THE SCHOOL DISTRICT OF PHILADELPHIA
Office of Capital Programs
440 North Broad Street, 3rd. Floor – Suite 371
Philadelphia, PA 19130

TELEPHONE: (215) 400-4730

ADDENDUM No. 01

Subject: Vare-Washington Major HVAC Upgrade
SDP Contract No. B-085c, 086c, 087c, 088c of 2020/21

Location: Vare-Washington Elementary School
1114-50 S. 5th St.
Philadelphia PA 19147

This ADDENDUM dated 06 December 2021 shall modify and become part of the Contract Documents for the work of this project. Any items not mentioned herein, or affected by, shall be performed strictly in accordance with the original documents.

Questions

Question #1:

Unit-Ventilators: UVs are on exterior walls with windows over units. Where do we mount safety switches shown on drawings? Can you provide a sketch?

Response:
Unit ventilators will be provided with an integral disconnect switch per Unit Ventilator Schedule on M502.

Question #2:

How do we conceal conduit and wiring with a remote safety switch?

Response:
Unit ventilators will be provided with an integral disconnect switch per Unit Ventilator Schedule on M502.

Question #3:

Drawing E-601: Note under existing panelboards AC1, AC2, and AC3 show uni-vent wiring as “Existing to Remain wiring”. Do we bid to install all new wiring to uni-vents or do we re-use the “existing to Remain wiring”?

Response:
Provide all new wiring to unit ventilators.

Question #4:

Per electrical summary of work (Section 01 1000 1.2.4), can you please confirm a short circuit and arc flash study is required. If yes, please confirm it is for new equipment only”?

Response:
Yes. The Electrical Contractor will provide short circuit and arc flash studies for *new* equipment.

Question #5:

At the walkthrough it was stated this project could possibly be performed after hours. Can you please clarify if this project will be performed during normal working hours, second shift, or third shift.

Response:

Work is restricted to the off hours whenever the school is in session. Work during unoccupied days (e.g. Winter Break and Summer Break) may be scheduled during normal working hours. If work on overtime, weekends or holidays is required to meet the project completion dates, it will be scheduled at no additional cost to the School District.

Drawings:

- M501: ADD the following to sheet M501: "GENERAL EQUIPMENT NOTE: PROVIDE FULL-SIZED ISOLATION VALVES AT EVERY HYDRONIC EQUIPMENT CONNECTION (i.e. AIR HANDLING UNIT, BOILER, CHILLER, CONDENSER, PUMP, FAN COIL, AIR/DIRT SEPARATOR, CABINET UNIT HEATER, CHEMICAL SHOT FEEDER, DUPLEX BAG FILTER, BUFFER TANK, AND UNIT VENTILATOR.) PROVIDE A LOCK-SHIELDED ISOLATION VALVE AT THE EXPANSION TANK CONNECTION.

- E601: REPLACE "**" with "PROVIDE NEW WIRING" for all new unit ventilators.

Specifications

- REPLACE Section 23 0923 Direct-Digital Control Systems for HVAC with attached.

- DELETE Paragraph 2.1.04 of Section 01 1165 UNDERGROUND STORAGE TANK INSTALLATION and REPLACE with the following:

  "Contractor is responsible for the removal and proper disposal of remaining product in the existing oil tank."

End of Addendum

SECTION 23 0923
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Direct-Digital Control (DDC) System Controllers
B. Operator Interface and Graphical User Interfaces (Software and Web Based)
C. Power Supplies and Line Filtering
D. Uninterruptible Power Supplies
E. Low Voltage Control Wiring and Raceways

1.02 SUBMITTALS

A. Product Data and Shop Drawings: Meet requirements of General and Supplementary Conditions on Shop Drawings, Product Data, and Samples. In addition, the contractor shall provide shop drawings or other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and three 11” x 17” prints of each drawing. When manufacturer’s cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:
   1. DDC System Hardware
      a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
      b. Manufacturer’s description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
         1) Direct digital controllers (controller panels)
         2) Transducers and transmitters
         3) Sensors (including accuracy data)
         4) Actuators
         5) Valves
         6) Relays and switches
         7) Control panels
         8) Power supplies
         9) Batteries
         10) Operator interface equipment
         11) Wiring
      c. Wiring diagrams and layouts for each control panel. Show termination numbers.
      d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.
   2. Central System Hardware and Software
      a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.

b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
   1) Central Processing Unit (CPU) or web server
   2) Monitors
   3) Keyboards
   4) Power supplies
   5) Battery backups
   6) Interface equipment between CPU or server and control panels
   7) Operating System software
   8) Operator interface software
   9) Color graphic software
   10) Third-party software
c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show interface wiring to control system.
d. Network riser diagrams of wiring between central control unit and control panels.
e. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, and DDC controller.
f. Description and technical data of all software provided and cross-referenced to products in which software will be installed.
g. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
h. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
i. Listing and description of each engineering equation used with reference source.
j. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
k. Description of operator interface to alphanumeric and graphic programming.
l. Description of each network communication protocol.
m. Description of system database, including all data included in database, database capacity and limitations to expand database.
n. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
o. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

3. Controlled Systems
   a. Riser diagrams showing control network layout, communication protocol, and wire types.
   b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
   c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
   d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

e. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
f. A point list for each control system. List I/O points and software points specified on projct drawings. Indicate alarmed and trended points.
g. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
h. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
i. Graphic sequence of operation, showing all inputs and output logical blocks.

4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.
5. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

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

C. Project Record Documents. Upon completion of installation, submit three copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and shall include:
1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD compatible files on magnetic or optical media (file format: .DWG, .DXF, .VSD, or comparable) and as 11" x 17" prints.
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 23 09 23 Article 3.14 (Control System Demonstration and Acceptance).
3. Operation and Maintenance (O&M) Manual.
4. As-built versions of submittal product data.
5. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
6. Operator’s manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
7. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
8. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
9. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be

viewed using furnished programming tools.

10. Graphic files, programs, and database on magnetic or optical media.
11. List of recommended spare parts with part numbers and suppliers.
12. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
13. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
14. Licenses, guarantees, and warranty documents for equipment and systems.
15. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

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

E. Shop Drawings: Indicate complete operating data, system drawings, wiring diagrams, and written detailed operational description of sequences. Submit schedule of valves indicating size, flow, and pressure drop for each valve. For automatic dampers, indicate arrangement, velocities, and static pressure drops for each system.

F. Manufacturer's Instructions: Provide for all manufactured components

G. Designer's Qualification Statement.

H. Manufacturer's Qualification Statement.

I. Installer's Qualification Statement.

J. Operation and Maintenance Data: Include inspection period, cleaning methods, recommended cleaning materials, and calibration tolerances.

K. Project Record Documents: Record actual locations of control components, including panels, thermostats, and sensors. Accurately record actual location of control components, including panels, thermostats, and sensors.
   1. Revise shop drawings to reflect actual installation and operating sequences.

L. Warranty: Submit manufacturer's warranty and ensure forms have been filled out in Owner's name and registered with the manufacturer.

M. Maintenance Materials: Furnish the following for Owner's use in maintenance projects:
   1. One (1) extra thermostat

1.03 DESCRIPTION

A. General: The existing obsolete non-functioning Honeywell system will be removed and replaced with a new complete state of the art DDC system. The control system shall consist of a open-source, non-proprietary, high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

B. System software shall be based on a server/thin client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the owner's local area network, and (at the owner's discretion) over the Internet.

C. The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.

D. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends and alarms specified on drawings.

E. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.

F. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.

G. System and product operation under each potential failure condition including, but not limited to, the following:
   1. Loss of power.
   2. Loss of network communication signal.
   3. Loss of controller signals to inputs and outpoints.
   4. Operator workstation failure.
   5. Server failure.
   6. Gateway failure.
   7. Network failure
   8. Controller failure.
   9. Instrument failure.
   10. Control damper and valve actuator failure.

H. Complete bibliography of documentation and media to be delivered to Owner.

I. Description of testing plans and procedures.

J. Description of Owner training.

K. The BMS shall provide full graphic software capable of complete system operation for up to 34 simultaneous Thin-Client workstations.

L. The BMS shall provide full Graphical User Interface (GUI). A project specific graphical user interface submittal is required prior to implementation. The GUI shall will include the following graphics as a minimum:
   1. Home page to include a minimum of critical points for each system represented on the BMS, e.g. Outside Air Temperature, Outside Air Relative Humidity, Supply Air Temperature, Return Air Temperature, damper positions, running or stopped status, etc. in order to allow the operator to be informed of the status of the system and make changes to setpoints and schedules.
   2. Graphic floor plans accurately depicting rooms, walls, hallways, and showing accurate locations of space sensors and major mechanical equipment.
   3. Detailed graphics for each mechanical system.
   4. Access corresponding system drawings, technical literature, and sequences of operations directly from each system graphic.

1.04 APPROVED CONTROL SYSTEM MANUFACTUERS

A. The following are approved control system suppliers.
   1. Loytec (Basis of Design)
   2. Johnson Controls Metasys - Verasys not permitted
   3. Siemens Factory Apogee Controls, Desigo Software - Talon not permitted

B. The list above does not indicate order of preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.
   1. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer

and product line unless Owner approves use of multiple manufacturers.

2. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.05 OPEN SYSTEM DESIGN

A. It is the owners express goal to implement an open Building Automaton System that will allow products from various suppliers to be integrated into a unified system in order to provide flexibility for expansion, maintenance, and service of the system The BAS provided shall maintain open interoperability in the following areas.

B. Communications - The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system that communicates across ANSI/ASHRAE Standard 135-2001 BACnet.

C. Network Management - The supplied computer software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. In addition, adherence to industry standards including ANSI / ASHRAE™ Standard 135-2001, BACnet to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a PICS document showing the installed device's compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet (BACnet Ethernet/IP).

D. All components and controllers supplied under this Division shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable. All available points in components and controllers which are required for BMS systems operation must be discoverable, whether or not they are included in the current system logic.

E. Network Architecture - A hierarchical topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network. Systems employing a "flat" single tiered architecture shall not be acceptable.

1. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 5 seconds for network connected user interfaces.
2. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.

F. User Access - The supplied system must incorporate the ability to access all data using standard Web Browsers without requiring proprietary operator interface and configuration programs. Systems requiring proprietary database and user interface programs shall not be acceptable. An Open DataBase Connectivity (ODBCU) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.

G. Databases - The database shall be stored on the owner PC and provide on a separate flash drive upon final acceptance of the project. An updated database shall be provided on a flash drive at the end of the warranty period.

H. Network Level Devices - All network level devices (devices that provide for communication interface between the BACnet and the Ethernet) shall conform to the current released version.

I. Software Tools - All software tools needed for full functional use, including programming of controllers, network management and expansion, and graphical user interface use and development, of the BAS described within these specifications shall be provided to the owner or his designated agent. Any licensing required by the manufacturer now and into the future,

including changes to the licensee of the software tools and the addition of hardware corresponding to the licenses, to allow for a complete and operational system for both normal day to day operation and servicing shall be provided. Any such changes to the designated license holders shall be made by the manufacturer upon written request by the owner or his agent. Any cost associated with the license changes shall be identified within the BAS submittals.

J. SOFTWARE LICENSE AGREEMENT – All Software licenses for access and control of the BAS are to be provided to the Owner. Such license shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software. The Owner shall be the named license holder of all software associated with any and all incremental work on the project(s). In addition, the Owner shall receive ownership of all job specific configuration documentation, data files, and application-level software developed for the project. This shall include all custom, job specific software code, databases and documentation for all configuration and programming that is generated for a given project and/or configured for use with the BCUU, BAS Server(s), and any related LAN / WAN / Intranet and Internet connected routers and devices. Any and all required IDs and passwords for access to any component or software program shall be provided to the owner. The System Integrator shall provide as part of the submittals a copy of the Compatibility Statement verifying that all aspect of the Framework maintains an Open System Design.

1.06 QUALITY ASSURANCE

A. Installer and Manufacturer Qualifications
   1. Installer shall have an established working relationship with Control System Manufacturer.
   2. Installer shall have successfully completed Control System Manufacturer’s control system training. Upon request, Installer shall present record of completed training including course outlines.
   3. Contractor to host a pre-installation meeting on-site.

1.07 CODES AND STANDARDS

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with the current editions in effect 30 days prior to the receipt of bids of the following codes:
   1. National Electric Code (NEC)
   2. International Building Code (IBC)
      a. Section 719 Ducts and Air Transfer Openings
      b. Section 907 Fire Alarm and Detection Systems
      c. Section 909 Smoke Control Systems
      d. Chapter 28 Mechanical
   3. International Mechanical Code (IMC)
   4. ANSI/ASHRAE Standard 135, BACnet - A Data Communication Protocol for Building Automation and Control Systems

1.08 SYSTEM PERFORMANCE

A. System Network Speed:
   1. LAN Connecting Operator Workstations and Network Controllers: 100Mbps.
   2. LAN Connecting Programmable Application Controllers: 100Mbps
   3. LAN Connecting Application-Specific Controllers: 100Mbps

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

1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 seconds.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 seconds and shall automatically refresh every 15 seconds.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 seconds.
4. Object Command. Devices shall react to command of a binary object within 2 seconds. Devices shall begin reacting to command of an analog object within 2 seconds.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 45 seconds.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 seconds. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per second. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 seconds of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
10. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table-1 - Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15º (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1 below)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2 below)
Electrical	±1% of reading (see Note 3 below)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO2)	±50 ppm

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

Table 2 - Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in.w.g.)	0–1.5 kPa (0–6 in. w.g.)

	±3 Pa (±0.01 in.w.g.)	-25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in.w.g.)	MPa (1–150 psi) 0–12.5 kPa (0–50 in. w.g.) differential

1.09 WARRANTY

A. Warrant work as follows:
   1. Warrant labor and materials for specified control system free from defects for a period of 24 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
   2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
   3. If the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
   4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
   5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.10 OWNERSHIP OF PROPRIETARY MATERIAL

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

1.11 ABBREVIATIONS

A. BACnet – Building Automation and Control Network

B. LCP – Local Control Panel

C. NAC – Network Area Controller

D. GUI – Graphical User Interface

E. LAN – Local Area Network
F. WAN – Wide Area Network
G. PIC Statement – Protocol Implementation Conformance Statement
H. HTML – Hypertext Markup Language
I. XML – Extensible Markup Language
J. PDF- Portable Document Format
K. ODBC – Open Database Connectivity
L. SQL – Structured Query Language

1.12 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
B. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
C. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
D. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
E. As-built versions of submittal Product Data.
F. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
G. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
H. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
I. Engineering, installation, and maintenance manuals that explain how to:
    1. Design and install new points, panels, and other hardware.
    2. Perform preventive maintenance and calibration.
    3. Debug hardware problems.
    4. Repair or replace hardware.
J. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
K. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
L. List of recommended spare parts with part numbers and suppliers.
M. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
N. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
O. Licenses, guarantees, and warranty documents.
P. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

Q. Owner training materials.

1.13 DEFINITIONS

TERM	DEFINITION
BACNET INTEROPERABILITY BUILDING BLOCKS (BIBB)	**A BIBB DEFINES A SMALL PORTION OF BACNET FUNCTIONALITY THAT IS NEEDED TO PERFORM A PARTICULAR TASK. BIBBS ARE COMBINED TO BUILD THE BACNET FUNCTIONAL REQUIREMENTS FOR A DEVICE IN A SPECIFICATION.**
BACNET/BACNET STANDARD	**BACNET COMMUNICATION REQUIREMENTS AS DEFINED BY THE LATEST VERSION OF ASHRAE/ANSI 135 AND APPROVED ADDENDA.**
BINARY	**TWO-STATE SIGNAL WHERE A HIGH SIGNAL LEVEL REPRESENTS ON" OR "OPEN" CONDITION AND A LOW SIGNAL LEVEL REPRESENTS "OFF" OR "CLOSED" CONDITION. "DIGITAL" IS SOMETIMES USED INTERCHANGEABLY WITH "BINARY" TO INDICATE A TWO-STATE SIGNAL**
CONTROL SYSTEMS SERVER	**A COMPUTER(S) THAT MAINTAIN(S) THE SYSTEMS CONFIGURATION AND PROGRAMMING DATABASE.**
CONTROLLER	**INTELLIGENT STAND-ALONE CONTROL DEVICE. CONTROLLER IS A GENERIC REFERENCE TO BUILDING CONTROLLERS, CUSTOM APPLICATION CONTROLLERS, AND APPLICATION SPECIFIC CONTROLLERS.**
DIRECT DIGITAL CONTROL	**MICROPROCESSOR-BASED CONTROL INCLUDING ANALOG/DIGITAL CONVERSION AND PROGRAM LOGIC.**
DISTRIBUTED CONTROL	**PROCESSING OF SYSTEM DATA IS DECENTRALIZED AND CONTROL DECISIONS ARE MADE AT SUBSYSTEM LEVEL. SYSTEM OPERATIONAL PROGRAMS AND INFORMATION ARE PROVIDED TO REMOTE SUBSYSTEMS AND STATUS IS REPORTED BACK. ON LOSS OF COMMUNICATION, SUBSYSTEMS SHALL BE CAPABLE OF OPERATING IN A STANDALONE MODE**

	USING THE LAST BEST AVAILABLE DATA
GATEWAY	**BI-DIRECTIONAL PROTOCOL TRANSLATOR CONNECTING CONTROL SYSTEMS THAT USE DIFFERENT COMMUNICATION PROTOCOLS.**
I/O	**SYSTEM THROUGH WHICH INFORMATION IS RECEIVED AND TRANSMITTED. I/O REFERS TO ANALOG INPUT (AI), BINARY INPUT (BI), ANALOG OUTPUT (AO) AND BINARY OUTPUT (BO). ANALOG SIGNALS ARE CONTINUOUS AND REPRESENT CONTROL INFLUENCES SUCH AS FLOW, LEVEL, MOISTURE, PRESSURE, AND TEMPERATURE. BINARY SIGNALS CONVERT ELECTRONIC SIGNALS TO DIGITAL PULSES (VALUES) AND GENERALLY REPRESENT TWO-POSITION OPERATING AND ALARM STATUS. "DIGITAL," (DI AND (DO), IS SOMETIMES USED INTERCHANGEABLY WITH "BINARY," (BI) AND (BO), RESPECTIVELY**
LOCAL AREA NETWORK	**COMPUTER OR CONTROL SYSTEM COMMUNICATIONS NETWORK LIMITED TO LOCAL BUILDING OR CAMPUS.**
LOW VOLTAGE	**AS DEFINED IN NFPA 70 FOR CIRCUITS AND EQUIPMENT OPERATING AT LESS THAN 50 V OR FOR REMOTE-CONTROL, SIGNALING POWER-LIMITED CIRCUITS**
MASTER-SLAVE/TOKEN PASSING	**DATA LINK PROTOCOL AS DEFINED BY THE BACNET STANDARD.**
NETWORK CONTROLLER	**DIGITAL CONTROLLER, WHICH SUPPORTS A FAMILY OF PROGRAMMABLE APPLICATION CONTROLLERS AND APPLICATION-SPECIFIC CONTROLLERS, THAT COMMUNICATES ON PEER-TO-PEER NETWORK FOR TRANSMISSION OF GLOBAL DATA.**
POINT-TO-POINT	**SERIAL COMMUNICATION AS DEFINED IN THE BACNET STANDARD.**
PRIMARY CONTROLLING LAN	**HIGH SPEED, PEER-TO-PEER**

	CONTROLLER LAN CONNECTING BCS AND OPTIONALLY AACS AND ASCS. REFER TO SYSTEM ARCHITECTURE BELOW.
PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT	**A WRITTEN DOCUMENT THAT IDENTIFIES THE PARTICULAR OPTIONS SPECIFIED BY BACNET THAT ARE IMPLEMENTED IN A DEVICE.**
ROUTER	**A DEVICE THAT CONNECTS TWO OR MORE NETWORKS AT THE NETWORK LAYER.**
WIRING	**RACEWAY, FITTINGS, WIRE, BOXES AND RELATED ITEMS.**

PART 2 PRODUCTS

2.01 MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Spare parts shall be available for at least five years after completion of this contract.

2.02 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.

B. Install new wiring and network devices as required to provide a complete and workable control network.

C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

D. DDC Controller peer-to-peer communication shall be BACnet/IP 100Base-T over CAT6

E. Wireless encrypted mesh communication network is allowable providing that every device has a wired communication port available. Wireless network must be tested, Mesh Point and Mesh Path Statistics reports must be available to prove network function. A live Wireless Mesh Floorplan graphic must be available to easily troubleshoot and identify poor connections. If a device is found that does not meet the following minimum requirements it must be wired at the contractor’s expense.
   1. Mesh Point Statistics: Weak performance or bad reliability in a Mesh network can have several reasons. one of them is a badly integrated Mesh point in the Mesh network. Such a weak point is revealed by bad connection to other Mesh points. The statistics data provides information on mesh point IP, MAC address, received and transmitted data, the signal strength, authentication status and time of inactivity.
      a. The most important values are the signal strength and the authentication status. The authentication status should always indicate successful authentication under normal operation and the signal strength should be no less than -70 dBm for an acceptable connection.
   2. Mesh Path Statistics: The Mesh path statistics report provides information on the Mesh paths to all Mesh points in the Mesh network. Each line of the report shows a Mesh path with the receiver Mesh point ID. Additionally, the Mesh point ID of the neighboring node is given for the respective path, to which packets are forwarded in order to reach the addressed receiver Mesh point. More statistics information is the Mesh path metric, the

sequence number, the expiration period, the buffered packets and the state of the Mesh path.

a. The most important figures are the Mesh path metric and the state of the Mesh path. The Mesh path metric reflects the path quality from the Mesh point to the receiver Mesh point. The smaller the path metric the better the connection quality to the receiver Mesh point. The smaller the path metric the better the connection quality to the receiver Mesh point. A value larger than 500, however, should not be reached. In this case the Mesh point white list should be optimized for this Mesh path. For normal operation the Mesh path state should always read ‘active’, ‘sn_valid’ or ‘resolved’. This indicates and active and resolved Mesh path with a valid sequence number.

3. Wireless Mesh Floorplan Graphic

a. By using a floorplan in the Mesh graph the local layout of the building can be considered when configuring the Mesh network. The Mesh network visualization using a floorplan from the top view of the building. If Mesh network visualization over UDP has been activated, the current signal strength between the Mesh points is added to the view. The connections are colored depending on the signal strength. Green stands for a good connection over -50 dBm, orange stands for a medium connection of about -50 dBm to -70 dBm and red stands for a weak connection under -70 dBm. By looking at the color-coded connection it is fairly easy to identify weak connections and go forward to troubleshoot weak spots in the configuration.

F. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in this section. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

G. Workstations, Building Control Panels, and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.

H. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.03 OPERATOR INTERFACE

A. Operator Interface. Web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information. The Operator Workstation or server shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L.

B. Communication. Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J.

C. Hardware.

1. Workstation or web server. Industry-standard hardware shall meet or exceed DDC system manufacturer’s recommended specifications and shall meet response times specified elsewhere in this document. The following hardware requirements also apply:

a. The hard disk shall have sufficient memory to store:
   1) All required operator workstation software.
   2) A DDC database at least twice the size of the delivered system database.
   3) One year of trend data based on the points specified to be trended at their specified trend intervals.
b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
c. Minimum hardware configuration shall include the following:
   1) Quad Core Processor
   2) 8 GB RAM
   3) 1 TB hard disk providing data at 3.0 Gb/sec
   4) 16x DVD+/-RW drive
   5) Serial, parallel, and network communication ports and cables as required for proper DDC system operation

D. System Software.
1. Building management software with management and operating features as engineering and user interface. The scalable building management system combines all functions from installation and configuration of automation stations for HVAC and room automation, input and output modules, gateways, DALI constant light controllers, touch panels and infrastructure products that are installed in the Ethernet/IP network. In addition, it is the user interface for the visualization and operation of the facility. The building managementsoftware provides a consistent user interface during all project phases from installation to operation.
2. The building management system uses a client-server architecture and thereby consists of a building management server application and one or more client applications as a user interface. As a central component, the server manages and stores system and operating parameters, historic data, access rights, and device configurations (backup) in an SQL data base. Via SSL-encrypted web services (OPC XML-DA), it exchanges real time data within the Ethernet/IP network distributed autonomous automation stations for HVAC and room automation, input and output modules, gateways, DALI constant light controllers, touch panels, and infrastructure products, independently of the underlying field bus technology.
3. The client application is the user interface of the building management system. The client can be installed locally together with the server or it can run on computers, distributed in the Ethernet/IP network. The use of SSL-encrypted web services for accessing the server allows a smooth and secure communication via firewalls and NAT routers and the use of Intranet and Internet to build a distributed building automation system. Moreover, this offers the user, independently of different communication technologies, a common view of information from the different communication systems.
4. All areas of the building management system are visualized and operated by installation schematics. Each schematic can consist of a large number of dynamic display elements which reflect the current status of the facilities in real time. It is also possible to directly integrate alarms, trend logs, schedules, web links, dynamic pages, and MP3 streams into the graphics. The configuration software to design the graphical representation of the installation with customized and dynamic schematics is built directly into the building management system. Dynamic information is shown in the form of numeric values, text, changing icons, bar graphs, trend logs, alarm and event lists, or schedule controls.
5. Workspaces can be arranged freely. Thereby, e.g. the dynamic schematics can be detached and shown in a separate window, respectively on a dedicated screen or it will be arranged in a window together with the alarm overview, the navigation tree, and data points in the watch view. The workspace arrangement can be done by the user and be

stored as a perspective.

6. For monitoring the buildings technical equipment, a standard web browser can be natively used. There is no difference, whether a smartphone, tablet, or PC is used. In contrast to the building management client application, the web application is limited to operate and monitor a building.
7. Alarms from different sources must be visualized in a uniform manner. Thereby, neither the source, nor the communication protocol is of importance. Alarms can be acknowledged or disabled in the alarm view.
8. Alarms must be acknowledged and sent, dependent on the weekday and time or free definable rules, to one or multiple recipients via e-mail or as a notification. If the alarm is not acknowledged within a configurable amount of time, an alternative action like an escalation can be triggered.
9. Apart from displaying and operating schedules and calendars of automation serves, also schedules and calendars of numerous automaton servers are grouped and structured hierarchically. The calendar functions must match the common office applications regarding their handling, to provide an easy to use user interface for the user. If schedules and calendars are grouped on different hierarchy levels, the entries on the highest hierarchy level affect all subordinated entries. Entries on a lower hierarchy level affect only those below this level. Local changes on the device are shown on a superordinate level and can either be acknowledged or disabled. The corresponding configurations of schedules and calendars are calculated and loaded into the relevant devices where they are carried out decentralized.
10. Historic data about the temporal cycle of values and operating states (trending) and also alarms from installed automation stations for HVAC and room automation, input and output modules, gateways, DALI constant light controllers, and touch panels are recorded periodically or event-driven and are stored in an SQL data base. If there is no fixed IP connection between the building management system and the relevant devices, the devices will send trend data and alarms automated as an e-mail attachment to the building management server.
11. Users can create ad hoc trend logs in choosing a random data point and activating the trend recording via the context menu.
12. Trend data can either be presented in tabular form or as a trend curve. In addition, the application offers the possibility of exporting trend data via CSV files.
13. The reporting template can be created or adjusted by the user. No programming skills are required. Information can be linked through mathematical operations in any way, e.g. as numerical series, tables, or diagrammed (graph, bar, or pie diagram). The integration of illustrations or graphics is possible. Reports can be triggered on demand at any time or automatically, according to time periods set (daily, weekly, monthly, etc.). Reports can be generated in PDF, Excel, or Word format. They can be automatically distributed via e-mail.
14. All system events are logged in the event log, displayed together on the management station and filtered according to freely selectable characteristics. The event data base records all alarm, system, user, and operating messages with time stamp, location, message text, username, and other important information like changes of a device configuration and system notifications. All system events and user interventions are documented.
15. A system-wide parameter view must allow, as configurable matrix, to clearly present, change, and save system and operating parameters throughout the entire system in a common view.
16. User administration determines the maximum user access rights. It is used to assign user access rights. The system must dispose of user groups that correspond these access rights and that can be assigned to individual users.
17. Programming of devices is carried out via an add-in, directly startable from the building management system (not included in the position). Thereby, programming must be carried

out in accordance with the IEC 61131-3 standard. Programming with the programming languages via functional blocks (FBS) or structured text (ST) must be possible. Both programming languages can be mixed within a project. The IEC 61131-3 programming software allows the online testing of an application via the Ethernet/IP network. IEC 61131-3 applications can be changed without interrupting ongoing projects. In addition, the programming software provides comprehensive diagnostic and debugging functions and also commissioning and service functions (e.g. with force list). An early fault detection is generated already at creating a function block diagram and an integrated graphical offline simulation. Oscilloscope and logic analyzer functions allow a chronological representation of values. Moreover, watch pages for the visualization and changing of runtime data are available.

18. For an effective project processing, a comprehensive and tested HVAC library has to be part of the system.
19. A function for central storage and management of configuration files including recovery, display of online status and also firmware update of automation stations, input and output modules, gateways, DALI constant light controller, touch panels, and infrastructure products that are installed in the Ethernet/IP network is an integral part of the building management software. In the case of programmable devices also the user program is included. A backup feature is responsible for a regular backup of all relevant device configurations on the server. In case of a device exchange, the system takes over the recovery of firmware and device configuration.
20. Through the building management software, protocol independent data point connections between different devices can be configured using drag and drop. After the connection is established, the devices exchange the data peer to peer independently of the system.
21. Licensing has to be carried out via the total number of embedded devices. The number of users shall not be used.
22. Alarm transmission rules: Unrestricted.
23. Perspectives: Unrestricted.
24. Web clients: Unrestricted.
25. Automated reports: Unrestricted.
26. Data bases: SQLite (included), Microsoft SQL server or MySQL.
27. Communication: OPC XML-DA, BACnet/IP, HTTP, HTTPS, SSL.
28. Applicable graphic formats: GIF, JPG, BMP, TIF, PNG, SVG.

2.04 CONTROLLERS

A. All controllers shall have 64-bit arithmetic logic units, CPU registers and databases. Program Cycle times shall be down to 10ms

B. The I/O Controllers are IP-enabled, compact, programmable automation stations for BACnet/ IP networks with physical inputs and outputs and integrated graphical visualization.

C. The I/O Controllers are equipped with two Ethernet ports including a built-in Ethernet switch. This allows for building a daisy chained line topology of up to 20 devices, which reduces costs for network installation. Dual Ethernet port devices also allow the setup of a redundant Ethernet installation (ring topology), which increases reliability. The redundant Ethernet topology is enabled by the Rapid Spanning Tree Protocol (RSTP), which is supported by most managed switches

D. Technology data points are automatically exposed as OPC tags for higher level OPC client applications or building management system via the integrated OPC server providing SSL encrypted web services (OPC XML-DA) or UA Secure Conversation (OPC UA). The I/ O Controllers further allow data exchange over global connections (network-wide data exchange), offer AST™ functions (Alarming, Scheduling, and Trending), store custom graphic pages for visualization, and can be seamlessly integrated in the Building Management System. I/ O Controllers implement the BACnet Building Controller (B-BC) profile and are BTL certified.

E. The automation station features a jog dial and a graphical display (128x64) with backlight. This allows both local configuration and monitoring of the correct function and also local override. The six relay outputs can be overridden via 3-way switches on the front panel of the device.

F. Programming is done with the IEC 61 499 and IEC 61 131-3 based graphical programming system.

G. The automation station manages user-specific graphical pages with dynamic content for the visualization of information. The visualization of dynamic graphical pages is carried out by (HTML5 PC Application) or (HTML5 in Web browser) on one or more PCs or mobile devices. The automation server can also be integrated in the Building Management System. For the dynamic visualization of information, no additional browser plug-in is required. Web services (OPC XML-DA) are used to access the data. Per Automation Server, multiple graphical applications can exist in parallel. The automation server can be accessed over an IP connection by several users simultaneously.

H. The automation station features scheduling, alarming, and trending. Time synchronization is done through a BACnet Time-Master or an NTP server.

I. An event-driven e-mail notification, as the result of a predefined action, informs about the operating status. The e-mail text can be freely chosen. The placement of dynamic values in the text is possible. Stored trend data (CSV file) can be forwarded as attachment.

J. Binary, analog, and multi-state objects (inputs and outputs) can be created as BACnet server objects or can be accessed via BACnet client functions (Write Property, Read Property, COV Subscription). The BACnet client configuration is done via the provided Configuration Software (network scan or EDE import).

K. Static and dynamic network variables (NVs) are supported likewise user defined NVs (UNVTs) and configuration parameters (SCPTs, UCPTs). NVs can be linked in the network via “binding” or they are available as “external data points.”

L. The automation station supports remote packet capturing and troubleshooting using Wireshark. In addition, recording of BACnet communication via BACnet/IP port for network diagnosis is supported.

M. A I/O module can be integrated via direct connection to other modules. The I/O module extends the automation station with additional physical I/Os (inputs, outputs).

N. An integrated web server provides access to configuration parameters and statistical information via a standard web browser. Additionally, data points, schedules, and calendars that have been created during device configuration can be accessed via the web server. Current operating conditions can be queried and parameters such as set points and switching times can be set by means of the web server. The configuration can also be done via the provided configuration software.

O. The automation server is equipped with two Ethernet ports. It can either be configured to use the internal switch to interconnect the two ports or every port is configured to work in a separate IP network.

P. When the Ethernet ports are configured for two separate IP networks, one port can be connected for instance to a WAN (Wide Area Network) with enabled network security (HTTPS) while the second port can be configure to be connected to an insecure network (LAN) where the standard building automation protocols of BACnet/IPt. These devices also feature firewall functionality of course to isolate particular protocols or services between the ports.

Q. Using the internal switch, a daisy chained line topology of up to 20 devices can be built, which reduces costs for network installation. The IP switch also allow the setup of a redundant Ethernet installation (ring topology), which increases reliability. The redundant Ethernet topology is enabled by the Rapid Spanning Tree Protocol (RSTP), which is supported by most managed switches.

R. The automation server features two 100Base-T Ethernet ports with integrated Ethernet switch. Up to 20 automation servers with dual Ethernet can be operated in an Ethernet ring, if the Ethernet ring is connected with an Ethernet switch featuring RSTP function (Rapid Spanning Tree Protocol) on both ends (not included in the position).

S. The built-in SNMP server (Simple Network Management Protocol) provides network management information of a device that can be used by customary IT tools. Via a configurable SNMP agent, status information and statistics with standard MIBs (Management Information Bases), system registers, and all OPC-exposed data points can be read and monitored, and also alarms can be sent.

T. The device is equipped with a three colored LED that shows the current device status. The LED informs about pending errors and inputs or outputs in manual mode. Moreover, the network status is indicated.

U. Installation: DIN rail mounting following DIN 43880, top hat rail EN 50022.

V. Operating conditions: 0°C to 50°C, 10–90% RH, noncondensing, degree of protection: IP40, IP20 (terminals).

W. Power supply: 24 V DC / 24 V AC ±10% via L-POW, or with an external power supply.

2.05 INPUT AND OUTPUT INTERFACE

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

B. UI – Universal Input
   1. UIs are universal inputs for four different input types. They have an input voltage range of 0 V to 10 V, and can withstand up to 30 V. The UIs correspond to class 1 with a relative accuracy of ±1% (of measured value) between 1 V and 10 V, and an absolute accuracy of ±10 mV between 0 V and 1 V. The ADC resolution is 16 bits. Galvanically isolated sensors resp. switches must be connected. Universal inputs can be configured as:

C. Binary Input (Digital Input)
   1. Input impedance > 20 kilohms, sampling period 10 ms.
   2. In voltage mode, the threshold values are < 0.8 V for low level and > 2 V for high level.
   3. In resistance mode, the threshold values are < 1.9 kilohms for low level and > 6.7 kilohms for high level. Between the threshold values, the resulting level of the UI is not defined.

D. Voltage Metering 0-10 V
   1. Input Impedance > 20 kilohms, sampling period < 1 s.

E. Current loop 4-20 mA
   1. Input Impedance > 20 kilohms, sampling period < 1 s. An internal shunt of 249 ohms is available for some universal inputs. Otherwise, an external resistor of 249 ohms must be used as a shunt.

F. Resistance Measurement
   1. Input Impedance 10 kilohms, sampling period < 1 s. Resistors in the range of 1 kilohm to 100 kilohms can be measured. For popular temperature sensors (e.g. Pt1000, NTC10K, NTC1K8, Ni1000) fixed internal translation tables are provided. For all other temperature sensors, translation tables can be defined in the configuration tool and used on the device.
   2. The average sampling period p of analog inputs depends on the number of active (non-disabled) universal inputs n that are configured in analog mode. The formula for p is: p = n × 125 ms.
   3. This means if e.g. only two UIs are configured as analog inputs, a new sample is taken every 250 ms (on average) for each of the two inputs. The UIs configured as digital inputs are unaffected (sampling period always 10 ms) by this formula.

G. DI – Digital Input, Counter Input (S0-Pulse)

1. DIs are fast binary inputs, which can also be used as counter inputs (S0). They follow the S0 specification for electric meters and have a sampling rate of 10 ms. They change state at a load of 195 ohms between the DI terminal and GND. Galvanically isolated sensors resp. switches must be connected.

H. AO – Analog Output
1. AOs are analog outputs with a signal range of 0 to 10 V (up to 12 V), a resolution of 10 bits, and a maximum output current of 10 mA (20 mA @ 12 V), short circuit proof (2 outputs at a time). The accuracy over the whole range is ±100 mV.

I. DO – Digital Output
1. The following digital outputs are available:
   a. Relay 6 A Output: Switching capacity 6 A, 250 V AC resp. 30 V DC. Max in-rush current 6 A, max. 600 W (resistive) @ 250 V AC.
   b. Relay 10 A Output: Switching capacity 10 A, 250 V AC resp. 30 V DC. Max in-rush current 10 A, max. 1600 W (resistive) @ 250 V AC.
   c. Relay 16 A Output: Switching capacity 16 A, 250 V AC resp. 30 V DC. Max in-rush current 80 A, max. 2000 W (resistive) @ 250 V AC.
   d. TRIAC Output: Switching capacity 0.5 A, 24 to 230 V AC. External relays must not be connected.

J. PRESS – Pressure Sensor
1. These inputs represent differential pressure sensors. They are equipped with two 3/16” (4.8 mm) hose connectors.

K. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.

2.06 POWER SUPPLIES AND LINE FILTERING

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
   a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
   b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.
1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
   a. Dielectric strength of 1000 V minimum
   b. Response time of 10 nanoseconds or less
   c. Transverse mode noise attenuation of 65 dB or greater
   d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

2.07 GRAPHICAL USER INTERFACE SOFTWARE

A. A software tool that provides for the development and management of the end user’s Graphical User Interface (GUI) and as the primary point of access to the BAS for the end user.

B. T he GUI shall employ browser-like functionality for ease of navigation. It shall include a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. In addition, menu-pull downs, and toolbars shall employ buttons, commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC Control System and basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.

C. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:

D. Graphic screens shall be developed using any drawing package capable of generating or assembling objects from a GIF, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.

E. Graphic screens shall have the capability to contain objects for text, real-time values, animation, color spectrum objects, logs, graphs, HTML or XML document links, schedule objects, hyperlinks to other URL's, and links to other graphic screens.

F. Modifying common application objects, such as schedules, calendars, and set points shall be accomplished in a graphical manner.
   1. Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
   2. Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.

G. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.

H. Adjustments to analog objects, such as set points, shall be done by right-clicking the selected object and using a graphical slider to adjust the value. No entry of text shall be required.

I. System Configuration. At a minimum, the GUI shall permit the operator to perform the following tasks, with proper password access:
   1. Create, delete or modify control strategies.
   2. Add/delete objects to the system.
   3. Tune control loops through the adjustment of control loop parameters.
   4. Enable or disable control strategies.
   5. Generate hard copy records or control strategies on a printer.
   6. Select points to be alarm-able and define the alarm state.
   7. Select points to be trended over a period of time and initiate the recording of values automatically.

J. On-Line Help. Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext. All system documentation and help files shall be in HTML format.

K. Security. Each operator shall be required to log on to that system with a user name and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system administrator shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the operators' access for viewing and/or changing each system application, full screen editor, and object. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected. This auto log-off time shall be set per operator password. All system

security data shall be stored in an encrypted format.

L. System Diagnostics. The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

M. Alarm Console
   1. The system will be provided with a dedicated alarm window or console. This window will notify the operator of an alarm condition, and allow the operator to view details of the alarm and acknowledge the alarm. The use of the Alarm Console can be enabled or disabled by the system administrator.
   2. When the Alarm Console is enabled, a separate alarm notification window will supersede all other windows on the desktop and shall not be capable of being minimized or closed by the operator. This window will notify the operator of new alarms and un-acknowledged alarms. Alarm notification windows or banners that can be minimized or closed by the operator shall not be acceptable.

2.08 USER INTERFACES (WEB BASED)

A. Web Browser Clients – The primary means of access to the BAS for day to day operation from any PC connected to the LAN (and or remote via the Internet if so required) without the need for any proprietary software.

B. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Internet Explorer™, Google Chrome™, Microsoft Edge™, Mozilla Firefox™, or Netscape Navigator™. Systems requiring additional software (to enable a standard Web browser) to be resident on the client machine, or manufacture-specific browsers shall not be acceptable.

C. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function with the Building Automation System (BAS), shall not be acceptable.

D. The Web browser shall provide the same view of the system, in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology as is provided by the Graphical User Interface. Systems that require different views or that require different means of interacting with objects such as schedules, or logs, shall not be permitted.

E. The Web browser client shall support at a minimum, the following functions:

F. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.

G. Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the GUI shall be supported by the Web browser interface.

H. HTML programming shall not be required to display system graphics or data on a Web page

I. Storage of the graphical screens shall be in the Building Controller (BCU), without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.

J. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.

K. Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
   1. Modify common application objects, such as schedules, calendars, and set points in a graphical manner.

a. Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
b. Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
c. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
d. View logs and charts
e. View and acknowledge alarms

L. The system shall provide the capability to specify a user's (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.

M. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

2.09 UN-INTERRUPTED POWER SOURCE POWER

A. Provide local UPS power for the Building Manager to allow for continued operation of the backend system upon power loss until back-up power is on-line.

B. Local UPS shall be as manufactured by APC Back-UPS Pro 700, model BR700G or approved equivalent.
1. Contractor shall verify required output capacity of UPS prior to purchasing.

2.10 WIRING AND RACEWAYS

A. General. Provide all wiring in conduit or enclosed in raceway. Plenum wiring in ceilings is not acceptable.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

C. All communications wiring will be in conduit. Rigid Metal Conduit required in Mechanical Rooms, Electrical Rooms, and Exterior the building. EMT is acceptable external to these rooms.
1. All conduit and wire required for a complete BAS system will be provided by this contractor.

D. All I/O wiring will be in conduit.
1. All conduit and wire required for a complete BAS system will be provided by this contractor.

PART 3 EXECUTION

3.01 EXAMINATION

A. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.

B. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate, or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others, the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by, and at the expense of, this contractor.

3.02 PROTECTION

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

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

3.03 COORDINATION

A. Site
   1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
   2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Submittals. See Section 23 0923 Article 1.02 (Submittals).

C. Test and Balance.
   1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
   2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.

D. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
   1. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

E. Life Safety.
   1. Integrate existing duct smoke detectors required for air handler shutdown. Interlock smoke detectors to air handlers for shutdown as specified in project drawings (Sequences of Operation).
   2. Integrate existing smoke dampers and actuators required for duct smoke isolation. Interlock smoke dampers to air handlers as specified in project drawings (Sequences of Operation).
   3. Fire and smoke dampers and actuators required for fire-rated walls are existing. Control fire and smoke damper control as specified in project drawings (Sequences of Operation).

F. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
   1. All communication media and equipment shall be provided as specified in Section 23 0923 Article 2.02 (Communication).
   2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in project drawings.
   3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
   4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are

described.

5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.04 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.05 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 23 09 23 Article 1.8 (Codes and Standards).

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

3.06 ENCLOSURES

A. For all I/O requiring field interface devices, these devices where practical will be mounted in a field interface panel (FIP). The Contractor shall provide an enclosure which protects the device(s) from dust, moisture, conceals integral wiring and moving parts.

B. FIPs shall contain power supplies for sensors, interface relays and contactors, safety circuits, and I/P transducers.

C. The FIP enclosure shall be of steel construction with baked enamel finish, NEMA 1 rated with a hinged door and keyed lock. The enclosure will be sized for twenty percent spare mounting space. All locks will be keyed identically.

D. All wiring to and from the FIP will be to screw type terminals. Analog or communications wiring may use the FIP as a raceway without terminating. The use of wire nuts within the FIP is prohibited.

E. All outside mounted enclosures shall meet the NEMA-4 rating.

F. The tubing and wiring within all enclosures shall be run in plastic track. Wiring within controllers shall be wrapped and secured.

G. Provide a clear lexan lockable cover for all thermostats.

3.07 WIRING

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence. All wiring within the mechanical room, electrical room, and external to the building shall be within Rigid Metal Conduit. All wiring external to these rooms shall be within EMT.

B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.

C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, shall be installed in raceway.

E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway.

F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

G. Do not install wiring in raceway containing tubing.

H. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

I. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

J. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.

K. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

L. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.

M. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

N. Use color-coded conductors throughout with conductors of different colors.

O. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

P. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).

Q. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

R. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.

S. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.

T. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

U. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

V. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

W. All controls wiring located above plenum ceilings, behind walls, and in mechanical rooms must be in conduit.

3.08 COMMUNICATION WIRING

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.

B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling

C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.

D. All communications wiring will be in conduit.

E. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.

F. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.

G. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer’s instructions.

H. All runs of communication wiring shall be unspliced length when that length is commercially available.

I. All communication wiring shall be labeled to indicate origination and destination data.

J. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

K. BACnet communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

L. The BACnet/IP Network shall use shielded, 4-pair unshielded twisted-pair cable with characteristic impedance 100±15 OHMS.

M. BACnet/MSTP shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)

N. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.

O. The maximum number of nodes per segment shall be 32 for BACnet/MSTP devices, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.

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

3.09 INSTALLATION OF SENSORS

A. Install sensors in accordance with the manufacturer's recommendations.

B. Mount sensors rigidly and adequately for environment within which the sensor operates.

C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.

D. All wires attached to sensors shall be sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.

E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each

bend shall be supported with a capillary clip.

F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (1 ft) of sensing element for each square meter (1 sq. ft.) of coil area.

G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.

H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.

J. Differential Air Static Pressure.
   1. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
   2. Return Duct Static Pressure: Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
   3. Building Static Pressure: Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
   4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
   5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.
   6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.

K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

L. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

3.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch according to manufacturer's instructions.

3.11 ACTUATORS

A. General. Mount and link control damper actuators according to manufacturer's instructions.
   1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
   2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

B. Provide all mounting hardware and linkages for actuator installation.

C. Electric/Electronic
   1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall

be mounted following manufacturer’s recommendations.

2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

D. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

E. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all hardware points listed in project drawing Points List and Sequences of Operation.

3.12 PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.

B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See project drawings (Sequences of Operation). Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.

C. Software Programming.

1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Embed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:
   a. Text-based:
      1) Must provide actions for all possible situations
      2) Must be modular and structured
      3) Must be commented
   b. Graphic-based:
      1) Must provide actions for all possible situations
      2) Must be documented
   c. Parameter-based:
      1) Must provide actions for all possible situations
      2) Must be documented.

D. Operator Interface.

E. Standard Graphics: Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all relevant input and output points for that equipment. Also show relevant calculated points such as setpoints. As a minimum, show
   a. on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in projct drawings.

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

3.13 CONTROL SYSTEM CHECKOUT AND TESTING

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

3.14 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration.
   1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
   2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.

B. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
   1. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all
      a. modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
   2. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
   3. Demonstrate compliance with Part 1, "System Performance."

4. Demonstrate compliance with sequences of operation through all modes of operation.
5. Demonstrate complete operation of operator interface.
6. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

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

3.15 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.16 TRAINING

A. Provide training for a designated staff of Owner’s representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.

B. Training shall enable students to accomplish the following objectives.
1. Day-to-day Operators:
   a. Proficiently operate the system
   b. Understand control system architecture and configuration
   c. Understand DDC system components
   d. Understand system operation, including DDC system control and optimizing routines (algorithms)
   e. Operate the workstation and peripherals
   f. Log on and off the system
2. Access graphics, point reports, and logs
   a. Adjust and change system set points, time schedules, and holiday schedules
   b. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
   c. Understand system drawings and Operation and Maintenance manual
   d. Understand the job layout and location of control components
   e. Access data from DDC controllers and ASCs
   f. Operate portable operator's terminals
3. Advanced Operators:
   a. Make and change graphics on the workstation
   b. Create, delete, and modify alarms, including annunciation and routing of these

c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
d. Create, delete, and modify reports
e. Add, remove, and modify system's physical points
f. Create, modify, and delete programming
g. Add panels when required
h. Add operator interface stations
i. Create, delete, and modify system displays, both graphical and others
j. Perform DDC system field checkout procedures
k. Perform DDC controller unit operation and maintenance procedures
l. Perform workstation and peripheral operation and maintenance procedures
m. Perform DDC system diagnostic procedures
n. Configure hardware including PC boards, switches, communication, and I/O points
o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
p. Adjust, calibrate, and replace system components

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

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.

D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.

E. The instructor(s) shall be factory-trained and experienced in presenting this material.

F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.17 SEQUENCE OF OPERATION

A. Sequences of Operation are located on the project drawings.

3.18 START-UP AND CHECKOUT PROCEDURES

A. Start up, check out, and test all hardware and software and verify communication between all components.
   1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
   2. Verify that all analog and binary input/output points read properly.
   3. Verify alarms and interlocks.
   4. Verify operation of the integrated system.

END OF SECTION