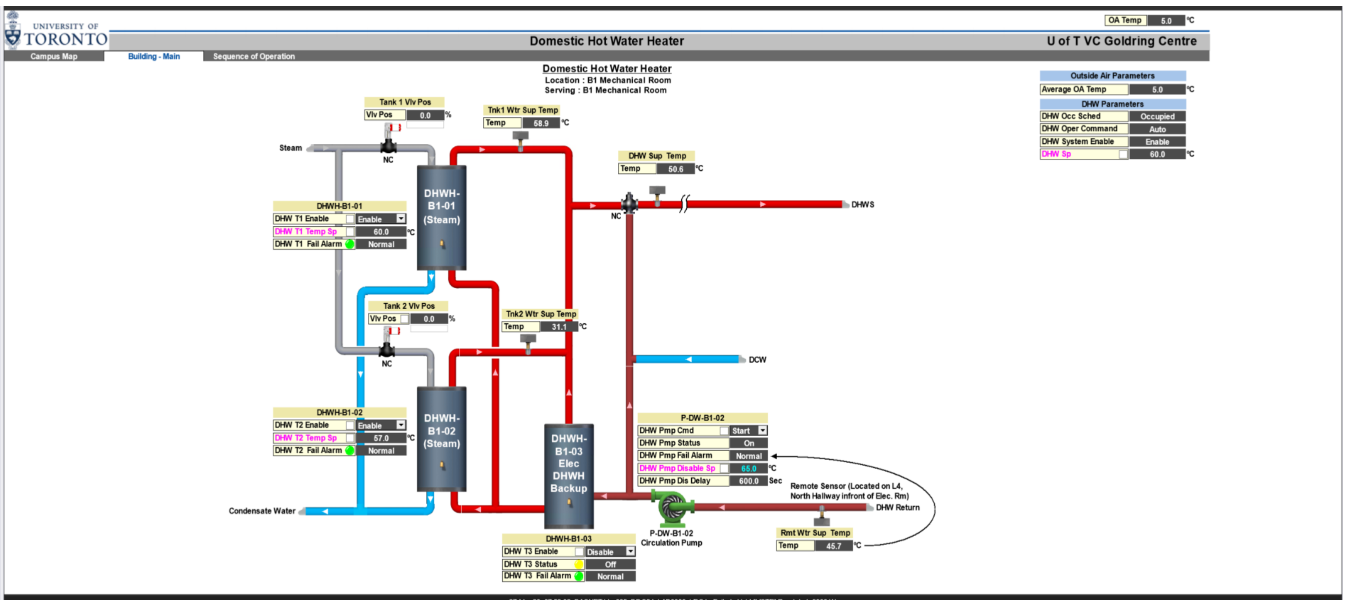


Figure 18 - Sample of heating water system graphic

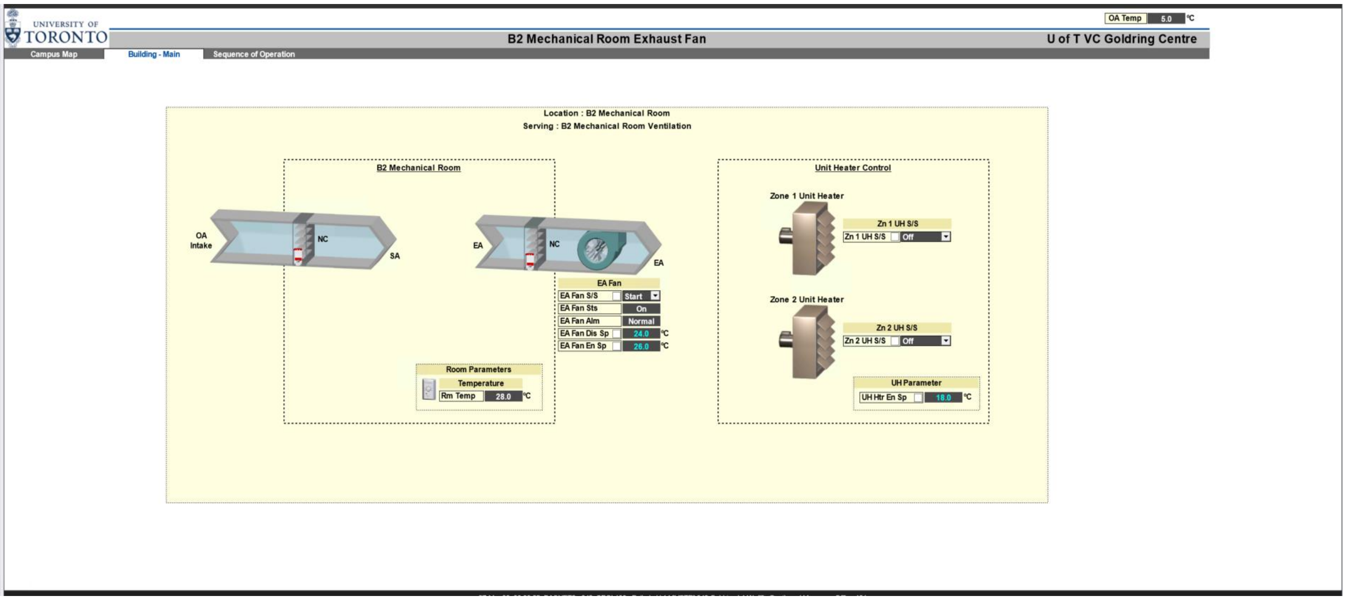


Figure 19 - Sample of exhaust fans

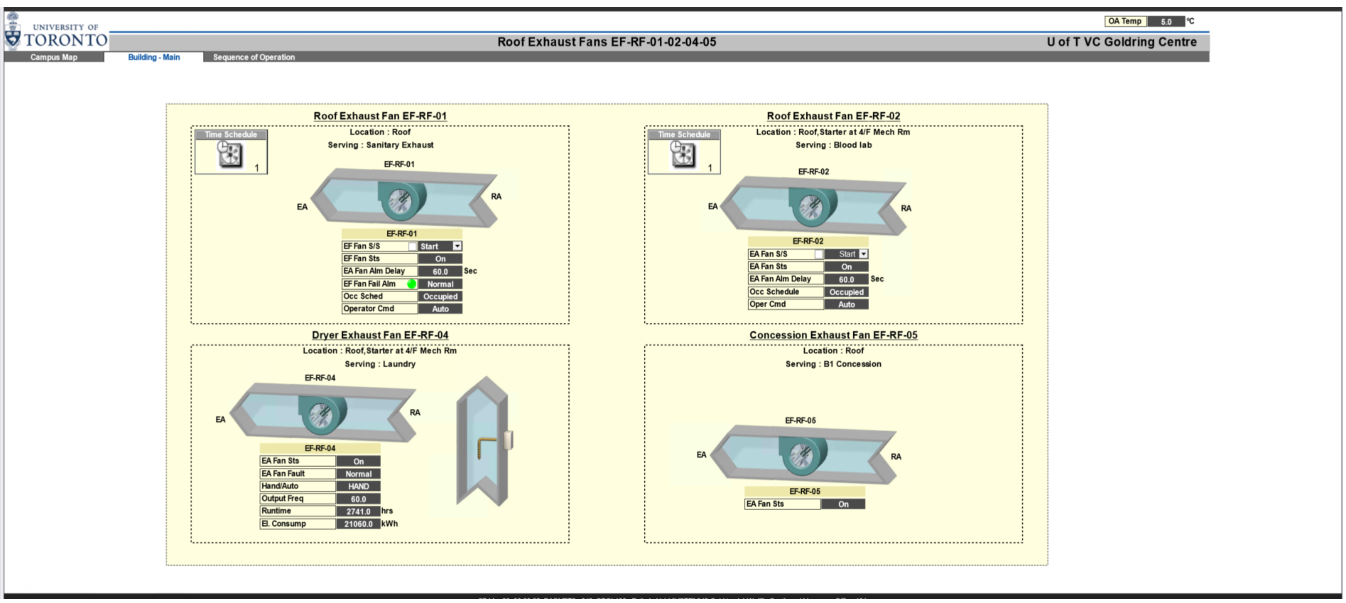


Figure 20 - Sample of detailed exhaust fans

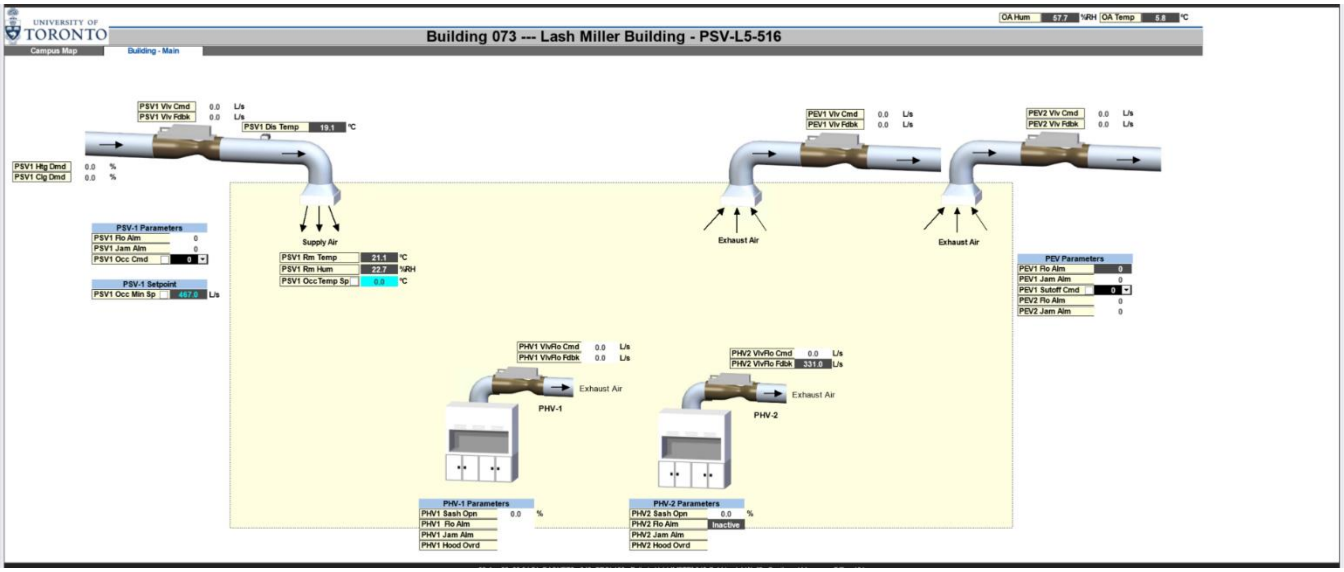


Figure 21 - Sample of laboratory controls

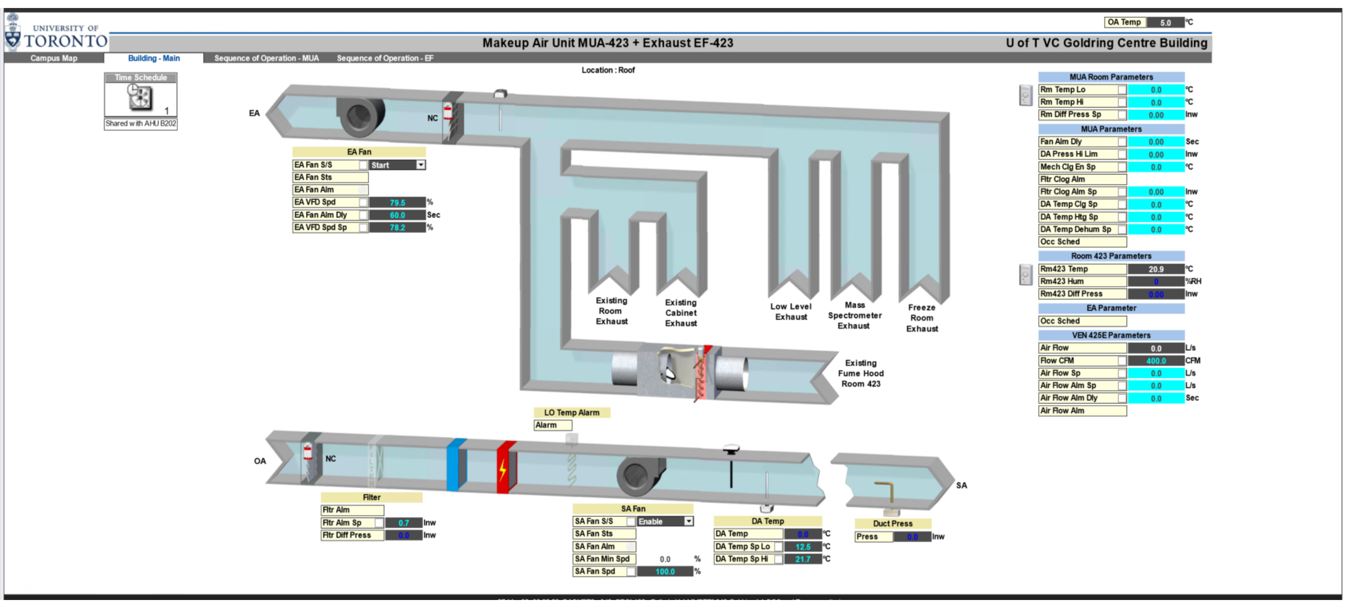


Figure 22 - Sample of makeup air unit

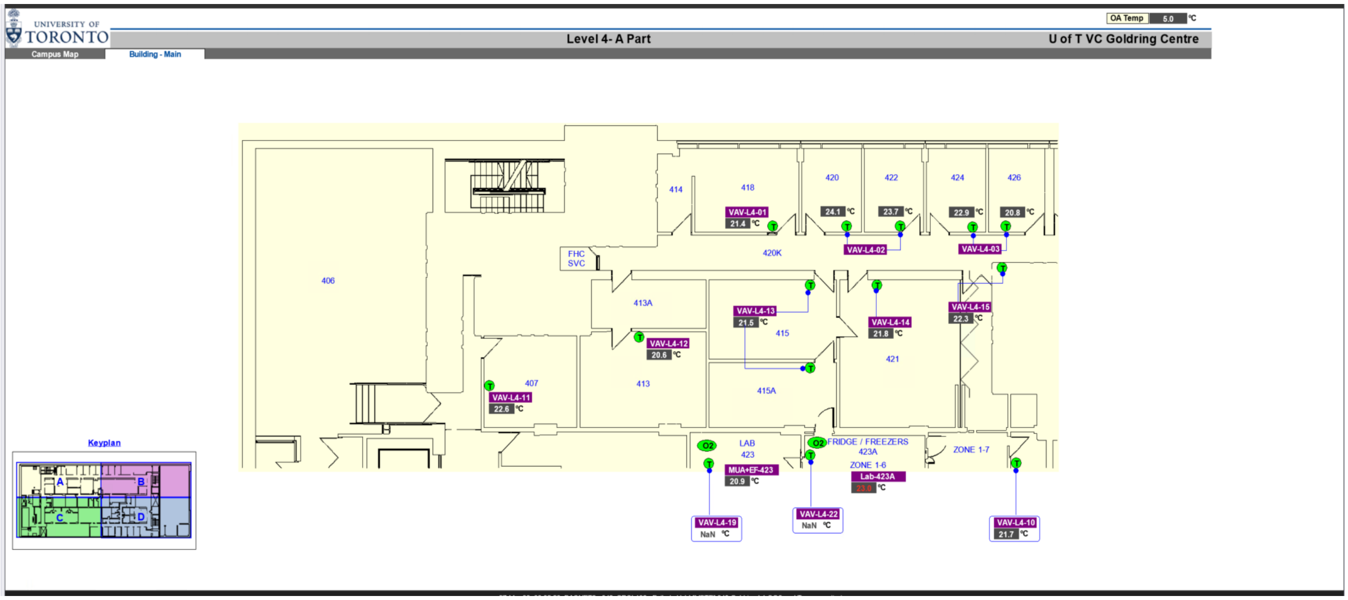


Figure 23 - Sample of floor level

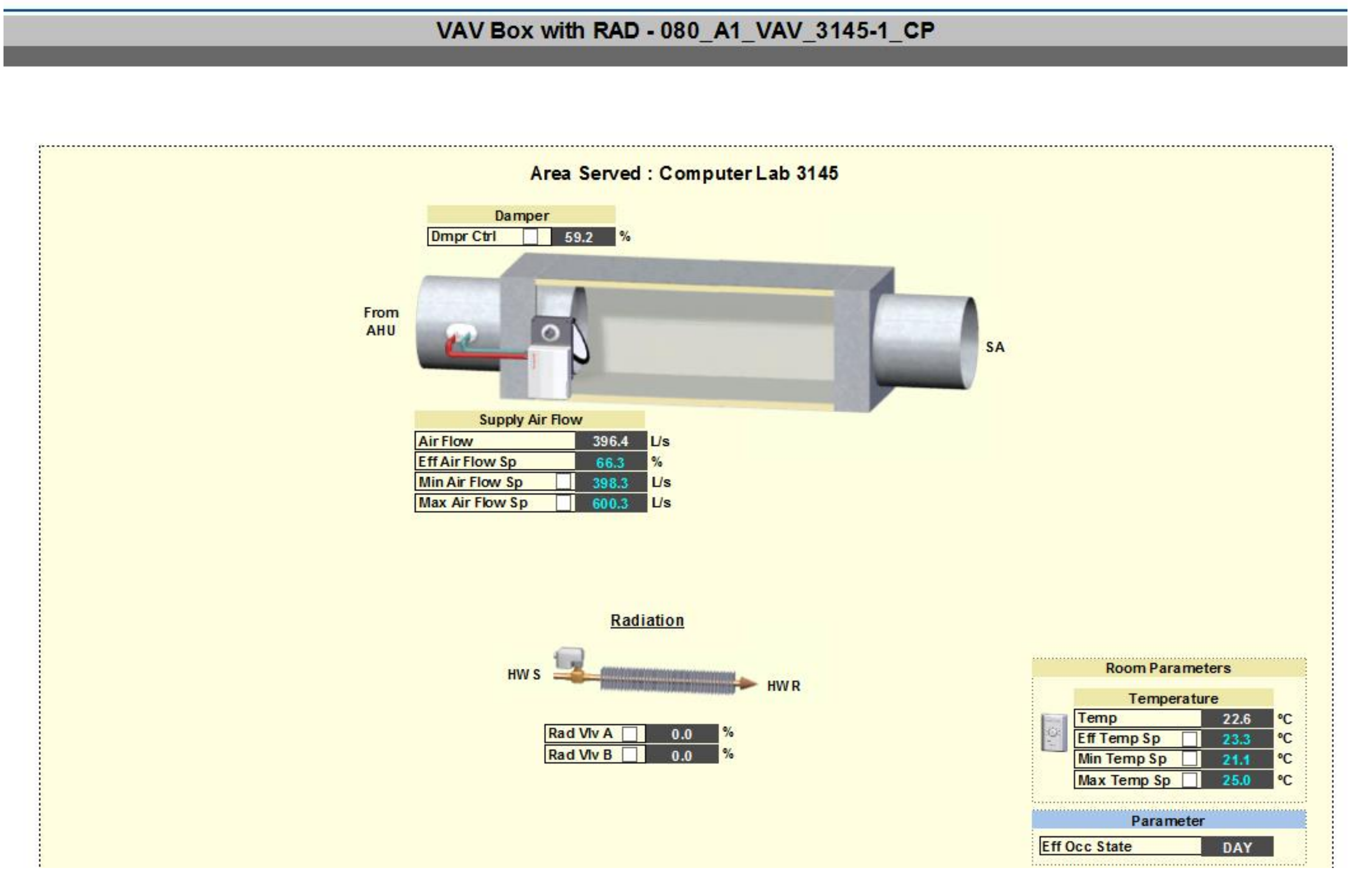


Figure 24 - VAV box with RAD

Appendix B – Typical control wire and cable schedule

U of T TYPICAL CONTROL WIRE & CABLE SCHEDULE

FIGURE 6

ITEM	WIRE USE	DISCRIPTION	WIRE SIZE	WIRE COLOUR
1	AC POWER WIRE	DISTRIBUTION (24/120 VAC)	12-14 AWG	BLACK
		DISTRIBUTION (NEUTRAL)	12-14 AWG	WHITE
2	DC POWER WIRE	DISTRIBUTION (+24VDC)	14-18 AWG	RED
		DISTRIBUTION (-24VDC)	14-18 AWG	BLACK
		DISTRIBUTION (+12VDC)	14-18 AWG	RED
		DISTRIBUTION (-12VDC)	14-18 AWG	BLACK
3	AC CONTROL SIGNAL WIRE	CONTROL SIGNAL (24/120VAC)	18 AWG	ORANGE
4	DC CONTROL SIGNAL WIRE	SIGNAL (+24VDC)	18-20 AWG	RED
		SIGNAL (-24VDC)	18-20 AWG	BLACK
5	GROUNDING	INSTRUMENT ISOLATION	12-14 AWG	GREEN/YELLOW
		SAFETY EARTHING	10-12 AWG	GREEN
6	ALARM	POWER SUPPLY FAILURE	18 AWG	YELLOW
ITEM	**CABLE USE**	**WIRE SIZE**	**CONDUCTOR**	**WIRE COLOUR**
7	POWER CABLE AC - DISTRIBUTION	12-14 AWG	1 (LINE)	BLACK
			2 (NEUTRAL)	WHITE
			3 (GROUND)	GREEN
8	POWER CABLE DC - DISTRIBUTION	14-18 AWG	1 (+24VDC)	RED
			2 (-24VDC)	BLACK
9	CONTROL CABLE DC - DISTRIBUTION	18 AWG	1 (+)	RED
			2 (-)	BLACK
10	SIGNAL ANALOG CABLE	SHIELDED/TWISTED PAIRED 18-20 AWG	1 (+)	RED
			2 (-)	BLACK
11	SIGNAL ANALOG MULTI CONDUCTOR CABLE	SHIELDED/TWISTED PAIRED 18-20 AWG	1 RED	2 BLACK
			3 WHITE	4 BLACK
			5 GREEN	6 BLACK
			7 BLUE	8 BLACK
12	CAT6 CONTROL NETWORK CABLE	COMMUNICATION		BLUE
13	SINGLE TRIAD RTD CABLE	18 AWG	1 (+)	RED
			2 (-)	WHITE
			3 (C)	BLACK

NOTE: 1. ALL WIRES CSA TYPE REW-600V FLEXIBLE, MUTISTRAND, TINNED COPPER, 105 °C
NOTE: 2. ALL SHIELDED CABLES SHALL BE CONTINUOUSLY SHIELDED. SHIELDS SHALL BE GROUNDED IN THE CONTROL PANEL AT THE POWER SOURCE END ONLY AND FLOATED AT THE OTHER END
NOTE: 3. BAS CONTROL NETWORK COMMUNICATION CABLE SHALL NOT BE SPLICED

Figure 25 - U of T cable specifications

Appendix C – Point naming convention

Campus	Building code	Building name
Other Federated Colleges	034	Massey College
Other Federated Colleges	433	Queen's Park Crescent East-43
Other Federated Colleges	434	Toronto School of Theology
Other Federated Colleges	478	Regis College
Other Federated Colleges	575	Knox College
Other Federated Colleges	575A	Nona Macdonald Visitors Centre
Other Federated Colleges	675	Wycliffe College
St. George	001	University College
St. George	002	Hart House
St. George	003	Gerstein Science Information Centre in the Sigmund Samuel Library
St. George	004	McMurrich Building
St. George	005	Medical Sciences Building
St. George	006	John P. Robarts Library Building
St. George	006A	Claude T. Bissell Building
St. George	006B	Thomas Fisher Rare Book Library Building
St. George	007	Lassonde Mining Building
St. George	008	Wallberg Building
St. George	008A	D.L. Pratt Building
St. George	009	Sandford Fleming Building
St. George	010	Simcoe Hall
St. George	010A	Convocation Hall
St. George	011	C. David Naylor Building
St. George	012A	Munk School of Global Affairs & Public Policy at Trinity
St. George	012B	Munk School of Global Affairs & Public Policy at Trinity
St. George	012C	Munk School of Global Affairs & Public Policy - Graham Library
St. George	013	Whitney Hall
St. George	014	Bloor Street West-371
St. George	016	Banting Institute
St. George	017	Queen's Park-90
St. George	018	Central Steam Plant
St. George	019	J. Robert S. Prichard Alumni House
St. George	020	Rosebrugh Building

Campus	Building code	Building name
St. George	021	Engineering Annex
St. George	022	Mechanical Engineering Building
St. George	023	University College Union
St. George	024	Haultain Building
St. George	025	FitzGerald Building
St. George	026	Cumberland House
St. George	027	Physical Geography Building - St. George Street-45
St. George	028	Student Commons
St. George	029	Sir Daniel Wilson Residence
St. George	030A	Varsity Centre
St. George	031	Hart House Circle-16 (Demolished 98/09)
St. George	032	Wetmore Hall-New College
St. George	032A	Wilson Hall-New College
St. George	033	Sidney Smith Hall
St. George	036	Astronomy & Astrophysics Building
St. George	038	Woodsworth College
St. George	040	Faculty of Law
St. George	041	Varsity Pavilion
St. George	042	Goldring Centre for High Performance Sport
St. George	043	School of Graduate Studies
St. George	047	Canadiana Gallery
St. George	050	Falconer Hall
St. George	051	Edward Johnson Building
St. George	053	Dr. Eric Jackman Institute of Child Study
St. George	054	Daniels Building
St. George	055	Highland Avenue-93
St. George	056	Graduate Students' Union
St. George	057	Bancroft Building
St. George	061	Borden Building South
St. George	061A	Borden Building North
St. George	062	Earth Sciences Centre
St. George	064	Graduate House
St. George	065	Dentistry Building
St. George	066	Spadina Avenue-665
St. George	067	Huron Street-215
St. George	068	Clara Benson Building
St. George	068A	Warren Stevens Building
St. George	070	Galbraith Building
St. George	072	Ramsay Wright Laboratories
St. George	073	Lash Miller Chemical Laboratories

Campus	Building code	Building name
St. George	075	Faculty Club
St. George	077	Sussex Court
St. George	078	McLennan Physical Laboratories
St. George	079	Anthropology Building
St. George	080	Bahen Centre for Information Technology
St. George	082	Gage Building
St. George	083	McCaul Street-254/256
St. George	087	Myhal Centre for Engineering Innovation and Entrepreneurship
St. George	088	St. George Street-123
St. George	089	Munk School of Global Affairs & Public Policy at the Observatory
St. George	090	College Street-88
St. George	091	Luella Massey Studio Theatre
St. George	092	Communications House
St. George	093	Electrometallurgy Lab
St. George	094	Back campus Fields
St. George	097	Queen's Park Crescent East-39
St. George	097A	Queen's Park Crescent. E.-39A
St. George	098B	Wellesley Street West-90
St. George	098C	Wellesley Street West-90
St. George	101	Morrison Hall
St. George	102	Soldiers' Tower
St. George	103	School of Continuing Studies
St. George	104	Max Gluskin House
St. George	105	Fields Inst for Research in Math Science
St. George	106	St. George Street-162
St. George	109	College Street-179
St. George	110	St. George Street-121
St. George	111	Factor-Inwentash Faculty of Social Work
St. George	112	College Street-185
St. George	114	College Street-187
St. George	118	Aura Lee Playing Field
St. George	120	Louis B. Stewart Observatory (UTSU)
St. George	122	North West Chiller Plant
St. George	123	Ontario Institute for Studies in Education
St. George	125	Spadina Avenue-703
St. George	127	Enrolment Services
St. George	128	Jackman Humanities Building
St. George	129	Early Learning Centre
St. George	130	Woodsworth College Residence

Campus	Building code	Building name
St. George	131	New College III
St. George	132	Innis College
St. George	133	Innis College Student Residence
St. George	134	Rotman School of Management
St. George	135	St. George Parking Garage
St. George	138	Huron Street-370
St. George	143	Koffler Student Services Centre
St. George	145	Koffler House
St. George	146	Sussex Avenue-40
St. George	147	College Street-171
St. George	151	Fasken Building
St. George	152	Rehabilitation Sciences Building
St. George	154	Health Sciences Building
St. George	155	Exam Centre
St. George	156	McCaul Street-263
St. George	158	Chestnut Residence and Conference Centre
St. George	160	Terrence Donnelly Ctr for Cellular & Biomolecular Res
St. George	161	Leslie L. Dan Pharmacy Building
St. George	171	Spadina Ave-455
St. George	172	Macdonald-Mowat House
St. George	179	College Street-229
St. George	189	Spadina Avenue-720
St. George	191	McCaul Street-207
St. George	192	Stewart Building
St. George	193	Edward Street-123
St. George	194	TWH - Krembil Discovery Tower
St. George	195	MARS 2
St. George	196	University Avenue-700
St. George	197	Bay Street-777
St. George	790	Charles St. West-30
St. George	791	Charles St. West-35
Trinity College	600	Trinity College
Trinity College	602	Gerald Larkin Building
Trinity College	603	George Ignatieff Theatre
Trinity College	608	St. Hilda's College
Victoria University	501	Victoria College
Victoria University	502	Emmanuel College
Victoria University	503	Birge-Carnegie Library
Victoria University	504	Burwash Hall
Victoria University	505	Burwash Residence (Lower Houses)

Campus	Building code	Building name
Victoria University	505A	Burwash Residence (Upper Houses)
Victoria University	506	Annesley Hall
Victoria University	507	Goldring Student Centre
Victoria University	508	Margaret Addison Hall
Victoria University	509	Isabel Bader Theatre
Victoria University	513	Stephenson House
Victoria University	514	E.J. Pratt Library
Victoria University	515	Northrop Frye Hall
Victoria University	516	Charles Street West-65
Victoria University	518	Rowell Jackman Hall
Victoria University	528	Lillian Massey Building

System name list	
Abbreviation	**Description**
AHU#	AIR HANDLING UNIT
ALN#	AUTOMATION LEVEL NETWORK
AMMICEPLT#	AMMONIA ICE PLANT SYSTEM
ATS#	AUTO TRANSFER SWITCH SYSTEM
BIOHLAB#	BIOHAZARD LABS SYSTEM
BLR#	BOILER SYSTEM
BLN#	BUILDING LEVEL NETWORK
CTRAIR#	CONTROL AIR SYSTEMS
CAV#	CONTSTANT AIR VOLUME TERMINAL BOX CONTROL SYSTEMS
CHLR#	CHILLER SYSTEM
CHLW#	CHILLED WATER SYSTEM
CLDRM#	COLD ROOM OR LAB COOLING SYSTEM
CLGPLT#	COOLING PLANT SYSTEM
CLGTWR#	COOLING TOWER SYSTEM
CGW#	CAGE WASHING SYSTEMS
COMPARE#	COMPRESSED AIR SYSTEM
CDNW#	CONDENSER WATER SYSTEM
CNDP#	CONDENSATE PUMP SYSTEMS
COR#	CORRIDOR/HALLWAY CONTROL POINTS
DCW#	DOMESTIC COLD-WATER SYSTEM
DHW#	DOMESTIC HOT WATER SYSTEM
DX#	DIRECT EXPANSION SYSTEMS (the # is stage #)
EMGEN#	EMERGENCY GENERATOR SYSTEM
FA#	FIRE ALARM SYSTEM
FAN#	MISCELLANEOUS & GENERAL-PURPOSE FANS

System name list	
Abbreviation	**Description**
FCU#	FAN COIL UNITS
FREECLG#	FREE COOLING SYSTEM
FLN#	FLOOR LEVEL NETWORK
FUELOIL#	FUEL OIL SYSTEM
FUMH#	FUME HOOD SYSTEM
HPMP#	HEAT PUMP SYSTEM
HRU#	HEAT RECOVERY UNIT/ENERGY HEAT WHEEL
HX#	HEAT EXCHANGER SYSTEM
HW#	HOT WATER SYSTEM
HWHX#	HOT WATER HEAT EXCHANGER SYSTEM
HTHWHX#	HIGH TEMP. HOT WATER HEAT EXCHANGER SYSTEM
HTR#	HEATER (i.e., UNIT, CABIENT, DUCT, GAS FIRED HEATERS)
IUCB#	INDUCTION UNIT CHILLED BEAM SYSTEM
KW#	ELECTRIC & ELECTRIC METERING SYSTEMS
LAB#	LABORATORY AREA/ZONE/LEVEL
LABAIR#	LABORATORY COMPRESSED AIR SYSTEMS
LABGAS#	LABORATORY GAS SYSTEMS (use gas type in device name)
LABRC#	LABORATORY ROOM CONTROLLER
LABVAC#	LABORATORY VACUUM COMPRESSED AIR SYSTEM
OR#	SURGICAL OPERATING ROOMS
RO#	REVERSE OSMOSIS SYSTEMS
SAS#	SUPPLY AIR SYSTEMS
SUMP#	SUMP PUMP
TNK#	TANK SYSTEMS
VACAIR#	VACUUM COMPRESSED AIR SYSTEM
VAV#	VARIABLE AIR VOLUME TERMINAL BOX SYSTEM
WSHR#	STERILIZED (WASHER)
WUM#	WARM-UP MODE
ZN#	ZONE SYSTEMS

Device name list	
Abbreviation	**Description**
AFM#	AIR FLOW METERING DEVICES
AFS#	AIR FLOW SWITCH DEVICES
AIRCOMP#	AIR COMPRESSOR
AIRX#	AIR CHANGES
ALM#	ALARM
AMP#	AMPERAGE

Device name list	
Abbreviation	**Description**
ANALZ#	ANALYSOR
AUTO#	AUTOMATIC
AVG#	AVERAGE
BAT#	BATTERY
BELL#	HORNS AND BELLS
BLDG#	BUILDING
BRG#	BEARINGS
BYP#	BYPASS DEVICES
CFM#	CUBIC FEET PER MINUTE
CD#	COLDDECK
CL#	CHLORINE
CLG#	COOLING
CLGDNM#	COOL-DOWN MODE
CLN#	CLEANING DEVICES (i.e., cage washer)
CLNRM#	CLEAN ROOM
CO#	CARBON MONOXIDE
COMP#	COMPRESSOR
COND#	CONDUCTIVITY
CO2#	CARBON DIOXIDE
CDNW#	CONDENSER WATER DEVICES
CTRL#	CONTROL
CYP#	CYPRUS T-STAT DEVICE
DAMP#	DAMPER
DAY#	DAY
DEC#	DECREMENT
DEWPT#	DEWPOINT
DEHUM#	DEHUMIDIFIER DEVICES
DISA#	DISABLE
DLY#	DELAY
DP#	DIFFERENTIAL PRESSURE DEVICES
DWDUCT#	DOWN DUCT DEVICES
EAF#	EXHAUST AIR FAN
EAST	EAST
ECON#	ECONOMIZER DEVICES
ENT#	ENTERING
ENTH#	ENTHALPY
EP#	ELECTRIC/PNEUMATIC COIL
EN#	ENABLE/DISABLE Points (NOT Based on a Schedule)
EMER#	EMERGENCY DEVICES

Device name list	
Abbreviation	**Description**
ESW#	END SWITCH
EH#	ELECTRIC HEAT DEVICES
EXHCFM#	EXHAUST CFM
EXH#	EXHAUST
EXHLAB#	LAB EXHAUST
EXHWASHRM#	WASHROOM EXHAUST
EXHGENRL#	GENERAL EXHAUST
EXP#	EXPANSION (OBJECTS)
FBDAMP#	FACE & BYPASS DAMPER
FAN#	FAN
FAULT#	FAULT
FAST#	FAST SPEED
FDBK#	FEEDBACK
FB#	FACE BYPASS
FLO#	FLOW
FLR#	FLOOR SPECIFICATION (where # is B3, B2, B1, 1,2, …, PH)
FLTR#	FILTER
FT#	FLOW TRANSMITTER
FZ#	FREEZE STAT PROTECTION
G#	GLOBAL OR VIRTUAL POINT
GEN#	GENERATOR
GILFLOM#	GILFLO METER
H2#	HYDROGEN
HD#	HOTDECK
HE#	HELIUM
HEPFLTR#	HEPA FILTER
HI#	HIGH
HR#	HOURLY
HS#	HIGH SPEED
HTHW#	HIGH TEMPERATURE HOT WATER
HTG#	HEATING
HTRC#	HEAT TRACE
HT#	HIGH TEMPERATURE
HL#	HIGH LIMIT
HLS#	HIGH LIMIT SUPPLY
HLR#	HIGH LIMIT RETURN
HOA#	HAND-OFF-AUTO
HOTRM#	HOT ROOM SYSTEM POINTS
HOUR#	TIME HOURS

Device name list	
Abbreviation	**Description**
HP#	HIGH PRESSURE DEVICES
HUM#	HUMIDITY DEVICES
HUMSPT#	HUMIDITY SETPOINT
INC#	INCREMENT
ISO#	ISOLATION DEVICES
LCN#	LOCATION (i.e., CONTROL PANEL RESIDENCE)
LEADLAG#	LEAD/LAG TOGGLE
LIT#	LIGHTS
LAB#	LABORATORY (where # is the room number)
LITON#	LIGHT ON TIME
LITOFF#	LIGHT OFF TIME
LITPRF#	LIGHT PROOF (photocell)
LL#	LOW LIMIT
LOAD#	LOAD (used for chillers, electrical)
LOC#	LOCAL CONTROL POINT
LOW#	LOW
LS#	LOW SPEED
LPO#	LOOP OUTPUT
LT#	LOW TEMPERATURE
LVG#	LEAVING
LVL#	LEVEL INDICATION
MAN#	MANUAL
MAKUP#	MAKE-UP
MD#	MODE
MECHRM#	MECHANICAL EQUIPMENT ROOM LOCATION
MEDGAS#	MEDICAL GAS SYSTEMS (use gas type in device name)
METER#	METERS
MIN#	MINIMUM
MED#	MEDIUM OR MEDIAN
M#	MODE
NORTH	NORTH
MON#	MONTHLY
MTHWHX#	MEDIUM TEMP. HOT WATER HEAT EXCHANGER SYSTEM
MXT#	MIXED AIR DEVICES
N2#	NITROGEN
O2#	OXYGEN
OA#	OUTSIDE AIR DEVICES
OCC#	OCCUPANCY (based on a schedule)
OCC-OVRD#	OCCUPANCY OVERRIDE

Device name list	
Abbreviation	**Description**
OFF#	OFF
OFFST#	OFFSET
ON#	ON
OPER#	OPERATOR
OVLD#	OVERLOAD DEVICES
OVRD#	OVERIDE DEVICES
PARKGR#	PARKING GARAGE SYSTEM
PB#	PROPORTIONAL BAND
PCT#	PERCENT
PF#	PREFILTER DEVICES
PH#	ACID/BASE LEVEL
PHT#	PREHEAT DEVICES
PLTPRTY#	PLANT PRIORITY
PMP#	PUMP DEVICES OR NUMBER
POS#	POSITION
PPM#	PARTS PER MILLION
PRC#	PRESSURIZD ROOM CONTROLLER
PRF#	PROOF
PRI#	PRIMARY
PRS#	PRESSURE SWITCH
PRV#	PRESSURE REDUCING VALVE
PSI#	PRESSURE GAUGE
PSPT#	PRESSURE SET POINT
PT#	PRESSURE TRANSMITTER
PMP#	PUMP
PWR#	POWER
PWRFAIL#	ON POWER RETURN POWER FAIL POINT FOR PANELS
R#	RETURN DEVICES
RA#	RETURN AIR DEVICES
RAREBKS#	RARE BOOKS
RAF#	RETURN AIR FAN
REFIGA#	REFRIGERANT ALARM DEVICES
RST#	RESET (command only)
RHT#	REHEAT DEVICES
RM#	ROOM NUMBER
RMTEMP #	ROOM TEMPERATURE
RMSPT#	ROOM TEMPERATURE SETPOINT
RMHUM#	ROOM HUMIDITY
RPC#	ROOM PRESSURIZATION CONTROLLER

Device name list	
Abbreviation	**Description**
RPM#	REVOLUTIONS PER MINUTE
RSR#	DUCT/PIPE RISER OBJECTS
SA#	SUPPLY AIR DEVICE
SAF#	SUPPLY AIR FAN
SCHED#	SCHEDULE
SEC#	SECONDS
SECD#	SECONDARY
SPT#	SET POINT (used as a suffix to any other device name)
SP#	STATIC PRESSURE
SIG#	SIGNAL
STS#	STATUS
S#	SUPPLY DEVICES
SW#	SUMMER/WINTER
SMK#	SMOKE CONTROL DEVICES
SOUTH	SOUTH
SS#	START/STOP
START#	START (command only)
STOP#	STOP (command only)
STS#	STATUS
STBY#	STANDBY DEVICES
STM#	STEAM DEVICES
STMFL#	STEAM FLOW
STMGEN#	CLEAN STEAM SYSTEMS
STMHX#	STEAM HEAT EXCHANGER SYSTEM
SURGYVACS#	SURGERY VACUUM AIR SYSTEM
SWIMPL#	SWIMMIMING POOL
TEC#	TERMINAL EQUIPMENT CONTROLLER
TIMEDLY#	TIME DELAY
TEMP#	TEMPERATURE
TIME#	TIME CONTROL UNITS
TOT#	TOTALIZED VALUE OR TOTAL
TT#	TEMPERATURE TRANSMITTTER
ULTRSFLOM#	ULTRA SONIC FLOW METER
UVLIT#	ULTRAVIOLET LIGHT
VANDAMP	VANE DAMPER
VEN#	VENTURI
VP#	VELOCITY PRESSURE
VFD#	VARIBLE FREQUENCY DRIVE OUTPUT SIGNAL
VTXFLOM#	VORTEX FLOW METER

Device name list	
Abbreviation	**Description**
VLV#	VALVE
WEST	WEST
WD#	WATER DETECTOR
#	IDENTIFICATION NUMBERS

Appendix D – Terminal equipment controller (TEC) submittal package

1. TEC BACnet point matrix

To complete the EMRS BACnet Compliance Test, the BAS vendor shall submit the Microsoft Excel (XLSX) digital version of the BACnet Point Matrix for every BACnet MSTP TEC that is connected and integrated to the EMRS BACnet communication layer (IP, MSTP). TEC includes any ASC or AAC controller used in the project.

The mandatory fields are:

A. Name of the ASC or AAC controller (TEC)
B. List of all the BACnet objects related to the application
C. BACnet object description
D. BACnet units
E. BACnet object type
F. BACnet object instance number
G. ASC/AAC application notes

All points intended for monitoring and control on the GUI shall be mapped to the respective B-BC controller using this standard nomenclature, ensuring that alarming points are enabled.

Below is the screenshot of the digital file (Excel XLSX) that is expected to be submitted:

072_CHLR1_BTU1 [372051]	5		fMRI CH BTU Metr																							
		AV_1	Total Energy	LAI	Y	1.5.1	Value																	Analog Value	1	AV_1
		AI_1	Energy Rate	LAI	Y	1.5.2	Value																	Analog Input	1	AI_1
		AV_2	Total Flow	LAI	Y	1.5.3	Value																	Analog Value	2	AV_2
		AI_2	Flow Rate	LAI	N	1.5.4	Value																	Analog Input	2	AI_2
		AI_3	Supply Temperature	LAI	N	1.5.5	Value																	Analog Input	3	AI_3
		AI_4	Return Temperature	LAI	N	1.5.6	Value																	Analog Input	4	AI_4
		AI_5	Delta T	LAI	Y	1.5.7	Value																	Analog Input	5	AI_5
		BV_1	Energy Total Reset	LDO	Y	1.5.8	On/Off																	Binary Value	1	BV_1
		BV_2	Flow Total Reset	LDO	Y	1.5.9	On/Off																	Binary Value	2	BV_2
		AV_3	Auxilliary Input Total	LDI	N	1.5.10	Pulse																	Analog Value	3	AV_3
		BV_3	Auxilliary Input Reset	LDO	Y	1.5.11	On/Off																	Binary Value	3	BV_3
072_VAV1.1_TEC1 [372061]	6		Mock Scanner 177																							
		ROOM TEMP	Room Temperature	LAI	N	1.6.4	Value				8	45	DegC	0.5					Y	25	18	60	1	Analog Input	4	AI_4
		HEAT.COOL	Heat or Cool Mode	LDO	Y	1.6.5	On/Off								N	COOL	HEAT	N	N					Binary Value	5	BV_5
		NGT OVRD	Night Override Mode	LDO	Y	1.6.21	On/Off								N	DAY	NIGHT	N	N					Binary Value	21	BV_21
		DAY.NGT	Schedule Point	LDO	Y	1.6.29	On/Off								N	DAY	NIGHT	N	N					Binary Value	29	BV_29
		AIR VOLUME	Measured Air Flow	LAO	Y	1.6.35	Value				0	10000	LPS	10					N					Analog Value	35	AV_35
		DMPR COMD	Damper Command	LAO	Y	1.6.48	Value				0	100	PCT	1					N					Analog Value	48	AV_48
		DMPR POS	Damper Position	LAO	Y	1.6.49	Value				0	100	PCT	1					N					Analog Value	49	AV_49
		VLV1 COMD	Reheat Command	LAO	Y	1.6.52	Value				0	100	PCT	1					N					Analog Value	52	AV_52
		VLV1 POS	Reheat Position	LAO	Y	1.6.53	Value				0	100	PCT	1					N					Analog Value	53	AV_53
		FLOW	Flow Percentage	LAO	Y	1.6.75	Value				0	1000	PCT	1					N					Analog Value	75	AV_75
		CTL FLOW MIN	Minimum Set Point	LAO	Y	1.6.76	Value				0	10000	LPS	1					N					Analog Value	76	AV_76
		CTL FLOW MAX	Maximum Set Point	LAO	Y	1.6.77	Value				0	10000	LPS	1					N					Analog Value	77	AV_77
		CTL TEMP	Current Temp Value	LAO	Y	1.6.78	Value				8	45	DegC	0.5					N					Analog Value	78	AV_78
		CTL STPT	Temperature Set Point	LAO	Y	1.6.92	Value				8	45	DegC	0.5					N					Analog Value	92	AV_92
		FLOW STPT	Airflow Set Point (%)	LAO	Y	1.6.93	Value				0	250	PCT	1					N					Analog Value	93	AV_93
		RM RH	Room Humidity	LAI	N	1.6.126	Value				0	100	%RH	1					N					Analog Value	126	AV_126

Figure 26 - TEC BACnet point matrix

A. TEC field layer network schedule (MSTP ASC/AAC TEC controllers)

To complete the EMRS BACnet compliance test, the BAS vendor shall submit the Microsoft Excel (XLSX) digital version of the TEC field layer network schedule containing the list of all MSTP controllers and their association with the routed networks and B-BC controllers.

The mandatory fields are:

A. Name of the ASC/AAC controller (TEC)
B. BACnet controller instance number
C. Description of the system or location served
D. MSTP routed network ID
E. ASC/AAC application ID or type

Below is the screenshot of the digital file (Excel XLSX) that shall be submitted:

MS/TP Field Level Network Schedule

Project: U of T - Ramsay Wright - fMRI Suite

Field Panel Information:

System Name: 072_DDC_01
Panel Location: Level B2, Mechanical Room
BACnet Instance No.: 372001
Panel Type: Modular
BACnet Object Name: 072DDC01

FLN1 Settings:

Panel MS/TP Address: 0
FLN Baud Rate: 38400 bps
BACnet Network No.: 372

Note: FLN2 and FLN3 are not available for BACnet MS/TP Connection.

Terminal Box Information:

Box Manufacturer: E.H. Price
Rotation Angle: 90 Degrees
Initial Flow Coefficient: 0.78

System Name	Description	Terminal Box ID	Mechanical Drawing		Box Unit Size (mm)	Duct Inlet Area (M2)	BACnet			Comm. Chk.	Served By	Type of Control
			No.	Ref			Master or Slave	Instance No.	MAC			
	Do Not Use - Reserved for Field Panel MS/TP Node Address								0			
072_CHLR1_PMP1	CH Evap Pump 1	P-CH-1	M802		-	-	M	372011	1		-	VFD (Pump)
072_CHLR1_PMP2	CH Evap Pump 2	P-CH-2	M802		-	-	M	372021	2		-	VFD (Pump)
072_CHLR1_PMP3	CH Cond Pump 3	P-CW-3	M802		-	-	M	372031	3		-	VFD (Pump)
072_CHLR1_PMP4	CH Cond Pump 4	P-CW-4	M802		-	-	M	372041	4		-	VFD (Pump)
072_CHLR1_BTU1	fMRI CH BTU Metr	BTU-1	M802		-	-	M	372051	5		-	BTU Meter
072_VAV1.1_TEC1	Mock Scanner 177	VAV-1.1	M502	F.5/8.3	250	0.050	M	372061	6		Exist AHU	VAV w/Reheat
072_VAV1.2_TEC2	Waiting Area 172	VAV-1.2	M502	E.5/9.5	250	0.050	M	372071	7		Exist AHU	VAV w/Reheat
					-	-						
					-	-						
072_FCU2.1_TEC3	Server Room 178	FC-2.1	M502	G/10.4	-	-	S	372081	128		-	Fan Coil, Cool Only
072_FCU2.2_TEC4	Equip Room 179	FC-2.2	M502	F.6/10.9	-	-	S	372091	129		-	Fan Coil, Cooling & Heating
072_FCU2.3_TEC5	Exam Room 180	FC-2.3	M502	D.5/13.5	-	-	S	372101	130		-	Heat Pump
072_FCU2.4_TEC6	Control Rm 181	FC-2.4	M502	D.4/13.4	-	-	S	372111	131		-	Fan Coil, Cooling & Heating

System Name	TEC Appl. No. (02)	Clg Flow Min (L/s) (31)	Clg Flow Max (L/s) (32)	Htg Flow Min (L/s) (33)	Htg Flow Max (L/s) (34)	Motor Setup (58)	MTR 1 Timing (51)	MTR 2 Timing (55)	MTR 3 Timing (39)	Custom PPCL	Check	Design Flow (L/s)	Actual Press Drop (kPa)	Valve Cv	Valve Body	3-Way Valve Piping Detail	Valve Size (mm)	Control Valve
072_CHLR1_PMP1	11201	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
072_CHLR1_PMP2	11201	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
072_CHLR1_PMP3	11201	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
072_CHLR1_PMP4	11201	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
072_CHLR1_BTU1	11202	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
072_VAV1.1_TEC1	6623	88	293	88	88	13	90	130	-			0.13	29.27	1.00	3W	D	15	260-02066
072_VAV1.2_TEC2	6623	35	115	35	35	13	90	130	-			0.13	29.27	1.00	3W	D	15	260-02066
												-	-	-			-	
												-	-	-			-	
072_FCU2.1_TEC3	6645	-	-	-	-	1	130	-	-	N		0.44	21.12	4.00	2WNC	-	15	260-02010
072_FCU2.2_TEC4	6645	-	-	-	-	13	130	130	-	N		0.10	17.65	1.00	2WNC	-	15	260-02004
												0.11	19.93	1.00	3W	D	15	260-02066
072_FCU2.3_TEC5	6674	-	-	-	-	-	130	-	-	Y		0.44	21.12	4.00	2WNC	-	15	260-02010
072_FCU2.4_TEC6	6645	-	-	-	-	13	130	130	-	N		0.10	17.65	1.00	2WNC	-	15	260-02004
												0.11	19.93	1.00	3W	D	15	260-02066

Figure 27 - TEC field layer network schedule