



SEDGWICK COUNTY, KANSAS
DIVISION OF FINANCE
PURCHASING DEPARTMENT
525 N. Main, Suite 823 ~ Wichita, KS 67203
Phone: 316 660-7255 Fax: 316 383-7055
<http://www.sedgwickcounty.org/finance/purchasing.asp>

REQUEST FOR BID
#16-0040
HVAC CONTROL SYSTEM

April 4, 2016

Sedgwick County, Kansas (hereinafter referred to as "County") is seeking a firm to provide and install an HVAC Control System at 271 W. 3rd. If your firm is interested in submitting a response, please do so in accordance with the instructions contained within the attached Request for Bid.

Sincerely,

A handwritten signature in cursive script that reads "Kimberly Evans".

Kim Evans
Purchasing Agent

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I. Purpose

Sedgwick County, located in south-central Kansas, is one of the most populous of Kansas' 105 counties with a population estimated at more than 508,000 persons. It is the sixteenth largest in area, with 1,008 square miles, and reportedly has the second highest per capita wealth among Kansas' counties. Organizationally, the County is a Commission/Manager entity, employs nearly 2,800 persons, and hosts or provides a full range of municipal services, e.g. – public safety, public works, criminal justice, recreation, entertainment, cultural, human/social, and education.

Sedgwick County is seeking a firm to supply and install a complete Direct Digital Control (DDC) system as required to accomplish the specified sequences of operation for control of heating, ventilating, air-conditioning and other building equipment and systems as described herein.

II. Submittals

Carefully review this Request for Bid. It provides specific technical information necessary to aid participating firms in formulating a thorough response. Should you elect to participate, submit one (1) original **AND** one (1) electronic copy (PDF/Word supplied on a flash drive) of the entire document with any supplementary materials to:

Kimberly Evans
Sedgwick County Purchasing Department
525 N. Main, Suite 823
Wichita, KS 67203

SUBMITTALS are due **NO LATER THAN 1:45 p.m. CDT, TUESDAY, April 26, 2016**. Responses must be sealed and marked on the lower left-hand corner with the firm name and address, bid number, and bid due date. Late or incomplete responses will not be accepted and will not receive consideration for final award.

Bid responses will be acknowledged and read into record at bid opening which will occur at 2:00 p.m. CDT, on the due date.

III. Scope of Work

[Attachment A-Scope of Work](#)

[Attachment B-Specifications for Air Test and Balance](#)

Building plans can be obtained by following this [link](#) to the Sedgwick County Plans website. You will be required to register if you are not already registered on the site.

IV. Sedgwick County's Responsibility

- Provide information, as legally allowed, in possession of the County, which relates to the County's requirements or which is relevant to this project.
- Designate a person to act as the County Contract Manager with respect to the work to be performed under this contract.

V. Bid Terms

A. Pre-Bid Meeting

There will be a Pre-Bid Meeting on Friday April 8, 2016 at 9:30 a.m. CDT at 271 W. 3rd Street. This meeting is NOT mandatory however this will be the only time allotted for interested vendors to view the facility.

B. Questions and Contact Information

Any questions regarding this document must be submitted in writing to Kim Evans at Kimberly.J.Evans@sedgwick.gov by 5:00 p.m. CDT Tuesday April 12, 2016. Any questions of a substantive nature will be answered in written form as an addendum and posted on the purchasing website at www.sedgwickcounty.org/finance/purchasing.asp, under view current RFQs and RFPs; to the right of the RFB number by 5:00 p.m. CDT Friday April 15, 2016. Firms are responsible for checking the website and acknowledging any addendums on their bid response form.

C. Minimum Qualifications

This section lists the criteria to be considered in evaluating the ability of firms interested in providing the service(s) and/or product(s) specified in this Request for Bid. Firms must meet or exceed these qualifications to be considered for award. Bids submitted must reflect in detail their inclusion as well as the degree to which they can be provided. Any exceptions to the requirements listed should be clearly detailed in proposer’s response.

Bidders shall:

1. Have proper certification(s) or license(s) for the services/product specified in this document.
2. Ensure that project work meets all local, state and federal laws, regulations and ordinances.
3. Have the capacity to acquire all required permits, bonds, escrows or insurances.
4. Provide appropriate project supervision and quality control procedures.
5. Have appropriate material, equipment and labor to perform job safely and efficiently. *All costs associated with meeting this requirement will be the sole responsibility of the vendor.*

D. Selection Criteria

An award will be made to the lowest responsible and responsive bidder. Warranties and the time to complete this project will be two major factors in the decision to award this bid request.

E. Request for Bid Timeline

The following dates are provided for information purposes and are subject to change without notice. Contact the Purchasing Department at (316) 660-7255 to confirm any and all dates.

Distribution of Request for Bid to interested parties	April 4, 2016
Pre-Bid Meeting	April 8, 2016
Clarification, Information and Questions submitted in writing by 5:00 p.m. CDT	April 12, 2016
Addendum Issued	April 15, 2016
Sealed Bid due before 1:45pm CDT	April 26, 2016
Evaluation Period	April 27-May 4, 2016
Board of Bids and Contracts Recommendation	May 5, 2016
Board of County Commission Award	May 11, 2016

F. Contract Period and Payment Terms

A contractual period will begin following Board of County Commissioners (BoCC) approval of the successful firm(s) for an initial purchase of quantities listed and establish unit pricing for ONE (1) year.

Either party may cancel its obligations herein upon thirty-day (30) prior written notice to the other party. It is understood that funding may cease or be reduced at any time, and in the event that adequate funds are not available to meet the obligations hereunder, either party reserves the right to terminate this agreement upon thirty (30) days prior written notice to the other. Payment will be remitted following receipt of monthly detailed invoice.

Payment and Invoice Provisions

http://www.sedgwickcounty.org/purchasing/payment_and_invoice_provisions.pdf

G. Insurance Requirements

Liability insurance coverage indicated below must be considered as primary and not as excess insurance. Contractor shall furnish a certificate evidencing such coverage, with County listed as an additional insured, except for professional liability, workers’ compensation and employer’s liability. Certificate shall be provided with bid/proposal submittals. Certificate shall remain in force during the duration of the project/services and will not be canceled, reduced, modified, limited, or restricted until thirty (30) days after County receives written notice of such change. All insurance must be with an insurance company with a minimum BEST rating of A-VIII and licensed to do business in the State of Kansas. It is the responsibility of Contractor to require that any and all approved subcontractors meet the minimum insurance requirements. Contractor shall obtain the above referenced certificate(s) of insurance, and in accordance with this Agreement, provide copies of such certificates to County.

Workers' Compensation:	
Applicable coverage per State Statutes	
Employer's Liability Insurance:	\$100,000.00
Commercial General Liability Insurance:	
Bodily Injury:	
Each Occurrence	\$500,000.00
Aggregate	\$500,000.00
Property Damage:	
Each Occurrence	\$500,000.00
Aggregate	\$500,000.00
Personal Injury:	
Each Occurrence	\$500,000.00
General Aggregate	\$500,000.00
Automobile Liability-Owned, Non-owned and Hired	
Each Occurrence Bodily Injury and Property damage	\$500,000.00
General Aggregate	\$500,000.00
Professional Liability	
If required	

H. [Indemnification](#)

To the fullest extent of the law, the provider, its subcontractor, agents, servants, officers or employees shall indemnify and hold harmless Sedgwick County, including, but not limited to, its elected and appointed officials, officers, employees and agents, from any and all claims brought by any person or entity whatsoever, arising from any act, error, or omission of the provider during the provider's performance of the agreement or any other agreements of the provider entered into by reason thereof. The provider shall indemnify and defend Sedgwick County, including, but not limited to, its elected and appointed officials, officers, employees and agents, with respect to any claim arising, or alleged to have arisen from negligence, and/or willful, wanton or reckless acts or omissions of the provider, its subcontractor, agents, servants, officers, or employees and any and all losses or liabilities resulting from any such claims, including, but not limited to, damage awards, costs and reasonable attorney's fees. This indemnification shall not be affected by any other portions of the agreement relating to insurance requirements. The provider agrees that it will procure and keep in force at all times at its own expense insurance in accordance with these specifications.

I. [Confidential Matters and Data Ownership](#)

The successful proposer agrees all data, records and information, which the proposer, its agents and employees, which is the subject of this bid, obtain access, remains at all times exclusively the property of Sedgwick County. The successful proposer agrees all such data, records, plans and information constitutes at all times proprietary information of Sedgwick County. The successful proposer agrees that it will not disclose, provide, or make available any of such proprietary information in any form to any person or entity. In addition, the successful proposer agrees it will not use any names or addresses contained in such data, records, plans and information for the purpose of selling or offering for sale any property or service to any person or entity who resides at any address in such data. In addition, the successful proposer agrees it will not sell, give or otherwise make available to any person or entity any names or addresses contained in or derived from such data, records and information for the purpose of allowing such person to sell or offer for sale any property or service to any person or entity named in such data. Successful proposer agrees it will take all reasonable steps and the same protective precautions to protect Sedgwick County's proprietary information from disclosure to third parties as with successful proposer's own proprietary and confidential information. Proposer agrees that all data, regardless of form that is generated as a result of this Request for Bid is the property of Sedgwick County.

I. [Bid Conditions](#)

[Request for Bid Conditions](#)

VI. [Required Response Content](#)

Bid response should include the following:

1. Lump sum bid on HVAC Control System as specified in this document.
2. Detailed warranty information, minimum three (3) year warranty; include any supplemental warranty documentation and the length of the warranty.
3. Any exclusions *clearly* delineated.
4. Any additional required items per Attachment A-Statement of Work, Section 1.07 Submittals.

END OF SECTION

VII. Response Form (1 of2)

REQUEST FOR BID
#16-0040
HVAC CONTROL SYSTEM

The undersigned, on behalf of the Bidder, certifies that: (1) this offer is made without previous understanding, agreement or connection with any person, firm, or corporation submitting a bid on the same project; (2) is in all respects fair and without collusion or fraud; (3) the person whose signature appears below is legally empowered to bind the firm in whose name the bidder is entered; (4) they have read the complete Request for Bid and understands all provisions; (5) if accepted by the County, this bid is guaranteed as written and amended and will be implemented as stated; and (6) mistakes in writing of the submitted bid will be their responsibility.

NAME _____

DBA/SAME _____

CONTACT _____

ADDRESS _____ CITY/STATE _____ ZIP _____

PHONE _____ FAX _____ HOURS _____

STATE OF INCORPORATION or ORGANIZATION _____

COMPANY WEBSITE ADDRESS _____ E-MAIL _____

NUMBER OF LOCATIONS _____ NUMBER OF PERSONS EMPLOYED _____

TYPE OF ORGANIZATION: Public Corporation _____ Private Corporation _____ Sole Proprietorship _____

Partnership _____ Other (Describe): _____

BUSINESS MODEL: Small Business _____ Manufacturer _____ Distributor _____ Retail _____

Dealer _____ Other (Describe): _____

Not a Minority-Owned Business: _____ Minority-Owned Business: _____ (Specify Below)

__ African American (05) __ Asian Pacific (10) __ Subcontinent Asian (15) __ Hispanic (20)

__ Native American (25) __ Other (30) - Please specify _____

Not a Woman-Owned Business: _____ Woman-Owned Business: _____ (Specify Below)

__ Not Minority -Woman Owned (50) __ African American-Woman Owned (55)

__ Asian Pacific-Woman Owned (60) __ Subcontinent Asian-Woman Owned (65) __ Hispanic Woman Owned (70)

__ Native American-Woman Owned (75) __ Other - Woman Owned (80) - Please specify _____

ARE YOU REGISTERED TO DO BUSINESS IN THE STATE OF KS: _____ Yes _____ No

Yes, I would like to be on the emergency vendor list.

No, I would not like to be on the emergency vendor list.

After Hours Phone #: _____ Emergency Contact Name: _____

After Hours Fax #: _____

In submitting a response to this document, vendor acknowledges acceptance of all sections of the entire document and has clearly delineated and detailed any exceptions.

Signature _____ Title _____

Print Name _____ Dated _____

Response Form (2 of 2)

Pricing Information

Lump Sum Cost for HVAC Control System per specifications	\$
Days to complete project	
Warranty Period Included (Min. three years. Provide any available supplementary warranty documentation with submittal)	

Please note- The County will evaluate bids based on price, warranty and time to complete the project, as specified in the bid terms. Lowest bid does not necessarily result in an award.

ACKNOWLEDGE RECEIPT OF ADDENDA: All addendum(s) are posted to our RFQ/RFP web page and it is the vendor's responsibility to check and confirm all addendum(s) related to this document by going to www.sedgwickcounty.org/finance/purchasing.asp.

NO. _____, DATED _____; NO. _____, DATED _____; NO. _____, DATED _____

In submitting a response to this document, vendor acknowledges acceptance of all sections of the entire document and has clearly delineated and detailed any exceptions.

Signature _____ Title _____

Print Name _____ Dated _____

ATTACHMENT A-SCOPE OF WORK
DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.01 DIRECT DIGITAL CONTROL (DDC) SYSTEM DESCRIPTION

- A. Intent. This Contractor shall supply and install a complete Direct Digital Control (DDC) system as required to accomplish the specified sequences of operation for control of heating, ventilating, air-conditioning and other building equipment and systems as described herein.

1.02 DDC SYSTEM REQUIREMENTS

- A. BACnet®. The control system shall consist of a high-speed, peer-to-peer internetwork of ANSI/ASHRAE 135 native BACnet® DDC devices. The control system shall also incorporate input/output devices, mechanical/electrical automatic temperature control devices, enclosures, interconnecting conduit and cabling.
1. The BACnet® operating stack must be embedded directly in each individual DDC device at the media access controller level and in all operator interface and configuration applications.
 2. Communication gateways, bridges, protocol translators or any other device that translates any proprietary communication protocol to BACnet® shall not be permitted as a part of the DDC system provided pursuant with this specification except as required to communicate to existing building systems.
- B. BTL. All DDC devices shall be tested, certified, clearly stamped and listed by the BACnet® Testing Laboratories (BTL) prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. Modularity. The DDC system shall be modular in nature and implemented in such a manner that it can be expanded in both capacity and functionality through the addition of DDC controllers, devices and wiring.
- D. Local Database. All logic required to perform the specified sequences of operation, trending and alarming as outlined in this specification shall reside in each individual DDC device. Should network communications fail, each device shall be capable of performing local control strategies without reliance upon any other device.
1. DDC devices that require any supervisory server software or hardware or any external platform to manage database execution or network management shall not be permitted as a part of the DDC system provided pursuant with this specification.

1.03 DDC SYSTEM ARCHITECTURE

- A. BACnet®. The DDC system as provided and installed under this specification shall comprise a BACnet® Internetwork. All communication shall conform to ANSI/ASHRAE Standard 135, BACnet®.
- B. Consistency. The DDC system as provided and installed under this specification shall be a complete system from a single manufacturer designed for use on intranets and the Internet.
- C. FLCN. Field Level Communication Networks (FLCNs) shall be comprised of BACnet® networks of unitary BACnet® controllers and devices using the BACnet® data link Master Slave/Token Passing (MS/TP).

- D. BLCN. Building Level Communication Networks (BLCNs) shall be comprised of a BACnet®/IP Local Area Network (LAN) for the interconnection of FLCNs, BACnet® devices and operator interfaces using the BACnet® data links BACnet®/IP (B/IP) or BACnet®/Ethernet (ISO 8802.3).
- E. ELCN. An Enterprise Level Communication Network (ELCN) shall be comprised of a BACnet®/IP Wide Area Network (WAN) for the interconnection of BLCNs and high level operator interface (HLI) using the BACnet® data link BACnet®/IP (B/IP).
- F. Internetwork. Internetwork operator interface and BACnet® communication shall be transparent to network architecture.

BACnet® communication shall be automatically routed to all configured BACnet® networks by DDC control devices on the internetwork. Dedicated, stand-alone BACnet® routers and/or routing devices shall not be necessary or accepted.

1.04 QUALITY ASSURANCE

- A. DDC System Manufacturer shall be engaged full-time in the manufacture of equipment and devices of the scope, size and service required.
- B. The DDC System Manufacturer shall operate a Quality Management System formally certified to be in compliance with ISO 9001:2008.
- C. The DDC system Contractor shall specialize and have a minimum of five (5) years of experience in the design, installation, programming and operation of DDC systems of the scope, size and service specified; and shall:
 - 1. Be an officially authorized representative of the DDC System Manufacturer with an established relationship of not less than three (3) years.
 - 2. Assign to the project technicians and engineers who are officially trained and certified by the DDC System Manufacturer in the design, installation, programming and operation of the DDC System components.
- D. The DDC BACnet® Internetwork shall be based upon and installed according to the DDC System Manufacturer's standard integrated hardware and software product design and in accordance with the Manufacturer's installation and application documentation.

1.05 CODES AND STANDARDS

- A. Workmanship, materials and equipment together with the resultant complete and operational DDC System shall be in compliance with the Authorities Having Jurisdiction (AHJ) for the project and the most restrictive of applicable local, state and federal codes and ordinances in cooperation with these plans and specifications. At a minimum, the installation shall comply with the applicable sections of the current editions in effect thirty (30) days prior to receipt of bids of the following codes:
 - 1. ANSI/ASHRAE Standard 135: BACnet® - A Data Communication Protocol for Building Automation and Control Networks.
 - 2. National Electric Code (NEC).
 - 3. International Building Code (IBC).
 - 4. International Mechanical Code (IMC).
 - 5. Underwriters Laboratories (UL).
 - a. UL-916 – Energy Management Systems (EMS).

1.06 SYSTEM PERFORMANCE

- A. Graphic Display. A minimum of 50 dynamic real-time data points within 10 seconds of the request and shall refresh with current data within 5 seconds.
- B. Operator Command. The maximum time between the command of a binary or analog object by the operator and the reaction initialization by the device shall be 5 seconds.
- C. Object Command. Devices shall respond to automatic command of a binary or analog object within 2 seconds.
- D. Object scan. Changes of state or analog shall be transmitted such that no reporting of a value is more than 15 seconds old.
- E. Alarm Response. The maximum amount of time from when an object goes into alarm until it is annunciated at the workstation shall not exceed 20 seconds.
 - 1. Each workstation on the network shall receive alarms within 10 seconds of other workstations.
- F. Program Execution. All programs in all DDC devices shall be able to execute at a minimum of at least one time every second. Program execution time shall be configurable to be consistent with the process under control.
- G. Control Loop Performance. All DDC devices shall be able to execute control loops at a frequency at least one time every second. The controller shall update the process value and output generated by this calculation at this same frequency at a minimum.
- H. Environmental Conditions. All DDC System components provided under this specification shall operate under ambient environmental conditions of -20°C (-4°F) to 55°C (131°F) dry-bulb and 10% to 90% relative humidity, non-condensing as a minimum. Sensors and control elements shall be constructed of material suitable and rated for the media sensed under the ambient environmental temperature, pressure, humidity, and vibration conditions encountered for the installed location.
- I. Power Conditions. Networked components of the DDC System shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%.
- J. Reporting Accuracy. System shall report values with minimum end-to-end accuracy as listed in Table 1.
- K. Control Stability and Accuracy. Control applications shall maintain process variables at setpoint within the tolerances listed in Table 2.
 - 1. Combined system repeatability of sensors, controllers and readout devices for a particular application shall be plus or minus 2% of full scale of the operating range.
 - 2. Repeatability of overall combined system of sensor, controller and readout device in a control loop application will be plus or minus 5% of full scale of the operating range.
 - 3. Long-term electronic drift shall not exceed 0.4% per year.

TABLE 1: REPORTING ACCURACY

PROCESS VARIABLE	REPORTING ACCURACY
Space Temperature	±0.5°C (±1.0°F)
Ducted Air Temperature	±1.0°C (±2.0°F)
Outdoor Air Temperature	±1.0°C (±2.0°F)
Water temperature	±0.5°C (±1.0°F)
Delta-T	±0.15°C (±0.25°F)
Relative humidity	±2% RH
Water flow	±2% of full scale
Air flow (terminal)	±10% of full scale (Note 1)
Air flow (measuring stations)	±2% of full scale
Air flow (pressurized spaces)	±3% of full scale
Air pressure (ducts)	±25 Pa (±0.1 in. WG)
Air pressure (space)	±3 Pa (±0.01 in. WG)
Water pressure	±2% of full scale (Note 2)
Electrical Power (A , W, V & PF)	±2% of reading (Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO ₂)	±50 PPM

NOTE Accuracy applies to 10%-100% of scale

1:

NOTE For both Absolute and Differential pressure

2:

NOTE Not including utility-provided meters

3:

TABLE 2: CONTROL STABILITY & ACCURACY

PROCESS VARIABLE	CONTROL ACCURACY	RANGE OF MEDIUM
Air Pressure	±50 Pa (±0.2 in. WG)	0-1.5 kPa (0-6 in. WG)
	±3 Pa (±0.01 in WG)	-25-25 Pa (-0.1-0.1 In. WG)
Air flow	±10% of full scale	
Space Temperature	±1.0°C (±2.0°F)	
Duct Temperature	±1.5°C (±3.0°F)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 kPa (±1.0 in. WG)	0-1 MPa (1-150 psi) ΔP 0-12.5 kPa (0-50 in WG) ΔP

1.07 SUBMITTALS

- A. Submit in compliance with all General Conditions of the Contract, Supplementary Conditions and General Requirements of the project and in conjunction with the requirements of this section.
- B. No work may begin on any segment of this project until submittals have been successfully reviewed for conformity with the design intent.
- C. All submittals and documentation including complete DDC System engineering design submittal & drawings, project record documents, application engineering documents and owner's & maintenance manuals shall be submitted electronically in the form of an ISO 32000 Portable Document Format (PDF). All control schematics, wiring diagrams, riser diagrams, etc. shall be formatted for A3 paper size (297mm x 420mm, 11" x 17"). All other documentation may be formatted for A4 (210mm x 297mm, 8.5" x 11").
- D. Submit in writing and so delineated at the beginning of each submittal, known conflicts, substitutions and deviations from requirements of Contract Documents. Deviation from Contract Documents must be approved by Owner and/or contracting officer prior to award of contract.
- E. Each submitted piece of literature and drawing shall clearly reference the applicable specification section and/or drawing that the submittal responds to. General catalogue sheets shall not be acceptable as cut sheets.
- F. Submittal documentation and drawings shall consistently use the same abbreviations, symbols, nomenclature and identifiers. Each control system element shall be assigned a unique identifier pursuant with the Contract Documents.
- G. Submittal documentation and drawings shall have at the beginning an index and design drawing legend.
 - 1. Index shall list all design drawings and elements including the drawing number, sheet number, drawing title, etc.
 - 2. Legend shall show and describe all symbols, abbreviations and acronyms used on the design drawings.
- H. DDC System Hardware Submittals.
 - 1. A complete bill of materials of all equipment, controllers, devices and sensors to be provided and/or used indicating unique equipment identifier, unique device identifier, manufacturer, model number and quantity.
 - 2. A Protocol Implementation Conformance Statement (PICS) including a BACnet® Interoperability Building Block (BIBB) table for each DDC device included in the submittal.
 - 3. Manufacturer's technical data including product specification sheets, performance curves and installation/maintenance instructions. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly called out by other means.
 - 4. Schematic diagrams for all field sensors and controllers providing floor plans indicating the locations of all sensors, devices and temperature control panels.
 - 5. Control enclosure details for each enclosure including panel identifier, location, physical lay-out, dimensions, instrumentation, labels, etc.

6. Wiring diagrams and schematics for each control enclosure showing and power source for each panel, secondary power and network termination as well as all individual terminations, terminal numbers, point type and mnemonic/name.
 7. Wiring diagrams for all packaged equipment, motor starters, relay wiring, equipment interlock, safety circuits, etc. clearly indicating all interconnecting wiring and termination of all conductors and cables including labels of all cables and point mnemonics.
 8. Wiring diagrams and schematics for each sensor.
- I. Controlled System Submittals.
1. Riser diagram showing the physical lay-out of the entire Internetwork.
 2. Riser diagram for each individual BACnet® network including the ELCN, and each BLCN and FLCN including:
 - a. Data link with physical characteristics and configuration.
 - b. Each BACnet® networked DDC device including location, service, device instance, MAC address and network number.
 - c. Each IP networking device including location, service and IP address.
 - d. Location of all interface devices including network interface jacks and workstation connections.
 - e. Location of all MS/TP network termination points and End-of-Line terminations.
 3. A schematic control flow diagram of each controlled system showing actual physical configuration and location of all control elements including each hardware point type, controller and mnemonic.
 4. A schematic wiring diagram of each controlled system showing actual physical wiring and termination of all control elements including each hardware point type, controller, mnemonic and terminal number.
 5. An instrumentation list for each controlled system displaying each control element, name, manufacturer, model and product data sheet number in a tabular format.
 6. A complete description of the operation of the DDC System including a specific Sequence of Operation for each controlled system. Sequences of operation shall:
 - a. Refer to equipment and control devices by their specific unique identifiers pursuant with the Contract Documents and the DDC System submittal package.
 - b. Clearly represent actual application programming methodology and functional control operation not merely a copy of the Contract Document specified sequence of control.
 - c. Include a concise description of functional system operation under specified normal and failure conditions.
 - d. Include a complete hardware input and output (I/O) points schedule identifying for each point its instance, type, name/mnemonic, controller, equipment/function, location, termination, and override, alarm and display criteria.
 7. Operational deviation from the specified Sequences of Operation as outlined in Contract Documents shall not be permitted under any circumstances without prior written approval.

J. Schedules.

1. Provide a schedule of work indicating at a minimum the intended sequence of work, start dates and durations for individual activities, delivery dates for major materials and equipment including anticipated lead times and milestones indicating possible restraints on work by other trades or construction delays.

K. Project Record Documentation.

1. Upon completion of installation and systems commissioning submit record (as-built) documents for review to include:
 - a. Testing and .commissioning reports and checklists.
 - b. Operation and Maintenance (O&M) manual.
 - c. As-built revisions of all submittal data updated to reflect actual field conditions, architecture and execution.
 - d. Names and 24-hour contact information for installing contractors and service representatives.
 - e. Operator's manual with administrator and operator level credentials and procedures for operating the DDC System including logging-on/off, handling alarms, generating points reports, trending data, overriding automatic control, changing setpoints and control variables.
 - f. Programming manual describing the programming language structure and syntax.
 - g. Engineering manual describing database management and modification.
 - h. Installation and maintenance manuals describing how to install and configure new hardware as well as how to perform routine preventative maintenance and calibration together with corrective diagnostic troubleshooting procedures.
 - i. Documentation of all programs created including setpoints, tuning parameters and final database.
 - j. Complete system database as functional at the conclusion of systems commissioning and functional testing including all graphics and images used by and/or created for DDC System on electronic format as accepted by Owner.
 - k. Final Bill of Material with all installed parts, manufacturers, manufacturers' part numbers and ordering information.
 - l. A schedule of recommended spare parts with part numbers and supplier.
 - m. All original-issue installation and maintenance manuals, user guides, and other documentation provided with all hardware and software provided as a part of this specification.
 - n. Licenses, guarantees and warrantee documentation for all equipment and systems.

L. Training.

1. Provide training course outline and curricula at least six (6) weeks prior to training. Engineer and/or Owner shall modify the curricula as necessary to meet the Owner's Project Requirements (OPR). Revised curricula shall be returned no later than three (3) weeks prior to the training.

1.08 WARRANTY

- A. The DDC System Manufacturer shall warranty all DDC controllers to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of three (3) years at a minimum.
 - 1. Sensors and field components integral to DDC controllers shall be warrantied to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of one (1) years at a minimum.
- B. The DDC System Contractor shall warranty the installation of all other DDC materials and labor to be free of defects under normal expected service and use for a period of one (1) year from the date of final acceptance.
- C. DDC System failures during the installation warranty period shall be adjusted, repaired or replaced at no additional cost or reduction in service to the Owner. Except in the event of property loss or damage, warranty service shall be provided during regular working hours Monday through Friday.

1.09 OWNERSHIP OF PROPRIETARY MATERIAL

- A. All project specific software and documentation shall become the owner's property including but not limited to graphics, record drawings, database, application programming code and documentation upon project acceptance.

END OF PART 1

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PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. All DDC devices shall be tested, certified, clearly stamped and listed by the BACnet® Testing Laboratories (BTL) prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- B. The order of manufacturers does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. DDC Systems shall comply with all of the requirements of this specification.
- C. The following are approved DDC System manufacturers and product lines:
 - 1. Johnson Controls – *Local Corporate Branch*
 - 2. Reliable Controls – *Five Star Mechanical*
 - 3. Trane – *Knipp Services*
- D. All DDC System networked devices specified herein including advanced operator workstations, operator workstations, controllers and routers shall be provided by one of the manufacturers listed above.
 - 1. OEM and/or private-labelled controllers or software manufactured or developed by a third-party and labelled or otherwise represented as being a product of one of the allowable manufacturers listed above shall not be accepted under this specification.
- E. Other non-networked system components specified herein (including sensors, valves, dampers, etc.) need not be manufactured by the above manufacturers.
- F. The DDC System Manufacturer product line selected shall be the most current and complete offering from the manufacturer and shall currently be actively manufactured and supported at the time that this project is bid.
- G. This project shall not be used as a test site. First release and test version hardware, software and firmware shall not be implemented on this project under any circumstances.
- H. DDC System devices and spare components or equivalent shall be readily available for a minimum of five (5) years after the completion and final acceptance of this project.

2.02 COMMUNICATION

- A. The DDC system as provided and installed under this specification shall comprise a BACnet® Internetwork. All communication shall conform to ANSI/ASHRAE Standard 135, BACnet®.
- B. Each individual DDC device shall provide a communication port for the connection of an operator workstation.
- C. The DDC system shall be modular in nature and implemented in such a manner that it can be expanded in both capacity and functionality through the addition of DDC controllers, devices and wiring. Expansion shall not require operator interface or configuration hardware additions, software revisions or hardware, operating system/feature licensing.

- D. All DDC System BACnet® networked devices with Real-Time Clocks (RTCs) shall utilize the BACnet® Time Synchronization service. The System shall automatically synchronize system clocks from a designated Time Master periodically via the Internetwork. The System shall also automatically adjust for configurable Daylight Savings Time and Standard Time as applicable.

2.03 BACNET® ADVANCED OPERATOR WORKSTATION (B-AWS)

- A. The BACnet® Advanced Operator Workstation provides complete configuration, monitoring, modification and operation of the entire DDC System by advanced building operators and technicians.
- B. BACnet® Advanced Operator Workstation software shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a B-AWS and shall be certified and listed by the BACnet® Testing Laboratories (BTL) as a B-AWS prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. BACnet® Advanced Operator Workstation shall reside on the ELCN or the BLCN using the BACnet®/IP data link as specified in ANSI/ASHRAE Standard 135.
- D. Security. Each operator shall be required to log on to the system with a unique user name and password in order to view, edit, add or delete data.
 - 1. System security permissions shall be multilayered and defined for each individual operator to restrict/permit day-to-day operations and system configuration.
 - 2. An administrator-level operator shall have the ability to configure credentials for all other operators.
 - 3. Each operator shall be automatically logged-off of the system after a configurable period of inactivity.
 - 4. Security data shall be stored in an encrypted format.
- E. Database Back-up & Restore. Each workstation shall provide operator interface and off-line storage of system information. An operator with the proper permissions shall be able to back-up, restore and/or clear the database from any device on the Internetwork.
 - 1. The workstation shall perform automated network back-up of runtime databases in all devices on the BACnet® internetwork according to operator configurable schedule and storage directory structure.
- F. System Configuration. The workstation shall provide a complete engineering tool for the configuration of the system. This shall allow for future system changes under proper password protection including dynamic creation, deletion and modification of all configuration parameters, programs, graphics, trend logs, alarms, schedules and every BACnet® object used in the installed system.
- G. Online Help. Provide a context-sensitive online help system to assist the user in operation and modification of the system. Online help shall be available for all system applications and shall provide the relevant data for the active window or screen. Additional help shall be available through the use of hypertext.
- H. System Diagnostics. The workstation shall be provided with fully automatic verification of internetwork communication. In the event of communications failure, the system shall automatically Alarm the condition. B-AWS Software shall be capable of remote annunciation to printer, pager and e-mail.
- I. Graphical User Interface (GUI). The operator interface shall be graphically oriented.

1. All color graphic displays shall be dynamic with current point data automatically updated from the BACnet® internetwork to the workstation without operator intervention.
 2. With the proper credentials the operator shall be able to manually adjust all data point values (hardware or software) in the system, adjust control loop parameters, schedules and command points to manual override, timed override and automatic mode.
 3. Operators shall have the ability to dynamically create messages saved as text files on the B-AWS associated with individual objects on a display or the display itself. These text files may be viewed and modified by other operators during other sessions.
 4. The windowing environment of the workstation shall allow the user to simultaneously view several graphics at the same time to analyze total building operation, and/or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
 5. Operator shall be able to easily navigate between the graphic displays and shall be able to individually change the size and location of the displays on the screen.
 6. B-AWS software shall support at a minimum BMP, GIF, TIF, JPG, EMF, PNG, SWF and DIB graphic file formats and allow for the use of custom animation objects and URL hyperlinks in each display.
 7. The operator shall have the ability to generate custom dynamic images for graphical representation of system design and system parameters. Graphic images may reside on a workstation or server; however, all dynamic data and attributes must reside in each controller.
 8. Library of standard HVAC graphic components consistent with the delivered graphics shall be available to the Owner including all of the equipment and standard symbols used in a file format compatible with the B-AWS software.
- J. Alarm Processing. The workstation shall display and log alarms and events from any BACnet® object in the system and shall support operator configuration of the alarm limits, differentials, states and reactions for each object in the system.
1. Alarm Classification. System shall provide a minimum of 50 configurable notification classes and 100 configurable alarm priorities.
 2. Alarm and Event Log. The operator shall be able to view all system alarms from any location in the internetwork. With the proper credentials, an operator shall be able to acknowledge and clear alarms. Alarm and Event Log shall be configurable per workstation and shall display at a minimum alarm time, received time, state, notification class, priority, message, source, time acknowledged, acknowledged by user and action.
 - a. Acknowledged and Cleared alarms shall be saved to the hard disk of the workstation.
 3. Alarm Messages. Alarm messages shall use the English language name for the object in alarm in such a way that the source, location and nature of the alarm is easily understood without relying upon mnemonics or object instances.
 - a. Alarm messages shall be fully customizable in size, content, behavior and sound.
 4. Alarm Actions. The operator shall be able to configure any of the following automatic alarm actions per workstation:
 - a. Logging.
 - b. Printing.

- c. Starting programs or routines.
 - d. Displaying messages.
 - e. Paging.
 - f. Audible annunciation.
 - g. Displaying specific graphical displays or files.
- K. Scheduling. The workstation shall support viewing and with proper user credentials, modification, creation and deletion of binary, analog and multistate BACnet® Schedule objects and parameters.
- 1. The schedule objects shall reside in each individual device. Workstation or server-based scheduling shall not be acceptable.
 - 2. Each schedule shall display the scheduled transitions for the calendar week. Each calendar day shall support up to a minimum of ten (10) transitions and each transition shall be modifiable via the workstation graphically or via manual entry.
 - 3. Display a monthly calendar allowing for indication and modification of Exception Schedules for any calendar day.
 - a. Each Exception Schedule and holiday shall be individually configurable including name, priority, transition values and times.
 - b. The operator shall have the ability to configure Exception Schedules to be active on specific dates, date ranges, recurring date patterns or as commanded by BACnet® Calendar objects or other override objects.
- L. Trend Logs. The workstation shall support both the BACnet® Trend Log and the BACnet® Trend Log Multiple standard objects for defining custom trend logs for any object in the system. This definition shall include interval, length, start time and end time.
- 1. The trend data shall be sampled and stored in each individual BACnet® device where the object is stored. The workstation or another field level integration platform shall not be required for storage of custom trend logs.
 - 2. All long-term data archival to hard-disk shall be performed by a BTL-Listed BACnet® device dedicated for this service.
 - 3. The workstation shall display all trend log data in a tabular and graphical format.
 - 4. All trend log data shall be able to be exported as a CSV or XLS and printed.
 - 5. The workstations shall display trend log data from controllers and archived BACnet® data from the archive server database seamlessly, in the same trend log display.
- M. Runtime Logs. The workstation shall support logging and reporting of runtime for every binary object in the system.
- 1. Runtime data shall be sampled and stored in each individual BACnet® device where the object is stored using standard BACnet® objects and published properties. The workstation shall not be required for storage of custom runtime logs.
 - 2. At a minimum, the Runtime data shall include: total accumulated active time, total accumulated active transitions, and active transitions for the current day, timestamp and duration for each change of state for the last 100 transitions.

- N. Object and Property Status and Control. The workstation shall provide a method for the operator to view and if permitted modify the status and present value of any standard object and property in the system.
1. The operator shall be able to build custom reports manually or by performing wildcard searches for object instances, mnemonics or names.

2.04 EMBEDDED BACNET® OPERATOR WORKSTATION (B-OWS)

- A. The embedded BACnet® Operator Workstation (B-OWS) provides day-to-day monitoring and basic operation of the DDC System. The embedded BACnet® Operator Workstation is not designed for configuration of the System.
- B. The embedded BACnet® Operator Workstations shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for both a B-OWS and a B-BC and shall be certified and listed by the BACnet® Testing Laboratories (BTL) as both a B-OWS and a B-BC prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. Embedded BACnet® Operator Workstations shall reside on the ELCN or the BLCN using the BACnet®/IP data link as specified in ANSI/ASHRAE Standard 135 Annex J.
- D. Each embedded BACnet® Operator Workstation shall store the entire device database and all necessary Graphical User Interface (GUI) resources including animations locally on the device. Web-enabled applications that require system graphics to be stored on the client machines or servers shall not be acceptable.
- E. Security. Each operator shall be required to log on to the system with a unique user name and password in order to view, edit, add or delete data.
1. System security permissions shall be multilayered and defined for each individual operator to restrict/permit day-to-day operations and system configuration.
 2. Each operator shall be automatically logged-off of the system after a configurable period of inactivity.
 3. Security data shall be stored and transmitted in an encrypted format.
- F. Graphical User Interface (GUI). The operator interface shall be graphically oriented.
1. All color graphic displays shall be dynamic with current point data automatically updated from the BACnet® internetwork to the embedded workstation without operator intervention.
 2. The operator with the proper credentials shall be able to manually adjust all data point values (hardware or software) in the system, adjust values of control loops, and command points to manual override, timed override and automatic mode.
 3. Operators shall have the ability to dynamically create messages saved a text files on the embedded B-OWS associated with individual objects on a display or the display itself. These text files may be viewed and modified by other operators during other sessions.
- G. Alarm Processing. The embedded workstation shall display and log alarms and events from any BACnet® object in the system and shall support operator configuration of the alarm limits, differentials, states and reactions for each object in the system.
1. Alarm Classification. System shall provide a minimum of 50 configurable notification classes and 100 configurable alarm priorities.

2. Alarm and Event Log. The operator shall be able to view all system alarms from any location in the internetwork. With the proper credentials, an operator shall be able to acknowledge and clear alarms. Alarm and Event Log shall display at a minimum alarm time, received time, state, notification class, priority, message, source, time acknowledged, acknowledged by user and action.
 3. Alarm Messages. Alarm messages shall use the English language name for the object in alarm in such a way that the source, location and nature of the alarm is easily understood without relying upon mnemonics or object instances.
 - a. Alarm messages shall be fully customizable in size, content and behavior.
 4. Alarm Actions. The operator shall be able to configure any of the following automatic alarm actions per workstation:
 - a. Logging.
 - b. Printing.
 - c. Starting programs or routines.
 - d. Displaying messages.
 - e. Paging.
 - f. Audible annunciation.
 - g. Displaying specific graphical displays or files.
- H. Scheduling. The embedded workstation shall support viewing and with proper user credentials modification of BACnet® binary, analog and multistate Schedule objects and parameters.
1. The schedule objects shall reside in each individual device. Workstation or server-based scheduling shall not be acceptable.
 2. Each schedule shall display the scheduled transitions for the calendar week. Each calendar day shall support up to a minimum of ten (10) transitions and each transition shall be modifiable via the workstation graphically or via manual entry.
 3. Display a monthly calendar allowing for indication and modification of Exception Schedules for any calendar day.
 - a. Each Exception Schedule and holiday shall be individually configurable including name, priority, transition values and times.
 - b. The operator shall have the ability to configure Exception Schedules to be active on specific dates, date ranges, recurring date patterns or as commanded by BACnet® Calendar objects or other override objects.
- I. Trend Logs. The embedded workstation shall support both the BACnet® Trend Log and the BACnet® Trend Log Multiple standard objects for defining custom trend logs for any object in the system. This definition shall include interval, length, start time and end time.
1. The trend log data shall be sampled and stored in each individual BACnet® device where the object is stored. The workstation shall not be required for storage of custom trend logs.
 2. All long-term data archival to hard-disk shall be performed by a BTL-Listed BACnet® device dedicated for this service.
 3. The workstation shall display all trend log data in a tabular and graphical format.

4. All trend log data shall be able to be exported as a CSV or XLS and printed.
 5. The embedded workstations shall display trend log data from controllers and archived BACnet® data from the archive server database seamlessly, in the same trend log display.
- J. Runtime Logs. The embedded workstation shall support logging and reporting of runtime data for every binary object in the system.
1. Runtime data shall be sampled and stored in the individual BACnet® device where the object is stored using standard BACnet® objects and published properties. The workstation shall not be required for storage of custom runtime logs.
 2. At a minimum the Runtime data shall include: total accumulated active time, total accumulated active transitions, and active transitions for the day, timestamp and duration for each change of state for that last 100 transitions.

2.05 BACNET® DATA ARCHIVE SERVER

- A. Acquisition of trend log data for archival and long-term secure storage of trend log data shall be performed by a BTL-Listed BACnet® device dedicated to this service. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- B. BACnet® Data Archive Server shall reside on the ELCN or the BLCN using the BACnet®/IP data link as specified in ANSI/ASHRAE Standard 135 Annex J.
- C. BACnet® Data Archive Server shall support at a minimum the following BACnet® Interoperability Building Blocks (BIBBs) as supported by the submitted PICS:
1. Data Sharing-ReadProperty-A (DS-RP-A).
 2. Data Sharing-ReadProperty-B (DS-RP-B).
 3. Data Sharing-ReadPropertyMultiple-A (DS-RPM-A).
 4. Data Sharing-ReadPropertyMultiple-B (DS-RPM-B).
 5. Data Sharing-WriteProperty-A (DS-WP-A).
 6. Trending-Automated Trend Retrieval-A (T-ATR-A).
 7. Trending-Automated Multiple Value Retrieval-A (T-AMVR-A).
 8. Trending-Archival-A (T-A-A).
 9. Device Management-Dynamic Device Binding-A (DM-DDB-A).
 10. Device Management-Dynamic Device Binding-B (DM-DDB-B).
 11. Device Management-Dynamic Object Binding-B (DM-DOB-B).
- D. At a minimum, the BACnet® data archive server shall be capable of performing the following:
1. Automatically retrieving the data from all BACnet® Trend Log and BACnet® Trend Log Multiple objects from any BACnet® device communicating on the internetwork without user-intervention.
 2. Automatically manage the connection to the internetwork based upon configurable data acquisition thresholds; retrieving data only when necessary rather than streaming data.
 3. Generate a standard, secure SQL database accessible by third-party applications.

4. Operate as a Microsoft Windows service.
5. Archived data shall be limited only by SQL license and hard disk space available.
6. BACnet® Advanced Operator Workstations (B-AWS), BACnet® Operator Workstations (B-OWS) and enterprise level BACnet® web servers shall display trend log data from controllers and archived BACnet® data from the archive server database seamlessly in the same trend log display.

2.06 BACNET® DATA ARCHIVE SERVER

- A. Acquisition of trend log data for archival and long-term secure storage of trend log data shall be performed by a BTL-Listed BACnet® device dedicated to this service. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- B. BACnet® Data Archive Server shall reside on the ELCN or the BLCN using the BACnet®/IP data link as specified in ANSI/ASHRAE Standard 135 Annex J.
- C. BACnet® Data Archive Server shall support at a minimum the following BACnet® Interoperability Building Blocks (BIBBs) as supported by the submitted PICS:
 1. Data Sharing-ReadProperty-A (DS-RP-A).
 2. Data Sharing-ReadProperty-B (DS-RP-B).
 3. Data Sharing-ReadPropertyMultiple-A (DS-RPM-A).
 4. Data Sharing-ReadPropertyMultiple-B (DS-RPM-B).
 5. Data Sharing-WriteProperty-A (DS-WP-A).
 6. Trending-Automated Trend Retrieval-A (T-ATR-A).
 7. Trending-Automated Multiple Value Retrieval-A (T-AMVR-A).
 8. Trending-Archival-A (T-A-A).
 9. Device Management-Dynamic Device Binding-A (DM-DDB-A).
 10. Device Management-Dynamic Device Binding-B (DM-DDB-B).
 11. Device Management-Dynamic Object Binding-B (DM-DOB-B).
- D. At a minimum, the BACnet® data archive server shall be capable of performing the following:
 1. Automatically retrieving the data from all BACnet® Trend Log and BACnet® Trend Log Multiple objects from any BACnet® device communicating on the internetwork without user-intervention.
 2. Automatically manage the connection to the internetwork based upon configurable data acquisition thresholds; retrieving data only when necessary rather than streaming data.
 3. Generate a standard, secure SQL database accessible by third-party applications.
 4. Operate as a Microsoft Windows service.
 5. Archived data shall be limited only by SQL license and hard disk space available.
 6. BACnet® Advanced Operator Workstations (B-AWS), BACnet® Operator Workstations (B-OWS) and enterprise level BACnet® web servers shall display trend log data from controllers and archived BACnet® data from the archive server database seamlessly in the same trend log display.

2.07 OPEN SYSTEM INFORMATION ARCHIVE REPORTING SOFTWARE

- A. The Open System Information Archive Reporting Software shall be a server-based application for fully-customizable analysis and reporting of archived DDC and Building Automation System (BAS) data including trend and runtime log data.
 - 1. Authorized users shall have the ability to search and import archived trend and runtime log data to the reporting software.
 - 2. Imported data shall be displayed, normalized and compiled into user-defined, custom reports for system performance analysis and verification, energy consumption and costs, after-hours occupancy, etc.
 - 3. Custom report templates shall be capable of being created and saved providing end-users with the ability to instantly create and/or distribute common reports based upon dynamic data.
 - 4. Individual reports shall be saved to the reporting server for user access and report distribution.
- B. User Administration. Each archive reporting software user shall be required to log-on to the system with a unique user name and password in order to view, edit, add or delete reports.
 - 1. System security permissions shall be multilayered and defined for each individual user to restrict/permit system administration, report creation, report modification and interaction, and approval of users created through online signup.
 - 2. Security data shall be stored in an encrypted format using the AES algorithm or better.
- C. User Interface. Archive reporting system shall host all administration, operation, report configuration and report interaction through standard desktop and/or mobile device web browsers.
- D. Data Sources. Reporting software shall be capable of importing data from multiple, standard SQL servers, SQL databases, SQL instances and Microsoft Excel spreadsheets.
 - 1. Reporting software shall automatically display all available databases.
 - 2. Reporting software shall provide the ability to browse databases for data and to select discrete archive entries and data ranges using standard and/or complex SQL queries.
- E. Report Generation. Each individual report shall be created by compiling imported data into customizable graphic and text-based report components including data over time, data as a contribution, profiled data and simple raw data. Reports shall also support customizable text, images, watermarks, user-configurable display date ranges.
 - 1. Reports shall be created through a simple drag-and-drop, graphically-oriented operator interface by any user with appropriate permissions.
 - 2. Users shall have the ability to apply standard mathematical functions, transforms, operators and conditional operations to archived system objects, benchmark and baseline data to create report components.
- F. Report Management. Report templates and individual reports shall be saved to the report server. Authorized users shall be able to characterize reports by report title, report author, user-defined category, created and updated dates.

2.08 CONTROLLERS

- A. BACnet® Compliance. All DDC controllers shall be tested, certified, clearly stamped and listed by the BACnet® Testing Laboratories (BTL) prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).

- B. Specification Compliance. All DDC controllers shall comply with the general requirements of all parts of this specification.
- C. Application. Each individual mechanical system or piece of equipment shall be controlled by no more than one (1) dedicated controller with sufficient hardware and database capacity such that it shall be connected to all field devices and sensors associated with that system and/or piece of equipment.
 - 1. Distributed control of one (1) single piece of mechanical equipment shall not be performed by multiple controllers.
- D. Memory. Each controller shall have sufficient memory to support its operating system, database, and programming requirements. Battery/capacitor shall maintain programming and clock memory and functions for a minimum of 72 hours.
 - 1. Each controller shall provide microprocessor based self-contained stand-alone fully programmable operation of local process control loops. All local level application programs shall be installed on individual controllers in non-volatile memory.
- E. Updates. All controllers shall permit simple operating system firmware updates at any time after installation, utilizing the BACnet® network. Operating system firmware that requires chip replacement or flash modification will not be acceptable.
- F. Data Sharing. Each controller shall be capable of locally executing global strategies for the DDC System based on information from any object in the internetwork. Control systems that require a higher-level host processor for update, time stamps, global point data, COS transfer, on-line control instruction, or communications control between panels shall not be acceptable.
- G. Serviceability. Each DDC controller shall be provided with diagnostic LEDs for power, communication and processor. All wiring connections shall be made to field-removable, modular terminal strips.
- H. Universal Inputs. All hardware inputs on all controllers shall be of the universal type and shall support the following physical characteristics at a minimum:
 - 1. Dry-contact.
 - 2. Pulse/Pulse-width accumulation.
 - 3. Resistance.
 - 4. Voltage.
 - 5. Current.
 - 6. 24 VAC over-voltage protection.
- I. Universal Outputs. All controllers with universal type hardware outputs and shall support the following physical characteristics at a minimum:
 - 1. Contact closure.
 - 2. Analog/Modulating.
 - 3. 24 VAC over-voltage and short protection.
- J. Operator Override. All BACnet® Building Controllers (B-BC) shall support operator-initiated timed overrides of hardware and software objects with user-configurable override periods. When the override period has expired, the controller shall automatically return the object to the automatic state without any additional action on the part of the Operator.

1. The timed override functionality shall exist entirely in the controller. A workstation shall not be required for the execution of the time period nor for returning the object to automatic.
- K. Database. Programming, configuration and modification shall be accomplished via the Internetwork from the B-AWS. The complete operational database and application program shall reside in each individual controller.
1. All controllers delivered as a part of this specification shall be configured using one (1) common B-AWS. Devices that require custom applications for configuration shall not be acceptable.
 2. The controllers shall function in a real-time, multi-tasking networked operating environment; able to display database values, programs, and control loops in real-time while functional and online using the B-AWS. The user shall be able to add, delete, or modify objects on-line as required without taking the controller offline. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary to execute the specified sequence of control.
- L. Programmability. All controllers shall be freely-programmable and support custom control strategies, programs and databases that are completely modifiable over the BACnet® Internetwork once installed.
1. All controllers delivered as a part of this specification shall be programmed using one (1) common programming language, means and method via the B-AWS. Devices that require custom applications for configuration shall not be acceptable.
 2. Control systems that exclusively utilize configurable-only 'canned' programs or programmable read only memory (PROM) level application programming are not acceptable.
- M. Alarm Processing. A controller's ability to report alarms shall not be affected by either operator activity, execution of programs or communications with other controllers on the network.
- N. Scheduling. All controllers shall support the standard BACnet® Schedule and BACnet® Calendar objects.
1. Schedule objects shall reside in each individual device. Workstation or server-based scheduling shall not be acceptable.
 2. BACnet® Schedule objects shall support binary, analog, and multi-state values.
 3. Each calendar day shall support up to a minimum of ten (10) transitions.
 4. BACnet® Schedule objects shall be able to directly command any BACnet® object in the internetwork without requiring custom programming.
 5. Exception Schedules shall be configurable for any calendar day.
 - a. Each Exception Schedule and holiday shall be individually configurable including name, priority, transition values and times.
 - b. The operator shall have the ability to configure Exception Schedules to be active on specific dates, date ranges, recurring date patterns or as commanded by BACnet® Calendar objects or other override objects.
- O. Trending. All BACnet® Building Controllers (B-BC) shall support both standard BACnet® Trend Log and BACnet® Trend Log Multiple objects.
- P. Runtime Logs. All controllers shall support logging and reporting of runtime for every binary object in the system.

1. Runtime data shall be sampled and stored in each individual BACnet® device using standard BACnet® objects and published properties. A workstation shall not be required for storage of custom runtime logs.
 2. Runtime data shall include at a minimum total accumulated active time, total accumulated active transitions, active transitions today, timestamp and duration for each change of state for the previous 100 transitions.
- Q. Workstation Connection. All controllers shall support a communications port for connection of a portable operator's terminal using a BACnet® physical data link.
- R. Communicating Sensors. All controllers shall support and be capable of monitoring and controlling a network of communicating space sensors without consuming physical hardware input/output points on the device.

2.09 BUILDING LEVEL CONTROLLERS

- A. Building Level Controllers. A dedicated building-level controller shall be provided for the execution of global strategies and for each large point-count major mechanical system and/or piece of equipment.
1. Any application exceeding eight (8) inputs or eight (8) outputs shall not be considered a terminal unit application and shall require a dedicated field-level equipment controller or a building-level controller.
- B. BACnet® Device Profile. All building level controllers shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a BACnet® Building Controllers (B-BCs) and shall be certified and listed by the BACnet® Testing Laboratories (BTL) as a B-BC prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. BACnet® Networking. Building level controllers shall reside on the ELCN, BLCN or FLCN using the BACnet®/IP, BACnet®/Ethernet or MS/TP data links as specified in ANSI/ASHRAE Standard 135.
- D. Communication. Building level controllers shall support the following communications requirements at a minimum:
1. Client and Server BACnet® Subscribe Change of Value (COV) Service.
 2. Client and Server BACnet® Read Property Multiple (RPM) Service.
 3. BACnet® transmit and receive frame segmentation.
 4. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout and APDU retries.
- E. Alarm Annunciation. Building level controllers shall support SMTP and provide stand-alone remote annunciation of alarms via e-mail without additional hardware, B-OWS, B-AWS or web-server.

2.10 FIELD-LEVEL EQUIPMENT CONTROLLERS

- A. BACnet® Field Level Equipment Controllers. One (1) dedicated field-level equipment controller shall be provided for the execution of global and local strategies for each mechanical system and/or building system piece of equipment.
1. Distributed control of one piece of mechanical equipment shall not be performed by multiple DDC controllers.

2. Multiple pieces of mechanical equipment comprising one mechanical system may be controlled by a single DDC controller provided that all of the points associated with the equipment are hosted by the controller.
 3. Any application exceeding eight (8) inputs or eight (8) outputs shall not be considered a terminal unit application and shall require a dedicated field-level equipment controller or a building-level controller.
 4. All field-level equipment controllers provided shall be the same controller model and manufacturer.
- B. BACnet® Device Profile. All field-level equipment controllers shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a BACnet® Building Controllers (B-BCs) prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. BACnet® Networking. Field-level equipment shall reside on the BACnet® MS/TP data link as specified in ANSI/ASHRAE Standard 135.
- D. BACnet® MS/TP Slave Device Support. Field-level equipment controllers shall be capable of automatically discovering BACnet® slave devices and shall be capable of serving as a proxy for BACnet® slave devices.
- E. Communication. Field-level equipment controllers shall support the following communications requirements at a minimum:
1. Client and Server BACnet® Subscribe Change of Value (COV) Service.
 2. Client and Server BACnet® Read Property Multiple (RPM) Service.
 3. BACnet® transmit and receive frame segmentation.
 4. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout and APDU retries.

2.11 TERMINAL UNIT CONTROLLERS

- A. Terminal Unit Controllers. One (1) dedicated terminal controller shall be provided for the execution of local strategies and for each mechanical terminal unit unless otherwise approved by Owner and/or contracting officer prior to award of contract .
1. Any application with fewer than eight (8) inputs and eight (8) outputs may be considered a terminal unit application.
 2. All terminal units with a common application shall be provided with the same unitary controller model and manufacturer.
- B. BACnet® Device Profile. All terminal unit controllers shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a BACnet® Building Controllers (B-BCs) and shall be certified and listed by the BACnet® Testing Laboratories (BTL) as a B-BC prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
- C. BACnet® Networking. Terminal unit controllers shall reside on the FLCN using the BACnet® MS/TP data link as specified in ANSI/ASHRAE Standard 135 in compliance with the following requirements at a minimum:

1. Automatically detect the baud of the MS/TP network and then configure the device's communication baud to match that of the MS/TP network.
 2. Be capable of efficiently communicating at a baud of 76.8 Kbps under normal network operational conditions with all devices executing the specified sequences of operation at the specified performance criteria.
- D. Communication. Terminal unit controllers shall support the following communications requirements at a minimum:
1. Client and Server BACnet® Subscribe Change of Value (COV) Service.
 2. Client and Server BACnet® Read Property Multiple (RPM) Service.
 3. BACnet® transmit and receive frame segmentation.
 4. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout and APDU retries.

2.12 SPACE MOUNTED TERMINAL UNIT CONTROLLERS

- A. Space Mounted Terminal Unit Controllers. As required, one (1) dedicated space mounted terminal controller shall be provided for the execution of local indoor environmental control and monitoring strategies and for each mechanical terminal unit.
1. Space mounted terminal controllers shall be aesthetically pleasing and specifically designed for permanent installation in a finished, occupied space.
 2. All terminal units with a common application shall be provided with the same unitary controller model and manufacturer.
 3. For space mounted controllers, any unitary application with between four (4) and eight (8) inputs or between four (4) and eight (8) outputs shall be considered an advanced terminal unit application.
- B. BACnet® Device Profile. All space mounted terminal controllers shall be certified and listed by the BACnet® Testing Laboratories (BTL) prior to the bid date for this project. BTL product listings are available from BACnet® International (<http://www.bacnetinternational.net/btl/>).
1. Advanced application space mounted terminal controllers shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a BACnet® Advanced Application Controllers (B-AACs).
- C. BACnet® Networking. Space mounted terminal controllers shall reside on the FLCN using the BACnet® MS/TP data link as specified in ANSI/ASHRAE Standard 135 in compliance with the following requirements at a minimum:
1. Be capable of efficiently communicating at a baud of 76.8 Kbps under normal network operational conditions with all devices executing the specified sequences of operation at the specified performance criteria.

2.13 COMMUNICATING SPACE SENSORS

- A. Communicating Space Sensors. All controllers of the DDC System as provided will support networked, communicating space sensors for monitoring of internal environmental conditions and low-level operator interface without consuming hardware inputs/outputs on the host DDC controller.

1. Communicating space sensors shall be aesthetically pleasing and specifically designed for permanent installation in a finished, occupied space.
 2. All communicating space sensors shall be developed, manufactured and supported by the same manufacturer of the DDC System components specified herein and provided by the DDC System Contractor.
 3. A minimum of four (4) communicating sensors shall be supported by each DDC controller.
 4. Space mounted terminal unit controllers with fewer than four (4) inputs and four (4) outputs shall not be required to support communicating space sensors.
- B. System Interface. Communicating space sensors shall be capable of providing access to the Internetwork for an operator workstation and/or portable operator terminal.

2.14 COMMUNICATING DUCT SENSORS

- A. Communicating Duct Sensors. All controllers of the DDC System as provided will support networked, communicating duct sensors without consuming hardware inputs/outputs on the host DDC controller.
1. All communicating duct sensors shall be developed, manufactured and supported by the same manufacturer of the DDC System components specified herein and provided by the DDC System Contractor.
 2. A minimum of four (4) communicating sensors shall be supported by each DDC controller.
 3. Space mounted terminal unit controllers with fewer than four (4) inputs and four (4) outputs shall not be required to support communicating sensors.

2.15 WIRELESS TEMPERATURE SENSORS

- A. Wireless Temperature Sensors will not be permitted unless otherwise approved by Owner and/or contracting officer prior to award of contract.
1. Wireless temperature sensors shall be developed, manufactured and supported by the same manufacturer of the DDC System components specified herein and provided by the DDC System Contractor.
 2. Wireless access points, transmitters and receivers shall be aesthetically pleasing and specifically designed for permanent installation in a finished, occupied space.
- B. EnOcean® Networking. All wireless components shall incorporate the EnOcean® interoperable communication protocol and be manufactured by a member of the EnOcean® Alliance.
1. Wireless components that utilize proprietary communication protocols shall not be acceptable.
 2. Wireless sensors shall utilize energy harvesting technology providing maintenance-free wireless operation utilizing a solar-powered photovoltaic cell. Batteries shall not be required.
- C. Communication. All wireless components shall comply with the following communication specifications:
1. Standards: FCC CFR-47 Part 15 Class B (TCM 300C, TCM 300U).
 2. Transceiver frequency: 900 MHz (TCM 300C, TCM 300U).
 3. Data rate/modulation type: 125 kbps/ASK, 315 Mhz, FSK, 902 Mhz.
 4. Receiver sensitivity (@25°C): -98 dB (315 MHz, 902 Mhz).

2.16 AUTOMATIC CONTROL ACTUATORS

- A. Electric Actuation. Unless otherwise specified or scheduled, all control actuators shall be electric/electronic direct-coupled type. Actuators shall have a means for reversing drive direction and a manual override accessible at the front cover.
 - 1. The actuator shall have electronic overload or stall protection to prevent damage to the actuator throughout rotation. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.
- B. Spring Return. Where shown, for power-failure or safety applications, an internal mechanical spring-return mechanism shall be built-in to the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable.
 - 1. All mechanical equipment with direct introduction of outside air shall require fail-safe spring return actuators.
 - 2. Terminal equipment without direct introduction of outside air are permitted to have actuators that maintain their last commanded position when power is lost to the actuator.
- C. Clutch/Gear Release. All non-spring return actuators shall have an external manual clutch/gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 7 Nm (60 in-LB) torque capacity shall have a manual crank for this purpose.
- D. Modulating Actuators. Unless otherwise specified or scheduled, all modulating actuators shall be positive positioning and accept a 0 to 10 VDC or 0 to 20 mA control signal and provide an operating range of 2-10 VDC or 4-20 mA.
- E. Position Feedback. All actuators shall feature a visual position feedback indicator. All non-terminal unit actuators shall provide a 2-10 VDC or 4-20 mA feedback signal.
- F. Power. All 24 VAC/VDC actuators shall operate in Class 2 circuits.
- G. Enclosure. Actuator casing and/or enclosures shall be appropriate to the application.
 - 1. Actuators used in or near outdoor air streams shall have NEMA 2 (IEC IP21) housings.
 - 2. Actuators exposed to moisture, in wet mechanical rooms or located outdoors shall be meet NEMA 4X (IEC IP66) requirements or as directed by the AHJ.

2.17 TEMPERATURE DEVICES

- A. Analog Temperature Sensors. Analog temperature sensors shall be precision element thermistor type.
- B. Duct Sensors. Duct temperature sensors shall include junction box for wiring connections and gasket to prevent air leakage and vibration noise.
 - 1. Single point duct temperature sensor probe shall consist of 316 stainless steel extending to the center of the duct.
 - 2. Averaging duct temperature sensor shall consist of a copper or stainless steel averaging element, junction box for wiring connections and gasket to prevent air leakage or vibration noise. Averaging sensors shall be a minimum of 1.5 m (5') in length per 1 m² (10 ft²) of duct cross sectional area.
 - 3. Immersion Sensors. Liquid immersion temperature sensor shall be provided with a separable stainless steel well, sensor and connection head for wiring connections. The well must be designed to be consistent and appropriate with the system operating pressure and velocity.

4. Space Sensors. Space temperature sensor shall consist of an element within a ventilated cover aesthetically pleasing and specifically designed for permanent installation in a finished, occupied space.
 - a. In private and semi-private spaces that serve full-time or full-time-equivalent occupants including but not limited to offices, work rooms, meeting rooms, conference rooms, etc., space sensors shall be provided with setpoint adjustment and occupancy bypass. Bypass not required in zones with occupancy sensors or applications that are constantly occupied.
 - b. In public spaces without full-time or full-time-equivalent occupants including but not limited to lobbies, hallways, atriums, break rooms, cafeterias, restrooms, theaters, gymnasiums, mechanical spaces, plenums, etc., simple temperature sensor without setpoint or bypass shall be provided.
 - c. Sensors with operator interface keypads and displays shall be provided as indicated or scheduled elsewhere.
5. Outdoor Air Temperature. Outdoor air temperature sensor shall consist of a single device sensor, ventilated non-metallic sun shield, utility box for terminations, and watertight gasket to prevent water seepage.
6. Differential Temperature. Provide matched sensors for differential temperature applications.
7. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL-Listed, vapor pressure type, with an element of 6 m (20') minimum length.
 - a. Provide one (1) low-limit thermostat for each 2 m² (20 ft²) of coil face.
 - b. Low-limit thermostat shall respond to the lowest temperature sensed in by any 30 cm (12") section of the element.
 - c. Low-limit thermostats shall be manual-reset, DPDT-style with a minimum of one (1) normally-open contact and one (1) normally-closed contact.
8. High-Limit Thermostats. High-limit airstream thermostats shall be UL-Listed, bimetal-operated, manual reset type.
9. Low-voltage Thermostats. Low-voltage thermostats shall be 24 VAC, bimetal-operated or electronic type with adjustable or fixed anticipation heater, concealed setpoint adjustment 13°C to 30°C (55°F to 85°F) setpoint range, 1°C (2°F) maximum differential and vented ABS plastic housing.
10. Line-voltage Thermostat. Line-voltage thermostats shall be UL-Listed bi-metal actuated, open contact type, enclosed, snap-switch type or equivalent solid-state type with adjustable or fixed anticipation heater, concealed setpoint adjustment 13°C to 30°C (55°F to 85°F) setpoint range, 1°C (2°F) maximum differential and vented ABS plastic housing.

2.18 HUMIDITY DEVICES

- A. Duct Sensors. Duct-mounted humidity sensors shall have a minimum sensing range of 20% to 80% RH and shall be provided with a sampling chamber.
- B. Space Sensors. Space sensors shall have a minimum sensing range of 20% to 90% RH.
- C. Outdoor Air Sensors. Outdoor air humidity sensors shall have a minimum sensing range of 20% to 95% RH and shall be suitable for ambient conditions of -40°C to 75°C (-40°F to 170°F).

- D. Drift. Sensor drift shall not exceed 1% of full scale per year.

2.19 CURRENT TRANSMITTERS

- A. AC Current Transmitters. AC current transmitters shall be UL-Listed self-powered, combination split-core current transformer type with two-wire voltage (0-5 VDC, 1-5 VDC, 0-10 VDC, 2-10 VDC) or current (4-20 mA) output.
 - 1. Ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A and 200 A full-scale with internal zero and span adjustment and $\pm 1\%$ full-scale accuracy at 500 ohm maximum burden.
 - 2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA certified.
- B. Current Transformers. Current transformers shall be UL/CSA recognized, split-core and completely encased (except for terminals) in approved plastic material. Transformers shall be selected for $\pm 1\%$ accuracy at 5 A full-scale output.

2.20 VOLTAGE TRANSMITTERS

- A. Voltage Transmitters. AC voltage transmitters shall be UL-Listed self-powered two-wire type with voltage (0-5 VDC, 1-5 VDC, 0-10 VDC, 2-10 VDC) or current (4-20 mA) output and with zero and span adjustment.
 - 1. Ranges shall include 100-300 VAC, 200-250 VAC, 250-330 VAC and 400-600 VAC full-scale, adjustable with $\pm 1\%$ full-scale accuracy with 500 ohm maximum burden.
 - 2. Transmitters shall be UL/CSA recognized at 600 VAC rating and meet or exceed the requirements of ANSI/ISA S50.1.
- B. Voltage Transformers. AC voltage transformers shall be UL/CSA recognized at 600 VAC rated, complete with built-in fuse protection and completely encased (except for terminals) in approved plastic material.
 - 1. Transformers shall be suitable for 4°C to 45°C (40°F to 130°F) and shall provide $\pm 0.5\%$ full-scale accuracy at 24 VAC and a 5 VA load.

2.21 PRESSURE TRANSDUCERS

- A. Pressure Transducers. Pressure transducers shall have a linear voltage (0-5 VDC, 1-5 VDC, 0-10 VDC, 2-10 VDC) or current (4-20 mA) output with field adjustable zero and span.
 - 1. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage.
- B. Water Pressure Transducers. Water pressure transducers shall have stainless steel diaphragm construction proof pressure of 1 MPa (150 psi) minimum provided with appropriate mounting brackets and a dust and watertight housing with gasket.
 - 1. Gauge water pressure transducers shall be provided with block and bleed valves.
 - 2. Differential water pressure transducers over-range differential pressure limit and maximum static pressure shall be 2 MPa (300 psi).
 - 3. Differential water pressure transducers shall be provided with five-valve manifold for isolation, bypass and bleed.

2.22 CURRENT SWITCHES

- A. Current Switches. Current-operated switches shall be UL-Listed self-powered, solid-state, split-core type with adjustable trip current, status LED and dry-contact output.

2.23 PRESSURE SWITCHES

- A. Differential Pressure Switches. Differential pressure switches provided as a part of this specification shall be UL-Listed, SPDT snap-acting, pilot-duty rated (125 VA minimum), NEMA 1 enclosure, with scale range and differential suitable for intended application or as specified.
 - 1. Snubbers shall be provided for all water pressure transducer connections to prevent system pressure hammers and surges from being fully transmitted to the pressure sensor.

2.24 FLOW SWITCHES

- A. Flow Proving Switches. Flow proving switches provided as a part of this specification shall be differential pressure type UL-Listed, SPDT snap-acting, pilot-duty rated (125 VA minimum), NEMA 2 enclosure, with scale range and differential suitable for intended application or as specified.

2.25 RELAYS

- A. Control Relays. Control relays shall be UL-Listed, enclosed with LED energized indicator. Contact rating, configuration and coil voltage shall be suitable for application. Coil current shall be less than 50 mA.

2.26 TEMPERATURE CONTROL PANELS

- A. Temperature Control Panels. Provide pedestal base or wall mounted local control enclosures to be fully enclosed NEMA 1 (IEC IP20) at a minimum with hinged door, key-lock latch and removable subpanels to house all control components appropriate to the environment, service, and/or as required by the code enforcing authorities and other AHJ.
 - 1. All enclosures shall be UL-Listed.
 - 2. Enclosures in mechanical rooms shall meet NEMA 2 (IEC IP21) requirements at a minimum or as directed by the AHJ.
 - 3. Enclosures in all locations not requiring NEMA 2 (IEC IP21) including occupied spaces, above ceilings and plenums shall be the same NEMA (IEC) classification as other enclosures located in the same environment, except if location requires additional protection due to potential vandalism or environmental conditions or as directed by the AHJ.
 - 4. Enclosures exposed to moisture, in wet mechanical rooms or located outdoors shall be meet NEMA 4X (IEC IP66) requirements or as directed by the AHJ.
 - 5. Unless otherwise required by local codes and/or AHJ, all enclosures shall be a minimum of 16 gauge steel or aluminum, totally enclosed on all sides and powder coated or painted with a baked enamel finish.

2.27 POWER SUPPLIES AND LINE FILTERING

- A. Power Supplies & Control Transformers. Control transformers and power supplies shall be UL-Listed. Provide Class 2 current-limiting type or over-current protection in both primary and secondary circuits for Class 2 service not to exceed 100 VA in accordance with the applicable following requirements or as directed by the AHJ.
 - 1. NEC 2011 (NFPA 70) Chapter 7 Article 725 – Class 1, Class 2 and Class 3 Remote-Control, Signaling and Power-Limited Circuits.
 - 2. NEC 2011 (NFPA 70) Chapter 9 Table 11(A) and Table 11(B).
 - 3. Canadian Electrical Code, Part 1 (CSA C22.1-12) Rule 16-200.
- B. DC Power Supplies. DC power supply output shall match output current and voltage requirements. Power supply shall be half-wave rectified type with the following minimum specifications:
 - 1. Output ripple: 5.0 mV maximum peak-to-peak.
 - 2. Regulation: 1.0% line and load combined.
 - 3. Response: 100 ms for 50% load changes.
 - 4. Built-in overvoltage and overcurrent protection and able to withstand a 150% current overload for a minimum of three (3) seconds without tripping or failure.
- C. Power Line Filtering. Provide transient voltage and surge suppression for all workstations and controllers either internally or as an external component.

2.28 INTERCONNECTING WIRING & RACEWAYS

- A. Wiring & Cable. All wiring regardless of service and/or voltage shall comply with the National Electric Code (NEC), CSA C22.1-12 and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ).
 - 1. All insulated wire to be copper conductors, UL labeled for 90 °C minimum service.

END OF PART 2

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PART 3 - EXECUTION

3.01 GENERAL

- A. The DDC System, all of its components, its execution and compliance with this specification is the responsibility of the DDC System Contractor. All control system components shall be installed in locations as required to properly sense the controlled medium and perform according to the intent of the specified sequence of operations and the requirements of the contract drawings and this specification.
- B. Unless specified otherwise, all DDC System devices and components as required to appropriately satisfy the intent of the specified sequence of operations and the requirements of the contract drawings and this specification shall be provided as a part of this section.
- C. BACnet® Advanced Operator Workstation software shall be provided with a library of standard HVAC graphical image components as outlined in this specification and consistent with the delivered graphical user interface for the use of Owner.
- D. Archive Server. Provide BACnet® Data Archive Server Software with sufficient capability for archival of critical system-level objects at 96 samples per day for a minimum of five (5) years.
- E. Open System Information Archive Reporting Software. Provide software as outlined in this specification for fully-customizable analysis and reporting of archived DDC and Building Automation System (BAS) data including trend and runtime log data.
- F. Terminal Unit Space Sensors. Provide one (1) space sensor with temperature, setpoint and occupancy bypass for each terminal unit.
- G. Training. Provide four (8) hours of on-site or classroom training sessions throughout the contract period for personnel designated by the Owner.

3.02 EXAMINATION

- A. The project plans and contract documents shall be thoroughly examined for control device and equipment locations. The DDC System Contractor shall inspect the site to verify that the equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the project construction management team for resolution before rough-in work is started.
- B. The DDC System Contractor shall examine the drawings and specifications for additional work requirements. If space appears inadequate or any discrepancies, conflicts, or omissions occur the DDC System Contractor shall report said issues to the project construction management team for resolution and written instruction to proceed.

3.03 PROTECTION

- A. The DDC System Contractor shall be responsible for his/her work and equipment until finally inspected, tested and accepted. The DDC System Contractor shall protect his/her work against theft or damage, and shall carefully store material and equipment received on site that is not immediately installed. The DDC System Contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent damage/contamination by foreign objects and construction debris.

3.04 COORDINATION

- A. Where the mechanical work will be installed in close proximity to, or will interfere with work of other trades, the DDC System Contractor shall assist in coordinating space requirements.
- B. Coordinate and schedule work with all other trades in the same area, or with work that is dependent upon other trades to facilitate mutual progress. Report all conflicts and anticipated delays to the project construction management team for resolution immediately upon identification.
- C. Life Safety.
 - 1. Duct smoke detectors required for air handling unit shut down are furnished under another division of this specification. The DDC System Contractor shall interlock smoke detectors to air handling units for shut down as described in the Sequences of Operation.
 - 2. Smoke dampers and actuators required for duct smoke isolation are provided under another division of this specification. The DDC System Contractor shall interlock smoke detectors to air handling units as described in the Sequences of Operation.
- D. Other sections and/or divisions of this specification include controls and control devices that are to be a part of or interfaced to the DDC System specified in this section. These devices shall be integrated into the DDC System and coordinated by the DDC System Contractor as follows:
 - 1. All communication and network media and equipment integrated with the DDC System provided by any Contractor or Vendor shall comply with the requirements of this specification.
 - 2. The Contractor/Supplier furnishing and/or providing any controls products to be integrated to the DDC System are responsible for the configuration, programming, start-up, testing, and proof-of-performance of that product to meet the requirements of the Sequences of Operation.
 - 3. The DDC System Contractor shall coordinate resolution of incompatibilities that arise between the control products provided as a part of this section and products provided as a part of other sections or divisions of the specification.

3.05 GENERAL WORKMANSHIP

- A. DDC System installation shall be performed by professionals in a workmanlike manner consistent with acceptable industry standards for performance and in compliance with the contract documents, Project Electrical System Specifications, the National Electric Code (NEC), CSA C22.1-12 and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ) and in compliance with the following at a minimum:
 - 1. Installation of all DDC devices, enclosures, wiring, equipment, control devices and sensors shall be installed in accordance with the manufacturers' recommended installation procedures and as specified.

2. All control devices are to be provided and installed with all required gaskets, seals, flanges, connection enclosures, thermal compounds, insulation, piping, fittings and valves as required for design operation, isolation, equalization, purging and calibration.
3. Install all equipment as to be readily accessible as defined by Chapter 1, Article 100, Part A of the National Electric Code (NEC) or CSA C22.1-12 Rule 2 (as applicable) and such that it provides sufficient clearance for system maintenance, component service, calibration, removal, repair or replacement.
4. Install all equipment, piping, and wiring/raceway parallel to building lines.
5. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
6. All control devices mounted outdoors shall be protected by a weather-shield, integral outdoor enclosure, etc. and from ambient elements in such a manner as to not impede design functionality and/or sensing.
7. Dielectric isolation shall be provided where dissimilar metals are used in installation for connection and support.
8. Penetrations through and mounting holes in the building exterior associated with the DDC System installation shall be sealed and made water-tight.

3.06 FIELD QUALITY CONTROL

- A. DDC System Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
- B. DDC System Contractor shall have all work inspected as required by local and/or regional code enforcing authorities and/or AHJ.

3.07 DDC SYSTEM ARCHITECTURE

- A. A Protocol Implementation Conformance Statement (PICS) including a BACnet® Interoperability Building Block (BIBB) table shall be provided for each DDC device (hardware and software) provided under this specification.
- B. No single MS/TP (Master-Slave/Token-Passing) segment shall exceed 32 full-load nodes.
- C. No single MS/TP segment shall exceed 32 devices that do not support Read Property Multiple (RPM) and Segmentation for both Transmit and Receive. For the purposes of this specification, devices that do not support both shall be considered full-load nodes.
- D. The DDC system as provided and installed under this specification shall implement the following BACnet® data links only:
 1. Point-to-Point (PTP).
 2. Master-Slave/Token-Passing (MS/TP).
 3. Ethernet (ISO 8802.3).

4. IP (B/IP).
 5. All other BACnet® data links shall be excluded from this project.
- E. Each mechanical system and/or piece of mechanical equipment shall be controlled by one (1) dedicated DDC device with sufficient hardware and software capabilities that it shall be connected to all field devices associated with the mechanical system and/or piece of mechanical equipment. Distributed control of one (1) mechanical system and/or piece of mechanical equipment by multiple controllers shall be strictly prohibited.
 - F. Where any licensing is required, the system shall be delivered with sufficient licensing for 100% expansion of objects, networks, devices and operator workstations for a minimum of five (5) years from the acceptance date as a part of this contract.
 - G. The DDC system shall support the ability for a common BACnet® Broadcast Management Device (BBMD) Broadcast Distribution Table (BDT) to be configured once and then broadcasted to all BBMDs provided as a part of this contract. Where the BDT must be manually and/or individually configured, the system contractor shall be responsible for maintenance and configuration of all system BDTs for the duration of the warranty period.

3.08 QUALITY ASSURANCE

- A. Upon request the DDC System Manufacturer shall provide documentation supporting certified compliance with ISO 9001:2008 containing the ISO 9001:2008 Certification Mark from an applicable registrar.
- B. The DDC System Contractor shall be responsible for inspection and Quality Assurance (QA) for all materials and workmanship provided under this specification section.
- C. Upon request, the DDC System Contractor shall present the following:
 1. Certification of technical training from the DDC System Manufacturer including hours of instruction and course outline for each installer, technician and application engineer that will be involved on this project.
 2. Resumes for each installer, technician, application engineer and project manager that will be involved on this project.
 3. References from previous projects of comparable scope, type and service specified.
 4. All qualifications shall be provided within seven (7) calendar days of initial request.
- D. The DDC System Contractor shall maintain a comprehensive service office within 100 miles (160 km) of the project location by the bid date and at a minimum until the completion of the warranty period.
 1. Comprehensive service office shall be defined as a full-time operational center where DDC system professionals are regularly employed performing at a minimum the responsibilities and services of installation, design, application engineering, service and project management of complete DDC systems consistent in scope, type and service specified.

3.09 WARRANTY

- A. The DDC System Manufacturer shall provide a warranty certificate covering all DDC devices for a period of at least three (3) years.

3.10 BACNET® ADVANCED OPERATOR WORKSTATION PLATFORM

- A. BACnet® Advanced Operator Workstation shall comply with all relevant sections of this specification.

- B. BACnet® Advanced Operator Workstation hardware platform shall comply with the following at a minimum:
1. Processor: Intel Core i3 (3 GHz).
 2. Memory: 4 GB RAM.
 3. Hard Drive: 500 GB 7200 RPM SATA.
 4. Optical Drive: CD-ROM 16x.
 5. Video: XGA.
 6. Keyboard: Enhanced style keyboard with 101 key layout, 10 function keys, numeric keypad and separate cursor control pads.
 7. Mouse: Two button with adjustable sensitivity.
 8. Ports:
 - a. Minimum one (1) NIC.
 - b. Minimum four (4) USB 2.0.
 9. Microsoft Windows Operating Systems:
 - a. Windows Server 2008 R2; or Windows Server 2012.
 - b. Windows 7 64-bit Professional; or 8 64-bit Professional or Enterprise.

3.11 GRAPHICAL USER INTERFACE (GUI) HVAC GRAPHICAL IMAGE COMPONENT LIBRARY

- A. BACnet® Advanced Operator Workstation shall be provided with a library of standard HVAC graphical image components consistent with the delivered graphical user interface for the use of Owner.
- B. The library of standard HVAC graphical image components shall allow the Owner to create custom graphics consistent with the delivered graphical user interface.
- C. The library of standard HVAC graphical image components shall include professionally rendered three-dimensional (3D) static and animated images.
1. The library shall be complete with representations of mechanical equipment (e.g., AHUs, chillers, boilers, etc.), mechanical components (e.g., pumps, fans, coils, compressors, dampers, sensors, etc.) and interconnecting ductwork, piping, etc.
 2. All graphical image components shall be available at the same perspective allowing for individual components to interlock for the construction of custom equipment, systems and piping schemes.
 3. The library shall include isometric piping components in colors compliant with the ANSI/ASME A13.1 standard for pipe and valve marking for the construction of custom piping systems consistent with the physical orientation and configuration.
- D. The library of standard HVAC graphical image components shall include all of the equipment and standard symbols used in the delivered graphical user interface.

- E. Individual static HVAC graphical image components in the library shall be accessible as one of the following standard image file formats:
 - 1. JPG/JPEG.
 - 2. GIF.
 - 3. BMP.
 - 4. PNG.
- F. The library of standard HVAC graphical image components shall allow the Owner to create custom graphics consistent with the delivered graphical user interface using standard image file formats and the drawing or graphical development application of choice.
 - 1. The library of standard HVAC graphical image components shall not require the use of any proprietary or specific graphics development application.
- G. For the duration of the warranty period, the Contractor shall make available to the Owner, upon request, custom components not included in the library of standard HVAC graphical image components as required to represent equipment included in this Contract.
 - 1. Giving the Owner access to a graphical image library or service that develops custom components on request is an acceptable alternative to Contractor-developed components.

3.12 EMBEDDED BACNET® OPERATOR WORKSTATION (B-OWS)

- A. Embedded BACnet® Operator Workstations provided shall comply with all relevant sections of this specification.
- B. Embedded BACnet® Operator Workstations shall comply with all of the Part 2 Product requirements for the BACnet® Building Controller (B-BC).
- C. Embedded BACnet® Operator Workstations shall provide native BACnet® communications directly with all devices on the internetwork. Applications that require translation of data, gateways, or mapping of any kind shall not be acceptable.
 - 1. Embedded BACnet® Operator Workstation shall provide BACnet® client and server functionality as delivered under this specification.
- D. Embedded BACnet® Operator Workstation shall not require any hardware, software or firmware licensing agreements; or if required, hardware, software or firmware licensing agreements shall not limit functionality, feature-set, database, network, time and operator/users or seats, shall be without expiration and without maintenance charges for the owner.
- E. Multiple embedded BACnet® Operator Workstations shall be capable of being deployed on the same BACnet® internetwork as needed for this project and/or future expansion without requiring any additional licensing or the addition of supervisory and/or coordinating hardware or software systems.
 - 1. Browser clients shall have the ability to access any individual embedded BACnet® Operator Workstation on the Internetwork directly.
 - 2. Where additional licensing could otherwise be required or implemented during the warranty period for the addition or expansion of embedded BACnet® Operator Workstations, said licensing or systems must be provided under this specification to accommodate 100% expansion of the system as specified.

- F. Functionality of the embedded BACnet® Operator Workstations shall neither be defined nor limited by feature licensing. Limited functionality includes but is not limited to memory, client/server service support, intrinsic communication protocol and/or data link support, archiving support, GUI support, etc.
 - 1. Where functionality could otherwise be restricted by licenses or other software means, the embedded BACnet® Operator Workstations provided under this specification shall be required to have all features intrinsic to the platform licensed and enabled.

- G. All embedded BACnet® Operator Workstations provided under this specification shall be required to provide the following simultaneous intrinsic and enabled physical communication networks at a minimum:
 - 1. One (1) ISO 8802-3 Ethernet port @ 100 Mbps.
 - 2. One (1) EIA-232 port @ 115.2 Kbps.
 - 3. Two (2) EIA-485 ports @ 76.8 Kbps.

- H. All embedded BACnet® Operator Workstations provided under this specification shall be required to provide the following simultaneous communication protocols and/or data links at a minimum:
 - 1. ANSI/ASHRAE Standard 135: BACnet®.
 - a. One (1) Point-to-Point (PTP): ANSI/ASHRAE Standard 135.10.
 - b. One (1) Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.
 - c. One (1) ISO 8802-3 (Ethernet): ANSI/ASHRAE Standard 135.7.
 - d. Two (2) BACnet®/IP: ANSI/ASHRAE Standard 135 Annex J.
 - 2. Modbus.
 - a. Remote Terminal Unit (RTU) Master or Slave.
 - b. TCP Master or Slave.
 - 3. Simple Mail Transfer Protocol (SMTP).
 - a. Transport Layer Security (TLS) for SMTP must be supported including compatibility with standard free email services (e.g., *Gmail, Yahoo!, Outlook.com*).
 - b. The ability to manage custom TLS certificates from SMTP must be supported.
 - c. The ability to transmit a simple test email to verify SMTP configuration with a single operator action (e.g., pressing a *Test Email* button) must be provided.
 - 4. Simple Network Management Protocol (SNMP).
 - 5. Hypertext Transfer Protocol (HTTP).

If any additional hardware including communication cards, ports, licenses or gateways are required to support these networks they must be provided as a part of this contract. Any additional hardware must be warranted by the manufacturer as proven by a certificate from the manufacturer for a period of three (3) years at a minimum.

- I. Embedded BACnet® Operator Workstations shall provide graphically-oriented thin-client operator interface.
 - 1. The current versions of the following standard web browsers shall be supported at a minimum:

- a. Microsoft Internet Explorer.
 - b. Google Chrome.
 - c. Mozilla Firefox.
 - d. Apple Safari.
2. Custom HTML programming shall not be required to create or display system graphics or data on a web page.
 3. A customizable navigation/file tree shall be provided.
 4. Individual user home pages as determined by the user credentials shall be supported. Each user's ability to navigate the B-OWS shall be determined by their log-in credentials.
- J. Each embedded BACnet® Operator Workstation shall support unlimited access for a minimum of five (5) simultaneous users.
- K. Embedded BACnet® Operator Workstations shall provide an Audit Trail feature that automatically records the date, time, user, and action associated with all user access and changes made via web browser clients.
- L. Embedded BACnet® Operator Workstations shall store complete help files describing system configuration, and use of the browser interface. The help files shall be served on-line as part of the browser interface.
1. The browser interface shall include tool tips to describe the features and functionality of the interface.

3.13 BACNET® DATA ARCHIVE SERVER

- A. The BACnet® data archive server provided shall comply with all relevant sections of this specification.
- B. BACnet® Data Archive Server software shall be a BTL-Listed BACnet® device and shall comply with all of the Part 2 Product requirements for the BACnet® Data Archive Server software.
- C. The BACnet® data archive server is designed for long-term storage of historical data and does not supersede the requirement for local short-term storage of BACnet® Trend Logs and runtime logs on individual BACnet® control devices.
- D. The BACnet® data archive server shall permit viewing of BACnet® Trend Logs and runtime logs within the installed BACnet® web-enabled application software or Operator Workstation Software operator interface using standard visualizations and methods without requiring a separate trend Log viewing application.
- E. The BACnet® data archive server shall support connection to multiple BACnet®/IP network segments and BACnet® internetworks with a single installation instance.
- F. All data acquired by the BACnet® data archive server shall be automatically stored in a standard SQL database, accessible by third-party SQL applications
- G. In addition to the BACnet® data archive server software, the following software shall also be provided and installed on the BACnet® data archive server platform at a minimum:
 1. Microsoft SQL Server 2008 R2 Express Edition.

- H. The BACnet® data archive server shall automatically acquire configured trend log and runtime log data from the BACnet® internetwork and archive the data at configured intervals without user intervention.
- I. The BACnet® data archive server shall support configurable automatic event notification via e-mail in the event of the following failures at a minimum:
 - 1. Communication failures.
 - 2. Corrupt data.
 - 3. Offline devices.
 - 4. SQL database/access errors.
 - 5. Archive service failures.
- J. In the event that there should be a temporary SQL database access or read/write error, the BACnet® data archive server shall be capable of building a storage queue of data to be written to the SQL database when it becomes available.
- K. The BACnet® data archive server hardware platform shall comply with the following minimum specification requirements:
 - 1. Processor: Intel Core i5 (3 GHz).
 - 2. Memory: 4 GB RAM.
 - 3. Hard Drive: 500 GB 7200 RPM SATA.
 - 4. Optical Drive: CD-ROM 16x.
 - 5. Ports:
 - a. Minimum one (1) NIC.
 - b. Minimum four (4) USB 2.0.
 - 6. Microsoft Windows Operating Systems:
 - a. Windows Server 2008 R2; or Windows Server 2012.
 - b. Windows 7 64-bit Professional; or Windows 8 64-bit Professional or Enterprise.

3.14 OPEN SYSTEM INFORMATION ARCHIVE REPORTING SOFTWARE

- A. Provide open system information archive reporting software package as a part of this contract. The software shall be licensed and/or provisioned to generate unlimited custom reports and to import unique, active data objects in all reports.
- B. Licensing. Reporting software feature and function set shall not be limited by license.
 - 1. If reporting software limits features or functions by license, it must be provided with an unlimited license activating all features and functions for the duration of the DDC system warranty.
 - 2. If reporting software access is limited by any time-period (e.g., annual) license or subscription, it must be provided with an unlimited license for a minimum of three (3) years.
- C. Service Integrity. Reporting software shall be capable of being installed on a server that is local or remote to the DDC system network. Proprietary and/or shared/leased cloud-based solutions that cannot be deployed individually and/or locally shall not be acceptable.

- D. Data Ownership. All DDC system report data, metadata and reports shall at all times be the exclusive property of the DDC system owner. The archive reporting software developer, manufacturer and/or service provider shall at no time assume ownership of the archived or report data.
- E. User Administration. Reporting software security permissions shall be multilayered and defined for each individual operator to restrict/permit day-to-day operations and system configuration.
 - 1. Reporting software shall support Microsoft Authentication/Active Directory integration for the credential definition and maintenance of each user.
 - 2. An administrator-level user shall have the ability to configure credentials and enable/disable user accounts for all users.
 - 3. Each user shall have ability to reset passwords without administrator intervention.
 - 4. Read/Write permissions for each individual report shall be configured by individual user account.
- F. Thin-client user interface. All archive reporting software administration and operation shall be performed using a standard web browser.
 - 1. The archive reporting software shall support the most current official release versions of all specified web browsers at the time of bid and of substantial completion.
 - 2. The archive reporting software shall support the following desktop browsers at a minimum:
 - a. Microsoft Internet Explorer.
 - b. Google Chrome.
 - c. Mozilla Firefox.
 - d. Apple Safari.
 - 3. The archive reporting software shall support the following mobile device browsers at a minimum:
 - a. iOS/Safari.
 - b. Android/Chrome.
 - c. Android/Firefox.
 - 4. Software applications, applets, plug-ins, add-ins, etc. installed on the client device for system administration, operation and/or report viewing shall not be acceptable.
- G. Security. Every session shall be secured using 128-bit SSL encryption at a minimum.
- H. Open Data Format. Reporting software shall support standard SQL and CSV data formats. Reporting software that requires proprietary data formats or databases shall not be acceptable.
- I. Data Source. A single instance of the archive reporting software provided under this contract must be capable of accessing multiple data locations; including multiple SQL servers, SQL databases, SQL instances and Excel spreadsheets. If the archive reporting software is limited by functionality or licensing to a single data source; sufficient software, hardware and/or licensing must be provided for 100% expansion of archive data sources provided as a part of this project.
- J. Data Management. Imported data shall be capable of being filtered by name, mnemonic, object instance and engineering units at a minimum. Users shall have the ability to categorize imported data with custom names for simple organization and access.

1. If the reporting software cannot filter data as specified, the system contractor shall provide a sortable data-map of all archived data objects by name, mnemonic, instance and engineering units.
 2. If the reporting software cannot categorize data into user-customizable groups, the system contractor shall be responsible for categorizing data into custom databases as required by the owner/end-user to provide ease of access for the entirety of the system warranty period.
- K. Report Components. Reporting software shall support the display of user-defined data in each report including static values, dynamic archived data, calculations and formulas in the following components at a minimum. System contractor shall provide pre-built sample templates for each of the following report components for easy replication by report software users.
1. Display data as bar, pie and line charts and in a tabular format.
 2. Display raw data with sample date and time stamps.
 3. Display data at user-defined sample intervals over a customizable date range. (e.g. daily energy consumption for one month).
 4. Display data as a contribution by comparing data for a configurable time period (e.g., energy sub-meters as components of total energy consumption for the month).
 5. Display data as an aggregate value for a user-defined day, week, month or year over a configurable time period (e.g., analyze energy costs on Monday mornings for the year to optimize system initialization).
 6. Interactive, dynamic report-sourced data field components that can be modified by report users for analysis of imported data (e.g., current price of energy or energy conservation measure (ECM) efficiency).
 7. Interactive, dynamic component that can be manipulated by report users for adjusting the displayed date range of the report.
 8. Formatted WYSIWYG custom text field for the addition, modification of descriptive text, report narratives, contact information, corporate/client letterhead, hyperlinks, etc.
 9. GIF, JPG and/or PNG image components.
- L. Customizable Formatting. Report format and data shall be fully customizable by the user including the following at a minimum:
1. Custom component, chart, background and line colors.
 2. User-defined component, data, legend, title and axis labels.
 3. User-defined font and font size.
- M. Sample Reports. Reporting software shall be provided with pre-built sample reports utilizing each of the specified report components at a minimum.
- N. Report Access. Reporting software shall save reports locally to the report server.
1. Reports shall be accessible by logging into the report server based upon the credentials of the user.
 2. Each report shall be saved with a custom URL to facilitate direct access to a report using a hyperlink without requiring navigation.

- O. Report Distribution. Reporting software shall support automated e-mail distribution of any report as a hyperlink or PDF to a user-defined recipient list at configurable times, days and dates with custom messages.
- P. The open system information archive reporting software hardware platform shall comply with the following minimum specification requirements:
 - 1. OS: Microsoft Windows Server 2012 64-bit; Windows Server 2008 R2 64-bit; Windows 8 64-bit; Windows 7 64-bit.
 - 2. Processor: Intel Xeon E3 (3.10 GHz).
 - 3. Memory: 16 GB.
 - 4. Hard Drive: 10 GB 10k RPM SAS.
 - 5. Network Interface Controller (NIC).

3.15 CONTROLLERS

- A. Provide a separate, dedicated DDC controller for each mechanical system or piece of equipment. Multiple pieces of mechanical equipment comprising one mechanical system may be controlled by a single DDC controller provided that all of the points associated with the equipment are hosted by the controller. Distributed control of one piece of mechanical equipment shall not be performed by multiple DDC controllers.
 - 1. Objects used for trim and respond or demand-based reset control such as outdoor air temperature, space temperatures or terminal loads are not included in this requirement.
- B. Building level controllers and field level equipment controllers shall be selected to provide a minimum of 20% spare I/O point capacity for each point type on each controller.
 - 1. Where universal inputs are not provided, 20% spare inputs of each individual type (e.g., analog, binary, etc.) are required.
 - 2. Where universal outputs are not provided, 20% spare outputs of each individual type (e.g., analog, binary, etc.) are required.
- C. For unitary and space-mounted controllers, where software-selectable universal inputs are not available, one (1) spare analog input and one (1) spare binary input shall be required on each terminal unit controller after the requirements of the sequence of operation specified in the contract documents have been satisfied.
- D. Operator Override. All DDC controllers shall support operator-initiated timed overrides of hardware and software objects with user-configurable override periods. When the override period has expired, the controller shall automatically return the object to the automatic state without any additional action on the part of the Operator.
 - 1. The timed override functionality shall exist entirely in the controller. A workstation shall not be required for the execution of the time period nor for returning the object to automatic.

3.16 BUILDING LEVEL CONTROLLERS

- A. The building level controllers provided shall comply with all relevant sections of this specification.
- B. Provide one (1) dedicated BACnet® Building Controller (B-BC) for the execution of global strategies and for each large point-count major mechanical system and/or piece of equipment.

1. Any application exceeding eight (8) inputs or eight (8) outputs shall not be considered a terminal unit application and shall require a dedicated field-level equipment controller or a building-level controller.
- C. Each building level controller shall be provided with an integral power switch or a dedicated fused transformer and switch inside the enclosure.
- D. All building level controllers provided under this specification shall be required to provide the following simultaneous intrinsic and enabled physical communication networks at a minimum:
 1. One (1) ISO 8802-3 Ethernet port @ 100 Mbps.
 2. One (1) EIA-232 port @ 115.2 Kbps.
 3. Two (2) EIA-485 ports @ 76.8 Kbps.
- E. All building level controllers provided under this specification shall be required to provide the following simultaneous communication protocols and/or data links at a minimum:
 1. ANSI/ASHRAE Standard 135: BACnet®.
 - a. One (1) Point-to-Point (PTP): ANSI/ASHRAE Standard 135.10.
 - b. One (1) Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.
 - c. One (1) ISO 8802-3 (Ethernet): ANSI/ASHRAE Standard 135.7.
 - d. Two (2) BACnet®/IP: ANSI/ASHRAE Standard 135 Annex J.
 2. Modbus.
 - a. Remote Terminal Unit (RTU) Master or Slave
 - b. TCP Master or Slave
 3. Simple Mail Transfer Protocol (SMTP).
 - a. Transport Layer Security (TLS) for SMTP must be supported including compatibility with standard free email services (e.g., *Gmail, Yahoo!, Outlook.com*).
 - b. The ability to manage custom TLS certificates from SMTP must be supported.
 - c. The ability to transmit a simple test email to verify SMTP configuration with a single operator action (e.g., pressing a *Test Email* button) must be supported.
 4. Simple Network Management Protocol (SNMP).
- F. All inputs shall be provided with a proportional brightness LED to display the status of each individual input.
- G. All outputs shall be provided with a proportional brightness LED to display the status of each individual output.
- H. All hardware outputs shall be provided with a physical Hand/Off/Auto switch.
 1. All analog outputs shall also be provided with a potentiometer for manual adjustment of voltage signal in the Hand position.
 2. Hand/Off/Auto switch position feedback shall be monitored and displayed by the operating system of the controller.

3. Controller shall alarm when each Hand/Off/Auto switch is not in the Auto position.

3.17 FIELD-LEVEL EQUIPMENT CONTROLLERS

- A. The field-level equipment controllers provided shall comply with all relevant sections of this specification.
- B. Provide one (1) dedicated field-level equipment controller for the execution of global and local strategies for each mechanical system and/or building system piece of equipment.
 1. Any application exceeding eight (8) inputs or eight (8) outputs shall not be considered a terminal unit application and shall require a dedicated field-level equipment controller or a building-level controller.
- C. Each field-level equipment controller shall be provided with an integral power switch or a dedicated fused transformer and switch inside the enclosure.
- D. All field-level equipment controllers provided under this specification shall be required to provide the following simultaneous intrinsic and enabled physical communication networks at a minimum:
 1. One (1) EIA-232 port @ 115.2 Kbps.
 2. One (1) EIA-485 ports @ 76.8 Kbps.
- E. All field-level equipment controllers provided under this specification shall be required to provide the following simultaneous communication protocols and/or data links at a minimum:
 1. ANSI/ASHRAE Standard 135: BACnet®.
 - a. One (1) Point-to-Point (PTP): ANSI/ASHRAE Standard 135.10.
 - b. One (1) Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.
- F. All inputs shall be provided with a proportional brightness LED to display the status of each individual input.
- G. All outputs shall be provided with a proportional brightness LED to display the status of each individual output.
- H. All hardware outputs shall be provided with a physical Hand/Off/Auto switch.
 1. All analog outputs shall also be provided with a potentiometer for manual adjustment of voltage signal in the Hand position.
 2. Hand/Off/Auto switch position feedback shall be monitored and displayed by the operating system of the controller.

3.18 TERMINAL UNIT CONTROLLERS

- A. The terminal unit controllers provided shall comply with all relevant sections of this specification.
- B. Provide one (1) dedicated BACnet® Building Controller (B-BC) for each individual terminal unit unless otherwise approved by the owner prior to contract bid deadline.
- C. Air Terminal Unit Controller Actuators. All air terminal unit damper actuators shall be brushless DC motors and shall be provided with the following at a minimum:
 1. 45 in-lb (5 Nm) of torque.

2. Damper position feedback must be provided and programmed as a hardware analog input to the controller. Calculated damper position based upon active command time is not acceptable.
 3. Damper-end/actuator-clutch switch must be provided and programmed as a hardware binary input to the controller to indicate that the actuator is at the end of the field-adjusted stroke. Switch must prove at 0% and 100% of the field-adjusted stroke of the damper. Calculated damper position based upon active command time is not acceptable.
 4. Software selectable rotation allowing the drive-to-open direction of the actuator to be selected by an operator via the B-AWS.
- D. Air Terminal Unit Controller Differential Velocity Sensor. All air terminal unit differential velocity sensors shall be provided with the following at a minimum:
1. ± 0.2 inwc (0-500 Pa) sensing range
 2. Zero point accuracy of 0.0008 inwc (0.2 Pa)
 3. Span accuracy of 3% of measured value
- E. Air Terminal Unit Controller Test & Balance Calibration (T&B). Air terminal unit airflow sensor calibration shall be performed using the operator interface of the local zone communicating temperature sensor via a dedicated handheld configuration tool connected to each individual air terminal unit controller or at the B-AWS.

Where software and/or dedicated applications are required for airflow sensor calibration, the following must be provided to the Owner as a part of this specification at a minimum:

1. One (1) dedicated hardware platform to host the T&B and airflow calibration software and/or application independent from and in addition to any requirement for an operator workstation with a three (3) year warranty.
2. All software updates and support for three (3) years from the completion and acceptance of the project T&B report.

3.19 SPACE MOUNTED TERMINAL UNIT CONTROLLERS

- A. The space mounted terminal controllers provided shall comply with all relevant sections of this specification.
- B. All space mounted terminal controllers series under this specification shall be available with the following the integral hardware sensors at a minimum:
1. Temperature.
 2. Setpoint.
 3. Relative Humidity.
 4. Bypass.
 5. PIR Occupancy.
 - a. Range: 5m/16'.
 6. CO₂.
- C. Each space mounted terminal controller shall be available with a keypad and display to permit low-level operator interface with following features at a minimum:

1. Configurable back-lighting.
2. Configurable to display icons, time, point names and engineering units.
3. Configurable to display and modify object values from any device on the internetwork.
 - a. Provide access to a minimum of ten (10) total object values.
4. Provide the ability to view and modify Schedules.
5. Advanced application space mounted terminal controllers shall provide the following enhanced features:
 - a. Provide access to a minimum of forty-eight (48) object values.
 - b. View/Acknowledge Alarms.
 - c. Annunciate unacknowledged alarms with display and audible notification.
 - d. Multilayer password protected display.

3.20 COMMUNICATING SPACE SENSORS

- A. Warranty. Each communicating space sensor must be warranted by the manufacturer as proven by a certificate from the manufacturer for a period of three (3) years at a minimum.
- B. The communication status and reliability of all communicating sensors shall be actively monitored by the system. When communication is lost with any communicating sensor, the system shall be capable of generating an alarm and performing automatic control strategy response until communication is restored.
 1. If the system is not capable of performing custom, freely-programmable and automatic control strategy response as a result of a loss of sensor communication, communicating sensors may be not be used.
- C. Hardware. Communicating space sensors provided under this specification shall be available with the following the integral hardware at a minimum:
 1. Temperature.
 2. Setpoint.
 3. Relative Humidity.
 4. Unoccupied Bypass.
 5. PIR Occupancy.
 - a. Range: 5m/16'.
 6. CO₂.
 7. Auxiliary onboard inputs.
 - a. Thermistor or dry-contact.
 8. Auxiliary onboard outputs.
 - a. Dry-contact outputs.

- D. Tamper-proof. Communicating space sensors provided under this specification shall be available as a stainless-steel or aluminum plate for tamper-proof applications in public spaces, corridors, restrooms, gymnasiums, etc.
 - 1. Tamper-proof communicating space sensors shall cover a standard, single-device utility box.
 - 2. Tamper-proof communicating space sensors shall be available with the following the integral hardware at a minimum:
 - a. Temperature.
 - b. Unoccupied Bypass.
- E. Except for in tamper-proof installations, each communicating space sensor shall be provided with a keypad and display to permit low-level operator interface with following features at a minimum:
 - 1. Configurable to display icons, time, point names and engineering units.
 - 2. Configurable to display and modify object values from any device on the internetwork.
 - a. Provide access to a minimum of ten (10) total object values.

3.21 COMMUNICATING DUCT SENSORS

- A. Warranty. Each communicating duct sensor must be warranted by the manufacturer as proven by a certificate from the manufacturer for a period of three (3) years at a minimum.
- B. The communication status and reliability of all communicating sensors shall be actively monitored by the system. When communication is lost with any communicating sensor, the system shall be capable of generating an alarm and performing automatic control strategy response until communication is restored.
 - 1. If the system is not capable of performing custom, freely-programmable and automatic control strategy response as a result of a loss of sensor communication, communicating sensors may be not be used.
- C. Enclosure. Communicating duct sensors provided under this specification shall be available with the following enclosures at a minimum:
 - 1. Galvanized box.
 - 2. Plastic box.
- D. Hardware. Communicating duct sensors provided under this specification shall be available with the following the integral hardware at a minimum:
 - 1. Temperature.
 - a. -40 to 120°C (-40 to 250°F)
 - b. Duct probe lengths 4" to 18".
 - 2. Relative Humidity.
 - a. ±2%.
 - 3. Auxiliary onboard inputs.
 - a. Thermistor or dry-contact.
 - 4. Auxiliary onboard outputs.

- a. Dry-contact outputs.

3.22 WIRELESS TEMPERATURE SENSORS

- A. Wireless Temperature Sensors will not be permitted unless otherwise approved by Owner and/or contracting officer prior to award of contract.
- B. The wireless temperature sensors provided shall comply with all relevant sections of this specification.
- C. All wireless temperature sensors provided under this specification shall be available with the following the integral hardware at a minimum:
 - 1. Temperature.
 - a. Minimum 10-bit linear active thermistor.
 - b. Minimum sensing range: $-8^{\circ}\text{C} - 39^{\circ}\text{C}$ ($18^{\circ}\text{F} - 102^{\circ}\text{F}$).
 - c. Resolution: $\pm 0.05^{\circ}\text{C}$ (0.09°F).
 - d. Accuracy: $\pm 0.1^{\circ}\text{C}$ (0.18°F).
 - 2. Setpoint Slider.
 - 3. Bypass.
- D. Wireless temperature sensors shall not be installed further than 30 m (100 ft) line of sight from the access point/receiver.
- E. Space mounted wireless components shall not be mounted using metal device boxes, plaster rings or mounting brackets.
- F. Wireless access points shall support the ability to transmit and receive.
- G. Wireless access points shall support 1BS, 4BS and RPS EnOcean™ devices at a minimum.
- H. If the DDC System Graphical User Interface (GUI) is not capable of intrinsically monitoring, displaying and alarming signal strength and diagnostics then one (1) signal strength monitoring and diagnosis tool including any necessary software and hardware must be provided for each wireless sensing receiver, each workstation or each building; (whichever is greater) as a part of this specification.
- I. If signal repeaters and/or amplifiers are required by the manufacturer's installation documentation and/or for normal day-to-day operation, a spare repeater and/or amplifier shall be provided for every repeater and/or amplifier installed providing the Owner 100% replacement/redundancy as a part of this specification.
- J. Where batteries are required by the manufacturer's installation documentation and/or for normal day-to-day operation; one (1) new battery shall be provided for each wireless sensor per year for the first three (3) years. Additionally, this contractor shall replace the battery for each wireless sensor annually at a minimum. Where installed batteries have a documented and certified minimum operational life-cycle of three (3) years; this contract shall test each battery a minimum of twice (2) in the first year and at least once for each remaining year of the three (3) year warranty.
- K. Where access points, transmitters and receivers cannot be installed directly in the space, necessary accessories, cabling and/or antennae must be provided for mounting within the space where the wireless sensors are mounted.

- L. If wireless device binding requires configuration tools or a software application, a spare configuration tool or software application must be provided for each wireless sensing receiver, each workstation or each building (whichever is greater) as a part of this specification.

Additionally, as a part of this contract and as required by the owner, bindings shall have to verified by this contractor a minimum of twice (2) in the first year and at least once for each remaining year of the three (3) year warranty.

- M. Access point/receiver shall be capable of confirming wireless sensor bindings visually (e.g. LEDs) and audibly (e.g., Piezo).

3.23 AUTOMATIC CONTROL ACTUATORS

- A. Mount and link all control actuators according to manufacturer's instructions.
 - 1. Check operation of damper/valve and actuator combination to confirm that actuator modulates smoothly throughout full stroke to both open and closed positions.
 - 2. To compress seats when spring-return actuators are used on normally-closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten linkages.
- B. All actuators shall be direct-coupled unless otherwise scheduled or indicated by manufacturer.
- C. Minimum torque and power output requirements of actuators shall not be less than 125% of the required design load.
- D. When the associated mechanical system or equipment is not in operation, control actuators shall remain in their "off" positions as indicated in the Sequences of Operation.
- E. For automatic control valve actuators, In lieu of a manual positioning device, it will be acceptable for the contractor to provide a full line size bypass around the control valve. Three bypass shut off valves shall be provided to allow the control valve to be isolated while the bypass allows flow around the control valve.

3.24 TEMPERATURE SENSORS

- A. All sensors shall be installed in accordance with the manufacturer's recommendations consistent with acceptable industry standards for performance compliant with the requirements of this specification.
- B. Mount sensors rigidly and adequately for the environment within the sensor operates.
- C. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor readings. Where necessary due to structural cavities, masonry walls, proximity to exterior openings, unconditioned spaces, etc. insulated mounting base shall prevent temperature of mounting location from affecting sensor temperature reading.
- D. Space temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
- E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type.
- F. All averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
- G. Low-limit sensors and/or thermostats used in mixing plenums shall be installed in a serpentine manner horizontally across the duct. Each bend shall be supported with a capillary clip. Provide a minimum of 3 m of sensing element for each 1 m² (1' of sensing element for each 1 ft²) of coil area.

- H. All pipe-mounted sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
 - 1. Assembly shall allow removal of sensor from well without loss of measured medium fluid.
- I. Outdoor air sensors shall be mounted outside on a northern exposure as high as serviceable on the building. The sensor shall be mounted within a ventilated enclosure to shield the sensor from the effects of the sun. The sensor location shall be selected such that it may not be affected by artificial and/or mechanical airstreams (i.e., building exhaust, building relief, &c.).
- J. In condensing environments use stainless steel sensing element and capillary mounting clips.
- K. Sensor guards shall be provided to protect sensor from damage in high-impact and/or high-traffic areas and/or where vandalism is a concern.
- L. Sensors shall be manually calibrated on site so that the wiring length and termination does not detract from the sensor accuracy specified.

3.25 PRESSURE SENSORS

- A. Locate all pressure transducers (except for those controlling air terminal units) in field device panels, not on mechanical equipment or ductwork, as close as possible to the sensing point and use tubing sized such as to prevent signal phase lag.
- B. Pressure transducer tubing shall be connected to a pitot tube or other pressure/airflow sensing device. Under no circumstances shall tubing pass through equipment housing or ductwork.
 - 1. Pitot tube probe shall be made of brass or aluminum with 8 inches of lead tube allowing insertion into duct.
- C. The piping to pressure ports on all pressure transmitters shall contain a capped test port adjacent to the transmitter.
- D. Static pressure sensing taps shall face down-stream in the airflow so as to eliminate velocity pressure effects.
- E. Supply and return air duct static pressure transmitters shall have the high-pressure port connected to a pitot tube installed in the ductwork and the low pressure port shall be left open to the plenum.
 - 1. Supply air duct static pressure transmitter pitot tube shall be located 60-70% of the total distance from the fan unit and in a straight section of ductwork with a minimum of four (4) duct diameters/widths in both directions.
- F. Positive static high-pressure safety cut-outs shall be located immediately downstream of the fan section and shall have the high-pressure port connected to a pitot tube installed in the ductwork and the low-pressure port shall be left open to the plenum.
- G. Negative static high-pressure safety cut-outs shall be located immediately upstream of the fan section and shall have the low-pressure port connected to a pitot tube installed in the ductwork and the high-pressure port shall be left open to the plenum.

- H. Building static pressure sensors high-pressure port connected to a sensing probe installed in the space and the low-pressure port connected to an outdoor air static pressure sensing probe through a high-volume accumulator. The tubing for both the high-pressure and the low-pressure ports shall be routed through a surge dampener installed between the transmitter and the sensing elements.
- I. Differential pressure taps shall be installed such that true differential of the monitored medium may be accurately sensed.
- J. Wet pressure sensors shall be installed with snubbers and isolation valves.
 - 1. Wet differential pressure sensors shall be installed with five-valve bypass assemblies.
- K. Differential pressure type switches shall be installed as per differential pressure transmitters and shall provide a maximum switching differential of 10% of the sensed operating range for the application at minimum and maximum designed flow rates. Setpoint shall be selected to operate at midpoint of span.

3.26 TEMPERATURE CONTROL PANELS

- A. Unless otherwise directed by the AHJ, all temperature control panels and enclosures shall be located as indicated such that visual observation and adjustment can be accomplished while standing flatfooted on the floor in a convenient location adjacent to the equipment served. Install all equipment in readily accessible location as defined by Chapter 1 Article 100 Part A of the NEC or CSA C22.1-12 Rule 2 (as applicable).
- B. All temperature control panels shall have keyed, locking latches and shall be keyed commonly such that one key shall open all enclosures.
- C. Provide each DDC panel with a surge suppressor, electrical disconnect, control fuse, and control transformer; all sized and provided by the control system contractor.
- D. Interconnections between internal termination points and face and/or panel-mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL-Listed for 600 volt service, individually identified per control drawings with adequate clearance for field connections.
 - 1. Provide insulated, modular, feed-through, clamp-style recessed captive screw-type terminal blocks suitable for rail-mounting with end plates and partitions for the termination of all field wiring in temperature control panels.
 - 2. Field wiring to equipment with integral terminals and/or unitary equipment shall not be required to have terminal blocks.
- E. All high-voltage wiring consistent with the definitions of NEC/CSA Class 1 and all low-voltage wiring consistent with the definitions of NEC/CSA Class 2 must be strictly separated by barriers, raceways or sub-panels according to the requirements of the NEC Chapter 7 Article 725 – Class 1, Class 2 and Class 3 Remote-Control, Signaling and Power-Limited Circuits and the CSA Canadian Electrical Code, Part 1 Rule 16-212 Separation of Class 2 circuit conductors from other circuits.
- F. Provide laminated nameplates or tags for all control system components. Unless otherwise directed in this specification or by the AHJ, nameplates shall be minimum 1 inch by 3 inches (2.5 cm X 7.5 cm), with minimum ¼ inch (6 mm) high block lettering. Nameplates for devices smaller than 1 inch by 3 inches (2.5 cm X 7.5 cm) shall be attached to adjacent surface.
- G. A legible reproduction of the “As-built” application engineering for the system served shall be laminated in clear plastic and mounted within each enclosure.

3.27 POWER SUPPLIES AND LINE FILTERING

- A. All connected loads shall not exceed 80% of the faceplate rating for each power supply or transformer.

3.28 WIRING

- A. DDC System control wiring shall be performed by professionals in a workmanlike manner consistent with acceptable industry standards for performance and in compliance with the contract documents, Project Electrical System Specifications, the National Electric Code (NEC), CSA C22.1-12 and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ). When non-code compliance requirements of the Electrical System Specifications and this specification section differ, this section shall take precedence.
- B. Unless otherwise specified it shall be the responsibility of the DDC System Contractor to provide all of the wiring necessary to provide a complete DDC System in compliance with the requirements of this specification.
- C. All wiring consistent with the definitions of NEC/CSA Class 1 (line voltage) shall be installed in UL-Listed raceway or conduit according to the requirements of the NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.
- D. All wiring consistent with the definitions of NEC/CSA Class 2 (low voltage) control wiring shall be sub-fused as required and installed according to the requirements of the NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.
- E. Class 2 wiring concealed in accessible locations not installed in UL-Listed raceways or conduit may be used provided that the cable is UL-Listed for the intended application.
 - 1. When Class 2 wiring is installed exposed, wiring is to be routed parallel or perpendicular (right-angles) with building and/or mechanical lines and neatly tied at 2 m (6') intervals.
 - 2. Exposed cabling shall be mechanically supported to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping or ceiling suspension systems.
 - 3. Exposed cabling shall be installed in sleeves where the route passes through walls, floors and other partitions. Maintain fire, smoke, envelope and pressure ratings of each space.
- F. All wiring in mechanical, electrical or service rooms, or where subject to mechanical damage shall be installed in UL-Listed raceway or conduit unless otherwise approved by the customer.
- G. Class 2 wiring shall not be installed in raceways or conduit containing Class 1 wiring. Junction boxes, enclosures 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, transformers, CTs, etc.). Refer to the requirements of the applicable code enforcing authorities and AHJ.
 - 1. NEC Chapter 7 Article 725 – Class 1, Class 2 and Class 3 Remote-Control, Signaling and Power-Limited Circuits.
 - 2. CSA C22.1-12 Rule 16-212 Separation of Class 2 circuit conductors from other circuits
- H. Sizing and selection of raceways, enclosures and conduit shall be the responsibility of the DDC System Contractor in keeping with the manufacturer's recommendations and the requirements of NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.
 - 1. Conceal all raceways and conduit, except within mechanical, electrical or service spaces.

2. Install raceways and conduit to maintain a minimum clearance of 15 cm (6") from high-temperature equipment (e.g., steam lines, flues, etc.).
 3. Secure and support raceways and conduit to the structure per the manufacturer's recommendations. Raceways and conduit may not be hung on flexible straps or tie rods, nor may they be attached to ductwork.
 4. Comply with the requirements of the Electrical System Specifications when raceways or conduit crosses building expansion joints.
 5. Include a minimum of one (1) pull string in each raceway or conduit a minimum of 2.5 cm (1").
- I. Flexible metal raceways, liquid-tight and other non-rigid conduit shall not exceed 1 m, (3') in length and shall be mechanically supported at each end.
 1. Flexible metal raceways, liquid-tight and other non-rigid conduit smaller than 12 mm (0.5") shall not be used.
 - J. Wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be made at a terminal block.
 1. Wire-to-wire connections shall be made in enclosures or approved junction boxes with a maximum fill of 50%.
 - K. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
 - L. Use color-coded conductors consistently throughout the entire DDC System installation.
 - M. Maximum allowable voltage for control wiring shall be 120 volts.
 - N. The DDC System Contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
 - O. Maximum pulling, tension, and bend radius for cable installation as specified by the manufacturer shall not be exceeded during installation.
 - P. The DDC System Contractor shall verify integrity of all wiring to ensure continuity and freedom from shorts and grounds after the installation is complete.
 - Q. When any cable enters or exits the building a lightning arrestor must be installed between the conductors and ground. The lightning arrestor shall be installed according to the manufacturer's recommendations.

3.29 COMMUNICATION WIRING

- A. Communication and network wiring shall adhere to the Wiring article in Part 3 of this specification and the manufacturer's recommendations.
- B. Communication wiring shall not be installed in any raceway or conduit with Class 1 or Class 2 wiring.
- C. All communication wiring shall be installed as continuous lengths, with no splices permitted between termination points.
- D. All communication cabling shall be labelled to indicate origination and destination devices.
- E. All communications shielding shall be grounded as per manufacturer's recommendations and in accordance with the NEC/CSA (as applicable).

3.30 IDENTIFICATION OF HARDWARE AND WIRING

- A. All wiring and cabling, including that within factory-fabricated panels shall be labelled at each end within 5 cm (2”) of the termination with the BACnet® object instance or termination number.
- B. Manufacturer’s name plates and UL or CSA labels are to be visible and legible after equipment is installed.
- C. All labels and identifiers shall match record documents.

3.31 PROGRAMMING

- A. Provide sufficient internal memory for the specified sequences of operation and data logging with a minimum of 25% of available memory remaining free for future use.
- B. At time of acceptance, all operating systems, DDC System software and hardware shall be the latest official release version available.
- C. Unless otherwise specified, DDC System shall be programmed using a standard naming convention. Objects names shall be modular in design, allowing easy operator interface without the use of a written object index. Use the following naming convention: AA-BBBBCCC-DDDDEE where:
 - 1. AA is used to designate the service location (e.g., room, floor, building, etc.).
 - 2. BBBB is used to designate the mechanical system with which the object is associated (e.g., AH, CHWS, HTG, CLG, LTG, etc.).
 - 3. CCC represents specific mechanical systems or pieces of equipment (e.g., 01, etc.).
 - 4. DDDD represents the equipment, device or material referenced (e.g., SF (supply fan), RF (return fan), DA (discharge air), etc.).
 - 5. EE represents the action or state of the equipment or measured medium (e.g., T (temperature), RH (relative humidity), P (pressure), etc.).
- D. Program the DDC System to adhere to this specification and to fully incorporate the features described. Optimize the program to provide the Sequences of Operation, minimize energy consumption and prolong equipment life.
 - 1. All DDC System programming necessary for the operation of the system to satisfy the design intention and performance requirements, but not specified in this document, shall be provided by the DDC System Contractor at the direction of the Engineer.
 - 2. Imbed in the programming sufficient comment statements and descriptions to clearly describe each section of the program. Comments shall reflect the language of the specified sequences of operation.
- E. Provide graphical user interface (GUI) consistent with the requirements of this specification and the Sequences of Operation. At a minimum:
 - 1. Provide dynamic graphics for all mechanical systems and/or each individual piece of mechanical equipment.
 - 2. All physical hardware, sensors, control devices and setpoints shall be visible in graphical format.
- F. All hardware inputs shall be programmed with appropriate alarms, configured to indicate genuine alarm conditions and/or failure to control while preventing nuisance alarm notification.
- G. Unless otherwise specified, all setpoints shall be adjustable.

- H. At a minimum, every analog hardware point shall be trended and every binary hardware point shall have active and cycle times logged consistent with the specification requirements for trend logs and runtime logs. At a minimum, all software (virtual) setpoints, control loops and operational modes shall be likewise trended and/or logged.
 - 1. Interrelated objects shall be logically grouped into Trend Log Multiple objects for individual mechanical and building systems. Unless otherwise scheduled, initial set-up shall be to log values once every 15 minutes.
- I. The system shall observe the following standard BACnet® command priorities (from highest to lowest):
 - 1. Smoke Control and Life Safety (Priority Level 1 & 2).
 - 2. Manual Operator Command (Priority Level 8).
 - 3. Energy Management (Priority Level 9).
 - 4. Normal Automatic Control (Priority Level 10).

3.32 TEST & BALANCE

- A. The DDC System Contractor shall provide a single set of all tools required to interface with the System for the purposes of Test & Balance.
- B. The DDC System Contractor shall provide instruction in the use of all tools required to interface with the System for the purposes of Test & Balance.
- C. The DDC System Contractor shall provide a qualified technician to assist in the test & balance for a period of eight (8) hours or until the first twenty (20) terminal units have been balanced.

3.33 DDC SYSTEM CHECK-OUT AND TESTING

- A. All testing listed in this article shall be performed by the DDC System Contractor. This testing shall be completed before system demonstration is initiated.
 - 1. The DDC System Contractor shall furnish all of the necessary labor and test and calibration apparatus required to calibrate and prepare for service all instruments, controls, and accessory equipment provided under this specification.
 - 2. Verify that all control terminations are tight and all control wiring is proper and free from shorts and faults.
 - 3. Enable normal operational control and verify calibration of all input devices individually according to manufacturer's recommendations.
 - 4. Verify the operation of all output devices including action, normal positions, fail-safe positions, start and span, and travel.
 - 5. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation.
 - a. Tune all control loops and optimum start/stop routines.
 - b. Check each alarm separately by providing an appropriate signal to trip the alarm.
 - c. Trip all safeties and interlocks to verify proper operation and fail-safe response.

- B. As each device is tested a log shall be completed showing the date, technician's initials and any corrective action taken as a result of operational failures. This log shall be submitted prior to scheduling acceptance demonstration and for inclusion in the final O&M manuals.

3.34 CONTROL ACCEPTANCE AND DEMONSTRATION

- A. At the Owners discretion, the DDC System Contractor may be requested to undergo a series of performance tests to verify proper operation and compliance with this specification.
- B. The tests described in this section are in addition and subsequent to the tests necessary for start-up, tuning, debugging and compliance with the requirements of the Check-out and Testing section of this specification. The Engineer or an appointed representative shall be present at the tests specified in this section and shall be notified ten (10) working days prior to the testing procedures.
- C. The DDC System Contractor shall provide at least two (2) qualified technical personnel equipped with means for two-way communication to demonstrate the actual operation of all control operations and modes including occupied, unoccupied, seasonal changeover and emergency/fail-safe operation.
 - 1. Compliance with this specification shall be demonstrated including all specification sections, schedules, drawings and Sequences of Operation.
- D. Demonstrate operator interface compliance with the requirements of the specification.
- E. Additionally, the following shall be demonstrated:
 - 1. Control loop response shall be proven in the form of trend data in a graphical format displaying the actual response to process variables of each control loop.
 - a. Trends shall include the process variable, setpoint, loop output and physical output position.
 - b. Trends shall show the loop's response to a change in setpoint which represents a change in output equal to at least 25% of its full range.
 - c. The sampling rate shall be between 10 seconds and 3 minutes.
 - d. Leading or following loops shall be required to be tuned by the DDC System Contractor.
 - 2. Operational logs for each system that demonstrate normal operation.
 - a. Trends shall include the process variable, setpoint, loop output and physical output position, operational mode and equipment status.
 - b. Trends shall cover three (3) 48-hour periods with a sampling interval of not more than 10 minutes.
 - 3. At the discretion of the Owner/Engineer trends from a random sampling of 25% of unitary controllers/applications may be submitted.
 - 4. Database backup of the entire network and database restoration for selected controllers.
- F. As each device is tested a log shall be completed showing the date, technician's initials and any corrective action taken as a result of operational failures.
- G. The DDC System Contractor shall display using a third-party data packet analytical tool that all DDC System data including operator interface requests are being performed using BACnet®.

- H. Any tests that fail to demonstrate the operational compliance of the DDC System shall be repeated at a later date when the issues have been resolved. The DDC System Contractor shall be responsible for any necessary repairs or revisions to successfully complete all tests.
- I. When all of the tests and documentation described herein have been successfully completed to the satisfaction of the specification, the Owner and the Engineer the DDC System shall be accepted as complete within fourteen (14) calendar days.
 - 1. Any tests that cannot be performed due to circumstances beyond the control of the DDC System Contractor may be performed at the discretion of the Owner after acceptance and as a part of the warranty period.

3.35 CLEANING

- A. The DDC System 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.
- B. At the completion of work in any area the DDC System Contractor shall clean all work, equipment, etc. keeping it free from dust, dirt, debris, etc.
- C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any other factory finish damage shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed or damaged shall be replaced with new material and painted to match the adjacent areas.

3.36 TRAINING

- A. The DDC System Contractor shall provide instruction on the adjustment, operation and maintenance of the DDC System including all hardware and software provided and installed in compliance with the requirements of this specification.
 - 1. Training shall be performed by a manufacturer's representative and/or instructor or a manufacturer-trained application engineer and/or technician with sufficient experience in the installation, programming and operation of the DDC system.
 - 2. All training equipment and material shall be provided by this Contractor.
- B. Training in the operation of the DDC System shall be performed utilizing a BACnet® network of working controllers representative of the installed network and/or the Owner's facility and shall include:
 - 1. Overview of the installed system and network architecture.
 - 2. DDC system components.
 - 3. Graphical User Interface (GUI) operation.
 - 4. Day-to-day operations including modification of system setpoints, schedules, calendars, manual overrides, trending, log retrieval, alarm handling, etc.
 - 5. Software operation, including navigating the workstation displays, database management, troubleshooting, diagnostics, report generation, etc.

6. Database design and modification including adding objects, modifying routines, optimizing operation, etc.
7. General operation of the workstation hardware and peripherals.
- C. On-site walk-through shall cover the deployment and execution of the complete DDC System and components including:
 1. Sequences of Operation.
 2. Location of all panels, enclosures, controllers, devices, sensors, etc. and equipment and panel layout.
 3. Hardware preventive maintenance, calibration, troubleshooting, maintenance and repair.
 4. Proper use of service tools and materials.

END OF PART 3

ATTACHMENT B
Air Test and Balance

GENERAL:

- A. System shall be balanced to airflow quantities as indicated on drawings. Check, adjust and balance to provide a complete and operational system.
- B. Tabulate results on acceptable type written forms. Minimum data to include:
 1. Air Systems:
 - a. Grille, register, & diffuser designation (each location)
 - b. Design CFM
 - c. Measured CFM
- C. Submit all tabulated data to the Owner for approval. Make special note of any discrepancies between tabulated data and specified conditions and call to Owners attention.
- D. Equipment Air Systems: Adjust each fan coil and VAV unit and each grille, register, and diffuser for the delivery of air quantities as indicated on the drawings.
- E. Balancing Report: After all adjustments are made, prepare a detailed report and submit to the Owner for approval. Final acceptance of the project will not be made until a satisfactory report is received and all final corrections as required by the Owner have been completed. Owner reserves the right to spot check the report prior to this final acceptance.

EXECUTION:

- A. Approved Testing and Balancing Agencies:
 1. The agency selected shall be approved by the Owner prior to bid submittal.
- B. Scope:
 1. The DDC Contractor shall obtain the services of an independent test and balance agency that specializes in total system air and hydronic balancing, testing and commissioning. The Balancing

Contractor shall provide all labor, engineering and test equipment required to adjust and balance all systems as hereinafter specified. All personnel involved in the execution of the work under the balancing contract shall be experienced and factory trained specifically in the total balancing of mechanical systems as well as being regular employees of the Balancing Contractor.

2. The balancing contract shall incorporate the following:
 - a. Adjust and balance the complete air system as hereinafter specified.
 - b. Record all test data and submit four(4) copies upon completion of the balancing contract.
 - c. At the completion of the balancing contract, instruct the Owner's personnel in the proper operation and maintenance of each piece of equipment.
3. All test equipment will be furnished by the Balancing Contractor and will remain his property. All instruments will have been calibrated immediately prior to balancing and verification of calibration provided with submittal data.
4. The DDC Contractor shall award the Test and Balance Contract within thirty (30) days of receipt of his contract to allow the Balancing Contractor to schedule this work in cooperation with other trades involved and comply with the completion date.
5. Testing and balancing shall not begin until the system has been completed and in full working order. The DDC Contractor shall put all heating, ventilating, and air conditioning systems and equipment into full operation and shall continue the operation of same during each working day of testing and balancing. Correct operation of equipment and system components, and cleanliness of process piping and ductwork shall be the responsibility of the appropriate contractor.
6. The Balancing Contractor shall warrant solely that the system will be set to the values as established by the plans and specifications, within system capabilities.

C. Testing Requirements:

Air Systems:

The testing and balancing shall include but is not necessarily limited to the following requirements:

1. Adjust all supply and return zones to design CFM.
2. Test and adjust each diffuser, grille, and register to within 5% of design requirements, and also adjust so as to minimize drafts in all areas.

D. Balancing Data

The test report shall include the following information:

1. Air Systems (Including Inlets and Outlets):
 - a. Grille or diffuser reference numbe.
 - b. Grille or diffuser location.
 - c. Design velocity.
 - d. Design CFM.

- e. Measured velocity.
- f. Measured CFM.