This in-house staff executive summary is intended to highlight commonly encountered issues in DDC system design & installation. Each item contains a short summary and specific reference to more detailed information contained within the full technical guideline document.

- Approved Manufacturer – Reliable Controls or Delta Controls 23 09 23 1.3.A.
  - Control system should match any existing controls 23 09 23 1.3.A.2.
  - Installing contractor shall be manufacturer authorized and trained 23 09 23 1.4.A.
- Control Hardware must be natively BACnet 23 09 23 1.1.A.1.
  - Gateways to non-BACnet systems are not acceptable 23 09 23 1.1.A.2.
  - New products of latest product line. 23 09 23 2.1.A.
- Internet or CoV Network access will be provided for every system 23 09 23 1.1.A.3.
- Controlled equipment – All Typical HVAC equipment including:
  - Exhaust fans 23 09 23 1.2.C.5.
  - Lighting Control where appropriate 23 09 23 1.2.C.8.
  - Irrigation Systems where appropriate 23 09 23 1.2.C.9.
  - Energy/Resource Meters 23 09 23 1.2.C.10.
- Stand Alone Operation – Each mechanical system controlled by a single DDC controller. Points are not split across multiple controllers. 23 09 23 2.2.C.4.
- Controllers to include built-in override switches where available. 23 09 23 2.3.F. & G.

- System Warranty – Minimum 12 Months after Final Acceptance 23 09 23 1.7.A.1.
- Machine/electrical and storage rooms – Install DDC sensors and control instead of stand alone devices. 23 09 23 2.5.F.
- Control Panel Requirements. Adequate space, wire installed in wire ducts and utility plug/shut off switch provided. 23 09 23 2.5.Q.
- Existing Equipment. Use of existing equipment should be carefully considered and approved for each project. 23 09 23 3.6.
- Hardware and Wiring Identification 23 09 23 3.13
    - Laminated As-built at control panels
    - Control sensors and control devices should have point tags attached
- System Checkout and Testing by Contractor 23 09 23 3.16.
    - Seasonal Calibration during Warranty Period 23 09 23 3.16.B.
- System Demonstration and Acceptance 23 09 23 3.17
- System Training to be provided 23 09 23 3.19
- Sequence of Operation for all systems to be provided during design phase of project. 23 09 23 3.20.
    - Sequences shall contain energy saving measures 23 09 23 3.20.A.8
    - Example Sequences provided in section 23 09 93.

DDC Technical Guidelines

Version 1.1

REAL ESTATE AND FACILITIES MANAGEMENT

Date: 04/11/2018

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23 09 23 Direct-Digital Control System for HVAC

PART 1: GENERAL

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1.1 Description

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controller and an operator interface.
   1. Each individual DDC device will be natively BACnet and will be capable of communicating directly using the BACnet communications protocol with other devices.
      a. All BACnet controllers shall be listed by the BACnet testing laboratories (BTL) for the appropriate device profile. Product listings are available from BACnet International (http://www.bacnetinternational.net/btl/).
   2. Communications gateways, bridges, protocol translators or any other device that translates any proprietary communication protocol to BACnet shall not be permitted as part of the DDC system.
Δ 3. Remote operator access shall be provided to each system/building of BACnet devices.
      a. In buildings without City of Vancouver (CoV) network infrastructure, this will require a separate internet connection for at least one IP connected controller within the site. Remote internet connection shall be provided by others and will have a static WAN IP address.
      b. In buildings with CoV network infrastructure managed by the CoV IT department, each DDC controller with an Ethernet connection shall be provided with an IP drop that is part of the overall building structured cabling system. Each IP drop shall be labeled and certified to the same standards as the entire structured cabling system.
         i. Structured cabling work within existing buildings shall be performed by a contractor authorized by the CoV IT department.
   4. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends and alarms specified in 23 09 93 – “Sequence of Operations for HVAC Controls” shall be BACnet objects.

1.2 Controlled Building Equipment

A. The intent of a Building Automation System is not to individually control the operation of each installed piece of equipment but to create a cohesively organized building that will coordinate all systems simultaneously. Systems shall be designed, selected, programmed and commissioned so that the end result is a building the both maximizes occupant comfort while still maintaining energy efficiency. The building shall be designed as a whole with sub-systems that communicate and coordinate wherever necessary in order to accomplish this goal.
B. Each controlled piece of equipment or equipment type shall be designed with a detailed sequence of operations and shall include energy optimization measures as detailed in Section 23 09 23 Article 3.20. This sequence of operations shall be

included in the design documentation. Example sequences of operations are also provided in Section 23 09 93 at the end of this document.

C. The control system shall be primarily designed to control all HVAC system equipment that has a direct influence on the comfort and energy utilization of the building. Where possible and desirable, the control system shall also be integrated/coordinated with other systems that affect the energy or resource usage of the building. This includes but is not limited to:
   1. Air Handler Units
   2. Roof Top Units
   3. Heat Recover Ventilators
   4. Terminal Equipment such as VAVs, Fan Coils, Heat Pumps, radiation equipment, etc.
   5. Exhaust fans
      a. This includes exhaust fans that operate to control temperature, on a schedule, or continuously. The DDC system shall control any necessary starts & stops and monitor fan status in order to detect and notify of any equipment failures.
   6. Heating and Cooling Pumps
   7. Central Plant equipment such as Boilers, Chillers, Cooling Towers, Domestic Hot Water systems, Heat Pump loops, etc.
   8. Lighting Systems
      a. Large common area spaces where occupancy control is not possible or exterior lighting control should be integrated or directly controlled by the DDC system. Scheduling shall be accomplished with DDC system interface.
      b. Smaller areas that require more user control such as dimming or where basic occupancy detection is sufficient should be designed as simple as possible and not be made part of a building wide lighting system.
   9. Irrigation Systems
      a. Small simple irrigation systems shall be directly controlled and scheduled by DDC system.
      b. Larger irrigation systems containing water saving features such as moisture or rain sensors shall be an independent irrigation controller provided it is capable of efficient and fully autonomous operation. In some cases it may be desirable to monitor the system operation with the DDC equipment. This should be evaluated on a project by project basis.
      c. DDC Control of irrigation system shall be provided with conveniently located manual overrides to allow local irrigation servicing and maintenance.
   10. Metering Equipment
      a. Any Electrical, Gas, Water or BTU meters installed for resource monitoring purposes shall be integrated into the DDC system to provide a convenient usage monitoring interface as part of the overall DDC system.

D. In certain applications, such as small satellite building or non-market housing facilities it may be preferable to operate parts of the system equipment with conventional

stand-alone control methods. These exceptions should be discussed and approved by the City of Vancouver during the project design.

Δ

1.3 Approved Control system Manufacturers

A. The following are approved control system suppliers, manufacturers, and product lines:

Supplier	Manufacturer	Product Line
ESC Automation	Delta Controls	Delta Controls
Houle Electric Webir Automation	Reliable Controls	Reliable Controls

1. The above list does not indicate order of preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.
2. The Contractor shall operate and maintain staff locally in the Vancouver area.
3. The Contractor shall be a manufacturer authorized dealer of the selected Control System
4. The Contactor shall be approved by key stakeholders within the City of Vancouver, Real Estate and Facilities Management, Facilities Operations department.
5. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
6. Control system selection shall match any existing control system equipment of the above approved product lines. Each building/system should only contain equipment from a single control manufacturer unless approved by Owner.
7. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.4 Quality Assurance

A. Installer and Manufacturer Qualifications
   1. Installer shall be a manufacturer authorized dealer of the selected Control System.
   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.

1.5 System Performance

A. 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 45 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 Annunciation. Each workstation on the network 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.
   10. 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	±0.15º (±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	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO2)	±50 ppm

Note 1: Accuracy applies to 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 Vari-	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

1.6 Submittals

A. Product Data and Shop Drawings: Meet requirements of any other contract document on Shop Drawings, Product Data, and Samples. In addition, the contractor shall provide shop drawings or other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as electronic files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, PDF or comparable). When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cutsheets 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. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:
   1. DDC System Hardware
      a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
      b. 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:
         i. Direct digital controllers (controller panels)
         ii. Transducers and transmitters
         iii. Sensors (including accuracy data)
         iv. Actuators
         v. Valves
         vi. Relays and switches
         vii. Control panels
         viii. Power supplies
         ix. Batteries
         x. Operator interface equipment
         xi. Wiring
      c. Wiring diagrams and layouts for each control panel. Show termination numbers.
      d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.
   2. Central System Hardware and Software
      a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical data.

b. 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:
   i. Central Processing Unit (CPU) or web server
   ii. Monitors
   iii. Keyboards
   iv. Power supplies
   v. Battery backups
   vi. Interface equipment between CPU or server and control panels
   vii. Operating System software
   viii. Operator interface software
   ix. Color graphic software
   x. Third-party software
c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show interface wiring to control system.
d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems
   a. Riser diagrams showing control network layout, communication protocol, and wire types.
   b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
   c. A 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.
   d. An 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.
   e. A mounting, wiring, and routing plan-view drawing. The design shall take into account HVAC, electrical and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.
   f. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
   g. A point list for each control system. List I/O points and software points specified in Section 23 09 93. Indicate alarmed and trended points.
4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.

5. Description of process, report formats, and checklists to be used in Section 23 09 23 Article 3.17(Control System Demonstration and Acceptance).
6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules
1. Within one month of contract award, provide a schedule of the work indicating the following:
   a. Intended sequence of work items
   b. Start date of each work item
   c. Duration of each work item
   d. Planned delivery dates for ordered material and equipment and expected lead times
   e. Milestones indicating possible restraints on work by other trades or situations
2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

C. Project Record Documents. Upon completion of installation, submit three copies of record (as-built) documents of the documents shall be submitted for approval prior to final completion and shall include:
1. Project Record Drawings. As-built versions of submittal shop drawings provided as electronic files on magnetic or optical media (file format: .DWG, .DXF, .VSD, PDF or comparable).
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 23 09 23 Article 3.17(Control System Demonstration and Acceptance).
3. Operation and Maintenance (O&M) Manual which should include a full set of the control as-built drawings.
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.

D. 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. Engineer will modify course outlines and materials if necessary to meet Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

1.7 Warranty

A. 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 Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
   2. Work shall have a single warranty date, even if Owner 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 the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer 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 the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
   5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be

warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.8 Ownership of Proprietary Material

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:
   1. Graphics
   2. Record drawings
   3. Database
   4. Application programming code
   5. Documentation

1.9 Definitions

Term	Definition
BACnet Interoperability Building Blocks (BIBB)	A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database.
Controller	Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.
Direct Digital Control	Microprocessor-based control including Analog/Digital conversion and program logic.
Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token Passing	Data link protocol as defined by the BACnet standard.
Point-to-Point	Serial communication as defined in the BACnet standard.
Primary Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.
Protocol Implementation Conformance Statement	A written document that identifies the particular options specified by BACnet that are implemented in a device.
Router	A device that connects two or more networks at the network layer.
Wiring	Raceway, fittings, wire, boxes and related items.

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2.1 Materials

A. Use new products of the latest product line 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 Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2 Controllers

A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 23 09 23 Article 1.5(System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

B. BACnet.
   1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L, and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
   2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
   3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
   4. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
   5. BACnet Communication.
      a. 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.
      b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
      c. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
      d. Each ASC shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.

e. Each SA shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using MS/TP Data Link/Physical layer protocol.

C. 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.
4. Stand-Alone Operation. Each piece of equipment specified in Section 23 09 93 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 such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

D. 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 -29°C to 60°C (-20°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).

E. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

F. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. 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.

G. 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.

H. 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).
I. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.3 Input and Output Interface

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.
B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.
C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.
D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.
E. 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.
F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on Building Controllers shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.
G. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0–10 Vdc or a 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.
H. Tri-State Outputs. Three-point floating electronic actuators should not be installed unless approved by owner.
I. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system

2.4 Power Supplies and Line Filtering

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for

Class 2 service in accordance with Canadian Electrical Code 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.
    a. 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.
    b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.
    1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
        a. Dielectric strength of 1000 V minimum
        b. Response time of 10 nanoseconds or less
        c. Transverse mode noise attenuation of 65 dB or greater
        d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz
C. Uninterruptible Power Supplies
    1. Provide UPS for each controller and associated control devices that are used to operate life safety equipment in critical environments.
    2. If supplied from an emergency generator, the UPS device shall be rated to withstand power fluctuations during monthly generator testing.
D. Line Voltage Supply Circuit.
    1. Each BC power supply shall be provided with a dedicated line voltage circuit that is not used for any other devices.
    2. Each ASC shall not be powered from associated equipment line voltage. ASCs shall be supplied with low voltage power from an accessibly mounted and appropriately sized transformer. Low voltage power shall be supplied to the field mounted ASCs using appropriately sized wiring for the installation distance. The Voltage measured at each ASC termination must conform to manufacturer requirements including while the controller is operating. The transformer shall be supplied with a dedicated line voltage circuit that is not used for any other devices.

2.5 Auxiliary Control Devices

A. Devices for swimming pool or other corrosive environment applications will need to be selected in order to limit device failure and maintenance issues that are seen with common device standards. Specific device selection standards will be specified by owner on a case by case basis.
B. Motorized Control Dampers.

1. Mechanical Consultant must ensure that damper design and installation provides a linear mixing of air streams throughout the full range of damper travel.

C. 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 N·m (60 in.-lb) torque capacity shall have a manual crank.

D. Pneumatic Damper and Valve Actuators and Positioners.
   1. Use. Pneumatic actuators shall be replaced with electric actuators wherever possible. Exceptions must be approved by engineer and owner representatives.
   2. Type. Pneumatic actuators shall be piston-rolling diaphragm type or diaphragm type. Diaphragm shall be easily replaceable, beaded, molded neoprene.
   3. Housing. Actuator housings shall be molded or die-cast zinc or aluminum. Exception: Actuator housings for terminal unit zone control dampers or valves may be of high-impact plastic construction with a minimum ambient temperature rating of 10°C–60°C (50°F–140°F). Isolate plastic devices from return air plenums in an auxiliary metal enclosure with a quick-opening access panel.
   4. Selection. Size actuators and select spring ranges suitable for intended application and in accordance with manufacturer's recommendations.
      a. Actuators shall have sufficient reserve power to operate related control damper or valve with smooth modulating or two-position action.
      b. Actuators shall have proper response speed at design velocity and pressure.
      c. Actuators shall be rated for a minimum 140 kPa (20 psig).
      d. Actuator close-off force shall effectively seal damper or valve at maximum design system pressure. At design flow and pressure actuator shall modulate smoothly.
      e. For sequencing applications, size valve and damper actuators for a maximum of 14 kPa (2 psi) shift in nominal spring range. Select spring ranges to prevent overlap or provide positive positioners.

5. Positive Positioners. Provide positive positioners on inlet vane actuators and on other actuators as required to provide smooth modulation or proper sequencing.
    a. Positive positioners shall be high-capacity force balance relay type with suitable mounting provisions and shall have a position feedback linkage tailored for its actuator.
    b. Positive positioners shall use full control air pressure at any point in stem travel to initiate stem movement or to maintain stem position. Positioners shall operate on a 20–100 kPa (3–15 psig) input signal unless otherwise required to satisfy specified sequences of operation.
    c. Positive positioners shall have the following performance characteristics.
        i. Linearity: ±10% of output signal span.
        ii. Hysteresis: 3% of span.
        iii. Response: 1.7 kPa (¼ psig) input change.
        iv. Maximum Pilot Signal Pressure: 140 kPa (20 psig).
        v. Maximum Control Air Supply Pressure: 420 kPa (60 psig).

E. Control Valves.
    1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.
    2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
        a. Water Valves:
            i. Two-way: 150% of total system (pump) head.
            ii. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
        b. Steam Valves: 150% of operating (inlet) pressure.
    3. Water Valves.
        a. Body and trim style and materials shall be in accordance with manufacturer’s recommendations for design conditions and service shown, with equal percentage ports for modulating service.
        b. Sizing Criteria:
            i. Two-position service: Line size.
            ii. Two-way modulating service: Pressure drop shall be equal to twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi, whichever is greater.
            iii. Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 35 kPa (5 psi) maximum.
            iv. Valves ½ in. through 2 in. shall be bronze body or cast brass ANSI Class 250, spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or stainless steel ball.

v. Valves 2½ in. and larger shall be cast iron ANSI Class 125 with guided plug and PTFE packing.

c. Water valves shall fail normally open or closed, as scheduled on plans, or as follows:
   i. Water zone valves—normally open preferred.
   ii. Heating coils in air handlers—normally open.
   iii. Chilled water control valves—normally closed.
   iv. Other applications—as scheduled or as required by sequences of operation.

4. Steam Valves.
   a. Body and trim materials shall be in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service.
   b. Sizing Criteria:
      i. Two-position service: pressure drop 10% to 20% of inlet psig.
      ii. Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig.
      iii. Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig.
      iv. Modulating service: over 350 kPa (50 psig); pressure drop as scheduled on plans.

F. Binary Temperature Devices.
   1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall not be installed without owner approval. DDC Temperature sensors, controllers and outputs should be used instead.
   2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall not be installed without owner approval. DDC Temperature sensors, controllers and outputs should be used instead.
   3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL 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.

G. Temperature Sensors.
   1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
   2. 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 m^2(10 ft^2) of duct cross-section.
   3. 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.
   4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.

5. Differential Sensors. Provide matched sensors for differential temperature measurement.

H. Humidity Sensors.
   1. For pools or any applications where the equipment will be exposed to corrosive atmosphere or hard service, device selection will need to be approved by the City of Vancouver operations staff. See Section 23 09 23 Article 2.5A.
   2. Duct and room sensors shall have a sensing range of 20%–80%.
   3. Duct sensors shall have a sampling chamber.
   4. Outdoor air humidity sensors shall have a sensing range of 20%–95% RH and shall be suitable for ambient conditions of -40°C–75°C (-40°F–170°F).
   5. Humidity sensors shall not drift more than 1% of full scale annually.

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

J. Relays.
   1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED “energized” indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
   2. Relays shall be of electro-mechanical type with field replaceable coils. The coil and associated contacts shall be replaceable without needing to reterminate field wiring.
   3. Solid state relays are not acceptable.

K. Current Transmitters.
   1. AC current transmitters shall be self-powered, combination split-core current transformer type with 4–20 mA or 0-10 VDC 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. Installed transmitters shall reliably detect the operation status of the monitored load. Transmitters installed where the measured operating current is at the low end of the measurement range shall be installed with multiple wire wraps and the appropriate corresponding range adjustment.
   3. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
   4. Unit shall be split-core type for clamp-on installation on existing wiring.

L. Current Switches.
   1. Current-operated switches are not to be installed. All applicable installations shall use Current transmitters.

M. Pressure Transducers.

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage.
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 or 0-10 VDC output, suitable mounting provisions, and 5-valve manifold.

N. Occupancy Sensors. Occupancy sensors shall utilize Passive Infrared (PIR) and/or Microphonic Passive technology to detect the presence of people within a room. Sensors shall be mounted as indicated on the approved drawings. The sensor output shall be accessible by any lighting and/or HVAC controller in the system. Occupancy sensors shall be capable of being powered from the lighting or HVAC control panel, as shown on the drawings. Occupancy sensor delay shall be software adjustable through the user interface and shall not require manual adjustment at the sensor.

O. Electro-Pneumatic (E/P) Transducers.
   1. E/P transducers shall proportionally convert a 4–20 mA or 0–10 Vdc analog control input to a 20–100 kPa (3–15 psig) output signal.
   2. E/P transducers shall have the following features:
      a. Separate span and zero adjustments.
      b. Manual output adjustments.
      c. Pressure gauge assembly.
      d. Feedback loop control.
      e. Mid-range air consumption of 0.05 L/s (0.1 scfm).

P. Device Enclosures shall be appropriate for the environmental conditions they will be exposed to. Enclosures mounted outdoors or within corrosive environments such as pools shall be rated as NEMA 4x construction.

Q. Local Control Panels.
   1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
   2. Cabinet size shall be selected to provide adequate space for all necessary controllers, control devices, terminal strips and plastic wire troughs to be mounted to the back plate of the panel. Adequate separation should be provided between all devices to allow easy labeling and manipulation of all terminations. 10 – 20% additional unused space shall be provided to allow any necessary changes in the future. If the installed controller allows for future expansion modules, extra unused space shall be provided for at least one additional expansion module.

3. All panel wiring shall be neatly installed in plastic troughs or wire ducts complete with removable covers. Troughs should be sized to allow extra space for future expansions as well as for easy access to installed conductors for troubleshooting purposes.
4. All wire terminations within the panel shall be made either at a controller terminal, control device terminal or at a mounted terminal strip. Wire terminations shall not be made with marettes or crimps within the plastic wiring trough.
5. Terminations shall be individually identified per control/interlock drawings.
6. Provide line voltage ON/OFF power switch in each local control panel in order to isolate control power sources and transformers.
7. Provide 120 VAC power plug for operator laptop connection at each local panel.

R. Energy and Resource Meters.
1. Meters supplied with a quantity related pulse output for DDC integration and monitoring shall be selected with pulse factors that are appropriate for the resource application. The meter and pulse ratios shall ensure that the DDC system will be signaled with multiple pulses per day during periods of low demand. This is to allow greater detail in the data collected by the DDC system.

2.6 Wiring and Raceways

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

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3.1 Examination

A. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.
B. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

3.2 Protection

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.
B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 Coordination

A. Site
    1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition 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.
B. Submittals. See Section 23 09 23 Article 1.10 (Submittals).
C. Test and Balance.
    1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
    2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
    3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
    4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

D. Life Safety.
    1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in Section 23 09 93 (Sequences of Operation).
    2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23. Interlock smoke dampers to air handlers as specified in Section 23 09 93 (Sequences of Operation).
    3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.
E. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
    1. All communication media and equipment shall be provided as specified in Section 23 09 23 Article 2.2 (Communication).
    2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Section 23 09 93.
    3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
    4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
    5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4 General Workmanship

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.
B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
C. Install equipment in readily accessible locations as defined by the Canadian Electric Code.
D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 Field Quality Control

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, provincial, and federal codes and ordinances.
B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
C. Contractor shall have work inspection by local and/or province authorities having jurisdiction over the work.

3.6 Existing Equipment

A. Wiring. The contractor may reuse any abandoned wires subject to owner approval. The integrity of the wire and its proper application to the installation are the responsibility of the contractor. The wire shall be properly identified and tested in accordance with this specification. Unused or redundant wiring must be properly identified as such.
B. Pneumatic Tubing. Interconnecting pneumatic control tubing shall be removed and shall become the property of the contractor unless specifically noted or shown to be reused. Unused tubing branches will be removed to ensure that all remaining braches will remain functional and without air leaks. Tees or junctions that are no longer necessary shall be removed. All new terminations shall be completed with a properly installed brass plug.
C. Local Control Panels. The contractor may reuse any existing local control panel to locate new equipment subject to owner approval. All redundant equipment within these panels must be removed. Panel face cover must be patched to fill all holes caused by removal of unused equipment or replaced with new.
D. Repair. Unless otherwise directed, the contractor is not responsible for repair or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the contractor find existing equipment that requires maintenance, the engineer is to be notified immediately.
E. Temperature Sensor Wells. The contractor may reuse any existing wells in piping for temperature sensors. These wells shall be modified as required for proper fit of new sensors.
F. Indicator Gauges. Where these devices remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy.
G. Room Thermostats. Room thermostats may be reused. Remove and deliver unnecessary thermostats to Owner unless otherwise noted. Patch and finish holes and marks left by removal to match existing walls.
H. Electronic Sensors and Transmitters. Unless specifically noted otherwise, existing sensors and transmitters may be reused. Remove and deliver unnecessary sensors and transmitters to Owner.
I. Controllers and Auxiliary Electronic Devices. Existing controllers and auxiliary electronic devices may be reused unless specifically noted otherwise. Recondition as necessary. Remove unnecessary sensors and transmitters.
J. Pneumatic Controllers and Relays. Remove and deliver pneumatic controllers and relays to Owner unless specifically noted otherwise.

K. Damper Actuators, Linkages, and Appurtenances. Existing damper actuators, linkages, and appurtenances may be reused unless specifically noted otherwise. Recondition as necessary. Remove and deliver unnecessary equipment to Owner.
L. Control Valves. Existing control valves may be reused unless specifically noted otherwise. Recondition as necessary.
M. Control Compressed Air Systems. Existing control compressed air systems may be reused unless specifically noted otherwise. Recondition as necessary.
N. Existing System Operating Schedule. Equipment modifications should be evaluated on a project by project basis to determine if existing mechanical system may be disabled during the work. If the mechanical system must remain in operation then it shall maintain space comfort at all times between the normal occupancy hours. No modifications to the system shall cause mechanical systems to be shut down for more than 15 minutes or to fail to maintain space comfort conditions during any such period. Perform cut-over of controls that cannot meet these conditions outside of operational hours.
O. The scheduling of fans through existing or temporary time clocks or control system shall be maintained throughout the DDC system installation
P. Install control panels where shown.
Q. Modify existing starter control circuits, if necessary, to provide hand-off-auto control of each controlled starter. If new starters or starter control packages are required, these shall be included as part of this contract.
R. Patch holes and finish to match existing walls.

3.7 Wiring

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.
B. All line voltage wiring shall be UL listed in approved raceway according to CEC and Division 26 requirements.
C. All low-voltage wiring shall meet CEC requirements. Low-voltage power circuits shall be sub-fused when required to meet Class 2 current limit.
D. Where wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.
E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway at levels below 3 m (10ft).
F. Do not install Class 2 wiring in raceways 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).
G. Do not install wiring in raceway containing tubing.
H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.

I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.
K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
L. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
O. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and CEC requirements, except as noted elsewhere.
P. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
Q. Use color-coded conductors throughout with conductors of different colors.
R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).
T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
U. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.
V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.
W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
X. 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. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
Z. In areas exposed to corrosive conditions such as swimming pools, PVC conduit shall be used instead of EMT or Rigid tubing.

3.8 Communication Wiring

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.
B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling
C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.
D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.
F. All runs of communication wiring shall be unspliced length when that length is commercially available.
G. All communication wiring shall be labeled to indicate origination and destination data.
Δ H. Ethernet wiring used by the control system shall be an integral part of the base building structured cabling system.
    1. Each controller with an Ethernet connection shall be provided with a separate IP drop that is labeled and certified to the same standards as the entire structured cabling system. See Section 23 09 23 Article 1.1A.3
I. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:
    1. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
    2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
    3. The maximum number of full nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
    4. An MS/TP EIA-485 network shall have no T connections.

3.9 Installation of Sensors

A. Install sensors in accordance with the manufacturer's recommendations.
B. Mount sensors rigidly and adequately for environment within which the sensor operates.
C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.
D. All wires attached to sensors shall be sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.

E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2(1 ft^2) of coil area.
G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.
H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
J. Differential Air Static Pressure.
    1. Supply Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the height-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
    2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
    3. Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
    4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
    5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.
    6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.
K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.
L. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.10 Flow Switch Installation

A. Use correct paddle for pipe diameter.
B. Install in a horizontal section of pipe where there is a straight horizontal run of at least 5 pipe diameters on each side of the flow switch.
C. Adjust flow switch according to manufacturer's instructions.

3.11 Actuators

A. General. Mount and link control damper actuators according to manufacturer's instructions.
    1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
    2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
    3. Provide all mounting hardware and linkages for actuator installation.
B. Electric/Electronic
    1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall be mounted following manufacturer’s recommendations.
    2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.12 Warning Labels

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the control system.
    1. Labels shall use white lettering (12-point type or larger) on a red background.
    2. 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 disconnect to"Off"position before servicing.

B. Permanent warning labels shall be affixed to all motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
    1. Labels shall use white lettering (12-point type or larger) on a red background.
    2. 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.

3.13 Identification of Hardware and Wiring

A. All controller enclosures shall internally include a laminated copy of the as-built control drawings for the appropriate controller. This drawing should include:
   1. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
   2. A 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. An 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. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
   5. A point list for each control system. List I/O points and software points specified in Section 23 09 93. Indicate alarmed and trended points.

Δ B. Where equipment is concealed from occupant spaces, attach appropriately sized labels to the ceiling grid or to the edge of access panels to indicate the presence of controls hardware.

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

D. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.

E. Permanently label or code each point of field terminal strips to show the instrument or item served.

F. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

G. Identify all other control components with permanent labels. Labels shall indicate component & system name, associated I/O point and controller address. Labels shall be readily visible once installed. All plug-in components shall be labeled such that removal of the component does not remove the label.

H. Identify room sensors related to terminal boxes or valves with nameplates.

I. Occupant interface controls such as override buttons shall include user instructions/labels where necessary and appropriate. Labels shall allow non-technical staff to understand how to use the interface, what the effects will be and any additional useful parameters. Content of labels must be approved by CoV operations staff.

J. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

K. Identifiers shall match record documents.

3.14 Controllers

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.
B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in Section 23 09 93 (Sequences of Operation).

3.15 Programming

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.
B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 23 09 93 (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix B to Section 23 09 93 may be used. 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.
C. Software Programming.
    1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Embed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation.
        a. Programming:
            i. Must provide actions for all possible situations
            ii. Must be modular and structured
            iii. Must be commented
        b. Changes made to existing programs shall include comments that indicate the date of the change, the name and company of the programmer, and any description of the change necessary.
D. Operator Interface.
    1. Standard Graphics. Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in the sequence of operation.

2. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

3.16 Control System Checkout and Testing

A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration.
   1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
   2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
   3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
   4. Verify installation, wiring and calibration of all Energy and Resource meters. Displayed values in DDC graphics shall match quantities and units of meter face readings.
   5. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
   6. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
   7. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
   8. Alarms and Interlocks:
      a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
      b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
      c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action
B. Seasonal Calibration. The functional tests listed under item A shall again be inspected, checked and calibrated by the contractor according to the following schedule during the warranty period.
   1. Visit Schedule

a. 1 full inspection and calibration during each heating season.
b. 1 full inspection and calibration during each cooling season.

2. At the completion of each visit, the contractor shall submit an itemized written report to the Owner showing the status of all performance checks. Report shall indicate any deficient items with proposed solutions.
3. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

3.17 Control System Demonstration and Acceptance

A. Demonstration.

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
5. As each control input and output is checked, a log shall be completed showing the date, technician’s initials, and any corrective action taken or needed.
6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:
    a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop’s response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled

variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.

b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
d. Interface to the building fire alarm system.
e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes.

10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

B. Acceptance.
1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

3.18 Cleaning

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.
B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.
C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has

been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.19 Training

A. Provide two training periods for a designated staff of Owner's representatives. Initial training should take place soon after control system acceptance with the second training scheduled approximately half way through the warranty period. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods. The intent of the training is to have owner staff representatives to be able to fully understand, operate and maintain the installed control system.

B. Training shall enable students to accomplish the following objectives.
   1. Day-to-day Operators:
      a. Proficiently operate the system
      b. Understand control system architecture and configuration
      c. Understand DDC system components
      d. Understand system operation, including DDC system control and optimizing routines (algorithms)
      e. Operate the workstation and peripherals
      f. Log on and off the system
      g. Access graphics, point reports, and logs
      h. Adjust and change system set points, time schedules, and holiday schedules
      i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
      j. Understand system drawings and Operation and Maintenance manual
      k. Understand the job layout and location of control components
      l. Access data from DDC controllers and ASCs
      m. Operate portable operator's terminals
   2. Advanced Operators:
      a. Make and change graphics on the workstation
      b. Create, delete, and modify alarms, including annunciation and routing of these
      c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
      d. Create, delete, and modify reports
      e. Add, remove, and modify system's physical points
      f. Create, modify, and delete programming
      g. Add panels when required
      h. Add operator interface stations
      i. Create, delete, and modify system displays, both graphical and others
      j. Perform DDC system field checkout procedures
      k. Perform DDC controller unit operation and maintenance procedures
      l. Perform workstation and peripheral operation and maintenance procedures

m. Perform DDC system diagnostic procedures
n. Configure hardware including PC boards, switches, communication, and I/O points
o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
p. Adjust, calibrate, and replace system components

3. System Managers/Administrators:
   a. Maintain software and prepare backups
   b. Interface with job-specific, third-party operator software
   c. Add new users and understand password security procedures

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.
D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.
E. The instructor(s) shall be factory-trained and experienced in presenting this material.
F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.20 Sequences of Operation

A. Each mechanical system shall be provided with a sequence of operation during the design phase of the project. Sequences that require revision during installation and commissioning shall be updated in the controls documentation for as built purposes.

1. See Section 23 09 93 (Sequences of Operation, With Points Lists) for examples of acceptable sequences of operations. Each project may require customization or sequences not contained within the examples.

2. Sequences shall include DDC monitoring of all controlled variables. In general, if the DDC system is controlling a system variable, then it shall also monitor the direct result of that control. For example, this means that all heating/cooling coils shall be monitored with supply air temperature sensors, HRV units shall monitor return air, exhaust air, fresh air and supply air temperatures, and units with economizer control shall monitor mixed air temperature.

3. Trend logs should be created for all points listed in the sequence of operation. At a minimum, all inputs, outputs and any variables integral to the control sequence such as setpoints shall be provided with BACnet trend logs.

4. Packaged mechanical equipment supplied with internal controls shall be specified and ordered so that the DDC control system will have direct control of the equipment operation. This is to allow full sequence customization and optimization of the unit operation. The packaged internal controls shall be used for safety and equipment protection only. For example, with a packaged

air handler unit, the DDC system shall be able to directly control the economizer dampers, start/stop the cooling, start/stop the heating, start/stop the fan and shall be provided with all other necessary temperature sensors and equipment status.

5. Freeze protection low limit thermostats shall be specified to electrically interlock with all devices that have an effect on freeze protection. For example, a freeze stat trip shall not only stop the associated fan but shall also close any fresh air dampers, open any heating coils, and start any heating pumps that also might be associated with the freeze protection. These interlocks to other devices shall all be accomplished through hardwired failsafe interlocks or relays.
6. Energy and Resource meters that are monitored by the DDC system shall include a long term trend log of the cumulative usage meter reading. This type of value is the most useful for external data analysis purposes. Other values such as instantaneous demand and shorter daily, weekly, or monthly usage amounts shall be primarily used for operational trends.
7. Building systems shall be designed and sequenced in order to prevent unnecessary simultaneous heating and cooling. Wherever possible, central equipment will be coordinated with terminal equipment in order to ensure the systems are using energy as efficiently as possible.
8. Final sequences shall include versions of the following energy optimization measures whenever possible and applicable:
    a. Occupancy Scheduling
        i. Unoccupied Night Set Back Operation
        ii. Unoccupied Night Set Up Operation
        iii. Timed Local override operation or Occupancy Detection
    b. System Run Request Coordination
    c. Occupant Setpoint Adjustment
    d. Optimal Start
    e. Current Outside Temperature Heating and Cooling Lockouts
    f. Predicted Daily high temperature heating lockout
    g. Free Cooling Operation
        i. This includes all applications where outside air is supplied to the building. Heat Recovery Ventilators shall be supplied with the ability to bypass the heat recovery method.
    h. Heat Recovery Operation

i. Demand Controlled Ventilation

j. KW Demand Limiting

k. Building Heating/Cooling System Demand Coordination

l. Supply Temperature Setpoint Optimization (Trim and Respond)

m. Supply Pressure Setpoint Optimization (Trim and Respond)

B. Proposed sequence of operations shall be included in Shop drawing submittals and are subject to approval.

3.21 Control Valve Installation

A. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.
B. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball type control valves shall be installed with the stem in the horizontal position.
C. Valves shall be installed in accordance with the manufacturer's recommendations.
D. Control valves shall be installed so that they are accessible and serviceable and so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.
E. Isolation valves shall be installed so that the control valve body may be serviced without draining the supply/return side piping system. Unions shall be installed at all connections to screw-type control valves.
F. Provide tags for all control valves indicating service and number. Tags shall be brass, 1.5 inch in diameter, with ¼ inch high letters. Securely fasten with chain and hook. Match identification numbers as shown on approved controls shop drawings.

3.22 Control Damper Installation

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.
B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure ¼ in. larger than damper dimensions and shall be square, straight, and level.
C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8 in.) of each other.
D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.
E. Install extended shaft or jackshaft according to manufacturer’s instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.
G. Provide a visible and accessible indication of damper position on the drive shaft end.
H. Support ductwork in area of damper when required to prevent sagging due to damper weight.
I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.23 Smoke Damper Installation

A. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the engineer no less than two weeks prior to inspection by the code authority having jurisdiction.
B. Provide complete submittal data to controls system subcontractor for coordination of duct smoke detector interface to HVAC systems.

3.24 Duct Smoke Detection

A. Submit data for coordination of duct smoke detector interface to HVAC systems as required in Part 1, "Submittals."
B. This Contractor shall provide a dry-contact alarm output in the same room as the HVAC equipment to be controlled.

23 09 93 Sequence of Operations for HVAC Controls

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1.1 Trim and Respond Setpoint Algorithm (Example Sequence)

Trim & Respond reset where referenced in sequences of operation shall be implemented as described below.

A “Request” is a call to reset a static pressure, temperature or other setpoint, generated by downstream zones or systems. These Requests are sent upstream to the plant or system that serves the zone or system which generated the request.

Downstream Requests:

Each piece of downstream equipment will generate requests according to one of the example methods listed below:

Each AHU shall include a heat request variable (AHU_Heat_Request). The heat request shall set to a value of 1.0(fixed) times the AHU importance multiplier (default 2) whenever:

- The AHU is proven on;
- the heating valve has been fully open for 10 minutes continuous; and
- the supply air temperature is more than 1ºC (adjustable) below the supply air temperature setpoint.
- otherwise the heat request shall be cleared.

Each AHU shall include a cooling request variable (AHUx_Cool_Request). The cooling request shall set to a value of 1.0 (fixed) times the AHU importance multiplier (default 2) whenever:

- the AHU is proven on;
- the AHU cooling valve has been fully open for 10 minutes continuous; and
- the AHU supply air temperature is more than 1ºC (adjustable) above the supply air temperature setpoint,
- otherwise the cool request shall be cleared.

Each heat exchanger valve shall include a heat demand request (HX-x_Heat_Request). The heat request shall be set to a value of 1.0(fixed) times the importance multiplier (default 2) whenever:

- the heating valve has been fully open for 10 minutes continuous, and
- the supply temperature is more than 1ºC (adjustable) below the temperature setpoint,
- otherwise the heat request shall be cleared.

Each Fan coil, Unit Heater and Reheat Coil shall include a heat request variable (FC/UH_Heat_Request). The heat request shall set to a value of 1.0(fixed) times the FC importance multiplier (default 1) whenever:

- The equipment is proven on; and
- the heating valve has been fully open for 10 minutes continuous, and
- the supply air temperature is more than 1ºC (adjustable) below supply air temperature set-point,
- otherwise the heat request shall be cleared.

Each Fan coil shall include a cooling request variable (FCx_Cool_Request). The cooling request shall set to a value of 1.0 (fixed) times the Fan Coil importance multiplier (default 1) whenever:

- the equipment is proven on;
- the cooling valve has been fully open for 10 minutes continuous; and
- the supply air temperature is more than 1ºC (adjustable) above the supply air temperature setpoint,
- otherwise the cool request shall be cleared.

Each VAV box shall include a static pressure request variable (VAV_STP_Request). The static pressure request shall set to a value of 1.0(fixed) times the VAV importance multiplier (default 1) whenever:

- The equipment is proven on; and
- the VAV damper has been fully open for 10 minutes continuous, and
- the VAV air flow is more than 20l/s (adjustable) below the VAV air flow setpoint,
- otherwise the static pressure request shall be cleared.

For each downstream zone/system and for each type of setpoint reset request listed for a zone/system, provide the following software points:

- Importance Multiplier (default = 1): Used to scale the number of requests a zone/system generates. A value of zero causes the requests from a zone/system to be ignored. A value greater than one can be used to increase the number of requests from the zone/system based on the critical nature of the spaces served.

- Request-Hours: Accumulates the integral of requests (prior to adjustment of Importance Multiplier) to assist in identifying zones/systems that are driving the reset logic. Rogue zone

identification is critical in this context, since a single rogue zone can keep the Trim & Respond loop at maximum, and prevent it from saving energy.

- Every x minutes (default 5 min), add x/60 times the current number of requests to a request-hours accumulator (totalizer) point. The request-hours point is reset to zero upon a global command from the system/plant serving the zone/system. The global point shall simultaneously reset the request-hours point for all zones/systems served by the system/plant.

- Cumulative%-Request-Hours: This is the zone/system Request-Hours divided by the zone/system run-hours (the hours in any Mode other than Unoccupied Mode) since the last reset, expressed as a percentage.

Upstream Setpoints:

For each upstream system or plant setpoint being controlled by a T&R, define the following variables. All variables below shall be adjustable from a reset graphic screen accessible from a link on the associated system/plant graphic. Initial values are defined in system/plant sequences. Values for trim, respond, time interval, etc. shall be tuned to provide stable control.

Variable	Definition	Notes
SP_0	Initial setpoint upon activation	
SP_{min}	Minimum setpoint	
SP_{max}	Maximum setpoint	
Td	Delay timer seconds or minutes	
T	Time interval seconds or minutes	
I	Number of ignored requests	
R	Number of requests from zones/systems	
SP_{trim}	Trim amount	
SP_{res}	Respond amount	must be opposite in sign to SP_{trim}
$SP_{res-max}$	Maximum allowable change in setpoint per time interval	must be same sign as SP_{res}

Trim & Respond logic shall reset the setpoint within the range SPmin to SPmax. When the associated device (e.g. fan, pump) is off, the setpoint shall be SP0. The reset logic shall be active while the associated device is proven on, starting Td after initial device start command. When active, every time interval T, trim the setpoint by SPtrim. If there are more than I Requests, respond by changing the setpoint by SPres * (R-I), (i.e. the number of Requests minus the number of Ignored Requests), but no more than SPres-max.

In other words, at each time interval T:

$SP = SP - SP_{trim}$

If R>I Then

If $SP_{res} > 0$ Then

$SP = SP + Min((R-I) * SP_{res} , SP_{res-max})$

Else

$SP = SP + Max((R-I) * SP_{res} , SP_{res-max})$

End If

End If

$SP = Limit(SP, SP_{min}, SP_{max})$

1.2 Exhaust Fan - On/Off (Example Sequence)

Run Conditions - Scheduled:
The fan shall run according to a user definable schedule.

Fan:
The fan shall have a user definable (adj.) minimum runtime.

Exhaust Air Damper:
The exhaust air damper shall open anytime the unit runs and shall close anytime the unit stops. The exhaust air damper shall close 30 sec (adj.) after the fan stops.

Damper Status:
The fan shall be enabled after the damper status has proven.

Alarms shall be provided as follows:

- Damper Failure: Commanded open, but the status is closed.
- Damper in Hand: Commanded closed, but the status is open.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Exhaust Air Damper Status			x						x		x
Fan Status	x								x		x
Fan Start/Stop				x					x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Exhaust Air Damper				x					x		x
Schedule								x			
Exhaust Air Damper Failure										x	
Exhaust Air Damper in Hand										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	**1**	**0**	**1**	**2**	**0**	**0**	**0**	**1**	**4**	**5**	**4**

Total Hardware (4) **Total Software (10)**

1.3 Exhaust Fan - Cooling (Example Sequence)

Run Conditions - Continuous:
The unit shall be continuously enabled to maintain a zone temperature cooling setpoint of 25.5°C (adj.).

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).

Fan:
The fan shall run anytime the zone temperature rises above cooling setpoint, unless shutdown on safeties.

Exhaust Air Damper:
The exhaust air damper shall open anytime the unit runs and shall close anytime the unit stops. The exhaust air damper shall close 30 sec (adj.) after the fan stops.

Damper Status:
The fan shall be enabled after the damper status has proven.

Alarms shall be provided as follows:

- Damper Failure: Commanded open, but the status is closed.
- Damper in Hand: Commanded closed, but the status is open.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Exhaust Air Damper Status			x						x		x
Fan Status	x								x		x
Fan Start/Stop				x					x		x
Exhaust Air Damper				x					x		x
Cooling Setpoint					x				x		x
High Zone Temp										x	
Exhaust Air Damper Failure										x	
Exhaust Air Damper in Hand										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	**2**	**0**	**1**	**2**	**1**	**0**	**0**	**0**	**6**	**6**	**6**

Total Hardware (5) **Total Software (13)**

1.4 Exhaust Fan - Building Static (Example Sequence)

Run Conditions - Interlocked:
The unit(s) EF --- shall be interlocked to run whenever Air Handling Unit ---- runs unless shutdown on safeties.

Control - Building Static Pressure:
The exhaust fan shall run when commanded on.

The controller shall measure building static pressure and modulate the exhaust fan VFD speed to maintain a building static pressure setpoint of 12.5Pa (adj.). The exhaust fan VFD speed shall not drop below 20% (adj.).

Alarms shall be provided as follows:

- High Building Static Pressure: If the building static pressure is 25% (adj.) greater than setpoint.
- Low Building Static Pressure: If the building static pressure is 25% (adj.) less than setpoint.
- Exhaust Fan VFD Fault.

Exhaust Air Damper:
The exhaust air damper shall open anytime the unit runs and shall close anytime the unit stops. The exhaust air damper shall close 30 sec (adj.) after the fan stops.

Damper Status:
The fan shall be enabled after the damper status has proven.

Alarms shall be provided as follows:

- Damper Failure: Commanded open, but the status is closed.
- Damper in Hand: Commanded closed, but the status is open.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Building Static Pressure	x								x		x
Fan VFD Speed		x							x		x
Fan VFD Fault			x							x	x
Exhaust Air Damper Status			x						x		x
Fan Status	x								x		x
Fan Start/Stop				x					x		x
Exhaust Air Damper				x					x		x
Building Static Pressure Setpoint					x				x		x
High Building Static Pressure										x	
Low Building Static Pressure										x	
Exhaust Air Damper Failure										x	
Exhaust Air Damper in Hand										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	**2**	**1**	**2**	**2**	**1**	**0**	**0**	**0**	**7**	**8**	**8**

Total Hardware (7) **Total Software (16)**

1.5 Unit Heater (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain a heating setpoint of 21°C (adj.).
- Unoccupied Mode (night setback): The unit shall maintain a heating setpoint of 18.5°C (adj.).

Alarms shall be provided as follows:

- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Fan:

The fan shall run anytime the zone temperature drops below heating setpoint, unless shutdown on safeties.

Heating Coil Valve:
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Heating Valve		x							x		x
Zone Override			x						x		x
Fan Start/Stop				x					x		x
Schedule								x			
Heating Setpoint									x		x
Low Zone Temp										x	
Totals	**2**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**5**	**1**	**6**
Total Hardware (5)					**Total Software (7)**						

1.6 Fan Coil Unit (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties.

Cooling Coil Valve:
The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the zone temperature is above cooling setpoint.
- AND the fan is on.

The cooling coil valve shall open whenever the freezestat (if present) is on.

Heating Coil Valve:
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

The heating coil valve shall open whenever the freezestat (if present) is on.

Heating - High Discharge Air Temperature Limit:
The controller shall measure the discharge air temperature and, on rising temperature, limit the heating as follows:

- As the discharge air temperature rises from 33°C to 49°C (adj.),
- The controller shall limit the heating output from 100% to 0% (adj.).

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

Zone Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the zone CO2 levels.

Alarms shall be provided as follows:

- High Zone Carbon Dioxide Concentration: If the zone CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Discharge Air Temp	x								x		x
Zone Carbon Dioxide PPM	x								x		x
Cooling Valve		x							x		x
Heating Valve		x							x		x
Zone Override			x						x		x
Fan Status	x										x
Fan Start/Stop				x					x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
High Zone Carbon Dioxide Concentration										x	
Totals	**5**	**2**	**1**	**1**	**0**	**0**	**0**	**1**	**9**	**8**	**11**

Total Hardware (9) **Total Software (18)**

1.7 Unit Ventilator (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a smoke detector status.

Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties.

Cooling Coil Valve:
The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the zone temperature is above cooling setpoint.
- AND the fan is on.

The cooling coil valve shall open whenever the freezestat (if present) is on.

Heating Coil Valve:
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

The heating coil valve shall open whenever the freezestat (if present) is on.

Heating - High Discharge Air Temperature Limit:
The controller shall measure the discharge air temperature and, on rising temperature, limit the heating as follows:

- As the discharge air temperature rises from 33°C to 49°C (adj.),
- The controller shall limit the heating output from 38°C to -18°C (adj.).

Economizer (ASHRAE Cycle II):
The controller shall measure the zone temperature and modulate the mixed air dampers in sequence to maintain the zone cooling setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open during heating and ventilation whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is at least 1.5°C (adj.) less than the Zone Temperature.
- AND the outside air temperature is less than 24°C (adj.)

The economizer shall close whenever the freezestat (if present) is on.

The outside air dampers shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

The controller shall monitor the discharge air temperature. Should discharge temperature drop below a user definable temperature (adj.), the controller shall enable the heating, close the outside damper and open the return damper.

Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:
When in the occupied mode, the controller shall measure the zone CO2 levels and open the outside air dampers on rising CO2 concentrations, overriding normal damper operation as CO2 concentrations rise from 750ppm to 800ppm (adj.) and above.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

Zone Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the zone CO2 levels.

Alarms shall be provided as follows:

- High Zone Carbon Dioxide Concentration: If the zone CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

Zone Humidity:
The controller shall monitor the zone humidity.

Alarms shall be provided as follows:

- High Zone Humidity: If the zone humidity is greater than 70% (adj.).
- Low Zone Humidity: If the zone humidity is less than 35% (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Discharge Air Temp	x								x		x
Zone Carbon Dioxide PPM	x								x		x
Zone Humidity	x								x		x
Cooling Valve		x							x		x
Heating Valve		x							x		x
Mixed Air Dampers		x							x		x
Zone Override			x						x		x
Freezestat			x						x	x	x
Smoke Detector			x						x	x	x
Fan Status	x								x		x
Fan Start/Stop				x					x		x
Zone Carbon Dioxide PPM Setpoint					x				x		x
Schedule								x			
Cooling Setpoint									x		x
Heating Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
High Zone Carbon Dioxide Concentration										x	
High Zone Humidity										x	
Low Zone Humidity										x	
Totals	**6**	**3**	**3**	**1**	**1**	**0**	**0**	**1**	**15**	**12**	**16**

Total Hardware (13) **Total Software (29)**

1.8 Air Source Heat Pump (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties.

Heating and Cooling - 1 Compressor Stage:
The controller shall measure the zone temperature and cycle the compressor to maintain its setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime. The compressor shall run subject to its own internal safeties and controls.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the fan is on.
- AND the reversing valve is in heat mode.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the fan is on.
- AND the reversing valve is in cool mode.

On mode change, the compressor shall be disabled and remain off until after the reversing valve has changed position..

Alarms shall be provided as follows:

- Compressor Runtime Exceeded: The compressor runtime exceeds a user definable limit (adj.).

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Discharge Temp	x								x		x
Zone Override			x						x		x
Fan Status	x								x		x
Fan Start/Stop				x					x		x
Reversing Valve				x					x		x
Compressor Stage 1				x					x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Compressor Runtime Exceeded										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Fan Failure										x	
Fan in Hand										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Fan Runtime Exceeded										x	
Totals	**4**	**0**	**1**	**3**	**0**	**0**	**0**	**1**	**9**	**8**	**10**

Total Hardware (8) **Total Software (18)**

1.9 Water Source Heat Pump (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a smoke detector status.

Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties.

Heating and Cooling - 1 Compressor Stage:
The controller shall receive a signal from the loop water source monitor indicating that there is water flow and that the water temperature is within acceptable limits.

The controller shall measure the zone temperature and cycle the compressor to maintain its setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime. The compressor shall run subject to its own internal safeties and controls.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the fan is on.
- AND the reversing valve is in heat mode.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the fan is on.
- AND the reversing valve is in cool mode.

On mode change, the compressor shall be disabled and remain off until after the reversing valve has changed position.

Alarms shall be provided as follows:

- Compressor Runtime Exceeded: The compressor runtime exceeds a user definable limit (adj.).

Supplemental Electric Heating Stage:
The controller shall measure the zone temperature and stage the heating to maintain its heating setpoint should the compressors not meet the heating demand. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- The heat pump is in heating mode.
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

Supplemental Heating - High Discharge Air Temperature Limit:
The controller shall measure the discharge air temperature and, on rising temperature, limit the supplemental heating as follows:

- As the discharge air temperature rises from 33°C to 49°C (adj.),
- The controller shall limit the heating output from 100% to 0% (adj.).

Filter Hours:
The controller shall monitor the fan runtime.

Alarms shall be provided as follows:

- Filter Change Required: Filter has been in use for more than 2200hr (adj.).

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

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

Zone Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the zone CO2 levels.

Alarms shall be provided as follows:

- High Zone Carbon Dioxide Concentration: If the zone CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

Zone Humidity:
The controller shall monitor the zone humidity.

Alarms shall be provided as follows:

- High Zone Humidity: If the zone humidity is greater than 70% (adj.).
- Low Zone Humidity: If the zone humidity is less than 35% (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Discharge Air Temp	x								x		x
Zone Carbon Dioxide PPM	x								x		x
Zone Humidity	x								x		x
Zone Override			x						x		x
Freezestat			x						x	x	x
Smoke Detector			x						x	x	x
Fan Status	x								x		x
Fan Start/Stop				x					x		x
Compressor Start/Stop				x					x		x
Reversing Valve				x							x
Heating Stage 1				x					x		x
Compressor Soft Shutdown						x					x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Compressor Runtime Exceeded										x	
Filter Change Required										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
High Zone Carbon Dioxide Concentration										x	
High Zone Humidity										x	
Low Zone Humidity										x	
Totals	**6**	**0**	**3**	**4**	**0**	**1**	**0**	**1**	**13**	**14**	**16**

Total Hardware (13) **Total Software (29)**

1.10 Makeup Air Unit - Supply Air Temp (Example Sequence)

Run Conditions - Interlocked:
The unit MAU --- shall be interlocked to run whenever Air Handling Unit ---- runs unless shutdown on safeties.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Outside Air Damper:
The outside air damper shall open anytime the unit runs and shall close anytime the unit stops. The supply fan shall start only after the damper status has proven the damper is open. The outside air damper shall close 4sec (adj.) after the supply fan stops.

Alarms shall be provided as follows:

- Outside Air Damper Failure: Commanded open, but the status is closed.
- Outside Air Damper in Hand: Commanded closed, but the status is open.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime, 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 (adj.).

Supply Air Temperature Setpoint - Optimized:
The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on unit(s) cooling and heating requirements.

The supply air temperature setpoint shall be reset for cooling based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 13°C (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 11.5°C (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 22°C (adj.) .

If more zones need heating than cooling, then the supply air temperature setpoint shall be reset for heating as follows:

- The initial supply air temperature setpoint shall be 28°C (adj.).
- As heating demand increases, the setpoint shall incrementally reset up to a maximum of 29.5°C (adj.).
- As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 22°C (adj.).

Cooling Coil Valve:
The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the supply air temperature is above cooling setpoint.
- AND the fan status is on.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat is on.

Heating Coil Valve:
The controller shall measure the supply air temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the supply air temperature is below heating setpoint.
- AND the fan status is on.

The heating coil valve shall open to 100% (adj.) whenever the freezestat is on.

Heating Coil Pump:
The recirculation pump shall run whenever:

- The heating coil valve is enabled.
- OR the freezestat (if present) is on.

Alarms shall be provided as follows:

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

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 49°C (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Air Temp	x								x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Cooling Valve		x							x		x
Heating Valve		x							x		x
Freezestat			x						x	x	x
Outside Air Damper Status			x						x		x
Supply Fan Status	x								x		x
Heating Coil Pump Status			x						x		x
Outside Air Damper				x					x		x
Supply Fan Start/Stop				x					x		x
Heating Coil Pump Start/Stop				x					x		x
Supply Air Temp Setpoint					x				x		x
Outside Air Damper Failure										x	
Outside Air Damper in Hand										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
Heating Coil Pump in Hand										x	
Heating Coil Pump Failure										x	
Heating Coil Pump Runtime Exceeded										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	**2**	**2**	**3**	**3**	**1**	**0**	**0**	**0**	**11**	**11**	**11**

Total Hardware (10) **Total Software (23)**

1.11 Dual Duct - AHU (Example Sequence)

Run Conditions - Requested:
The unit shall run whenever:

- Any zone is occupied.
- OR a definable number of unoccupied zones need heating or cooling.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

High Static Shutdown:
The unit shall shut down and generate an alarm upon receiving an high static shutdown signal.

AHU Optimal Start:
The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoints. The start time shall automatically adjust based on changes in outside air temperature and zone temperatures.

Demand Limiting - Setpoint Adjust:
To lower power consumption, the supply air temperature setpoint shall automatically relax (raised for cooling; lowered for heating) when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be accomplished by one of the following methods:

- The supply air temperature setpoint shall relax by 1°C (adj.) for each demand threshold exceeded.
- The setpoints in the zones supplied by this unit shall be relaxed as specified in the Sequence of Operations for the zones. This shall in turn relax the unit's supply air temperature setpoint by a user definable amount.

All setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Disallow simultanuous hot & cold deck operation:
To lower power consumption, the hot deck and cold deck shall not run simultaneously. The hot

deck will be enabled if more zones require heating than cooling. The cold deck will be enabled if more zones require cooling than heating.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

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 (adj.).

Supply Air Duct Static Pressure Control:
The controller shall take the lowest of the two duct static pressure readings from the cold and hot ducts and shall modulate the supply fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 30% (adj.). The static pressure setpoint shall be reset based on zone cooling requirements.

- The initial duct static pressure setpoint shall be 373.6Pa (adj.).
- As cooling demand increases, the setpoint shall incrementally reset up to a maximum of 448.4Pa (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset down to a minimum of 323.8Pa (adj.) .

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan VFD Fault.

Cold Deck - Cooling Supply Air Temperature Setpoint - Optimized:

The cooling supply air temperature setpoint shall be reset based on zone cooling requirements as follows:

- The initial cooling supply air temperature setpoint shall be 13°C (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 11.5°C (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 22°C (adj.).

Cold Deck - Cooling Coil Valve:
The controller shall measure the cooling supply air temperature and and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

Alarms shall be provided as follows:

- High Cooling Supply Air Temp: If the cooling supply air temperature is 3°C (adj.) greater than setpoint

Hot Deck - Heating Supply Air Temperature Setpoint - Optimized:
The heating supply air temperature setpoint shall be reset based on zone heating requirements as follows:

- The initial heating supply air temperature setpoint shall be 28°C (adj.).
- As heating demand increases, the setpoint shall incrementally reset up to a maximum of 33°C (adj.).

- As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 22°C (adj.).

Hot Deck - Heating Coil Valve:
The controller shall measure the heating supply air temperature and modulate the heating coil valve to maintain its setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the supply fan status is on.

The heating coil valve shall open whenever:

- Heating supply air temperature drops from 4.5°C to 1.5°C (adj.).
- OR the freezestat (if present) is on.

Alarms shall be provided as follows:

- High Heating Supply Air Temp: If the heating supply air temperature is greater than 49°C (adj.).
- Low Heating Supply Air Temp: If the heating supply air temperature is 3°C (adj.) less than setpoint.

Heating Coil Pump:
The recirculation pump shall run whenever:

- The heating coil valve is enabled.
- OR the freezestat (if present) is on.

Alarms shall be provided as follows:

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

- Heating Coil Pump Runtime Exceeded: Status runtime exceeds a user definable limit.

Economizer:
The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 1°C less than the cooling supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the outside air temperature is less than the return air temperature.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 4.5°C to 1.5°C (adj.).
- OR on loss of supply fan status.
- OR the freezestat (if present) is on.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. During Optimal Start Up or Night Set Back Heating, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:
When in the occupied mode, the controller shall measure the return air CO2 levels and modulate the outside air dampers open on rising CO2 concentrations, overriding normal damper operation to maintain a CO2 setpoint of 750 ppm (adj.).

Mixed Air Temperature:

The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 33°C (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 8°C (adj.).

Return Air Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the unit is running.

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 33°C (adj.).
- Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Cold Duct Static Pressure	x								x	x	x
Hot Duct Static Pressure	x								x	x	x
Cooling Supply Air Temp	x								x		x
Heating Supply Air Temp	x								x		x
Mixed Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Temp	x								x		x
Supply Fan VFD Speed		x							x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Cooling Valve		x							x		x
Heating Valve		x							x		x
Mixed Air Dampers		x							x		x
Freezestat			x						x	x	x
High Static Shutdown			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Heating Coil Pump Status			x						x		x
Supply Fan Start/Stop				x					x		x
Heating Coil Pump Start/Stop				x					x		x
Demand Limit Level					x						x
Supply Air Static Pressure Setpoint					x						x
Cooling Supply Air Temp Setpoint					x				x		x
Heating Supply Air Temp Setpoint					x				x		x
Economizer Mixed Air Temp Set-point					x				x		x
RA Carbon Dioxide PPM Setpoint					x				x		x
High Supply Air Static Pressure										x	
Low Supply Air Static Pressure										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
High Cooling Supply Air Temp										x	
High Heating Supply Air Temp										x	
Low Heating Supply Air Temp										x	
Heating Coil Pump Failure										x	
Heating Coil Pump in Hand										x	
Heating Coil Pump Runtime Ex-ceeded										x	
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
High Return Air Carbon Dioxide Concentration										x	
High Return Air Temp										x	
Low Return Air Temp										x	
Totals	**7**	**4**	**5**	**2**	**6**	**0**	**0**	**0**	**21**	**21**	**24**

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Total Hardware (18)					**Total Software (48)**						

1.12 Dual Duct - Terminal Unit (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Flow Control:
The unit shall maintain zone setpoints by controlling the airflow through each of the following:

Occupied:

- When zone temperature is greater than its cooling setpoint, the cold duct damper shall modulate up to its maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is between the cooling setpoint and the heating setpoint, the hot duct damper shall maintain the minimum required zone ventilation (adj.).
- When zone temperature is less than its heating setpoint, the hot duct damper shall modulate between the minimum occupied airflow (adj.) and the maximum heating airflow (adj.) until the zone is satisfied. If available, the controller shall enable any auxiliary heating to maintain the zone temperature at its heating setpoint.

Unoccupied:

- When the zone is unoccupied the hot duct damper shall control to its minimum unoccupied airflow (adj.).
- When the zone temperature is greater than its cooling setpoint, the cold duct damper shall modulate up to its unoccupied maximum cooling airflow (adj.) until the zone is satisfied.
- When zone temperature is less than its unoccupied heating setpoint, the hot duct damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum heating airflow (adj.) until the zone is satisfied. If available, the controller shall enable any auxiliary heating to maintain the zone temperature at its heating setpoint.

Perimeter Heating Coil Valve:

The controller shall measure the zone temperature and modulate the perimeter heating coil valve open on dropping temperature to maintain its heating setpoint.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Cold Duct Airflow	x								x		x
Total Airflow	x								x		x
Discharge Air Temp	x								x		x
Cold Duct Damper		x							x		x
Hot Duct Damper		x							x		x
Perimeter Heating Valve		x							x		x
Zone Override			x						x		x
Cold Duct Airflow Setpoint					x				x		x
Hot Duct Airflow					x				x		x
Hot Duct Airflow Setpoint					x				x		x
Total Airflow Setpoint					x				x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
High Discharge Air Temp										x	
Low Discharge Air Temp										x	
Totals	**5**	**3**	**1**	**0**	**4**	**0**	**0**	**1**	**14**	**4**	**15**

Total Hardware (9) **Total Software (23)**

1.13 Multizone - AHU (Example Sequence)

Run Conditions - Requested:
The unit shall run whenever:

- Any zone is occupied.
- OR a definable number of unoccupied zones need heating or cooling.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Supply Air Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

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 (adj.).

Cold Deck - Cooling Supply Air Temperature Setpoint - Optimized:
The cooling supply air temperature setpoint shall be reset using a trim and respond algorithm based on zone cooling requirements. If there is a demand for cooling then the setpoint shall be reset to a lower value (adj.). If the demand for cooling decreases then the setpoint shall reset to a higher value (adj.). Once the zones are satisfied then the setpoint shall gradually moderate over time to reduce cooling energy use.

The supply air temperature setpoint shall be reset based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 13°C (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 11.5°C (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 22°C (adj.).

Cold Deck - Cooling Coil Valve:
The controller shall measure the cooling supply air temperature and and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

Alarms shall be provided as follows:

- High Cooling Supply Air Temp: If the cooling supply air temperature is 3°C (adj.) greater than setpoint.

Hot Deck - Heating Supply Air Temperature Setpoint - Optimized:
The heating supply air temperature setpoint shall be reset using a trim and respond algorithm based on zone heating requirements. If there is a demand for heating then the setpoint shall be reset to a higher value (adj.). If the demand for heating decreases then the setpoint shall reset to a lower value (adj.). Once the zones are satisfied then the setpoint shall gradually moderate over time to reduce heating energy use.

The supply air temperature setpoint shall be reset based on zone heating requirements as follows:

- The initial supply air temperature setpoint shall be 28°C (adj.).

- As heating demand increases, the setpoint shall incrementally reset up to a maximum of 33°C (adj.).
- As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 22°C (adj.).

Hot Deck - Heating Coil Valve:
The controller shall measure the heating supply air temperature and modulate the heating coil valve to maintain its setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the supply fan status is on.

The heating coil valve shall open whenever:

- Heating supply air temperature drops from 4.5°C to 1.5°C (adj.).
- OR the freezestat (if present) is on.

Alarms shall be provided as follows:

- High Heating Supply Air Temp: If the heating supply air temperature is greater than 49°C (adj.).
- Low Heating Supply Air Temp: If the heating supply air temperature is 3°C (adj.) less than setpoint.

Economizer:
The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 1°C less than the cooling supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).

- AND the outside air temperature is less than the return air temperature.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 4.5°C to 1.5°C (adj.).
- OR on loss of supply fan status.
- OR the freezestat (if present) is on.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. During Optimal Start Up or Night Set Back Heating, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Fixed Percentage:
The outside air dampers shall maintain a minimum position (adj.) during building occupied hours and be closed during unoccupied hours.

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) and preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 33°C (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 8°C (adj.).

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 33°C (adj.).
- Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Cooling Supply Air Temp	x								x		x
Heating Supply Air Temp	x								x		x
Mixed Air Temp	x								x		x
Return Air Temp	x								x		x
Cooling Valve		x							x		x
Heating Valve		x							x		x
Mixed Air Dampers		x							x		x
Freezestat			x						x	x	x
Supply Air Smoke Detector			x						x	x	x
Supply Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x
Cooling Supply Air Temp Setpoint					x				x		x
Heating Supply Air Temp Setpoint					x				x		x
Economizer Mixed Air Temp Set-point					x				x		x
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
High Cooling Supply Air Temp										x	
High Heating Supply Air Temp										x	
Low Heating Supply Air Temp										x	
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
Low Return Air Temp										x	
High Return Air Temp										x	
Totals	**4**	**3**	**3**	**1**	**3**	**0**	**0**	**0**	**14**	**12**	**14**

Total Hardware (11) **Total Software (29)**

1.14 Multizone - Zone Damper (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Zone Damper Control:
The cooling and heating deck zone dampers shall modulate in sequence to maintain zone temperature cooling and heating setpoints.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 49°C (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 4.5°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Discharge Air Temp	x								x		x
Zone Damper		x									
Zone Override			x						x		x
Cold Deck Damper Position					x				x		x
Hot Deck Damper Position					x				x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
High Discharge Air Temp										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Low Discharge Air Temp										x	
Totals	**3**	**1**	**1**	**0**	**2**	**0**	**0**	**1**	**7**	**4**	**8**

Total Hardware (5) **Total Software (14)**

1.15 Single Zone Unit – Cooling Coil – Heating Coil (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.

- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Supply Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

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 (adj.).

Cooling Coil Valve:
The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the zone temperature is above cooling setpoint.
- AND the supply fan status is on.
- AND the heating is not active.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

Heating Coil Valve:
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the zone temperature is below heating setpoint.
- AND the supply fan status is on.
- AND the cooling is not active.

The heating coil valve shall open whenever the freezestat (if present) is on.

Economizer:
The controller shall measure the zone temperature and modulate the economizer dampers in sequence to maintain a setpoint 1°C less than the zone cooling setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the outside air temperature is less than the return air temperature.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 8°C to 4.5°C (adj.).
- OR on loss of supply fan status.
- OR the freezestat (if present) is on.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. During Optimal Start Up or Night Set Back Heating, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:
When in the occupied mode, the controller shall measure the return air CO2 levels and modulate the outside air dampers open on rising CO2 concentrations, overriding normal damper operation to maintain a CO2 setpoint of 750 ppm (adj.).

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 33°C (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 8°C (adj.).

Return Air Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 33°C (adj.).

- Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 49°C (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Mixed Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Cooling Valve		x							x		x
Heating Valve		x							x		x
Mixed Air Dampers		x							x		x
Zone Override			x						x		x
Freezestat			x						x	x	x
Supply Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x
Economizer Zone Temp Setpoint					x				x		x
Return Air Carbon Dioxide PPM Setpoint					x				x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
High Mixed Air Temp										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Low Mixed Air Temp										x	
High Return Air Carbon Dioxide Concentration										x	
High Return Air Temp										x	
Low Return Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	**6**	**3**	**3**	**1**	**2**	**0**	**0**	**1**	**16**	**13**	**17**

Total Hardware (13) **Total Software (32)**

1.16 Single Zone Unit - DX - Gas (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.
- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Supply Fan:
The fan shall run continuously during Occupied or Optimal Start Modes and on an as needed basis for Night Set Back operation, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

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 (adj.).

Cooling Stages:
The controller shall measure the zone temperature and stage the cooling to maintain its cooling setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the zone temperature is above cooling setpoint.
- AND the supply fan status is on.

- AND the heating is not active.

Gas Heating Stages:
The controller shall measure the zone temperature and stage the heating to maintain its heating setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the zone temperature is below heating setpoint.
- AND the supply fan status is on.
- AND the cooling is not active.

Economizer:
The controller shall measure the zone temperature and modulate the economizer dampers in sequence to maintain a setpoint 1°C less than the zone cooling setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the outside air temperature is less than the return air temperature.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 8°C to 4.5°C (adj.).
- OR on loss of supply fan status.
- OR the freezestat (if present) is on.

The outside and exhaust air dampers shall close and the return air damper shall open when

the unit is off. During Optimal Start Up or Night Set Back Heating, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:
When in the occupied mode, the controller shall measure the return air CO2 levels and modulate the outside air dampers open on rising CO2 concentrations, overriding normal damper operation to maintain a CO2 setpoint of 750 ppm (adj.).

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 33°C (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 8°C (adj.).

Return Air Carbon Dioxide (CO2) Concentration Monitoring:
The controller shall measure the return air CO2 levels.

Alarms shall be provided as follows:

- High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the occupied mode.

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 33°C (adj.).
- Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 49°C (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Mixed Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Mixed Air Dampers		x							x		x
Zone Override			x						x		x
Freezestat			x						x	x	x
Supply Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x
Cooling Stage 1				x					x		x
Cooling Stage 2				x					x		x
Heating Stage 1				x					x		x
Heating Stage 2				x					x		x
Economizer Zone Temp Setpoint					x				x		x
Return Air Carbon Dioxide PPM Setpoint					x				x		x
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Compressor Runtime Exceeded										x	
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
High Return Air Carbon Dioxide Concentration										x	
High Return Air Temp										x	
Low Return Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	**6**	**1**	**3**	**5**	**2**	**0**	**0**	**1**	**18**	**14**	**19**

Total Hardware (15) **Total Software (35)**

1.17 Variable Air Volume - AHU (Example Sequence)

Run Conditions - Requested:
The unit shall run whenever:

- Any zone is occupied.
- OR a definable number of unoccupied zones need heating or cooling.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

High Static Shutdown:
The unit shall shut down and generate an alarm upon receiving an high static shutdown signal.

Supply Air Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.

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 (adj.).

Supply Air Duct Static Pressure Control:
The controller shall measure duct static pressure and shall modulate the supply fan VFD speed to maintain a duct static pressure setpoint of 373.6Pa (adj.). The supply fan VFD speed shall not drop below 30% (adj.).

Alarms shall be provided as follows:

- High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
- Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
- Supply Fan VFD Fault.

Supply Air Temperature Setpoint - Optimized:
The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on zone cooling and heating requirements

The supply air temperature setpoint shall be reset for cooling based on zone cooling requirements as follows:

- The initial supply air temperature setpoint shall be 13°C (adj.).
- As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 11.5°C (adj.).
- As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 22°C (adj.) .

If more zones need heating than cooling, then the supply air temperature setpoint shall be reset for heating as follows:

- The initial supply air temperature setpoint shall be 28°C (adj.).
- As heating demand increases, the setpoint shall incrementally reset up to a maximum of 29.5°C (adj.).
- As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 22°C (adj.).

Cooling Coil Valve:
The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- Outside air temperature is greater than 15.5°C (adj.).
- AND the economizer (if present) is disabled or fully open.
- AND the supply fan status is on.
- AND the heating (if present) is not active.

The cooling coil valve shall open to 50% (adj.) whenever the freezestat (if present) is on.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is 3°C (adj.) greater than setpoint.

Heating Coil Valve:
The controller shall measure the supply air temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the supply fan status is on.
- AND the cooling (if present) is not active.

The heating coil valve shall open whenever:

- Supply air temperature drops from 4.5°C to 1.5°C (adj.).
- OR the freezestat (if present) is on.

Alarms shall be provided as follows:

- Low Supply Air Temp: If the supply air temperature is 3°C (adj.) less than setpoint.

Economizer:

The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 1.1°C (adj.) less than the supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied.

The economizer shall be enabled whenever:

- Outside air temperature is less than 18.5°C (adj.).
- AND the outside air temperature is less than the return air temperature.
- AND the supply fan status is on.

The economizer shall close whenever:

- Mixed air temperature drops from 4.5°C to 1.5°C (adj.).
- OR the freezestat (if present) is on.
- OR on loss of supply fan status.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. During Optimal Start Up or Night Set Back Heating, the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed.

Minimum Outside Air Ventilation - Fixed Percentage:
The outside air dampers shall maintain a minimum adjustable position during building occupied hours and be closed during unoccupied hours.

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 33°C (adj.).

- Low Mixed Air Temp: If the mixed air temperature is less than 8°C (adj.).

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for setpoint control or economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 33°C (adj.).
- Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 49°C (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Air Static Pressure	x								x	x	x
Mixed Air Temp	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Supply Fan VFD Speed		x							x		x
Cooling Valve		x							x		x
Heating Valve		x							x		x
Mixed Air Dampers		x							x		x
Freezestat			x						x	x	x
High Static Shutdown			x						x	x	x
Supply Air Smoke Detector			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Supply Fan Start/Stop				x					x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Air Static Pressure Setpoint					x				x		x
Supply Air Temp Setpoint					x				x		x
Economizer Mixed Air Temp Set-point					x				x		x
High Supply Air Static Pressure										x	
Low Supply Air Static Pressure										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
High Return Air Temp										x	
Low Return Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	**4**	**4**	**5**	**1**	**3**	**0**	**0**	**0**	**16**	**18**	**17**

Total Hardware (14) **Total Software (37)**

1.18 Variable Air Volume - Terminal Unit (Example Sequence)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 23.5°C (adj.) cooling setpoint
  - A 21°C (adj.) heating setpoint.

- Unoccupied Mode (night setback): The unit shall maintain
  - A 29.5°C (adj.) cooling setpoint.
  - A 13°C (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize

the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Reversing Variable Volume Terminal Unit - Flow Control:
The unit shall maintain zone setpoints by controlling the airflow through one of the following:

Occupied:

- When zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When the zone temperature is between the cooling setpoint and the heating setpoint, the zone damper shall maintain the minimum required zone ventilation (adj.).
- When zone temperature is less than its heating setpoint, the controller shall enable heating to maintain the zone temperature at its heating setpoint. Additionally, if warm air is available from the AHU, the zone damper shall modulate between the minimum occupied airflow (adj.) and the maximum heating airflow (adj.) until the zone is satisfied.

Unoccupied:

- When the zone is unoccupied the zone damper shall control to its minimum unoccupied airflow (adj.).
- When the zone temperature is greater than its cooling setpoint, the zone damper shall modulate between the minimum unoccupied airflow (adj.) and the maximum cooling airflow (adj.) until the zone is satisfied.
- When zone temperature is less than its unoccupied heating setpoint, the controller shall enable heating to maintain the zone temperature at the setpoint. Additionally, if warm air is available from the AHU, the zone damper shall modulate between the

minimum unoccupied airflow (adj.) and the auxiliary heating airflow (adj.) until the zone is satisfied.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Temp	x								x		x
Zone Setpoint Adjust	x										x
Airflow	x								x		x
Zone Damper		x									x
Zone Override			x						x		x
Airflow Setpoint					x				x		x
Heating Mode						x			x		
Schedule								x			
Heating Setpoint									x		x
Cooling Setpoint									x		x
High Zone Temp										x	
Low Zone Temp										x	
Totals	**3**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**7**	**2**	**8**
Total Hardware (5)					**Total Software (12)**						

1.19 Single Water Cooled Chiller and Cooling Tower (Example Sequence)

Chiller - Run Conditions:
The chiller shall be enabled to run whenever:

- A definable number of chilled water coils need cooling
- AND the outside air temperature is greater than 12°C (adj.).

To prevent short cycling, the chiller shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The chiller shall run subject to its own internal safeties and controls.

Refrigerant Detection:
The chiller shall shut down and an alarm generated upon receiving a refrigerant leak detection status.

Chilled Water Pump Lead/Standby Operation:
The two chilled water pumps shall run anytime the chiller is called to run. The chilled water pump shall also run for freeze protection whenever the outside air temperature is less than a user definable setpoint (adj.).

The lead pump shall start prior to the chiller being enabled and shall stop only after the chiller is disabled. The pump(s) shall therefore have:

- A user adjustable delay on start.
- AND a user adjustable delay on stop.

The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The two pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.

- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Chilled Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

- Chilled Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

Chilled Water Differential Pressure Control:
The controller shall measure chilled water differential pressure and modulate the lead chilled water pump VFD to maintain its chilled water differential pressure setpoint. The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate chilled water pump speed to maintain a chilled water differential pressure of 82.7kPa (adj.). The VFD minimum speed shall not drop below 10% (adj.).

Alarms shall be provided as follows:

- High Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) greater than setpoint.
- Low Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) less than setpoint.

Chilled Water Bypass Valve - Minimum Flow Control:
The controller shall measure chilled water flow through the chiller and, as the chilled water flow drops below setpoint, the controller shall modulate the chilled water bypass valve open to maintain the minimum chilled water flow setpoint.

Alarms shall be provided as follows:

- Low Chilled Water Flow: If the chilled water flow is 25% (adj.) less than setpoint.

Condenser Water Pump Lead/Standby Operation:
The condenser water pumps shall run anytime the chiller is called to run.

The lead pump shall start prior to the chiller being enabled and shall stop only after the chiller is disabled. The pumps shall therefore have:

- A user adjustable delay on start.
- AND a user adjustable delay on stop.

The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The condenser water pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.

- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Condenser Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

- Condenser Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

Chiller:
The chiller shall be enabled a user adjustable time after pump statuses are proven on.
The chiller shall therefore have a user adjustable delay on start.

The delay time shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The chiller shall run subject to its own internal safeties and controls.

Alarms shall be provided as follows:

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

Chilled Water Supply Temperature - Setpoint Reset:
The chilled water supply temperature setpoint shall reset based on outside air temperature and using a trim and respond algorithm based on cooling requirements

As outside air temperature drops from 24°C (adj.) to 10°C (adj.) the chilled water supply temperature setpoint shall reset upwards by adding from 0°C (adj.) to 5.5°C (adj.) to the current setpoint.

The chilled water supply temperature setpoint shall reset to a lower value as the facility's chilled water valves open beyond a user definable threshold (90% open, typ.). Once the chilled water coils are satisfied (valves closing) then the chilled water supply temperature setpoint shall gradually rise over time to reduce cooling energy use.

Cooling Tower VFD Fan - Condenser Water Temperature Control:
The controller shall measure the cooling tower condenser water supply (basin) temperature and modulate the condenser water bypass valve and fan VFD in sequence to maintain setpoints.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

On rising supply temperature, the controller shall modulate the condenser water bypass valve to maintain setpoint of 25.5°C (adj.) and the fan VFD to maintain setpoint of 28°C (adj.).

Alarms shall be provided as follows:

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

- High Cooling Tower Supply (Basin) Temp: If greater than 30°C (adj.).
- Low Cooling Tower Supply (Basin) Temp: If less than 4°C (adj.).

Chilled Water Temperature Monitoring:
The following temperatures shall be monitored:

- Chilled water supply.
- Chilled water return.

Alarms shall be provided as follows:

- High Chilled Water Supply Temp: If the chilled water supply temperature is greater than 13°C (adj.).
- Low Chilled Water Supply Temp: If the chilled water supply temperature is less than 4°C (adj.).

Condenser Water Temperature Monitoring:
The following temperatures shall be monitored:

- Condenser water supply temperature.
- Condenser water return temperature.

Alarms shall be provided as follows:

- High Condenser Water Supply Temp: If the condenser water supply temperature is greater than 30°C (adj.).
- Low Condenser Water Supply Temp: If the condenser water supply temperature is less than 18.5°C (adj.).

- High Condenser Water Return Temp: If the condenser water return temperature is greater than 38°C (adj.).
- Low Condenser Water Return Temp: If the condenser water return temperature is less than 24°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Chilled Water Differential Pressure	x								x		x
Chilled Water Flow	x								x		x
Condenser Water Supply (Basin) Temp	x								x		x
Chilled Water Return Temp	x								x		x
Chilled Water Supply Temp	x								x		x
Condenser Water Return Temp	x								x		x
Condenser Water Supply Temp	x								x		x
Chilled Water Pump 1 VFD Speed		x							x		x
Chilled Water Pump 2 VFD Speed		x							x		x
Chilled Water Bypass Valve		x							x		x
Chilled Water Supply Temp Setpoint Reset		x							x		x
Condenser Water Bypass Valve		x							x		x
Fan VFD Speed		x							x		x
Refrigerant Leak Shutdown			x						x	x	x
Chilled Water Pump 1 Status			x						x		x
Chilled Water Pump 2 Status			x						x		x
Chilled Water Pump 1 VFD Fault			x							x	x
Chilled Water Pump 2 VFD Fault			x							x	x
Condenser Water Pump 1 Status			x						x		x
Condenser Water Pump 2 Status			x						x		x
Chiller Status			x						x		x
Fan Status			x						x		x
Fan VFD Fault			x							x	x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Chilled Water Pump 1 Start/Stop				x					x		x
Chilled Water Pump 2 Start/Stop				x					x		x
Condenser Water Pump 1 Start/Stop				x					x		x
Condenser Water Pump 2 Start/Stop				x					x		x
Chiller Enable				x					x		x
Fan Start/Stop				x							x
Outside Air Temp					x						x
Chilled Water Differential Pressure Setpoint					x				x		x
Chilled Water Flow Setpoint					x				x		x
Chilled Water Pump 1 Failure										x	
Chilled Water Pump 2 Failure										x	
Chilled Water Pump 1 Running in Hand										x	
Chilled Water Pump 2 Running in Hand										x	
Chilled Water Pump 1 Runtime Exceeded										x	
Chilled Water Pump 2 Runtime Exceeded										x	
High Chilled Water Differential Pressure										x	
Low Chilled Water Differential Pressure										x	
Low Chilled Water Flow										x	
Condenser Water Pump 1 Failure										x	
Condenser Water Pump 1 Running in Hand										x	
Condenser Water Pump 1 Runtime Exceeded										x	
Condenser Water Pump 2 Failure										x	
Condenser Water Pump 2 Running in Hand										x	
Condenser Water Pump 2 Runtime Exceeded										x	
Chiller Failure										x	
Chiller Running in Hand										x	
Chiller Runtime Exceeded										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Low Condenser Water Supply (Basin) Temp										x	
High Condenser Water Supply (Basin) Temp										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
High Chilled Water Supply Temp										x	
Low Chilled Water Supply Temp										x	
High Condenser Water Return Temp										x	
Low Condenser Water Return Temp										x	
High Condenser Water Supply Temp										x	
Low Condenser Water Supply Temp										x	
Totals	**7**	**6**	**10**	**6**	**3**	**0**	**0**	**0**	**27**	**33**	**32**

Total Hardware (29) **Total Software (63)**

1.20 Single Cooling Tower - Open Circuit (Example Sequence)

Cooling Tower - Run Conditions:
The cooling tower shall be enabled to run whenever the chiller runs.

Vibration Switch:
The cooling tower shall shut down and an alarm generated upon receiving a vibration switch status.

Condenser Water Pump Lead/Standby Operation:
The condenser water pumps shall run anytime the chiller is called to run.

The lead pump shall start prior to the chiller being enabled and shall stop only after the chiller is disabled. The pumps shall therefore have:

- A user adjustable delay on start.
- AND a user adjustable delay on stop.

The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The condenser water pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.
- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly

- monthly

Alarms shall be provided as follows:

- Condenser Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

- Condenser Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

Cooling Tower VFD Fan - Condenser Water Temperature Control:
The controller shall measure the cooling tower condenser water supply (basin) temperature and modulate the bypass valve and fan VFD in sequence to maintain setpoints.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

On rising condenser water supply temperature, the controller shall modulate the bypass valve to maintain setpoint of 25.5°C (adj.) and the fan VFD to maintain setpoint of 28°C (adj.).

Alarms shall be provided as follows:

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

- VFD Fault.

- High Condenser Water Supply (Basin) Temp: If greater than 30°C (adj.).
- Low Condenser Water Supply (Basin) Temp: If less than 4°C (adj.).

Condenser Water Temperature Monitoring:
The following temperatures shall be monitored:

- Condenser water supply temperature.
- Condenser water return temperature.

Alarms shall be provided as follows:

- High Condenser Water Supply Temp: If the condenser water supply temperature is greater than 30°C (adj.).
- Low Condenser Water Supply Temp: If the condenser water supply temperature is less than 18.5°C (adj.).

- High Condenser Water Return Temp: If the condenser water return temperature is greater than 38°C (adj.).
- Low Condenser Water Return Temp: If the condenser water return temperature is less than 24°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Condenser Water Supply (Basin) Temp	x								x		x
Condenser Water Return Temp	x								x		x
Condenser Water Supply Temp	x								x		x
Bypass Valve Output		x							x		x
Fan VFD Speed		x							x		x
Vibration Status			x						x	x	x
Condenser Water Pump 1 Status			x						x		x
Condenser Water Pump 2 Status			x						x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Fan Status			x						x		x
Fan VFD Fault			x							x	x
Condenser Water Pump 1 Start/Stop				x							x
Condenser Water Pump 2 Start/Stop				x							x
Fan Start/Stop				x							x
Outside Air Temp					x						x
Condenser Water Pump 1 Failure										x	
Condenser Water Pump 1 Running in Hand										x	
Condenser Water Pump 1 Runtime Exceeded										x	
Condenser Water Pump 2 Failure										x	
Condenser Water Pump 2 Running in Hand										x	
Condenser Water Pump 2 Runtime Exceeded										x	
Low Condenser Water Supply (Basin) Temp										x	
High Condenser Water Supply (Basin) Temp										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
High Condenser Water Return Temp										x	
Low Condenser Water Return Temp										x	
High Condenser Water Supply Temp										x	
Low Condenser Water Supply Temp										x	
Totals	**3**	**2**	**5**	**3**	**1**	**0**	**0**	**0**	**9**	**17**	**14**

Total Hardware (13) **Total Software (27)**

1.21 Steam to Hot Water Converter (Example Sequence)

Heat Exchanger System Run Conditions:
The heat exchanger system shall be enabled to run whenever:

- A definable number of hot water coils need heating.
- AND outside air temperature is less than 18.5°C (adj.).

To prevent short cycling, the heat exchanger shall run for and be off for minimum adjustable times (both user definable).

The heat exchanger system shall also run for freeze protection whenever outside air temperature is less than 4°C (adj.).

Hot Water Pump Lead/Lag Operation:
The two hot water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.
- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing hot water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain hot water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Hot Water Pump 1

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

- Hot Water Pump 2
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.

Hot Water Differential Pressure Control:
The controller shall measure hot water differential pressure and modulate the hot water pump VFDs in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate hot water pump speeds to maintain a hot water differential pressure of 83kPa (adj.). The VFDs minimum speed shall not drop below 20% (adj.).

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 90% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising hot water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speeds drops back to 60% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.

Alarms shall be provided as follows:

- High Hot Water Differential Pressure: If 25% (adj.) greater than setpoint.
- Low Hot Water Differential Pressure: If 25% (adj.) less than setpoint.

Hot Water Supply Temperature Setpoint Reset:
The hot water supply temperature setpoint shall reset based on outside air temperature and using a trim and respond algorithm based on heating requirements.

As outside air temperature rises from -17°C (adj.) to 21°C (adj.) the hot water supply temperature setpoint shall reset downwards by subtracting from 0°C (adj.) up to 11°C (adj.) from the current boiler setpoint.

As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy user.

Alarms shall be provided as follows:

- High Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Hot Water Supply Temp: If less than 38°C (adj.).

Heat Exchanger Steam Valves - Hot Water Control:
The controller shall measure the hot water supply temperature and modulate the two steam valves in sequence to maintain its setpoint.

The steam valves shall be enabled whenever:

- The heat exchanger is called to run.

- AND hot water supply temperature is below setpoint.

The steam valves shall open to 100% (adj.) whenever the heat exchanger is in freeze protection due to low outside air temperature.

The steam valves shall close whenever the hot water supply temperature rises from 88°C to 94°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Hot Water Differential Pressure	x								x		x
Hot Water Supply Temp	x								x		x
Hot Water Return Temp	x								x		x
Hot Water Pump 1 VFD Speed		x							x		x
Hot Water Pump 2 VFD Speed		x							x		x
Steam Valve 1/3		x							x		x
Steam Valve 2/3		x							x		x
Hot Water Pump 1 VFD Fault			x							x	x
Hot Water Pump 2 VFD Fault			x							x	x
Hot Water Pump 1 Status			x						x		x
Hot Water Pump 2 Status			x						x		x
Hot Water Pump 1 Start/Stop				x							x
Hot Water Pump 2 Start/Stop				x							x
Outside Air Temp					x						x
Hot Water Differential Pressure Set-point					x						x
Hot Water Supply Temp Setpoint					x				x		x
Hot Water Pump 2 Runtime Ex-ceeded										x	
High Hot Water Differential Pressure										x	
Low Hot Water Differential Pressure										x	
Hot Water Pump 1 Failure										x	
Hot Water Pump 1 Running in Hand										x	
Hot Water Pump 1 Runtime Ex-ceeded										x	
Hot Water Pump 2 Failure										x	
Hot Water Pump 2 Running in Hand										x	
High Hot Water Supply Temp										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Low Hot Water Supply Temp										x	
Totals	**3**	**4**	**4**	**2**	**3**	**0**	**0**	**0**	**10**	**12**	**16**

Total Hardware (13) **Total Software (25)**

1.22 Single Boiler System (Example Sequence)

Boiler System Run Conditions:
The boiler system shall be enabled to run whenever:

- A definable number of hot water coils need heating.
- AND outside air temperature is less than 18.5°C (adj.).

To prevent short cycling, the boiler system shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The boiler shall run subject to its own internal safeties and controls.

The boiler system shall also run for freeze protection whenever outside air temperature is less than 4°C (adj.).

Boiler Safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Low Water Level.

Alarms shall be provided as follows:

- Boiler alarm.
- Low Water Level alarm.

Hot Water Pump Lead/Lag Operation:
The two hot water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.
- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing hot water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain hot water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Hot Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

- Hot Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

Hot Water Differential Pressure Control:
The controller shall measure hot water differential pressure and modulate the hot water pump VFDs in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate hot water pump speeds to maintain a hot water differential pressure of 83kPa (adj.). The VFDs minimum speed shall not drop below 20% (adj.).

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 90% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising hot water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speeds drops back to 60% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.

Alarms shall be provided as follows:

- High Hot Water Differential Pressure: If 25% (adj.) greater than setpoint.
- Low Hot Water Differential Pressure: If 25% (adj.) less than setpoint.

Circulation Pump:
The circulation pump shall run anytime the boiler is called to run and shall have a user definable (adj.) delay on stop.

Alarms shall be provided as follows:

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

Boiler Enable:
The boiler shall be enabled when the boiler system is commanded on. The boiler shall be enabled after pump status is proven on and shall run subject to its own internal safeties and controls.

Alarms shall be provided as follows:

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

Secondary Hot Water Supply Temperature Setpoint:
The secondary hot water supply temperature setpoint shall reset based on outside air temperature and using a trim and respond algorithm based on heating requirements.

As outside air temperature rises from -17°C (adj.) to 21°C (adj.) the hot water supply temperature setpoint shall reset downwards by subtracting from 0°C (adj.) up to 11°C (adj.) from the current boiler setpoint.

As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy use.

Alarms shall be provided as follows:

- High Secondary Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Secondary Hot Water Supply Temp: If less than 38°C (adj.).

Mixing Valve:
The controller shall measure the secondary hot water supply temperature and modulate the mixing valve to maintain its setpoint.

The mixing valve shall be enabled whenever the hot water system is called to run.

The mixing valve shall close whenever the hot water supply temperature rises from 88°C to 94°C (adj.).

Primary Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

- Primary hot water supply.
- Primary hot water return.

Alarms shall be provided as follows:

- High Primary Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Primary Hot Water Supply Temp: If less than 38°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Hot Water Differential Pressure	x								x		x
Secondary Hot Water Supply Temp	x								x		x
Secondary Hot Water Return Temp	x								x		x
Primary Hot Water Return Temp	x								x		x
Primary Hot Water Supply Temp	x								x		x
Hot Water Pump 1 VFD Speed		x							x		x
Hot Water Pump 2 VFD Speed		x							x		x
Mixing Valve		x							x		x
Boiler Alarm Status			x						x	x	x
Low Water Level			x						x	x	x
Hot Water Pump 1 VFD Fault			x							x	x
Hot Water Pump 2 VFD Fault			x							x	x
Hot Water Pump 1 Status			x						x		x
Hot Water Pump 2 Status			x						x		x
Circulation Pump Status			x						x		x
Boiler Status			x						x		x
Hot Water Pump 1 Start/Stop				x							x
Hot Water Pump 2 Start/Stop				x							x
Circulation Pump Start/Stop				x					x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Boiler Enable				x							x
Outside Air Temp					x						x
Hot Water Differential Pressure Set-point					x						x
Secondary Hot Water Supply Temp Setpoint					x				x		x
High Hot Water Differential Pressure										x	
Low Hot Water Differential Pressure										x	
Hot Water Pump 1 Failure										x	
Hot Water Pump 1 Running in Hand										x	
Hot Water Pump 1 Runtime Ex-ceeded										x	
Hot Water Pump 2 Failure										x	
Hot Water Pump 2 Running in Hand										x	
Hot Water Pump 2 Runtime Ex-ceeded										x	
Circulation Pump Failure										x	
Circulation Pump Running in Hand										x	
Circulation Pump Runtime Exceed-ed										x	
Boiler Failure										x	
Boiler Running in Hand										x	
Boiler Runtime Exceeded										x	
High Secondary Hot Water Supply Temp										x	
Low Secondary Hot Water Supply Temp										x	
High Primary Hot Water Supply Temp										x	
Low Primary Hot Water Supply Temp										x	
Totals	**5**	**3**	**8**	**4**	**3**	**0**	**0**	**0**	**16**	**22**	**23**

Total Hardware (20) **Total Software (41)**

1.23 Two Boiler System (Example Sequence)

Boiler System Run Conditions:
The boiler system shall be enabled to run whenever:

- A definable number of hot water coils need heating.
- AND outside air temperature is less than 18.5°C (adj.).

To prevent short cycling, the boiler system shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The boiler shall run subject to its own internal safeties and controls.

The boiler system shall also run for freeze protection whenever the outside air temperature is less than 4°C (adj.).

Boiler 1 Safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Low water level.

Alarms shall be provided as follows:

- Boiler alarm.
- Low water level alarm.

Boiler 2 Safeties:
The following safeties shall be monitored:

- Boiler alarm.
- Low water level.

Alarms shall be provided as follows:

- Boiler alarm.
- Low water level alarm.

Hot Water Pump Lead/Lag Operation:
The two hot water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.
- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing hot water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain hot water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Hot Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

- Hot Water Pump 2
    - Failure: Commanded on, but the status is off.

- Running in Hand: Commanded off, but the status is on.
- Runtime Exceeded: Status runtime exceeds a user definable limit.
- VFD Fault.

Hot Water Differential Pressure Control:
The controller shall measure hot water differential pressure and modulate the hot water pump VFDs in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate hot water pump speeds to maintain a hot water differential pressure of 83kPa (adj.). The VFDs minimum speed shall not drop below 20% (adj.).

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 90% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising hot water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speeds drops back to 60% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.

Alarms shall be provided as follows:

- High Hot Water Differential Pressure: If 25% (adj.) greater than setpoint.

- Low Hot Water Differential Pressure: If 25% (adj.) less than setpoint.

Circulation Pump 1:
The Circulation Pump 1 shall run anytime Boiler 1 is called to run and shall have a user definable delay (adj.) on stop.

Alarms shall be provided as follows:

- Circulation Pump 1 Failure: Commanded on, but the status is off.
- Circulation Pump 1 Running in Hand: Commanded off, but the status is on.
- Circulation Pump 1 Runtime Exceeded: Status runtime exceeds a user-definable limit.

Circulation Pump 2:
The Circulation Pump 2 shall run anytime Boiler 2 is called to run and shall have a user definable delay (adj.) on stop.

Alarms shall be provided as follows:

- Circulation Pump 2 Failure: Commanded on, but the status is off.
- Circulation Pump 2 Running in Hand: Commanded off, but the status is on.
- Circulation Pump 2 Runtime Exceeded: Status runtime exceeds a user-definable limit.

Boiler Lead/Lag Operation:
The two boilers shall operate in a lead/lag fashion.

- The lead boiler shall run first.
- On failure of the lead boiler, the lag boiler shall run and the lead boiler shall turn off.
- As hot water temperature drops below a setpoint of 65.5°C, the lag boiler shall stage on and run in unison with the lead boiler to maintain hot water temperature setpoint.

- As hot water temperature rises back to 11°C above setpoint, the lag boiler shall stage off.

The designated lead boiler shall rotate upon one of the following conditions: (user selectable):

- manually through a software switch
- if boiler runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Boiler 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

- Boiler 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.

- Lead Boiler Failure: The lead boiler is in failure and the standby boiler is on.

Hot Water Supply Temperature Setpoint Reset:
The hot water supply temperature setpoint shall reset based on outside air temperature and using a trim and respond algorithm based on heating requirements.

As outside air temperature rises from -17°C (adj.) to 21°C (adj.) the hot water supply temperature setpoint shall reset downwards by subtracting from 0°C (adj.) up to 11°C (adj.) from the current boiler setpoint.

As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy use.

Primary Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

- Primary hot water supply.
- Primary hot water return.

Alarms shall be provided as follows:

- High Primary Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Primary Hot Water Supply Temp: If less than 38°C (adj.).

Boiler 1 Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

- Boiler 1 hot water supply.
- Boiler 1 hot water return.

Alarms shall be provided as follows:

- High Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Hot Water Supply Temp: If less than 38°C (adj.).

Boiler 2 Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

- Boiler 2 hot water supply.
- Boiler 2 hot water return.

Alarms shall be provided as follows:

- High Hot Water Supply Temp: If greater than 94°C (adj.).
- Low Hot Water Supply Temp: If less than 38°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Hot Water Differential Pressure	x								x		x
Primary Hot Water Return Temp	x								x		x
Primary Hot Water Supply Temp	x								x		x
Boiler 1 Hot Water Return Temp	x								x		x
Boiler 1 Hot Water Supply Temp	x								x		x
Boiler 2 Hot Water Return Temp	x								x		x
Boiler 2 Hot Water Supply Temp	x								x		x
Hot Water Pump 1 VFD Speed		x							x		x
Hot Water Pump 2 VFD Speed		x							x		x
Boiler 1 Hot Water Supply Temp Setpoint Reset		x							x		x
Boiler 2 Hot Water Supply Temp Setpoint Reset		x							x		x
Boiler 1 Alarm Status			x						x	x	x
Boiler 1 Low Water Level			x						x	x	x
Boiler 2 Alarm Status			x						x	x	x
Boiler 2 Low Water Level			x						x	x	x
Hot Water Pump 1 VFD Fault			x							x	x
Hot Water Pump 2 VFD Fault			x							x	x
Hot Water Pump 1 Status			x						x		x
Hot Water Pump 2 Status			x						x		x
Circulation Pump 1 Status			x						x		x
Circulation Pump 2 Status			x						x		x
Boiler 1 Status			x						x		x
Boiler 2 Status			x						x		
Hot Water Pump 1 Start/Stop				x							x
Hot Water Pump 2 Start/Stop				x							x
Circulation Pump 1 Start/Stop				x					x		x
Circulation Pump 2 Start/Stop				x					x		x
Boiler 1 Enable				x							x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Boiler 2 Enable				x							x
Outside Air Temp					x						x
Hot Water Differential Pressure Set-point					x				x		x
High Hot Water Differential Pressure										x	
Low Hot Water Differential Pressure										x	
Hot Water Pump 1 Failure										x	
Hot Water Pump 1 Running in Hand										x	
Hot Water Pump 1 Runtime Ex-ceeded										x	
Hot Water Pump 2 Failure										x	
Hot Water Pump 2 Running in Hand										x	
Hot Water Pump 2 Runtime Ex-ceeded										x	
Circulation Pump 1 Failure										x	
Circulation Pump 1 Running in Hand										x	
Circulation Pump 1 Runtime Ex-ceeded										x	
Circulation Pump 2 Failure										x	
Circulation Pump 2 Running in Hand										x	
Circulation Pump 2 Runtime Ex-ceeded										x	
Boiler 1 Failure										x	
Boiler 2 Failure										x	
Boiler 1 Running in Hand										x	
Boiler 2 Running in Hand										x	
Boiler 1 Runtime Exceeded										x	
Boiler 2 Runtime Exceeded										x	
Lead Boiler Failure										x	x
High Primary Hot Water Supply Temp										x	
Low Primary Hot Water Supply Temp										x	
Boiler 1 High Hot Water Supply Temp										x	
Boiler 1 Low Hot Water Supply Temp										x	
Boiler 2 High Hot Water Supply Temp										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Boiler 2 Low Hot Water Supply Temp										x	
Totals	**7**	**4**	**12**	**6**	**2**	**0**	**0**	**0**	**24**	**33**	**31**

Total Hardware (29) **Total Software (59)**

1.24 Heat Pump Loop Monitor and Pumps (Example Sequence)

Water Source Heat Pump Loop Monitor - Run Conditions:
The loop monitor shall run whenever:

- Any zone is occupied.
- OR a definable number of unoccupied zones need heating or cooling.

The following loop water conditions shall be monitored:

- Flow status.
- Supply temperature.
- Return temperature.

Alarms and a heat pump shutdown signal shall be generated upon any of the following loop water conditions:

- No Loop Flow.
- High Loop Water Supply Temp Shutdown: If the loop water supply temperature is greater than 34°C (adj.).
- Low Loop Water Supply Temp Shutdown: If the loop water supply temperature is less than 14.5°C (adj.).

Alarms shall be provided as follows:

- High Loop Water Supply Temp: If the loop water supply temperature is greater than 33°C (adj.).
- Low Loop Water Supply Temp: If the loop water supply temperature is less than 15.5°C (adj.).

Loop Water Pump Lead/Lag Operation:
The two loop water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.

- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing loop water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain loop water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Loop Water Pump 1
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

- Loop Water Pump 2
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Status runtime exceeds a user definable limit.
    - VFD Fault.

Loop Water Differential Pressure Control:
The controller shall measure loop water differential pressure and modulate the loop water pump VFDs in sequence to maintain its loop water differential pressure setpoint. The following

setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate loop water pump speeds to maintain a loop water differential pressure of 83kPa (adj.). The VFD minimum speed shall not drop below 20% (adj.).

On dropping loop water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 90% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising loop water differential pressure, the VFDs shall stage off as follows:

- If the VFD speeds then drops back to 60% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.

Alarms shall be provided as follows:

- High Loop Water Differential Pressure: If the loop water differential pressure is 25% (adj.) greater than setpoint.
- Low Loop Water Differential Pressure: If the loop water differential pressure is 25% (adj.) less than setpoint.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Loop Water Return Temp	x								x		x
Loop Water Supply Temp	x								x		x
Loop Water Differential Pressure	x								x		x
Loop Water Pump 1 VFD Speed		x							x		x
Loop Water Pump 2 VFD Speed		x							x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Loop Water Flow Status			x								x
Loop Water Pump 1 VFD Fault			x							x	x
Loop Water Pump 2 VFD Fault			x							x	x
Loop Water Pump 1 Status	x								x		x
Loop Water Pump 2 Status	x								x		x
Loop Water Pump 1 Start/Stop				x							x
Loop Water Pump 2 Start/Stop				x							x
Outside Air Temp					x						x
Loop Water Differential Pressure Setpoint					x						x
No Loop Flow										x	
High Loop Water Supply Temp Shutdown										x	
Low Loop Water Supply Temp Shutdown										x	
High Loop Water Supply Temp										x	
Low Loop Water Supply Temp										x	
High Loop Water Differential Pressure										x	
Low Loop Water Differential Pressure										x	
Loop Water Pump 1 Failure										x	
Loop Water Pump 1 Running in Hand										x	
Loop Water Pump 1 Runtime Exceeded										x	
Loop Water Pump 2 Failure										x	
Loop Water Pump 2 Running in Hand										x	
Loop Water Pump 2 Runtime Exceeded										x	
Totals	**5**	**2**	**3**	**2**	**2**	**0**	**0**	**0**	**7**	**15**	**14**

Total Hardware (12) **Total Software (24)**

1.25 Heat Pump Loop Cooling (Example Sequence)

Water Source Heat Pump Cooling Tower System - Run Conditions:
The cooling tower system shall be enabled to run whenever:

- The loop monitor is enabled by zone requirements.
- AND outside air temperature is greater than 3°C (adj.).

Cooling Tower Loop Water Temperature Control:
The cooling tower will stage its components (spray pump, fan, etc.) in sequence to maintain supply temperature setpoint. The following setpoints are recommended values. All setpoints will be field adjusted during the commissioning period to meet the requirements of actual field conditions.

Cooling Tower Water Supply Temperature - Setpoint Reset:
The cooling tower water supply temperature setpoint shall reset based on outside air temperature and using a trim and respond algorithm based on cooling requirements.

The setpoint will be restricted to a range between 20°C (adj.) and 32°C (adj.).

As outside air temperature drops from 24°C (adj.) to 10°C (adj.) the cooling tower water supply temperature setpoint shall reset upwards by adding from 0°C (adj.) to 5.5°C (adj.) to the current setpoint.

The cooling tower water supply temperature setpoint shall reset to a lower value as the number of the facility's heat pumps requesting cooling increases beyond an adjustable threshold. Once the heat pumps are satisfied then the cooling tower water supply temperature setpoint shall gradually rise over time to reduce energy use.

Cooling Tower Damper - Supply Water Temperature Control:
The controller will measure the supply water temperature and open the damper to maintain setpoint.

On rising supply water temperature, the controller will open the damper to maintain the cooling tower water supply temperature setpoint.

Alarms will be provided as follows:

- Damper Failure: Commanded open, but the status indicates closed.
- Damper in Hand: Commanded closed, but the status indicates open.
- Damper Runtime Exceeded: Status runtime exceeds a user definable limit.

Cooling Tower Spray Pump - Supply Water Temperature Control:
The controller will measure the supply water temperature and start the spray pump to maintain setpoint.

On rising supply water temperature, the controller will start the spray pump to maintain the cooling tower water supply temperature setpoint plus1.5°C (adj.).

Alarms will be provided as follows:

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

Cooling Tower Fan – Supply Water Temperature Control:
The controller will measure the supply water temperature and modulate the fan VFD to maintain setpoint.

On rising supply water temperature, the controller will modulate the fan VFD to maintain the cooling tower water supply temperature setpoint plus 3°C (adj.).

Alarms will be provided as follows:

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

Cooling Tower Fan VFD Feedback Monitor:
The controller will monitor the cooling tower fan speed as feedback from the variable frequency drive.

Condenser Water Return Temperature Monitoring:
The condenser water return temperature will be monitored.

Alarms will be provided as follows:

- High Condenser Water Return Temp: If the condenser water return temperature is greater than 38°C (adj.).
- Low Condenser Water Return Temp: If the condenser water return temperature is less than 24°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Loop Water Supply Temp	x								x		x
Spray Pump Amps	x								x		x
Fan Amps	x								x		x
Fan VFD Feedback	x								x		x
Loop Water Return Temp	x								x		x
Fan VFD Speed		x							x		x
Damper Status			x						x		x
Fan VFD Fault			x							x	x
Damper Open/Close				x					x		x
Spray Pump Start/Stop				x					x		x
Fan Start/Stop				x					x		x
Outside Air Temp					x						x
Loop Water Supply Temp Setpoint					x				x		x
Spray Pump Status	x								x		x
Fan Status	x								x		x
Loop Water Pump Failure										x	
Loop Water Pump Running in Hand										x	
Loop Water Pump Runtime Exceed-ed										x	
Damper Failure										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Damper in Hand										x	
Damper Runtime Exceeded										x	
Spray Pump Failure										x	
Spray Pump Running in Hand										x	
Spray Pump Runtime Exceeded										x	
Low Loop Water Supply Temp										x	
High Loop Water Supply Temp										x	
Fan Failure										x	
Fan Running in Hand										x	
Fan Runtime Exceeded										x	
High Loop Water Return Temp										x	
Low Loop Water Return Temp										x	
Totals	**7**	**1**	**2**	**3**	**2**	**0**	**0**	**0**	**15**	**17**	**17**

Total Hardware (13) **Total Software (36)**

1.26 Heat Pump Loop Heating (Example Sequence)

Water Source Heat Pump Boiler System - Run Conditions:
The boiler system shall run subject to its own internal safeties and controls. The boiler system shall be enabled to run whenever:

- The loop monitor is enabled by zone requirements.
- AND outside air temperature is less than 20°C (adj.).

The boiler system shall also run for freeze protection whenever outside air temperature is less than 4°C (adj.).

Two Stage Boiler Loop Water Temperature Control:
The controller shall measure the loop water supply temperature and stage the boiler, its circulation pump and heating stages on in sequence to maintain setpoints. The boiler system shall run subject to its own internal safeties and controls.

The heat pump loop Heating Setpoint shall be coordinated with the setpoints used for the heat pump loop cooling to ensure there is no simultaneous heating and cooling.

The setpoint will be restricted to a range between 16°C (adj.) and 22°C (adj.).

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The boiler and its circulation pump shall stage on when the loop supply temperature drops below the Heating Setpoint. The boiler and its circulation pump shall turn off when the loop supply temperature rises above the Heating Setpoint plus 3°C (adj.).

Boiler Stage 1 shall start when the loop supply temperature drops below the Heating Setpoint minus 1°C (adj.) and turn off when the loop supply temperature rises above the Heating Setpoint Plus 2°C (adj.).

Boiler Stage 2 shall start when the loop supply temperature drops below the Heating Setpoint minus 2°C (adj.) and turn off when the loop supply temperature rises above the Heating Setpoint Plus 1°C (adj.).

To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

- Boiler
    - Failure: Commanded on, but the status is off.
    - Running in Hand: Commanded off, but the status is on.
    - Runtime Exceeded: Runtime exceeds a user definable limit.

- Low Boiler Supply Temp: If the boiler supply temperature is less than 49°C (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Loop Water Supply Temp	x								x		x
Boiler Supply Temp	x								x		x
Boiler Return Temp	x								x		x
Boiler Status			x						x		x
Boiler & Pump Enable				x							x
Boiler Stage 1				x							x
Boiler Stage 2				x							x
Outside Air Temp					x						x
Boiler Failure										x	
Boiler Running in Hand										x	
Boiler Runtime Exceeded										x	
Low Boiler Supply Temp										x	
Totals	**3**	**0**	**1**	**3**	**1**	**0**	**0**	**0**	**4**	**4**	**8**

Total Hardware (7) **Total Software (9)**

1.27 Electric Demand Meter (Example Sequence)

Electric Demand Meter:
The controller shall monitor the electric meter for electric consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the electric meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the electric meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record electric meter readings so as to provide a power consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Demand Levels:
The controller shall set the system demand level (adj.) based on the current power consumption readings from the electric meter. There shall be six daily time periods in which the demand shall be adjusted on three levels. These demand levels shall be available for facility equipment to utilize for demand limiting.

- Demand Level 1: Power consumption has exceeded the first demand level threshold (adj.).
- Demand Level 2: Power consumption has exceeded the second demand level threshold (adj.).
- Demand Level 3: Power consumption has exceeded the third demand level threshold (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
kW Pulse	x										x
Current Demand Level					x						x
kW Demand									x		x
kW Peak Today									x		x
kW Peak Month-to-Date									x		x
kW Peak Year-to-Date									x		x
kWh Today									x		x
MWh Month-to-Date									x		x
MWh Year-to-Date									x		x
Meter Failure										x	
Demand Level 1										x	
Demand Level 2										x	
Demand Level 3										x	
Totals	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**7**	**4**	**9**

Total Hardware (1) **Total Software (12)**

1.28 Gas Demand Meter (Example Sequence)

Gas Demand Meter:
The controller shall monitor the gas meter for gas consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the gas meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the gas meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record gas meter readings so as to provide a gas consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Gas Flow Rate	x										
Demand									x		x
Peak Today									x		x
Peak Month-to-Date									x		x
Peak Year-to-Date									x		x
Usage Today									x		x
Usage Month-to-Date									x		x
Usage Year-to-Date									x		x
Meter Failure										x	
Totals	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**1**	**7**

Total Hardware (1) **Total Software (8)**

1.29 Water Flow Meter (Example Sequence)

Water Flow Meter:
The controller shall monitor the water meter for water consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Meter Failure: Sensor reading indicates a loss of pulse output from the water meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the water meter. These readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record water meter readings so as to provide a water consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Water Flow Rate	x										
Demand									x		x
Peak Today									x		x
Peak Month-to-Date									x		x
Peak Year-to-Date									x		x
Usage Today									x		x
Usage Month-to-Date									x		x
Usage Year-to-Date									x		x
Meter Failure										x	
Totals	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**1**	**7**

Total Hardware (1) **Total Software (8)**

1.30 Outside Air Conditions (Example Sequence)

Outside Air Conditions:
The controller shall monitor the outside air temperature and humidity and calculate the outside air enthalpy on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Sensor Failure: Sensor reading indicates shorted or disconnected sensor. In the event of a sensor failure, an alternate outside air conditions sensor shall be made available to the system without interruption in sensor readings.

If an OA Temp Sensor cannot be read, a default value of 18.5°C will be used.

If an OA Humidity Sensor cannot be read, a default value of 50 % will be used.

Outside Air Temperature History:
The controller shall monitor and record the high and low temperature readings for the outside air. These readings shall be recorded on a daily, month-to-date, and year-to-date basis.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Outside Air Temp	x								x		x
Outside Air Humidity	x								x		x
Outside Air Enthalpy					x				x		x
High Temp Today									x		x
High Temp Month-to-Date									x		x
High Temp Year-to-Date									x		x
Low Temp Today									x		x
Low Temp Month-to-Date									x		x
Low Temp Year-to-Date									x		x
Sensor Failure										x	
Totals	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**9**	**1**	**9**
Total Hardware (2)					**Total Software (11)**						

1.31 Indoor Lighting (Example Sequence)

Run Conditions - Schedule Enabled Switch:
The user will be able to turn the lights on and off from the BAS interface or a low-voltage wall switch at any time. The BAS will automatically turn the lights off according to a user-definable schedule or override parameters in the following modes:

Occupied Mode:

- The BAS will turn off the lights when the schedule expires.

Unoccupied Mode:

- The wall switch will turn on (override) the lights for 1 hour (adj).
- The user may turn off the lights at any time with the wall switch.
- The BAS will provide a blink warning at the expiration of an override event as if it were the expiration of a schedule.

Blink Warning:
The BAS will provide a blink warning 15 minutes (adj) before a schedule expires to alert occupants that the lights are about to turn off. The BAS will turn the lights off when the schedule expires.

Typical Use:
A school environment that requires wall switches to be disabled to prevent student operation during school hours, but to be enabled for teacher use after hours.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Lights On/Off						x					x
Lights Status						x			x		x
Schedule								x			x
Totals	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**1**	**1**	**0**	**4**

Total Hardware (0) **Total Software (4)**

1.32 Scheduled Light Level (Example Sequence)

Run Conditions - Schedule Enabled Light Level:
When the user-definable schedule from the BAS allows, the lights will turn on when the light level is less than 20 footcandles (adj).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Light Level	x										x
Lights On/Off						x					x
Lights Status						x					x
Schedule								x			x
Totals	**1**	**0**	**0**	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**4**
Total Hardware (1)					**Total Software (3)**						

1.33 Outdoor Lighting (Example Sequence)

Run Conditions - Scheduled:
The lights will turn on and off based on a user-definable schedule.

Typical Use:
Exterior lighting, such as a parking lot, that requires automatic control based on a schedule:

Nighttime Energy Savings
The BAS will turn off the lights between 11:30 PM (adj) and 4:00 AM (adj).

Light Level Control
The BAS will turn on the lights when the light level is less than 20 foot-candles (adj) unless otherwise prevented.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Light Level	x										x
Lights On/Off						x					x
Lights Status						x			x		x
Schedule								x			x
Schedule								x			x
Totals	**1**	**0**	**0**	**0**	**0**	**2**	**0**	**2**	**1**	**0**	**5**

Total Hardware (1) **Total Software (5)**

APPENDIX A: Glossary of Terms

Terms used within the Specification Text:

- **Advanced Application Controller (AAC):**

A fully programmable control module. This control module may be capable of some of the advanced features found in Building Controllers (storing trends, initiating read and write requests, etc.) but it does not serve as a master controller. Advanced Application Controllers may reside on either the Ethernet/IP backbone or on a subnet.

- **Application Specific Controller (ASC):**

A pre-programmed control module which is intended for use in a specific application. ASCs may be configurable, in that the user can choose between various pre-programmed options, but it does not support full custom programming. ASCs are often used on terminal equipment such as VAV boxes or fan coil units. In many vendors' architectures ASCs do not store trends or schedules but instead rely upon a Building Controller to provide those functions.

- **BACnet/IP:**

An approved BACnet network type which uses an Ethernet carrier and IP addressing.

- **BACnet MS/TP:**

An approved BACnet network type which uses a Master-Slave Token Passing configuration. MS/TP networks are unique to BACnet and utilize EIA485 twisted pair topology running at 9600 to 76,800 bps.

- **BACnet over ARCNET:**

An approved BACnet network type which uses an ARCNET (attached resource computer network) carrier. ARCNET is an industry standard that can utilize several speeds and wiring standards. The most common configuration used by BACnet controllers is an EIA485 twisted pair topology running at 156,000 bps.

- **Building Controller (BC):**

A fully programmable control module which is capable of storing trends and schedules, serving as a router to devices on a subnet, and initiating read and write requests to other controllers. Typically this controller is located on the Ethernet/IP backbone of the BAS. In many vendors' architectures a Building Controller will serve as a master controller, storing schedules and

trends for controllers on a subnet underneath the Building Controller.

- **Direct Digital Control (DDC):**

A control system in which a digital computer or microprocessor is directly connected to the valves, dampers, and other actuators which control the system, as opposed to indirectly controlling a system by resetting setpoints on an analog pneumatic or electronic controller.

- **PICS - Protocol Implementation Conformance Statement:**

A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.

- **Smart Actuator (SA):**

An actuator which is controlled by a network connection rather than a binary or analog signal. (0-10v, 4-20mA, relay, etc.)

- **Smart Sensor (SS):**

A sensor which provides information to the BAS via network connection rather than a binary or analog signal. (0-10000 ohm, 4-20mA, dry contact, etc.)

- **Web services:**

Web services are a standard method of exchanging data between computer systems using the XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services can be used at any level within a Building Automation System (BAS), but most commonly they are used to transfer data between BAS using different protocols or between a BAS and a non-BAS system such as a tenant billing system or a utility management system.

Terms used within the Sequences of Operation:

- **adj.**

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

- **AI, AO, etc. (Column Headings on Points List)**

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.
BI = Binary Input. A physical input to the control module.
BO = Binary Output. A physical output from the control module.

BV = Binary Value. An intermediate (software) point that may be editable or read-only. Editable BVs are typically used to allow the user to set a fixed control parameter, such as a setpoint. Read Only BVs are typically used to display the status of a control operation.
Loop = A control loop. Most commonly a PID control loop. Typically a control loop will include a setpoint, an input which is compared to the setpoint, and an output which controls some action based upon the difference between the input and the setpoint. A PID control loop will also include gains for the proportional, integral, and derivative response as well as an interval which controls how frequently the control loop updates its output. These gains may be adjustable by the end user for control loop "tuning," but in self-tuning control loops or loops which have been optimized for a specific application the gains may not be adjustable.
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.

In a typical implementation, 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.

- **Trim and Respond, or Setpoint Optimization: ***

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 with a supply air setpoint that is 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 to allow the specified control and monitoring functions of the equipment to be performed via the control system.

APPENDIX B: Abbreviations

The following abbreviations may be used in graphics, schematics, point names, and other UI applications where space is at a premium.

AC - Air Conditioning
ACU - Air Conditioning Unit
AHU - Air Handling Unit
AI - Analog Input
AO - Analog Output
AUTO - Automatic
AUX - Auxiliary
BI -Binary Input
BO -Binary Output
C -Common
CHW - Chilled Water
CHWP - Chilled Water Pump
CHWR - Chilled Water Return
CHWS - Chilled Water Supply
COND - Condenser
CW - Condenser Water
CWP - Condenser Water Pump
CWR - Condenser Water Return
CWS - Condenser Water Supply
DA - Discharge Air
EA - Exhaust Air
EF - Exhaust Fan
EVAP - Evaporators
FCU - Fan Coil Unit
HOA - Hand / Off / Auto
HP - Heat Pump
HRU - Heat Recovery Unit
HTEX - Heat Exchanger
HW - Hot Water
HWP - Hot Water Pump
HWR - Hot Water Return
HWS - Hot Water Supply
MAX - Maximum
MIN - Minimum
MISC - Miscellaneous

NC - Normally Closed
NO - Normally Open
OA - Outdoor Air
PIU - Powered Induction Unit
RA - Return Air
RF - Return Fan
RH - Relative Humidity
RTU - Roof-top Unit
SA - Supply Air
SF - Supply Fan
SP - Static Pressure
TEMP - Temperature
UH - Unit Heater
UV - Unit Ventilator
VAV - Variable Air Volume
VVTU - Variable Volume Terminal Unit
W/ - with
W/O - without
WSHP - Water Source Heat Pump

APPENDIX C: Change Log

#	Version	Date	Reference	Description
1	1.0	04/11/2018	23 09 23 1.1	Added clarity for DDC Ethernet networks in buildings with or without CoV IT network infrastructure.
2	1.0	04/11/2018	23 09 23 1.2	Added clarity for the use of Stand-Alone irrigation controllers.
3	1.0	04/11/2018	23 09 23 1.3	Added clarity for approved control system contractors. Specific contractors are now listed and the approval criteria indicated.
4	1.0	04/11/2018	23 09 23 3.8	Added clarity for Ethernet networks and reference to change in section 1.1
5	1.0	04/11/2018	23 09 23 3.13	Added labeling requirement for controls hardware concealed above ceilings or behind hatches.
6	1.0	04/11/2018	23 09 93 1.1	Added example sequence of operation for Trim & Respond algorithm

Ice Plant Notification Guideline

1. DDC system Notification Details
    a. The DDC system in each ice plant shall monitor plant operation and provide alarm notifications via email to the building operator(s). These alarms are intended to provide additional detail to site staff about any identified issues related to the ice plant. The ammonia detection and exhaust systems shall operate independently from this notification system and will automatically trigger parallel alarm notifications through a remote monitoring system. DDC email notifications are not indented to replace the monitoring requirements of the remote monitoring system.
    b. Alarm Types - The list below shows the types of alarms that shall be configured for each ice plant. Plant variations will need to be accounted for in each specific installation. As-built documentation for each site shall include a complete list of site specific alarms to the same level of detail shown below.
        i. Critical Alarms
            1. Destinations
                a. Email notification to Operator accounts
                b. Critical Plant Failure Alarm to Life Safety Notification system
                    i. The presence of any Critical Alarms shall trigger a DDC output monitored by the Life Safety Notification System.
            2. Examples:
                a. Chiller High Liquid Level Alarm
                    i. Monitor status of latching high level safety limit for each chiller. Alarm if safety signals is engaged.
                b. Exhaust Fan Failure Alarm
                    i. Monitor status of each exhaust fan. Alarm if exhaust fan is commanded to run and status is not detected for more than 30 seconds (adj.).
                c. High Discharge Pressure Alarm
                    i. Monitor compressor discharge pressure and alarm if it exceeds a high pressure setpoint of 200PSI (adj.) for more than 1 minute.
                d. Room - Low Level NH3 Alarm
                    i. Monitor NH3 Detector output signal and alarm if it exceeds a low alarm setpoint of 35PPM (adj.).
                e. Room - High Level NH3 Alarm
                    i. Monitor NH3 Detector output signal and alarm if it exceeds a high alarm setpoint of 100PPM (adj.).
                f. Exhaust Duct - Low Level NH3 Alarm

            i. Monitor NH3 Detector output signal and alarm if it exceeds a low alarm setpoint of 35PPM (adj.).
        g. Exhaust Duct - High Level NH3 Alarm
            i. Monitor NH3 Detector output signal and alarm if it exceeds a high alarm setpoint of 100PPM (adj.).
        h. Emergency Switch Alarm
            i. Monitor status of emergency plant shut down switch and alarm if the emergency shut down is engaged.
        i. PRV Vent - Low Level NH3 Alarm
            i. Monitor NH3 Detector output signal and alarm if it exceeds a low alarm setpoint of 2000PPM (adj.).
        j. PRV Vent - High Level NH3 Alarm
            i. Monitor NH3 Detector output signal and alarm if it exceeds a high alarm setpoint of 5000PPM (adj.).
ii. High Priority Maintenance Alarms
    1. Destinations
        a. Email notification to Operator accounts
    2. Examples:
        a. NH3 Level Signal Loss Alarm
            i. Monitor each NH3 Detector output signal and alarm if it drops below -50PPM for more than 1 minute. A negative signal is assumed to indicate a failure in either the input wiring or gas detector output.
        b. Compressor Failure to run
            i. Monitor status of each compressor. Alarm if compressor is commanded to run and status is not detected for more than 30 seconds (adj.).
        c. Pump Failure to Run
            i. Monitor status of each pump. Alarm if pump is commanded to run and status is not detected for more than 30 seconds (adj.).
        d. Condenser Pump Failure Alarm
            i. Monitor status of each condenser pump. Alarm if pump is commanded to run and status is not detected for more than 30 seconds (adj.).
        e. Condenser Fan Failure Alarm
            i. Monitor status of each condenser fan. Alarm if fan is commanded to run and status is not detected for more than 30 seconds (adj.).
        f. Jacket Pump Failure Alarm

i. Monitor status of each jacket pump. Alarm if pump is commanded to run and status is not detected for more than 30 seconds (adj.).

iii. Normal Priority Maintenance Alarms
1. Destinations
a. Email notification to Operator accounts
2. Examples:
a. High Machine Room Temperature Alarm
i. Monitor temperature in Ice Plant Machine room. Alarm if temperature exceeds high limit setpoint of 28°C (adj.) for more than 1 minute.
b. Low Machine Room Temperature Alarm
i. Monitor temperature in Ice Plant Machine room. Alarm if temperature falls below low limit setpoint of 10°C (adj.) for more than 1 minute.
c. High Glycol Return Temperature Alarm
i. Monitor each glycol return temperature. Alarm if temperature exceeds high limit setpoint of -0.5°C (adj.) for more than 1 minute.
d. Low underfloor Temperature Alarm
i. Monitor each rink underfloor temperature. Alarm if temperature falls below low limit setpoint of 3°C (adj.) for more than 1 minute.
e. High Ice Temperature Alarm
i. Monitor each rink Ice temperature. Alarm if temperature exceeds high limit setpoint of -0.5°C (adj.) for more than 1 minute.
f. Low Ice Temperature Alarm
i. Monitor each rink ice temperature. Alarm if temperature falls below low limit setpoint of -9°C (adj.) for more than 1 minute.

c. Email Alarm Configuration
i. Email alarm recipients for each site shall be identified as part of the installation project. Record initial recipient configuration in as-built documentation.
1. Common Operator Email address
a. A common email address shall be created for each facility. This email address shall be accessible to all assigned building operators.
2. Chief Engineer
3. Any other addresses deemed necessary for each site.
ii. Notification Class
1. The BACnet notification class for all alarm objects shall be configured to be Notification Class 11.
iii. Email Method

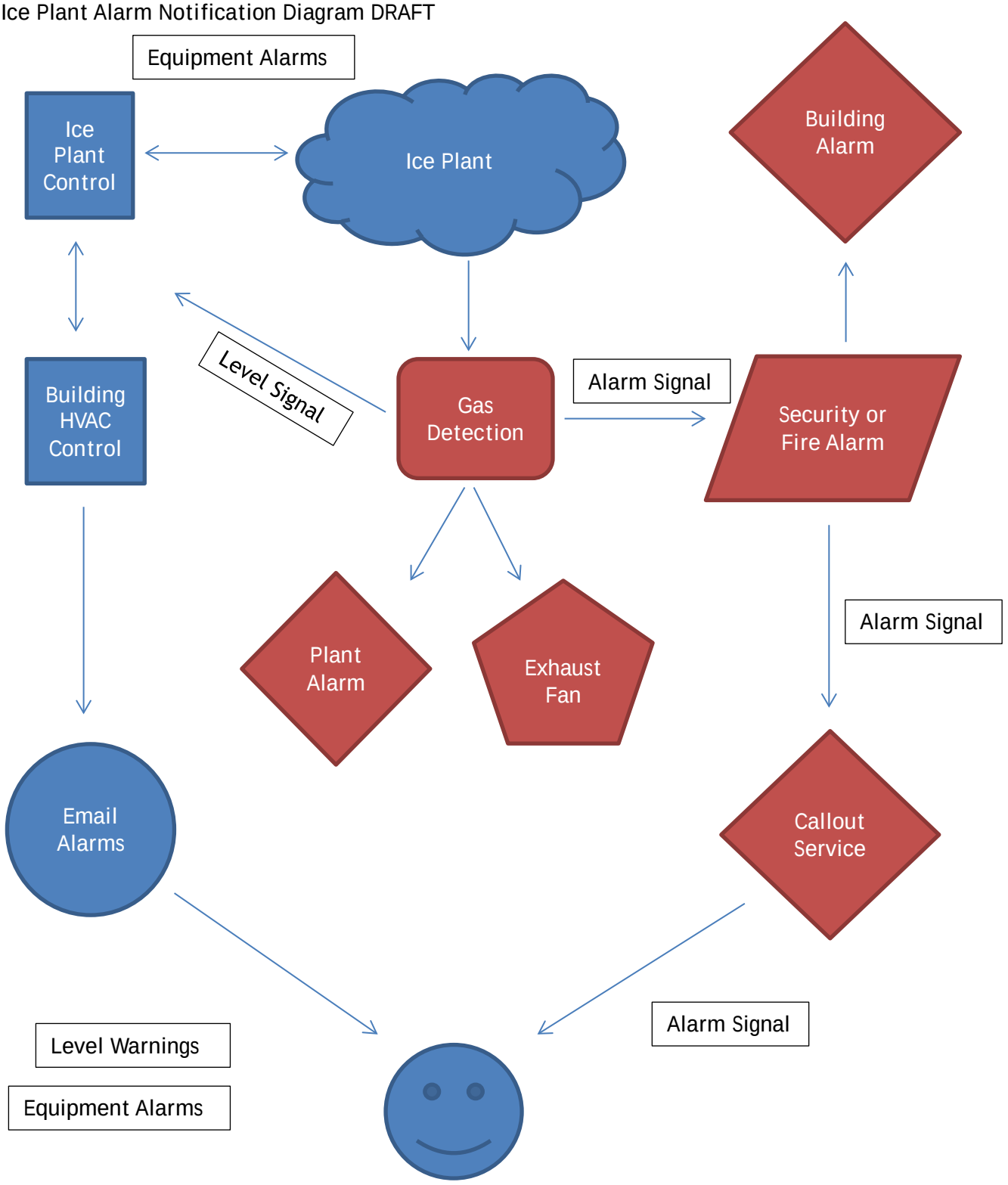
1. Reliable Sites
    a. A CoV network connected Mach-Pro series controller shall be configured at each site to send designated alarms via email notifications.
    b. The configured panel should indicate this use in the controller name.
    c. Email server configuration addresses and settings shall be coordinated for each site.
2. Delta Sites
    a. The CoV Enteliweb server shall be configured for each site with an alarm filter specific to the site and alarm notification class.
    b. Each specified recipient shall be subscribed to email notifications on the defined filer.

d. Alarm History
    i. Logging of alarm events shall be accomplished with the built in alarm lists within the DDC system.
e. NH3 Level Trend Log Configuration
    i. Reliable:
        1. Configure two BACnet trend logs for each signal input
            a. Trend 1:
                i. Configure for COV subscription
                ii. COV Min Increment = 3PPM
            b. Tend 2:
                i. Configure for Poll
                ii. Poll Interval = 5 min
        2. Configure trend logs to archive to RC-Archive for long term data storage
    ii. Delta
        1. Configure two BACnet trend logs for each signal input
            a. Trend 1:
                i. Configure for COV subscription
                ii. COV Min Increment = 3PPM
            b. Tend 2:
                i. Configure for Poll
                ii. Poll Interval = 5 min
        2. Confirm Level Trend Logs to archive to Copper Cube for long term data storage
f. DDC Graphics
    i. The DDC system graphics for each ice plant shall clearly indicate the currently measure NH3 level for each detector and provide links to defined trend logs for the ongoing historical data.
    ii. The main DDC graphic for the ice plant shall provide indication if any Ice plant alarm is active and link to an alarm summary page. The summary page will list each defined alarm, its current state, and any configurable values for the alarm logic.

2. Gas Detection System External Communication
    a. Gas detection controller shall provide:

i. Digital Alarms
    1. Dry contact output to signal alarm event to life safety system
        a. Normally Open Held Closed contact should indicate a normal condition
        b. Open Contacts should indicate an alarm or system fault condition
ii. Analog Gas Level signal
    1. Analog output to DDC System for remote level monitoring and trend logs
        a. 4-20ma analog output that corresponds to the full scale detection range of the gas sensors. 4ma should indicate a 0PPM concentration while 20ma should indicate a full scale PPM reading.
        b. A 0ma reading at the DDC input indicates a loss of signal from the gas detection sensor. This should show as "-99PPM" on the input value and will trigger a signal loss alarm notification to the building operator(s).

3. Life Safety Notification System
    a. Signals to be monitored:
        i. NH3 Alarm signal
            1. 35PPM or Higher
            2. Call out to operator list
            3. Hazmat if no responses
        ii. Catastrophic NH3 Alarm Signal
            1. 250PPM or Higher
            2. Immediate Call to Hazmat
            3. Call out to operator list
        iii. PRV Vent Stack NH3 Alarm
            1. Normal/Alarm status set to trigger an alarm if high concentration of NH3 detected in PRV Vent stack
            2. No PPM signal monitoring necessary
                a. Vent stack volume to NH3 PPM ratio makes PPM levels meaningless. There is either a high level of NH3 detected or none.
            3. Call out to operator list
        iv. Critical Plant Failure Alarm
            1. Common output for all defined Critical Alarms
            2. Call out to operator list

Updated 17/07/2018

Ice Plant Alarm Notification Diagram DRAFT