PART 1 GENERAL

1.1 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

1. Control valves
2. Immersion wells for temperature sensors
3. Control Dampers (Except packaged Units)
4. Variable Speed Drives

1.2 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

1. Airflow switches for packaged Make-up Air unit

1.3 PRODUCTS NOT INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION

1. HRV-1
2. Packaged Air Handling units

1.4 RELATED SECTIONS

1. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.
2. This section applies to and is part of all sections of Division 23.

1.5 DESCRIPTION

1. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and an Operator Workstation. The Operator Workstation shall be a personal computer (PC) with a LCD color monitor, mouse, keyboard, and printer. The PC shall allow operators to interface with system via dynamic color graphics. Depict each mechanical system and building floor plan by a point-and-click graphic. Furnish a modem or network interface card for remote access to the network and for paging operators when an alarm occurs.
2. The system shall directly control HVAC equipment as specified in Section 25 09 10 Appendix A (Sequences of Operation) and as noted on the control drawings.
3. System shall use the BACnet protocol for communication to the Operator Workstation and for communication between control modules. Schedules, setpoints, trends, and alarms specified (Sequences of Operation) shall be BACnet objects.

1.6 APPROVED CONTROL SYSTEM MANUFACTURERS

1. The following are approved control system manufacturers:

    1. Allerton
    2. Delta
    3. Honeywell

4. Johnson

2. The above list of manufacturers is alphabetical and does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.
3. Use Operator Workstation software, controller software, custom application programming language, and controllers only from one these manufacturers.
4. Other products specified herein (such as sensors, and actuators) need not be manufactured by these manufacturers except as noted.

1.7 QUALITY ASSURANCE

1. Installer and Manufacturer Qualifications

    1. Installer shall have an established working relationship with Control System Manufacturer.
    2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.

1.8 CODES AND STANDARDS

1. Work, materials, and equipment shall comply with the most restrictive of local, provincial, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:

    1. Canadian Electric Code (CEC), to the satisfaction of the Authority having Jurisdiction.
    2. National Building Code (NBC), to the satisfaction of the Authority having Jurisdiction.
    3. ASHRAE/ANSI 135-2004: Data Communication Protocol for Building Automation and Control Systems (BACnet)

1.9 SYSTEM PERFORMANCE

1. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

    1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
    2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
    3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
    4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.

5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 5 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciations. Each workstation on the network (one only required initially) shall receive alarms within 5 sec of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.

Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table 1
Reporting Accuracy

Measured Variable	**Reported Accuracy**
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
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 (±0.01 in. w.g.)
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 (CO_2)	±25 ppm

Note 1: 10% - 100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

Table 2
Control Stability and Accuracy

Controlled Variable	**Control Accuracy**	**Range of Medium**
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 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.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.10 SUBMITTALS

1. Product Requirements: Meet requirements of General Section on Shop Drawings, Product Data, and Samples. Provide six copies of shop drawings and other submittals on hardware, software, and equipment to be installed or furnished. Begin no work until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2007 or higher (or Visio Professional) compatible files on magnetic or optical disk. When manufacturer's specification data sheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered specification and drawing on each submittal. General catalogs shall not be accepted as specification data sheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Provide submittals within 4 weeks of contract award on the following:

2. Direct Digital Control System Hardware

    1. Complete bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
    2. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

        1. Direct digital controllers (controller panels)
        2. Transducers and transmitters
        3. Sensors (include accuracy data)
        4. Actuators
        5. Valves
        6. Relays and switches
        7. Control panels
        8. Power supplies
        9. Batteries
        10. Operator interface equipment (OWS, printer, UPS)
        11. Wiring

    3. Wiring diagrams and layouts for each control panel. Show termination numbers.
    4. Floor plan schematic diagrams indicating field sensor and controller locations.

3. Central System Hardware and Software

    1. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
    2. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
        1. Central Processing Unit (CPU)
        2. Monitors
        3. Keyboards
        4. Power supplies
        5. Battery backups
        6. Printers
        7. Modems
        8. Routers and Network switches
        9. Interface equipment between CPU or server and control panels
        10. Operating System software
        11. Operator interface software
        12. Color graphic software
        13. Third-party software
        14. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
        15. Network riser diagrams of wiring between central control unit and control panels.

4. Controlled Systems

    1. Schematic diagram of each controlled system. Label control points with point names and point address. Graphically show locations of control elements.
    2. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
    3. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
    4. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points as noted on the control schematics. Indicate alarmed and trended points.
    5. Description of process, report formats, and checklists to be used in Section 25 09 10 Article 3.17 (Control System Demonstration and Acceptance).
    6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.
    7. Schedules: Within one month of contract award, provide schedule of work indicating:

        1. Intended sequence of work items
        2. Start date of each work item
        3. Duration of each work item

4. Planned delivery dates for ordered material and equipment and expected lead times
5. Milestones indicating possible restraints on work by other trades or situations
6. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

5. Project Record Documents. Submit three copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:

1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2007 or higher (or MS Visio 2003 or later) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and as full-size drawings.
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of section 25 09 10 Article 3.17 (Control System Demonstration and Acceptance).
3. Operation and Maintenance (O&M) Manual. Printed, electronic, or online help documentation of the following:
4. As-built versions of submittal product data.
5. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
6. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
7. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
8. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
9. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
10. Graphic files, programs, and database on magnetic or optical media.
11. List of recommended spare parts with part numbers and suppliers.
12. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
13. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
14. Licenses, guarantees, and warranty documents for equipment and systems.
15. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

6. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Contract Administrator will modify course outlines and materials if necessary to meet the City's needs. Contract Administrator will review and approve course outlines and materials at least three weeks before first class.

1.11 WARRANTY

1. Warrant work as follows:

    1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the City. Respond during normal business hours within 24 hours of the City's warranty service request.
    2. Work shall have a single warranty date, even if the City receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
    3. If Contract Administrator determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Contract Administrator will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
    4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, the City can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without the City's written authorization.
    5. All OWS components including PC, LCD Display, printer and UPS shall have a full 3 year on-site warranty.

1.12 THE CITYSHIP OF PROPRIETARY MATERIAL

1. Project-specific software and documentation shall become the City's property. This includes, but is not limited to:

    1. Graphics
    2. Record drawings
    3. Database
    4. Application programming code
    5. Documentation

PART 2 PRODUCTS

2.1 MATERIALS

1. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved

in writing by the City. Spare parts shall be available for at least ten years after completion of this contract.

2.2 COMMUNICATION

1. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ASHRAE/ANSI Standard 135-2004, BACnet.
2. Provide Ethernet backbone for network segments noted on project drawings.
3. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
4. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
5. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
6. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 25 09 10 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.
7. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. When applicable, system shall automatically adjust for daylight saving and standard time.
8. System shall be expandable to at least six times the required input and output objects with additional controllers, associated devices, and wiring. Expansion shall not require Building Controller/WebServer (BC) or operator interface hardware additions or software revisions.

2.3 OPERATOR INTERFACE

1. Operator Interface. PC-based workstations shall reside on high-speed network with building controllers. Each workstation shall be able to access all system information.
2. Workstation and controllers shall communicate using BACnet protocol. Workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ASHRAE/ANSI 135-2004, BACnet Annex J.
3. Connection to ISP for Web Access is the City's responsibility.
4. Hardware. Each workstation shall consist of the following:

    1. Hardware Base. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified in Section 25 09 10 Paragraph 1.9. Hard disk shall have sufficient memory to store system software, one year of data for trended points (all analog and digital inputs), and a system database at least six times the size of the existing database at system acceptance. Configure computers and network

connections if multiple computers are required to meet specified memory and performance. Workstations shall be a DELL OPTIPLEX PC with a minimum of:

1. Intel® Core™ 2 Quad Q8400 (2.66GHz, 4M, 1333MHz FSB)
2. 4.0 GB DDR3 SDRAM 1066MHz
3. 250 GB SATA, Hard Drive (3.0 GB/s)
4. 16X DVD+/-RW SATA
5. 256 MB ATI RADEON Video
6. Keyboard with 8 Hot Keys
7. Laser Mouse
8. Internal Speakers
9. Data/Fax modem
10. Windows 7 Professional or XP Professional
11. Dell Professional P2010H 20 inch Wide LCD Display (VGA, DVI, DP)
12. Microsoft Office Small Business Edition
13. 800 VA APC UPS
14. 3 Year ProSupport Onsite Service
15. Approved product (no exceptions): DELL OPTIPLEX 780 MiniTower
16. HP P2025n Colour Laser Printer.

5. Operator Functions. Operator interface shall allow each authorized operator to execute the following functions as a minimum:

    1. Log In and Log Out. System shall require user name and password to log in to operator interface.
    2. Point-and-click Navigation. Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
    3. View and Adjust Equipment Properties. Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.
    4. View and Adjust Operating Schedules. Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.
    5. View and Respond to Alarms. Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.
    6. View and Configure Trends. Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.
    7. View and Configure Reports. Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.
    8. Manage Control System Hardware. Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.
    9. Manage Operator Access. Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in.

Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

10. A minimum of 3 operators shall be able to access the system concurrently.

2.4 WEB BROWSER OPERATOR INTERFACE

1. The operator interface shall also be fully available through a web browser. From a browser such as Microsoft's Internet Explorer, an operator shall be able to perform all functions on the same standard and custom graphics as used in the standard operator interface. All custom graphics, alarm graphics and standard graphics shall be available without modification or reengineering through a browser user interface and shall be fully functional.
2. The browser interface shall provide login and security authentication in the same way as the standard operator interface. It shall be possible to operate the facility through the browser user interface in the same way as the standard user interface and perform all functions described in section 2.3.4 for example: acknowledge alarms, view graphics, control points, execute reports, and modify configuration settings and the like.
3. The Web Browser software may be hosted in the Building Controller (BC) or in a dedicated Web Server. It may not be hosted in the Operator Workstation. The hardware and software shall be provided to accommodate a minimum of six times the required data and graphic file without any additions or modifications to the server.

2.5 SYSTEM SOFTWARE

1. Operating System. Workstation shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows XP Professional, Windows 2000 Professional.
2. System Graphics. Operator interface shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

    1. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.
    2. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
    3. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
    4. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, or GIF.

3. System Tools. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard

IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

1. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
2. Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. System Configuration. Operators shall be able to configure the system.
4. Online Help. Context-sensitive online help for each tool shall assist operators in operating and editing the system.
5. Security. System shall require a user name and password to view, edit, add, or delete data.

    1. Operator Access. Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object.
    2. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
    3. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

6. System Diagnostics. System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).
7. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Section 25 09 10 Appendix A (Sequences of Operation). As a minimum provide high and low alarm setpoints for all analog inputs. For reset loops provide floating setpoint deviation alarms. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
8. Alarm Messages. Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.
9. Alarm Reactions. Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
10. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.
11. Trend Configuration. Operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to

archive data to the hard disk.). The contractor shall set up trending for all inputs and outputs to facilitate system verification and fine-tuning. System must have sufficient memory and storage to continuously trend all data points (including 300 future hardware data points) at a minimum interval of 30 minutes for 24 months. Trends shall be BACnet trend objects.

12. Object and Property Status and Control. Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.
13. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
14. Standard Reports. Furnish the following standard system reports:

    1. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
    2. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    3. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period (Minimum 1 year):

        1. Alarm History.
        2. Trend Data. Operator shall be able to select trends to be logged.
        3. Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

15. Custom Reports: Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.
16. Graphics Generation. Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.
17. Graphics Library. Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.
18. Custom Application Programming. Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

    1. Language. Language shall be graphically based or English language oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and

operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall allow for free-form programming that is not column-oriented or "fill-in-the-blanks."

2. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment or character editor that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
3. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
4. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
5. Conditional Statements. Operator shall be able to program conditional statements (IF/THEN/ELSE/ELSE-IF) using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
6. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.
7. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.
8. Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.
9. System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

19. Other Operator Workstation (OWS) Capabilities: Each OWS and/or the server shall have a copy of all as-built control drawings and the entire O&M manual loaded in electronic form (PDF) for operator reference. The Control Sequences shall be available as a subordinate graphic to each mechanical system graphic.

4. Portable Operator's Terminal.

1. Provide all necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect

configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

2.6 CONTROLLER SOFTWARE

1. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation or engineering workstation.
2. Scheduling. System shall provide the following schedule options as a minimum:

    1. Weekly. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
    2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
    3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

3. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.
4. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.
5. Demand Limiting.

    1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer, if specified on the control schematics and the Appendix A.
    2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand where and as specified in Section 25 09 10 Appendix A (Sequences of Operation). When demand drops below adjustable levels, system shall restore loads as specified.

6. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Section 25 09 10 Appendix A (Sequences of Operation).
7. Sequencing. Application software shall sequence all equipment, including air handling units, chillers, boilers, and pumps as specified in Section 25 09 10 Appendix A (Sequences of Operation).
8. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.
9. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.
10. Energy Calculations.

1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s) to energy usage data.
2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.
3. System shall calculate a fixed-window average. Window interval start shall be defined by utility meter digital input signal to synchronize system's and utility's fixed-window averages.

11. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.
12. On and Off Control with Differential. System shall provide direct and reverse acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.
13. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and object. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms for all digital inputs.

2.7 CONTROLLERS

1. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), and Smart Actuators (SA) as required to achieve performance specified in Section 25 09 10 Article 1.9 (System Performance).
2. BACnet.

    1. Building Controllers (BC). Each BC shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Building Controller (B-BC) device profile as specified in ASHRAE/ANSI 135-2004, BACnet Annex L.
    2. Advanced Application Controllers (AACs). Each AAC shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ASHRAE/ANSI 135-2004, BACnet Annex L. Each AAC shall include a built-in English language Local Operator Terminal (LOT). If built in LOT is not available, provide a Laptop PC with the following specifications:

        1. DELL LATITUDE E5400, 2 DUO P8700 (2.53GHz, 3M L2 Cache, 1066MHz FSB), WINDOWS 7 or XP Professional, 14.1 inch Wide Screen WXGA, 4GB DDR2-800 RAM, 160GB Hard Drive 7200RPM, 16X DVD+/-RW, Modem, 802.11 a/g/n Wireless, Bluetooth module, 3 year ProSupport (No Exceptions).

    3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ASHRAE/ANSI 135-2004, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
    4. Smart Actuators (SA). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ASHRAE/ANSI 135-2004, BACnet Annex L and

shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.

3. BACnet Communication.

    1. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
    2. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
    3. Each AAC and ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    4. Each SA shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.

4. Communication.

    1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
    2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
    3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.

5. Stand-Alone Operation. Each piece of equipment specified in Section 25 09 10 Appendix A shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.
6. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

    1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -40°C to 60°C (-40°F to 140°F).
    2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
    3. Controllers used in conditioned space in areas served by sprinklers shall have appropriate sprinkler shields installed.

7. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not provide a keypad and display for each BC and AAC, provide a Portable Operator's Terminal (Notebook PC) for the system.
8. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.
9. Serviceability.

    1. Controllers shall have diagnostic LEDs for power, communication, and processor.

2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

10. Memory.

    1. Controller memory shall support operating system, database, and programming requirements.
    2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
    3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

11. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
12. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.8 INPUT AND OUTPUT INTERFACE

1. General: Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

2. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

3. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

4. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

5. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

6. Binary Outputs. Binary outputs shall send a pulsed low-voltage signal for pulse width modulation control or an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

7. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

8. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs) in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

9. Universal Inputs and Outputs. Controller inputs and outputs shall be universal. Input or output shall be designated binary or analog in software and shall be assigned appropriate properties. Non-universal inputs and outputs may be substituted for universal inputs and outputs provided control meets the requirements of Section 25 09 10 Appendix A (Sequences of Operation).

2.9 POWER SUPPLIES AND LINE FILTERING

1. Power Supplies. Control transformers shall be CSA listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

    1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

        1. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
        2. Line voltage units shall be UL recognized and CSA listed.

2. Power Line Filtering.

    1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

        1. Dielectric strength of 1000 V minimum
        2. Response time of 10 nanoseconds or less
        3. Transverse mode noise attenuation of 65 dB or greater
        4. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.10 AUXILIARY CONTROL DEVICES

1. Motorized Control Dampers.

1. Type. Control dampers shall have linear flow characteristics and shall be parallel- or opposed-blade type as specified below or as scheduled on drawings.

    1. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
    2. Other modulating dampers shall be opposed-blade.
    3. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.
2. Frame. Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (1/8 in.) extruded aluminum with reinforced corner bracing.
3. Blades. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).
4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 50 L/s·m2 (10 cfm per ft2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).
6. Sections. Damper sections shall not exceed 125 cm - 150 cm (48 in. - 60 in.). Each section shall have at least one damper actuator.
7. Linkages. Dampers shall have exposed linkages.
8. Dampers supplied by this section shall be TAMCO 1000 for return air and TAMCO 9000BF for outdoor and exhaust air applications (No exceptions).

2. Electric Damper and Valve Actuators.

    1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
    2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
    3. Signal and Range. Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range.
    4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
    5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 Nm (60 in.-lb) torque capacity shall have a manual crank.

3. Control Valves.

    1. General. Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.
    2. Type: Provide two- or three-way control valves for two-position or modulating service as shown.
    3. Water Valves.

1. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball (Stainless Steel).
2. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.

    1. Two-way: 150% of total system (pump) head.
    2. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

3. Ports: Valves providing modulating service shall have equal percentage ports.
4. Sizing.

    1. Two-position service: line size.
    2. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 21 kPa (3 psi).
    3. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 21 kPa (3 psi).

5. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.

    1. Water zone valves: normally open.
    2. Heating coils in air handlers: normally open.
    3. Chilled water control valves: normally closed.

6. Heating Coil Valves: 2 way and 3 way valves for heating coils and heat exchangers shall be Globe type. Other valves may be ball type to a maximum size of 50 mm (2 inch)..

4. Unitary Control Valves.

    1. Radiation and Reheat control valves shall be of the fully modulating type and shall have a spring return feature. The valve capacity shall be selected with a maximum pressure drop of 21kPa (3 psi).
    2. These valves shall be used for all unitary applications such as radiators, convectors, radiant panels, force flows and reheat coils with flow rates up to 12 GPM (.75 l/s) in both two-way and three-way (mixing and diverting service) configurations as noted on the control drawings and on the mechanical drawings.
    3. The valve body shall be brass with stainless steel stems and brass seats. Ball valves shall have stainless steel balls. Valves to be suitable for water and 60% glycol solutions with temperature range of at least 20 C to 110 C. Rangeability shall be 50:1 or better, leakage rate not to exceed 0.02%. Two-way valves shall have close-off ratings of at least 45 psi (310 kPa), three-way valves at least 25 psi (170 kPa).
    4. Valve actuators shall be linear electric actuators to provide proportional control (2-10Vdc Input). The actuator shall have a spring return feature for normally

open operation. The actuator shall be readily removable for servicing and replacement

5. Where valves are required for control of unitary devices such as radiator convectors, fin tube convectors, radiant panels, reheat coils, etc., ensure that operator tops are small enough to fit neatly inside corresponding enclosures without cutting. Total size (valve plus actuator) shall not exceed 140 mm (height) to allow mounting inside radiation enclosures.

5. Binary Temperature Devices.

1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL/CSA listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL/CSA listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

6. Temperature Sensors.

1. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.

1. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m2 (10 ft2) of duct cross-section.
2. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
3. Space temperature sensors shall have LCD displays or blank covers as noted.
4. Differential Sensors. Provide matched sensors for differential temperature measurement.
5. Sensors shall be non-proprietary and shall be readily available from multiple vendors.

7. Humidity Sensors.

1. Duct and room sensors shall have a sensing range of 20%-80% with 2% accuracy.
2. Duct sensors shall have a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 10%-95% RH and shall be suitably for ambient conditions of -40°C to +50°C and an accuracy of 1%.

4. Space humidity sensors shall have blank covers.
5. Humidity sensors shall not drift more than 1% of full scale annually.

8. Flow Switches.

1. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be CSA listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
2. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
3. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

9. Relays.

1. Control Relays. Control relays shall be plug-in type, CSA listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, CSA listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

10. Current Transmitters.

1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

11. Current Transformers.

1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

12. Voltage Transmitters.

1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.

2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

13. Voltage Transformers.

1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

14. Power Monitors.

1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL/CSA listed voltage transformers, and UL/CSA listed split-core current transformers.
2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

15. Current Switches.

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

16. Pressure Transducers.

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer-sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

17. Differential Pressure Switches.

1. Differential pressure switches (air or water service) shall be UL/CSA listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

18. Static Pressure Transmitters.

    1. Transmitters shall have an Output signal of 4-20 mA linear into 500 ohm maximum load. Calibrated span shall not exceed 150% of maximum static pressure expected. Accuracy shall be 0.4% of span and Repeatability within 0.5% of output. Linearity to be within 1.5% of span and Deadband or Hysteresis of 0.1% of span. Provide external exposed zero and span adjustment. The sensing element in the space shall be inside a protective cover to match the room temperature sensor.

19. Liquid Level Switches

    1. Liquid level activated switch sealed in waterproof and shockproof enclosure.
    2. Complete with float, flexible cord, weight. Instrument casing to be suitable for immersion in measured liquid.
    3. N.O./N.C. Contacts rated at 15 amps at 120V AC. CSA approval for up to 250 volt 10 amps AC.

20. Air Quality Sensors (CO2).

    1. Microprocessor controlled, fully digital, non-dispersive, dual wavelength infrared, temperature compensated.
    2. Sensor shall be equipped with the following features:
    3. 0-3000 PPM and 0-2000 PPM
    4. Accuracy ± 25 PPM in 15 to 30C range
    5. Outputs: RS232, 4-20mA, 0-10V
    6. Supply Voltage 12VDC or 24VAC/DC
    7. Duct mounting: Approved Product for duct applications: COMAQ IR PPM 4022H (No Exceptions).
    8. Approved Product for space mount applications: VULCAIN 90DM3A (No Exceptions).

21. Gas Detection Sensors (CO and NO2).

    1. Transmitter certified to CA/CSA C22.2 No. 61010-1
    2. Sensor shall be Electrochemical
    3. 0-100 ppm (CO) and 0-10 ppm (NO2)
    4. Accuracy ± 3%
    5. Outputs: 4-20mA and Relay 5A
    6. Audible alarm 65dBA at 1m
    7. Supply Voltage 17-27Vac or 24-38 Vdc
    8. Approved Product: VULCAIN VA201T c/w LCD display

22. Override Timers.

    1. Override timers shall be spring-wound line voltage, UL listed, with contact rating and configuration as required by application. Provide 0 to 6 hour calibrated dial unless otherwise specified. Timer shall be suitable for flush mounting on control panel face and located on local control panels or where shown.
    2. Approved Product: Paragon

23. Variable Frequency Drives

1. Provide Variable Frequency Drives consisting of a Pulse Width Modulated (PWM) inverter designed for use on standard NEMA Design B induction motors.
2. The VFD manufacturing facility shall be ISO 9001 certified. The VFD shall be UL (UL508C) listed, Canadian UL listed and CSA listed.
3. Submit manufacturer's performance data including dimensional drawings, power circuit diagrams, installation and maintenance manuals, warranty description, VFD's FLA rating, certification agency file numbers and catalogue information
4. Provide VFDs to convert three phase, 60 Hz, 600 volt utility power to an adjustable voltage and frequency, 3 phase power output for stepless motor speed control from 10% to 100% of the motors normal 60 Hz speed.
5. The VFD shall be enclosed in a UL listed Type 12 enclosure and shall be completely assembled.
6. For VFD's operating Standard /High efficiency, non inverter rated motors, output LC-DV/DT Filters must be used. Output LC- DV/DT filters to be manufactured by TCI or MTE.
7. Provide input DC Line Choke. Line noise shall be no greater than 3% harmonic distortion in accordance with IEEE Standard 519 as measured from the 3rd to 21st harmonic at the branch circuit connection. Install harmonic filters to meet this condition.
8. VFD shall have integral 5% impedance line reactors to reduce harmonics to the power line.
9. Provide VFDs capable of accepting full 575V, 3 phase line voltage at the input terminals and capable of operating within rated input voltage of +\- 10% at 60 Hz.
10. Design VFD to suppress all electrical and radio interference. The VFD shall comply with FCC Part 15, Class A.
11. Provide communication capability using R485 or 232 serial Bus. Standard communication shall include Siemens FLN, Johnson N2 and Modbus RTU. Provide communication through BACnet BUS.
12. A minimum of Class 20 I2t electronic motor overload protection for single motor applications and thermal-mechanical overloads for multiple motor applications shall be provided.
13. VFD shall be capable of starting into a rotating motor operating forward or reverse up to full speed.
14. Hand/Start, Off/Stop and Auto/Start selector switches shall be provided to start and stop the VFD and determine the speed reference.
15. Run permissive circuit shall be provided to accept a "system ready" signal to ensure that the VFD does not start until dampers or other auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of sending an output signal as a start command to actuate external equipment before allowing the VFD to start.
16. The VFD shall store in memory the last 10 faults and related operational data.
17. Two programmable relay outputs, one Form C 240 V AC, one Form A 30 V AC, shall be provided for remote indication of VFD status.
18. Two programmable analog inputs shall be provided and shall accept a direct-or-reverse acting signal. Analog reference inputs accepted shall include two voltage (0 to 10 V DC, 2 to 10 V DC) and one current (0 to 20 mA, 4 to 20 mA) input.
19. Two PID Setpoint controllers for pressure or flow signals

20. Two programmable 0 to 20 mA analog outputs shall be provided for indication of VFD status. These outputs shall be programmable for output speed, frequency, current and power. They shall also be programmable to provide a selected 24 V DC status indication.
21. Unless otherwise noted, all VFD's shall be supplied with the following:

    .1 Speed potentiometer or speed selection via keypad
    .2 5% DC Line Choke for the reduction of line harmonics and transient voltages
    .3 HOA function
    .4 Hand Run/Stop switch
    .5 Input fused disconnect switch
    .6 Thermal motor overload relay
    .7 Main fused disconnect switch where applicable
    .8 Control transformer 150 VA, 600/120 volt, fused primary and secondary
    .9 Output DV/DT filter (where required as per 2.1.2)

22. Approved manufacturers

    .1 ABB
    .2 Cutler Hammer

24. Local Control Panels.

    1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
    2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be CSA listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
    3. Each local panel shall have a control power source power switch (on-off) with over-current protection.
    4. Provide sprinkler shields for panel located in sprinklered areas.

25. Motion Detectors.

    1. The Dual Technology sensor shall be capable of detecting presence in the control area by detecting doppler shifts in transmitted ultrasound and passive infrared heat changes.
    2. Sensor shall utilize Dual Sensing Verification Principle for coordination between ultrasonic and PIR technologies. Detection verification of both technologies must occur in order to activate lighting systems. Upon verification, detection by either shall hold lighting on.
    3. Sensor shall have a retrigger feature in which detection by either technology shall retrigger the lighting system on within 5 seconds of being switched off.
    4. Ultrasonic sensing shall be volumetric in coverage with a frequency of 40 KHz. It shall utilize Advanced Signal Processing which automatically adjusts the detection threshold dynamically to compensate for constantly changing levels of activity and air flow throughout controlled space.

5. Sensor shall be capable of corner mounting to a wall or ceiling in order to eliminate detection through open doorways and outside of controlled area. To provide superior small motion detection and immediate activation upon entry, coverage of both technologies must be complete and overlapping throughout the controlled area.
6. To avoid false ON activations and to provide immunity to RFI and EMI, Detection Signature Analysis shall be used to examine the frequency, duration, and amplitude of a signal, to respond only to those signals caused by human motion.
7. Sensor shall operate at 24 VDC/VAC and half-wave rectified and utilize a Watt Stopper power pack.
8. The PIR technology shall utilize a temperature compensated, dual element sensor and a multi-element Fresnel lens. The lens shall be Poly IR4 material to offer superior performance in the infrared wavelengths and filter short wavelength IR, such as those emitted by the sun and other visible light sources. The lens shall have grooves facing in to avoid dust and residue build up which affects IR reception.
9. The lens shall cover up to 2000 sq ft for walking motion when mounted at 10 ft and 1000 sq ft of desktop motion.
10. Sensors shall have an additional single-pole, double throw isolated relay with normally open, normally closed and common outputs. The isolated relay is for use with HVAC control, data logging, and other control options.
11. Sensors shall utilize SmartSet™ technology to optimize time delay and sensitivity settings to fit occupant usage patterns. The use of SmartSet shall be selectable with a DIP switch.
12. Sensors shall have a time delay that is adjusted automatically (with the SmartSet setting) or shall have a fixed time delay of 5 to 30 minutes, set by DIP switch.
13. Sensors shall feature a walk-through mode, where lights turn off 3 minutes after the area is initially occupied if no motion is detected after the first 30 seconds.
14. Sensor shall have an override ON function for use in the event of a failure.
15. Sensor shall have a built-in light level sensor that works from 10 to 300 foot candles.
16. Sensor shall have 8 occupancy logic options for customized control to meet application needs.
17. Sensor shall have a manual on function that is facilitated by installing a momentary switch.
18. Each sensing technology shall have an LED indicator that remains active at all times in order to verify detection within the area to be controlled. The LED can be disabled.
19. To ensure quality and reliability, sensor shall be manufactured by an ISO 9002 certified manufacturing facility and shall have a defect rate of less than 1/3 of 1%.
20. Sensor shall have standard 5 year warranty and shall be UL and CUL listed.
21. Acceptable Product: Watt Stopper DT-200 or approved equal.

2.11 WIRING AND RACEWAYS

1. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.
2. Insulated wire shall use copper conductors and shall be UL/CSA listed for 90°C (200°F) minimum service.

PART 3: EXECUTION

3.1 EXAMINATION

1. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Contract Administrator for resolution before starting rough-in work.
2. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Contract Administrator for resolution before starting rough-in work.
3. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Contract Administrator and obtain written instructions for changes necessary to accommodate Section 25 09 10 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

1. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.
2. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

1. Site.

    1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
    2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

2. Test and Balance.

    1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
    2. Train Test and Balance Contractor to use control system interface tools.
    3. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
    4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

3. Life Safety.

    1. Duct smoke detectors required for air handler shutdown are provided under Electrical Division.

2. Smoke dampers and actuators required for duct smoke isolation are provided under Mechanical Division.
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Mechanical. Division. Fire and smoke damper control is provided under Electrical Division.

4. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows.

    1. Communication media and equipment shall be provided as specified in Section 25 09 10 Article 2.2 (Communication).
    2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described in Section 25 09 10 Appendix A regardless of where within the contract documents those products are described.
    3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
    4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 GENERAL WORKMANSHIP

1. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.
2. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.
3. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.
4. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

3.5 FIELD QUALITY CONTROL

1. Work, materials, and equipment shall comply with rules and regulations of applicable local, provincial, and federal codes and ordinances as identified in Section 25 09 10 Article 1.8 (Codes and Standards).
2. Continually monitor field installation for code compliance and workmanship quality.
3. Contractor shall arrange for work inspection by local or provincial authorities having jurisdiction over the work.

3.6 EXISTING EQUIPMENT (WHERE APPLICABLE)

1. Wiring. Interconnecting control wiring shall be removed and shall become Contractor's property unless specifically noted or shown to be reused.
2. Local Control Panels. Remove and deliver existing control panels to the City.
3. Repair. Unless otherwise directed, Contractor is not responsible for repair or replacement of existing energy equipment and systems, valves, dampers, or actuators. Notify Contract Administrator in writing immediately of existing equipment that requires maintenance.

4. Indicator Gauges. Ensure operation of and recalibrate for reasonable accuracy or replace existing gauges.
5. Room Thermostats. Remove and deliver existing room thermostats to the City unless otherwise noted. Where the existing device is replaced with a new device in the same location, provide blank off plates if the new device does not cover the void left.
6. Electronic Sensors and Transmitters. Remove and deliver existing sensors and transmitters to the City.
7. Controllers and Auxiliary Electronic Devices. Remove and deliver existing controllers and auxiliary electronic devices to the City.
8. Damper Actuators, Linkages, and Appurtenances: Remove and deliver existing damper actuators, linkages and appurtenances to the City.
9. Control Valves. Replace existing control valves with new. Deliver removed control valves to the City.
10. Existing System Operating Schedule. Existing mechanical system may be disabled during this work.
11. Maintain fan scheduling using existing or temporary time clocks or control systems throughout the control system installation.
12. Modify existing starter control circuits if necessary to provide hand-off-auto control of each controlled starter. Furnish new starters or starter control packages as required.

3.7 WIRING

1. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26, and manufacturer's recommendations. Where the requirements of Section 25 09 10 differ from the Electrical Division, Section 25 09 10 shall take precedence.
2. NEC Class 1 (line voltage) wiring shall be UL/CSA listed in approved raceway as specified by NEC and Division 26.
3. Low-voltage wiring shall meet NEC Class 2 requirements. Sub fuse low-voltage power circuits as required to meet Class 2 current limit.
4. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL/CSA listed for the intended application.
5. Install wiring in raceway where subject to mechanical damage and at levels below 3 m (10ft) in mechanical, electrical, or service rooms.
6. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
7. Install Class 1 and Class 2 wiring in separate raceways. 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.
8. Do not install wiring in raceway containing tubing.
9. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 3 m (10 ft) intervals.
10. 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.
11. 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.
12. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

13. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
14. Use color-coded conductors throughout.
15. 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.
16. 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.
17. Adhere to requirements in Division 26 where raceway crosses building expansion joints.
18. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.
19. 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.
20. 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.
21. 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. Do not make terminations in boxes with bushings.

3.8 COMMUNICATION WIRING

1. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).
2. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.
3. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.
4. Verify entire network's integrity following cable installation using appropriate tests for each cable.
5. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.
6. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
7. Label communication wiring to indicate origination and destination.
8. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding".
9. Use the the City's existing Ethernet LAN, where available. Where the existing LAN needs to be expanded, obtain approval form the the City's IT department or have the department install the extension at the contractor's expense. Where no Ethernet exists, provide and install suitable Ethernet LAN segment.

3.9 INSTALLATION OF SENSORS

1. Install sensors according to manufacturer's recommendations.
2. Mount sensors rigidly and adequately for operating environment.
3. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

4. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.
5. Use averaging sensors in mixing plenums and hot and cold decks and where noted on the control drawings. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.
6. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (10 ft) of sensing element for each 1 m2 (10 ft2) of coil area.
7. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
8. Install outdoor air temperature sensors on north wall at designated location with sun shield.
9. Install CO and NO2 sensors according to manufacturer's installation guide.
10. Differential Air Static Pressure.

    1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
    4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
    5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
    6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

3.10 FLOW SWITCH INSTALLATION

1. Use correct paddle for pipe diameter.
2. Adjust flow switch according to manufacturer's instructions.

3.11 ACTUATOR INSTALLATION

1. General. Mount actuators and adapters according to manufacturer's recommendations.
2. Electric and Electronic Damper Actuators. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.

    1. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
    2. To compress seals when spring-return actuators are used on normally closed dampers, power actuators to approximately 5° open position, manually close the damper, and then tighten linkage.
    3. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

4. Provide necessary mounting hardware and linkages for actuator installation.

3. Valve Actuators. Connect actuators to valves with adapters approved by actuator manufacturer.

3.12 VFD INSTALLATION

1. General: Variable frequency drives to be installed by Division 26, in locations shown on the contract drawings, or as instructed by the Contract Administrator to provide the best possible connection arrangement and accessibility for service. Ensure mounting location of VFD conforms to maximum allowable distance between VFD and motor load. Include for the filters where maximum recommended distances are exceeded.
2. Start-up Service: The manufacturer shall provide start-up commissioning of the VFD and its optional circuits by a factory certified service technician who is experienced in start-up and repair services. Start-up services shall include checking for verification of proper operation and installation for the VFD, its options and its interface wiring to the building automation system.
3. Warranty: The VFD shall be warranted by the manufacturer for a period of 24 months from date of certified start up, not to exceed 30 months from date of shipment. The warranty shall include parts, labour, travel costs and living expenses incurred by the manufacturer to provide factory authorized on-site service. The warranty shall be provided by the VFD manufacturer.

3.13 WARNING LABELS

1. Affix permanent warning labels to equipment that can be automatically started by the control system.
2. Labels shall use white lettering (12-point type or larger) on a red background.
3. Warning labels shall read as follows.

C A U T I O N
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnects to "Off" position before servicing.

4. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
5. Labels shall use white lettering (12-point type or larger) on a red background.
6. Warning labels shall read as follows.

C A U T I O N
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.14 IDENTIFICATION OF HARDWARE AND WIRING

1. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.

2. Label pneumatic tubing at each end within 5 cm (2 in.) of termination with a descriptive identifier.
3. Permanently label or code each point of field terminal strips to show instrument or item served.
4. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates, attached with self-tapping screws
5. Label each control component with a permanent plastic encased card, attached with a tie. Label plug-in components such that label remains stationary during component replacement. Submit a sample of the label to the Contract Administrator for approval.
6. Label room sensors related to terminal boxes or valves with nameplates.
7. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.
8. Label identifiers shall match record documents.

3.15 PROGRAMMING

1. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 25 09 10 Appendix A (Sequences of Operation). Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.
2. Software Programming. Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.

    1. Application Programming. Provide application programming that adheres to sequences of operation specified in Section 25 09 10 Appendix A. Program documentation or comment statements shall reflect language used in sequences of operation.
    2. System Programming. Provide system programming necessary for system operation.

3. Operator Interface.

    1. Standard Graphics. Provide graphics as specified in Section 25 09 10 Article 2.5.2 (System Graphics). Show on each graphic input and output points for system or equipment displayed. Show relevant calculated points such as setpoints. Point information on graphics shall dynamically update.
    2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation) as described in Section 25 09 10.

3.16 CONTROL SYSTEM CHECKOUT AND TESTING

1. Startup Testing. Complete startup testing to verify operational control system before notifying Contract Administrator of system demonstration. Provide Contract Administrator with schedule for startup testing. The City and Contract Administrator may have representative present during any or all startup testing.

2. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 25 09 10.
3. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
4. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
5. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
6. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
7. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
8. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
9. Submit complete documentation of the check out and calibration performed for all data points, including details on offsets and other calibration functions performed. The documentation shall have the date and time information and the name and sign off of the technician.
10. Alarms and Interlocks.

    1. Check each alarm with an appropriate signal at a value that will trip the alarm.
    2. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.

3.17 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

1. Demonstration. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified in Article 3.16 (Control System Checkout and Testing). Provide Contract Administrator with log documenting completion of startup tests.

    1. Contract Administrator will be present to observe and review system demonstration. Notify Contract Administrator at least 10 days before system demonstration begins.
    2. Demonstration shall follow process submitted and approved under Section 25 09 10 Article 1.10 (Submittals). Complete approved checklists and forms for each system as part of system demonstration.
    3. Demonstrate actual field operation of each sequence of operation as specified in Section 25 09 10 Appendix A. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Contract Administrator. Provide and operate test equipment required to prove proper system operation.
    4. Demonstrate compliance with Section 25 09 10 Part 1 (System Performance).
    5. Demonstrate compliance with sequences of operation through each operational mode.
    6. Demonstrate complete operation of operator interface.

7. Demonstrate each of the following:

    1. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Contract Administrator will require further tuning of each loop that displays unreasonably under- or over-damped control.
    2. Demand limiting (where applicable). Supply trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
    3. Building fire alarm system interface (where applicable)
    4. Trend logs for each system. Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation in Section 25 09 10 Appendix A. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified in Section 25 09 10 Article 2.5.3.11 (Trend Configuration).

8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

2. Acceptance.

    1. After tests described in this specification are performed to the satisfaction of both Contract Administrator and the City, Contract Administrator will accept control system as meeting completion requirements. Contract Administrator may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Contract Administrator will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
    2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 25 09 10 Article 1.10 (Submittals).

3.18 CLEANING

1. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.
2. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.
3. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.19 TRAINING

1. Provide training for a designated staff of the City's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.
2. Training shall enable students to accomplish the following objectives.

    1. Proficiently operate system
    2. Understand control system architecture and configuration
    3. Understand DDC system components
    4. Understand system operation, including DDC system control and optimizing routines (algorithms)
    5. Operate workstation and peripherals
    6. Log on and off system
    7. Access graphics, point reports, and logs
    8. Adjust and change system setpoints, time schedules, and holiday schedules
    9. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
    10. Understand system drawings and Operation and Maintenance manual
    11. Understand job layout and location of control components
    12. Access data from DDC controllers
    13. Operate portable operator's terminals
    14. Create and change system graphics
    15. Create, delete, and modify alarms, including configuring alarm reactions
    16. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs
    17. Configure and run reports
    18. Maintain software and prepare backups

3. Divide presentation of objectives into two sessions (1-13, 14-18). Participants will attend one or more of sessions, depending on knowledge level required.

    1. Day-to-day Operators (objectives 1-13)
    2. Advanced Operators (objectives 1-13 and 14-18)

4. Provide course outline and materials according to Section 25 09 10 Article 1.10 (Submittals). Provide one copy of training material per student.
5. Instructors shall be factory-trained and experienced in presenting this material.
6. Perform classroom training using a network of working controllers, representative of installed hardware.
7. Training shall be a minimum of 8 hours. Allow for an additional 4 hours of training during the warranty period.

3.20 SEQUENCE OF OPERATION

See Section 25 09 10 Appendix A (Sequences of Operation).

3.21 POINTS LIST

Refer to control schematics.

3.22 GLOSSARY OF TERMS

See Section 25 09 10 Appendix B (Glossary of terms).

APPENDIX A: Sequences of Operation

A. GYM AIR HANDLING UNIT AHU-1

General:

This unit is a packaged air handling unit complete with all temperature controls and a BACnet interface for connection to the Temperature Control System (TCS). The TCS shall provide motion detection (via 4 motion detectors into 2 Digital Inputs) in the Gym and time scheduling of the air handling unit (via a Digital Output to the AHU control panel).

BACnet Interface:

The TCS shall connect to the AHU's BACnet server and shall make all related data points available to the TCS. Provide a graphic, complete alarm management and trending for the system.

B. GENERAL AIR HANDLING UNIT AHU-2 CONTROL

General:
The air handling unit is supplied with a digital supply air temperature controller for the cooling section only. The controller has a BACnet server to transfer pertinent information to the TCS.

Run Conditions – Occupied/Unoccupied:
The system shall run continuously during occupied hours and shall maintain a supply air setpoint. The system shall be off during the unoccupied hours, unless started by the Night Cycle Program.

Supply Air Temperature Control:

The supply air temperature setpoint shall be reset between 13°C (55°F) and 22°C (72°F) (adj.) by the average of the temperature sensor in the areas served by the unit (reheat coil temperature sensors). The setpoint shall modulate the 2-way valve on the heating coil, in sequence with the economizer dampers.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 2°C greater than the supply air setpoint in heating mode.
- Low Supply Air Temp: If the supply air temperature is 2°C less than the supply air setpoint.

Mixed Air Dampers:
The mixing dampers shall activate only when the supply air temperature loop requires free cooling, as determined by the supply air temperature loop.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a low temperature status from the supply air temperature sensor.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run. The fan shall run for a minimum of 5 min (adj.) and be off a minimum of 5min (adj.) unless shutdown on safeties.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit.

HRV:
The HRV is associated with this air handling unit and provides preheated outdoor air to the unit. The HRV shall be enabled whenever the air handling unit is operating and the system is in heating mode or mechanical cooling (DX) mode.

The HRV exhaust fan EF-1 normally runs when the air handling unit supply fan is in the occupied mode. The HRV supply fan SF-1 shall run in the heating mode and in the mechanical cooling (DX) mode. When the air handling unit is in the free cooling mode and the return air damper is closed, the exhaust fan EF-2 shall start and run as long as the air handling unit is in the free cooling mode.

The VFDs for SF-1 and EF-1 are provided for balancing purposes only.

The HRV isolation dampers (outdoor air and exhaust air) shall open when the HRV's exhaust fan EF-1 is running and shall close when the exhaust fan is off.

CO2 (IAQ) Monitoring:

Provide monitoring of the CO2 concentration in the return air ducts (to the HRV and to the air handling unit).

Alarms shall be provided as follows:

- Return air CO2 above 1200PPM.

Filter Monitoring:

Monitor the filter pressure drop. Alarms shall be provided as follows:

- Filter Status: An alarm shall be generated if the filter differential pressure exceeds its programmed high limit setting (adjustable).

C. KITCHEN MAKE UP AIR UNIT MUA-1 and KITCHEN EXHAUST FAN

General:

This unit is a packaged air handling unit complete with all temperature controls and a Remote Panel. An airflow switch is provided by the unit manufacture for the exhaust fan interlock and for wiring by the electrical Division.

TCS Monitoring:

The TCS shall provide monitoring of the supply air temperature, unit status and heat status. Also provide monitoring of the kitchen exhaust fan status

D. ZONE VAV TERMINAL AND TERMINAL REHEAT COIL CONTROL (typical)

Occupied/Unoccupied:
The system shall maintain a day (occupied) setpoint of 22°C (72°F) (adj.) and night (unoccupied) setpoint of 15°C (60°F) (adj.).

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is 2°C greater than the setpoint.
- Low Zone Temp: If the zone temperature is 2°C less than the setpoint.

VAV Terminal and Terminal Tempering Coil Valve
The controller shall measure the zone temperature and modulate VAV damper (Cooling) in sequence with the electric reheat coil to maintain setpoint. The VAV terminal shall have minimum and maximum flow settings as noted in the specifications.

On a call for cooling the VAV damper shall modulate to the open (maximum) position. On a call for heating the damper will modulate closed to the minimum position and on a further call for heating the reheat coil will energize. If this is insufficient to maintain the temperature the VAV damper will modulate to the open (maximum) position.

E. HEATING PLANT

General:
Provide all monitoring functions as noted on the control drawings.

Temperature Control:
The boilers shall be controlled by a packed control system, provided with the boilers. The control system has a MODBUS communications board to facility communicating all pertinent boiler data to the TCS. The integral boiler circulators are interlocked with the boiler controls. The 2 boilers shall be enabled by the TCS on a Lead/Lag function via the MODBUS communications. The lead boiler shall be selected weekly. The boilers shall only be enabled when the primary (lead) circulator pump is operating.

Primary Loop Circulating Pumps P-1, P-2 Control:
The pumps are 100 percent pumps in a Lead and Stand-by control. When the building is in the heating mode (outdoor air temperature below 10ºC) the Lead pump shall start and run continuously. If the Lead pump fails the Stand-by pump shall start and an alarm shall be initiated at the OWS. If both pumps fail, a critical alarm shall be initiated.
The Lead pump shall be selected weekly.

Alarms shall be provided as follows:

- Pump Failure: Commanded on, but the status is off.
- Pump in Hand: Commanded off, but the status is on.

- Pump Runtime Exceeded

Secondary Loop Circulating Pump P-3 Control:
The pump will typically run continuously in the heating mode, as determined by an outdoor temperature setpoint (initial setting 10ºC (50ºF)). The pump shall be off when heating is not required, as determined by an outdoor temperature setpoint (initial setting 12ºC (53ºF)).
The loop differential pressure shall be controlled at a setpoint as instructed by the Contract Administrator, by modulating the output of the variable speed drive on the pump.

Alarms shall be provided as follows:

- Pump Failure: Commanded on, but the status is off.
- Pump in Hand: Commanded off, but the status is on.
- Pump Runtime Exceeded

Glycol Tank Level Alarm:
A float level switch in the glycol tank shall signal the TCS when the glycol level drops below its setpoint.

F. DOMESTIC HOT WATER SYSTEM

Recirc pump control:
The pump shall run continuously when the building is occupied and shall be off when the building is unoccupied.

Tank Temperature

The system shall monitor the tank temperature and generate alarms if it is above or below the desired temperature.

G. FORCE FLOW HEATER

Temperature Control
The thermostat shall measure the zone temperature and cycle the force flow fan and heater to maintain setpoint.

H. SUMP PIT ALARM

High Level alarm
A critical alarm shall be generated if the water level in the sump pit exceeds the high limit setpoint.

APPENDIX B: Glossary of Terms

Control Terms used within the Sequences of Operation:

- **adj.**

  Adjustable by the end user, through the supplied user interface.

- **AI, AO, etc.**

  AI = Analog Input. A physical input to the control module.
  AO = Analog Output. A physical output from the control module.
  AV = Analog Value. An intermediate (software) point that may be editable or read-only. Editable AVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only AVs are typically used to display the status of a control operation.
  DI = Digital (or Binary) Input. A physical input to the control module.
  DO = Digital (or Binary) Output. A physical output from the control module.
  DV = Digital (or Binary) Value. An intermediate (software) point that may be editable or read-only. Editable DVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only DVs are typically used to display the status of a control operation.
  Sched = Schedule. The control algorithm for this equipment shall include a user editable schedule.
  Trend. The control system shall be configured to collect and display a trend log of this object. The trending interval shall be no less than one sample every 5 minutes. (Change of Value trending, where a sample is taken every time the value changes by more than a user-defined minimum, is an acceptable alternative.)
  Alarm. The control system shall be configured to generate an alarm when this object exceeds user definable limits, as described in the Sequence of Controls.

  Note: If the specifications require use of the BACnet protocol, all of the above shall be provided as BACnet objects.

- **KW Demand Limiting:**

  An energy management strategy that reduces energy consumption when a system's electric power meter exceeds an operator-defined threshold.

  When power consumption exceeds defined levels, the system automatically adjust setpoints, de-energizes low priority equipment, and takes other pre-programmed actions to avoid peak demand charges. As the demand drops, the system restores loads in a predetermined manner.

- **Occupant Override Switch, or Timed Local Override:**

  A control option that allows building occupants to override the programmed HVAC schedule for a limited period of time.

  When the override time expires, the zone returns to its unoccupied state.

- **Occupant Setpoint Adjustment:**

  A control option that allows building occupants to adjust - within limits set by the HVAC control system - the heating and cooling setpoints of selected zones. Typically the user interface for this function is built into the zone sensor.

- **Optimal Start-Up:**

  A control strategy that automatically starts an HVAC system at the latest possible time yet ensures comfort conditions by the time the building becomes occupied.

  A controller measures the temperature of the zone and the outside air. Then, using design heating or cooling capacity at the design outside air temperature, the system computes how long a unit must run at maximum capacity to bring the zone temperature to its occupied setpoint.

  The optimal start algorithm often includes a self-learning feature to adjust for variations from design capacity.

  A distributed system must use Run on Request with Optimal Start. (See below.)

- **Requested, or Run on Request:**

  A control strategy that optimizes the runtime of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service. Source equipment runs only when needed, not on a fixed schedule.

  The source equipment runs when one or more receiving units request its services. An operator determines how many requests are required to start the source equipment.

  For example, if all the zones in a building are unoccupied and the zone terminal units do not need heating or cooling, the AHU will shut down. However, if a zone becomes occupied or needs cooling, the terminal unit will send a run request to the AHU to initiate the start-up sequence. If this AHU depends on a central chiller, it can send a run request to the chiller.

  The run on request algorithm also allows an operator to schedule occupancy for individual zones based on the needs of the occupants without having to adjust the schedules of related AHUs and chillers.

  Setpoint Optimization, or Trim and Respond:

  A control strategy that optimizes the setpoint of a source piece of equipment that supplies one or more receiving units - such as an air handler unit supplying zone terminal units with heating, cooling, ventilation, or similar service.

  The source unit communicates with receiving units to determine heating, cooling, and other requirements, and then adjusts its setpoint.

For example, if all zones are comfortable and do not request cooling, the AHU will gradually increase (trim) its supply air setpoint. When a zone requests cooling, the AHU responds by dropping its setpoint. The more zones that request cooling, the more it drops the setpoint. The AHU repeats this process throughout the day to keep zones cool, but no cooler than necessary.

Contracting Terms:

- **Furnished or Provided:**

  The act of supplying a device or piece of equipment as required meeting the scope of work specified and making that device or equipment operational. All costs required to furnish the specified device or equipment and make it operational are borne by the division specified to be responsible for providing the device or equipment.

- **Install or Installed:**

  The physical act of mounting, piping or wiring a device or piece of equipment in accordance with the manufacturer's instructions and the scope of work as specified. All costs required to complete the installation are borne by the division specified to include labor and any ancillary materials.

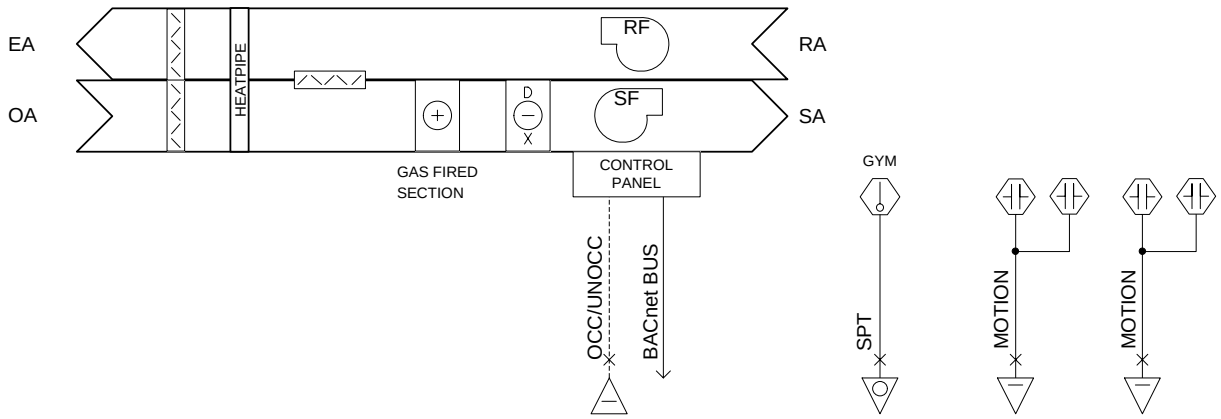
- **Interface:**

  The physical device required to provide integration capabilities from an equipment vendor's product to the control system. The equipment vendor most normally furnishes the interface device. An example of an interface is the chilled water temperature reset interface card provided by the chiller manufacturer in order to allow the control system to integrate the chilled water temperature reset function into the control system.

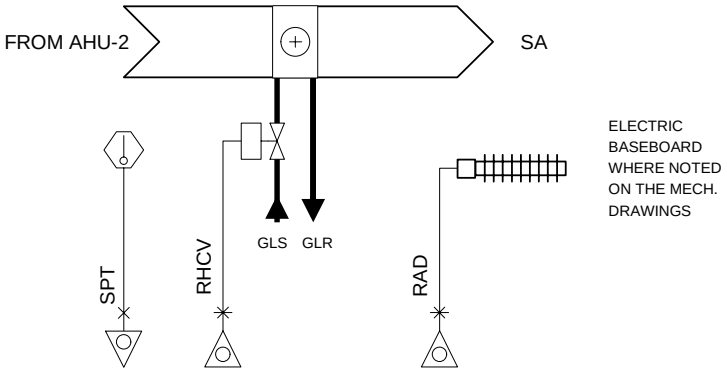
- **Integrate:**

  The physical connections from a control system to all specified equipment through an interface as required allowing the specified control and monitoring functions of the equipment to be performed via the control system.

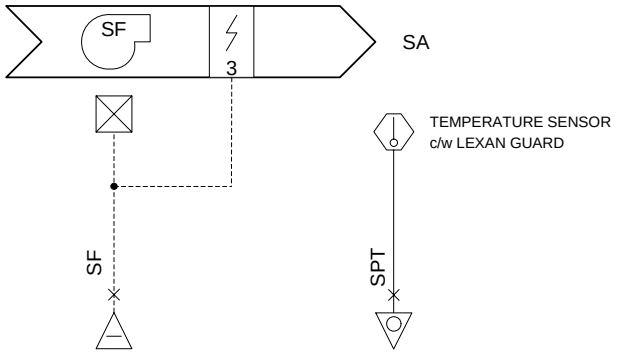
END OF SECTION



GYM AIR HANDLING UNIT AHU-1



REHEAT AND RADIATION CONTROL



FORCE FLOW CONTROL

NOTES

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ARCHITECTS INC.
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PROJECT

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490 SINCLAIR STREET, WINNIPEG

DRAWING

GYMNASIUM
AIR HANDLING UNIT AHU-1
MISCELLANEOUS

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CHECKED BY: CMD	DATE
SCALE: NTS	
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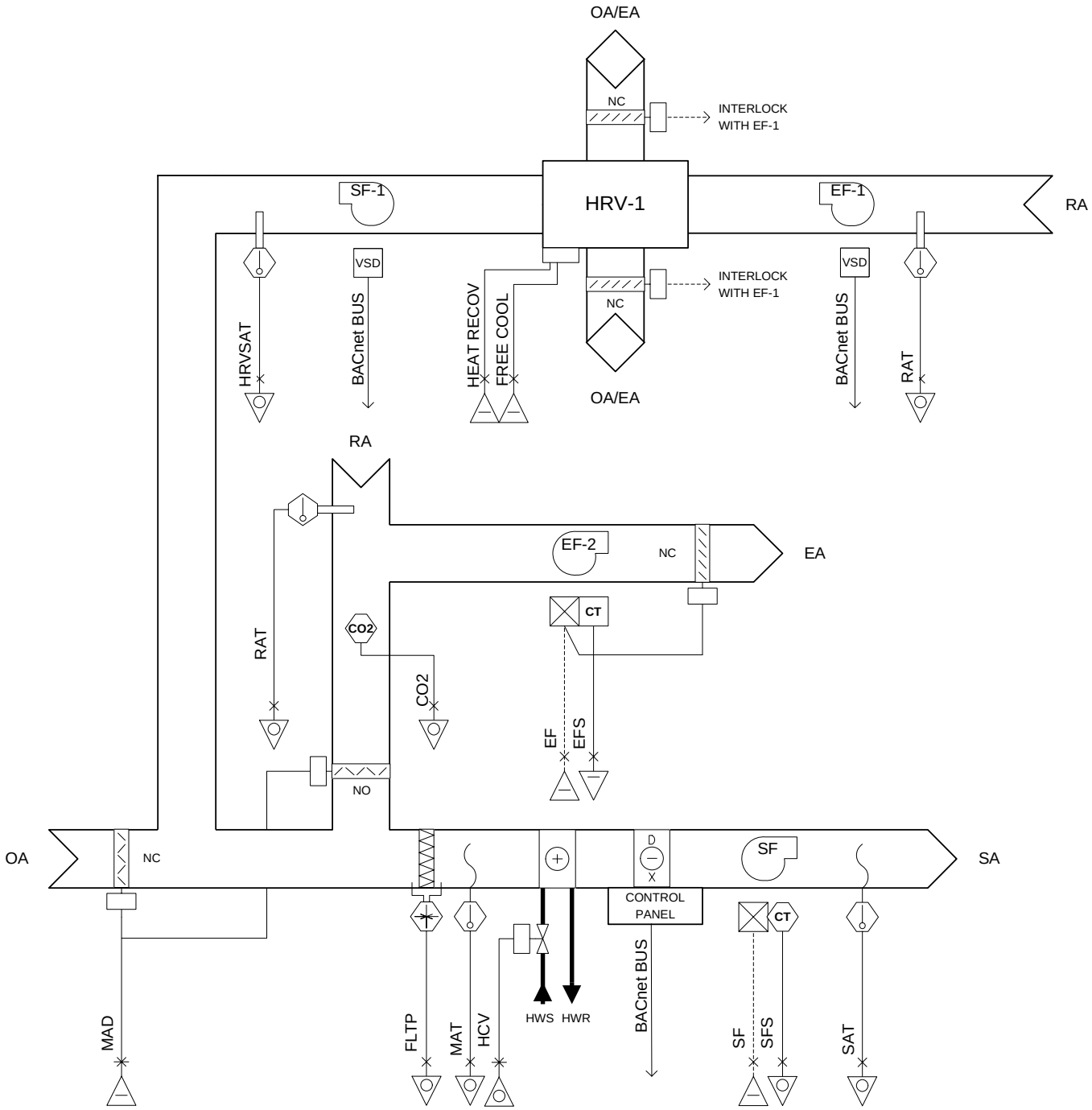

GENERAL AIR HANDLING UNIT AHU-2

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GENERAL AIR HANDLING UNIT AHU-2

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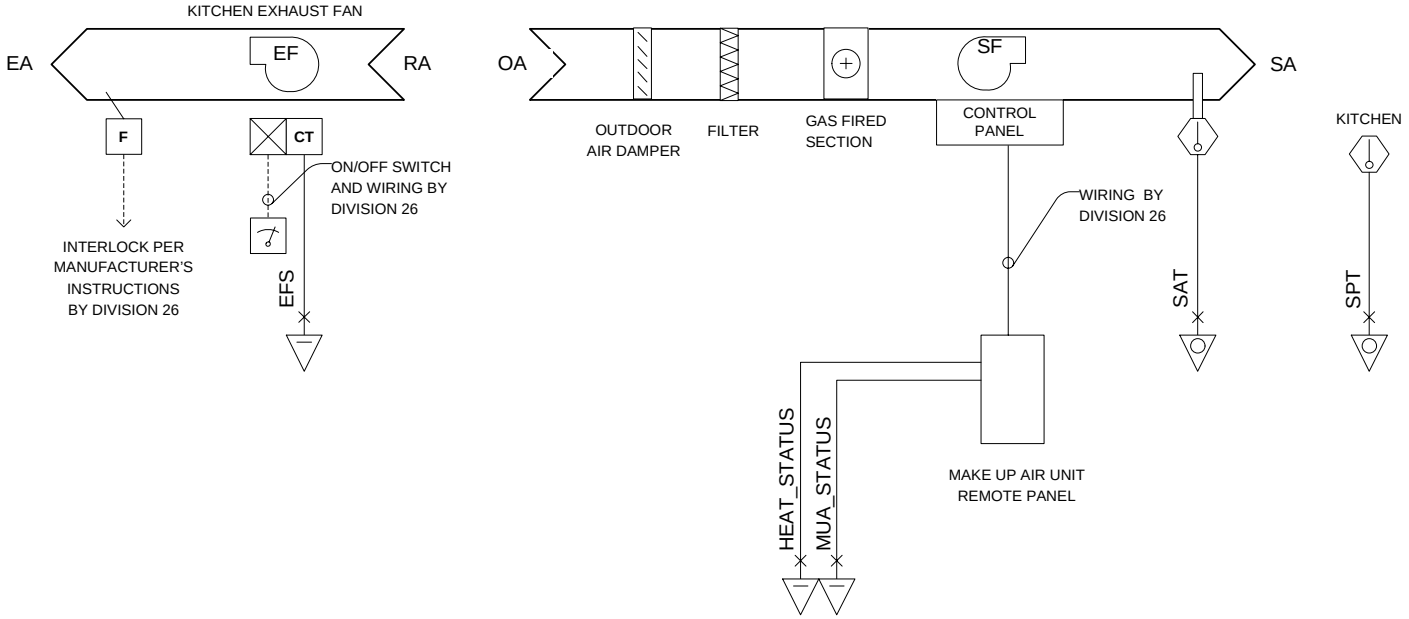

KITCHEN MAKE UP AIR UNIT MUA-1

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KITCHEN MAKE UP AIR UNIT MUA-1

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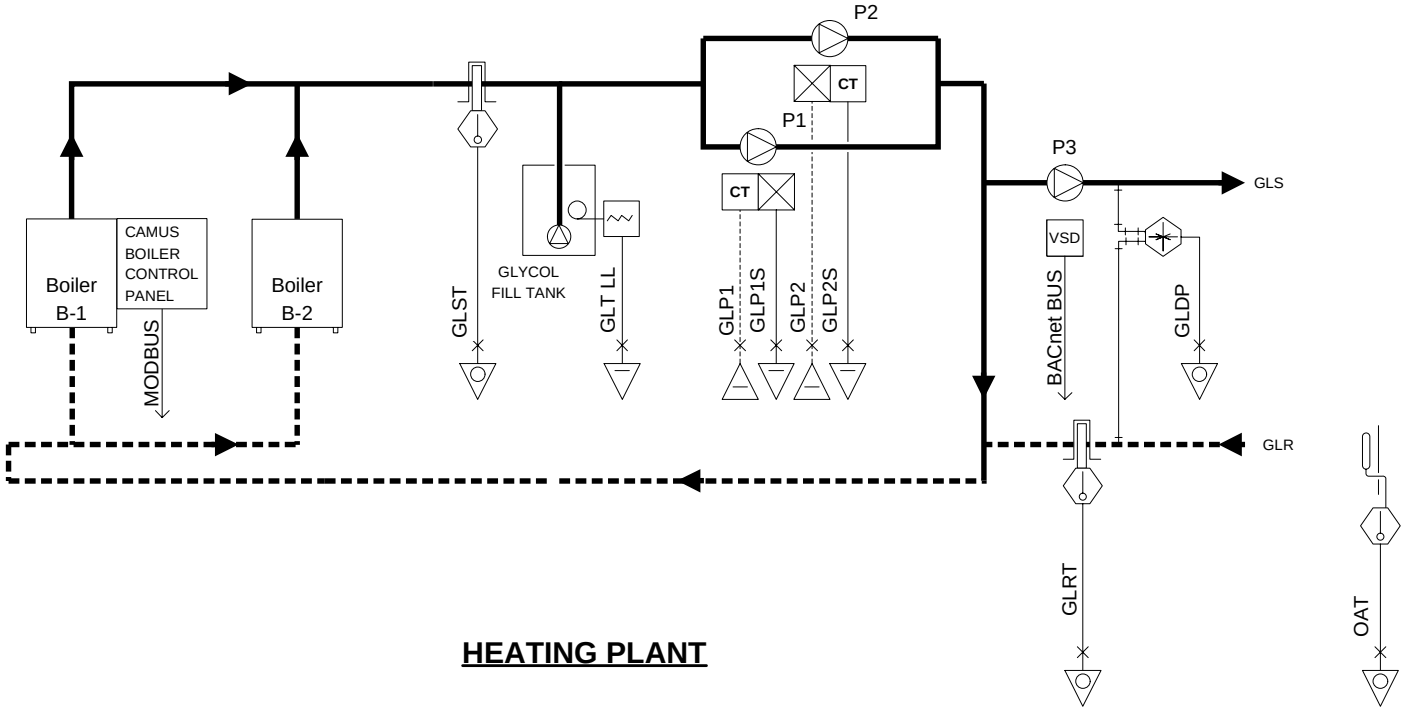
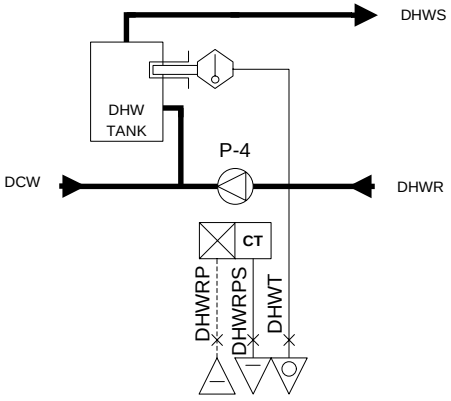
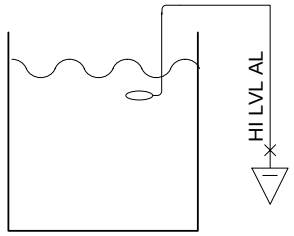


HEATING PLANT



DHW SYSTEM



SUMP PIT ALARM

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DRAWING

HEATING PLANT
DHW SYSTEM
SUMP PIT

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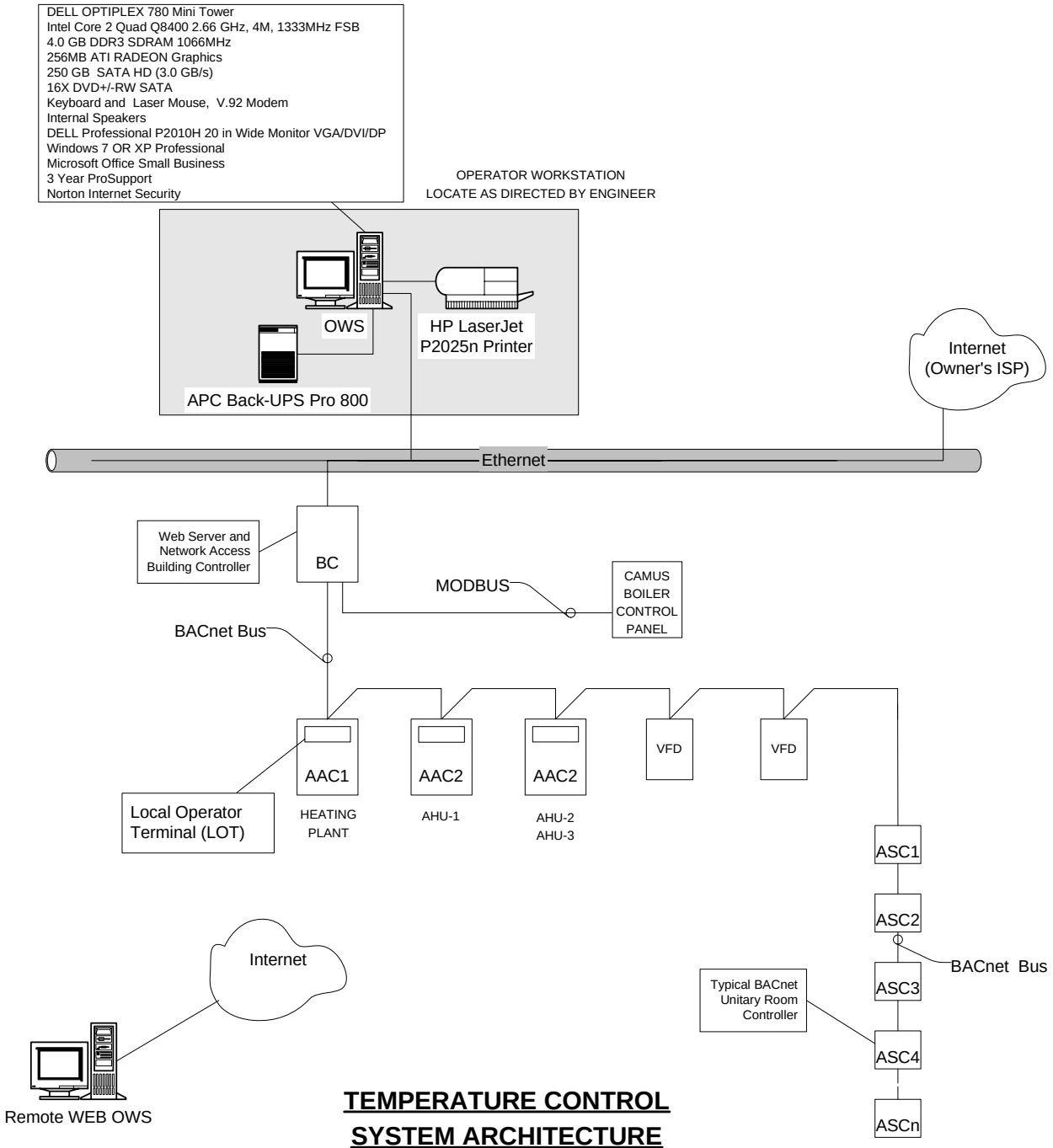

TEMPERATURE CONTROL SYSTEM ARCHITECTURE

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TEMPERATURE CONTROL SYSTEM ARCHITECTURE

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