SECTION 23 09 23

DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Complete System of Automatic Controls.

B. Control Devices, Components, Wiring and Material.

C. Instructions for Owners.

D. Remodeling.

1.2 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Control Valves.

B. Temperature Sensor Sockets.

C. Gauge Taps.

D. Automatic Dampers.

1.3 RELATED REQUIREMENTS

A. Section 23 09 93 – Sequence of Operations for HVAC Controls.

1.4 REFERENCES

A. AMCA 500 - Test Methods for Louvers, Dampers and Shutters.

B. ANSI/ASHRAE Standard 135-2001: BACnet® – A Data Communication Protocol for Building Automation and Control Networks, including all amendments.

C. ANSI/NEMA 250 - Enclosures for Electrical Equipment (1000 volts Maximum).

D. ANSI/NFPA 70 - National Electrical Code.

E. ANSI/NFPA 90A - Installation of Air-Conditioning and Ventilation Systems.

F. ASHRAE 85 - Automatic Control Terminology for Heating, Ventilating, Air Conditioning.

G. ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings.

1.5 AGENCY AND CODE APPROVALS

A. All products shall have the following agency approvals. Provide verification that the approvals exist for all submitted products with the submittal package.
   1. UL-916; Energy Management Systems.
   2. C-UL listed to Canadian Standards Association C22.2 No. 205-M1983 “Signal Equipment.”
   3. EMC Directive 89/336/EEC (European CE Mark).
   4. FCC, Part 15, Subpart J, Class A Computing Devices.

1.6 ACRONYMS

A. Acronyms used in this specification are as follows:
   1. BACnet Building Automation and Control Networks
   2. B-AAC BACnet Advanced Application Controller
   3. B-ASC BACnet Application Specific Controller
   4. BTL BACnet Testing Laboratories
   5. DDC Direct Digital Controls
   6. FMCS Facility Management and Control System
   7. GUI Graphic User Interface
   8. IBC Interoperable BACnet Controller

9. IDC Interoperable Digital Controller
10. LAN Local Area Network
11. LCU Local Control Unit
12. MS/TP Master-Slave/Token-Passing
13. NCU Network Control Unit
14. ODBC Open DataBase Connectivity
15. OOT Object Oriented Technology
16. OPC Open Connectivity via Open Standards
17. PICS Product Interoperability Compliance Statement
18. TCC Temperature Control Contractor
19. TCS Temperature Control System
20. TCU Terminal Control Unit
21. WAN Wide Area Network
22. WBI Web Browser Interface

1.7 SUMMARY

A. Provide new standalone FMCS for this project.

B. The Installer, otherwise identified as the Temperature Controls Contractor (TCC), who is furnishing the Direct Digital Control (DDC) network shall meet with the Installers of the heating, ventilating and air-conditioning (HVAC) equipment and related products which are specified to be equipped with factory furnished unitary controllers to coordinate details between their HVAC equipment's unitary controllers and the DDC network. The Owner or his designated representative shall be present at this meeting. The purpose of this meeting shall be to insure there are no unresolved issues regarding the specified integration of the proposed HVAC equipment into the DDC network and overall control system performance. Each HVAC equipment Installer shall furnish to the Owner and all other Installers the details of their proposed control interfaces including but not limited to the hardware and software identifiers for interface points, control point mapping requirements, wiring requirements, communication speeds and network accessories. Required coordination efforts shall extend to any 3rd party integral control systems which are furnished with a BACnet interface for integration into the DDC system described within. Equipment and DDC controls submittals, including but not limited to those required under Part 3 section – "Sequences of Operation for HVAC" shall not be approved prior to the satisfactory completion of this coordination meeting.

1.8 SYSTEM DESCRIPTION

A. The entire TCS shall be comprised of a network of interoperable, standalone digital controllers communicating via BACnet MS/TP protocol to an NCU. Temperature Control System products shall be as specified below.

B. The FMCS shall include NCUs within each facility. The NCU shall connect to the Owner's local or wide area network, depending on configuration. Provide access to the system, locally in each building through standard Web browsers and/or via local area network. Coordinate all requirements for network access with the Owner.

C. Provide materials and labor necessary to connect factory supplied control components.

D. Provide central and remote hardware, software, and interconnecting wire and conduit. New, manufacturer approved wire shall be used for communication network. Coordinate with Iowa Army National Guard wire and cabling standards.

E. The FMCS shall include automated alarming software capable of calling e-mail compatible cellular telephones and pagers. The e-mail alarm paging system shall be able to segregate users, time schedules, and equipment and be capable of being programmed by the Owner.

F. For the dedicated configuration tool provided, it is preferable that it be launched from within the applicable Network Management Software. If not, include any software required for controller configuration as a leave-behind tool with enough license capability to support the installation.

G. All licenses shall be open and turned over to the Owner. The front end controller shall be fully unlocked to allow programming, scheduling, and set point adjustments by the Owner and to allow the Owner the option to solicit alternate service contractors at the Owner's discretion.

H. Furnish one legal copy of all software tools, configuration tools, management tools, and utilities used during system commissioning and installation. All tools shall be readily available in the market. Contractor shall convey to the Owner all software tools and their legal licenses at project closeout.

I. TCC to extend CAT5 cable from NCUs to existing server. Coordinate all requirements with Owner.

J. All inputs and outputs (I/O) shall come from field-level controllers. Extended I/O from NCUs will not be allowed. Satellite points (unused I/O re-purposed through network programming) will not be allowed.

K. Field-level communication system shall utilize daisy-chained topography; no tees or star configuration. Communication layout shall be pre-approved by Owner prior to construction.

L. This FMCS will communicate back the Distech Web Supervisor located at the Joint Forces Headquarters building in Johnston Iowa. The connection to the Web Supervisor will be performed by the Owner. This contractor shall assist the owner in this process and be responsible for any additional software or licenses necessary for that connection to take place.

M. Niagara version shall be revision 4.7.109. JACE platform user name and password shall be provided to Owner's HVAC Specialist. Embedded WorkBench shall be loaded and enabled on the system JACE(s).

N. Operating system shall be open ANSI/ASHRAE Standard 135-(current version): BACnet-A Data Communication Protocol for Building Automation and Control Networks (ANSI Approved).

O. There is an existing BAS server which resides at JFHQ Camp Dodge. Network topographies that provide a local BAS server will not be allowed. BAS shall be connected to the Camp Dodge server.

P. To prevent a confusing array of GUIs, standardization of graphics packages is mandatory and shall be DG-lux or Distech Envysion.

Q. Graphics shall reside in the local JACE unless directed to save trend data in a separate SQL database. For Owner records JACE MAC address shall be provided. JACE primary port will be for the secure network (Guard network), the secondary port shall be enabled and its IP shall be set to 192.168.100.100. All graphics shall be pre-approved by Owner and must be complete prior to award of substantial completion.

R. Graphics shall include a time/date stamp for the JACE on the system home page. Graphics shall also include pages for sequence of operation for the equipment, Network topography with device address and location, and on systems with ductwork, a ductwork layout page shall also be included.

S. All installations shall include a point to point checkout with the results signed "verified" by the contractor and the results provided to the Owner."

T. JACE will have a surge protection device installed to protect the hardware in power quality events.

1.9 SUBMITTALS

A. Equipment Coordination:
   1. The Controls Contractor shall obtain approved equipment submittals from other contractors to determine equipment wiring connections, to choose appropriate controllers, and to provide programming.
   2. Control valve selections shall be based on flow rates shown in approved shop drawings.
   3. Coordinate the control interface of all equipment with the equipment manufacturers prior to submittal submission.

B. Shop Drawings:
   1. Submit in accordance with Section 01 33 00 - Submittal Procedures and Section 01 33 05 – Electronic Submittal Procedures.
   2. Refer to Section 23 01 00 – Administrative Requirements.
   3. Cross-reference all control components and point names in a single table located at the beginning of the submittal with the identical nomenclature used in this section.
   4. Submittal shall also include a trunk cable schematic diagram depicting control panel locations and a description of the communication type, media and protocol.
   5. System Architecture: Provide riser diagrams of wiring between central control unit and all control panels. This shall include specific protocols associated with each level within the architecture. Identify all interface equipment between CPU and control panels.
   6. Diagrams shall include:
      a. Wiring diagrams and layouts for each control panel showing all termination numbers.
      b. 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 all interface wiring to the control system.
      c. Schematic diagrams for all field sensors and controllers.
      d. A schematic diagram of each controlled system. The schematics shall have all control points labeled. The schematics shall graphically show the location of all control elements in the system.
      e. A schematic wiring diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, label it with the same name. Label all terminals.
      f. A tabular instrumentation list for each controlled system. The table shall show element name, type of device, manufacturer, model number and product data sheet number.
      g. All installation details and any other details required to demonstrate that the system will function properly.
      h. All interface requirements with other systems.
      i. BAS subnet communication wiring routing.
   7. The network infrastructure shall conform to the published guidelines for wire type, length, number of nodes per channel, termination, and other relevant wiring and infrastructure criteria as published. The number of nodes per channel shall be no more than 80% of the defined segment (logical or physical) limit in order to provide future system enhancement with minimal infrastructure modifications.
   8. Sequences: Submit 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. The wording of the control sequences in the submittal shall match verbatim that included in the construction documents to ensure there are no sequence deviations from that intended by the Engineer. Clearly highlight any deviations from the specified sequences on the submittals.
   9. Points List Schedule:
      a. Submit a complete points list of all points to be connected to the TCS and FMCS. The points list for each system controller shall include both inputs and outputs (I/O), point number, the controlled device associated with the I/O point, the location of the I/O device, and reference drawings. Where a control point is the same as that shown on the control system schematic, label it with the same name. Points list shall specifically identify alarms, trends, event history, archive, totalization, graphic points, and all mapped points from other systems. Provide point lists, point naming convention, and factory support information for systems provided and integrated into the FMCS.
   10. Submit a description of the proposed processes and timelines along with proposed report formats and detailed checklists to be used in Part 3 subsection: "Control System Commissioning, Demonstration and Acceptance.
   11. Damper Schedule: Schedule shall include a separate line for each damper and a column for each of the damper attributes:

a. Damper Identification Tag.
b. Location.
c. Damper Type.
d. Damper Size.
e. Duct Size.
f. Arrangement.
g. Blade Type.
h. Velocity.
i. Pressure Drop.
j. Fail Position.
k. Actuator Identification Tag.
l. Actuator Type.
m. Mounting.

12. Valve Schedule: Valve manufacturer shall size valves and create a valve schedule. Schedule shall include a separate line for each valve and a column for each of the valve attributes:
    a. Valve Identification Tag.
    b. Location.
    c. Valve Type.
    d. Valve Size.
    e. Pipe Size.
    f. Configuration.
    g. Flow Characteristics.
    h. Capacity.
    i. Valve CV.
    j. Design Pressure Drop.
    k. Pressure Drop at Design Flow.
    l. Fail Position.
    m. Close-off Pressure.
    n. Valve and Actuator Model Number and Type.

C. Operation and Maintenance Manual:
    1. Submit in accordance with Section 01 33 05 – Electronic Submittal Procedures and Section 01 77 00 - Closeout Procedures.
    2. Each O&M manual shall include:
        a. Table of contents with indexed tabs dividing information as outlined below.
        b. Definitions: List of all abbreviations and technical terms with definitions.
        c. Warranty Contacts: Names, addresses, and 24-hour telephone numbers of contractors installing equipment and controls and service representatives of each.
        d. Licenses, Guarantees, and Warranties: Provide documentation for all equipment and systems.
        e. System Components: Alphabetical list of all system components, with the name, address, and telephone number of the vendor.
        f. Operating Procedures: Include procedures for operating the control systems; logging on/off; enabling, assigning, and reporting alarms; generating reports; collection, displaying, and archiving of trended data; overriding computer control; event scheduling; backing up software and data files; and changing setpoints and other variables.
        g. Programming: Description of the programming language (including syntax), statement descriptions (including algorithms and calculations used), point database creation and modification, program creation and modification, and use of the editor.
        h. Engineering, Installation, and Maintenance: Explain how to design and install new points, panels, and other hardware; recommended preventive maintenance procedures for all system components, including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions; how to debug hardware problems; and how to repair or replace hardware. A list of recommended spare parts.

i. Original Software: Complete original issue CDs for all software provided, including operating systems, programming language, and graphics software.
j. Software: One set of CDs containing an executable copy of all custom software created using the programming language, including the setpoints, tuning parameters, and object database.
k. Graphics: A glossary or icon symbol library detailing the function of each graphic icon and graphics creation and modification. One set of CDs containing files of all color graphic screens created for the project.

D. Training Manual:
1. Provide a course outline and training manuals for each training class.
2. Contractor shall submit to Engineer for review and comment, course outlines and training materials for controls training classes at least four weeks before scheduling said training classes. Engineer shall review and return course outlines and training materials at least two weeks prior to respective training class scheduled date after modifying, if necessary, to best meet the Owner's staff needs.

E. Record Documents:
1. Submit record documentation per Section 23 05 00.
2. Provide a complete set of "as-built" drawings and application software on CDs. Provide drawings as AutoCAD™ or Visio™ compatible files. Provide two copies of the "as-built" drawings with revisions clearly indicated in addition to the documents on compact disk. All as-built drawings shall also be installed on the FMCS server in a dedicated directory. Provide all product data sheets in PDF format.
3. Submit two hard copies and one electronic copy of as-built versions of the shop drawings, including product data and record drawings with revisions clearly indicated. Provide floor plans showing actual locations of control components including panels, thermostats, sensors, and hardware.
4. Testing and Commissioning Reports and Checklists: Provide completed versions of Testing and Commissioning Reports and Checklists, along with trend logs for each system identified in the points list and which are used to satisfy requirements of Part 3 subsection: "Control System Testing, Commissioning, Demonstration and Acceptance.
5. Submit printouts of all graphic screens with current values (temperatures, pressures, etc.) to the A/E verifying completion and proper operation of all points.
6. Installation Operation and Maintenance Manual (IOM):
a. Operation section of manual shall include detailed procedures for operating control systems such as: logging on and off, handling alarms, adding and modifying schedules, establishing data trending, producing point reports and trend logs, overriding computer controls, and revising set-points and adjustable system variables.
b. Programming section of manual shall include detailed descriptions of programming languages and syntax for algorithms and calculations used, point database creation and modification, programming subroutines creation and modification and editor usage.
c. Maintenance and Engineering section of manual shall show instructions on how to design, install, program and implement new points, panels and hardware; how to calibrate sensors, plan and accomplish preventative maintenance; how to diagnose and if needed repair or replace hardware. Preventative maintenance procedures shall include recommended schedules of required tasks such as inspections, cleanings and calibrations.
7. Listings of all initial set-points including allowable ranges of adjustments, initial time of day schedules, and notes for each controlled device.
8. Listing of Names, addresses, phone numbers of installing contractors and service technician representatives for equipment and control systems.

1.10 SOFTWARE LICENSE AGREEMENT

A. 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, configuration tools, and application-level software developed for the project. This shall include, but is not limited to, all custom, job-specific software code and documentation for all configuration and programming that is generated for a given project and/or configured for use with the NCU, FMCS Server(s), and any related LAN/WAN/intranet and/or Internet connected routers and devices. Provide the Owner with all required IDs and passwords for access to any component or software program. The Owner shall determine which organizations shall be named in the System Integrator organization ID ("orgid") of all software licenses. Owner shall be free to direct the modification of the "orgid" in any software license, regardless of supplier. ALL LICENSES OF THE ACTUAL HARDWARE BEING INSTALLED SHALL BE SUBMITTED TO THE OWNER FOR APPROVAL BEFORE ANY CONTROL SYSTEM HARDWARE IS INSTALLED

1.11 DELIVERY, STORAGE AND HANDLING

A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage. Store equipment and materials inside and protected from weather.

B. Factory-Mounted Components: Where control devices specified in this section are indicated to be factory mounted on equipment, arrange for shipping control devices to unit manufacturer.

1.12 JOB CONDITIONS

A. Cooperation with Other Trades: Coordinate the Work of this section with that of other sections to ensure that the Work will be carried out in an orderly fashion. It is this Contractor's responsibility to check the Contract Documents for possible conflicts between the Work of this section and that of other crafts in equipment location; pipe, duct and conduit runs; electrical outlets and fixtures; air diffusers; and structural and architectural features.

1.13 QUALITY ASSURANCE

A. All new building automation system products on this project shall be provided by a firm that is a registered ISO 9001:2000 manufacturer at time of bid.
   1. The manufacturer of the Building Automation System digital controllers shall provide documentation supporting compliance with ISO 9001:2000 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing).
   2. Provide a copy of the registration certificate that contains the ISO 9001:2000 Certification bearing the name of the registered auditor.

B. Control products such as direct digital controllers, control valves, actuators, sensors and transmitters shall be provided from a single manufacturer.

C. Provide product literature that bears the name of the manufacturer on all direct digital controllers, control valves, actuators, sensors and transmitters.

D. The Building Automation System shall be furnished, engineered, installed, tested and calibrated by factory certified technicians qualified for this work. The contractor shall have in place a support facility located within 70 miles, further with approval, of the project site with technical staff, spare parts inventory and all necessary test and diagnostic equipment. The contractor shall be a Factory Authorized System Integrator in good standing with the Manufacturer Factory trained technicians shall provide instruction, routine maintenance, and emergency service within 24 hours upon receipt of request.

E. Upon request, installer shall present records of successful completion of factory training courses including course outlines.

F. Upon request the installer shall provide a letter from the manufacturer that they are a Factory Authorized System Integrator in good standing.

G. The system integrator must employ a field staff of no less than 5 factory certified trained technicians, where their primary daily duties' are working on Building Automation Systems. These

technicians must reside in the state of Iowa. Upon request names and addresses of these technicians will be provided before work begins.

H. Provide satisfactory operation without damage at 110% above and 85% below rated voltage and at 3 hertz variation in line frequency. Provide static, transient, and short circuit protection on all inputs and outputs. Communication lines shall be protected against incorrect wiring, static transients and induced magnetic interference. Bus connected devices shall be AC coupled, or equivalent so that any single device failure will not disrupt or halt bus communication.

I. TCC: Company specializing in the work of this section with minimum five years temperature control experience.

J. Technician: Minimum five years' experience installing commercial temperature control systems.

1.14 WARRANTY

A. Refer to Section 23 05 00 for warranty requirements.

B. Within the warranty period, any defects in the work provided under this section due to faulty materials, methods of installation or workmanship shall be promptly (within 48 hours after receipt of notice) repaired or replaced by this Contractor at no expense to the Owner.

C. Warranty requirements include furnishing and installing all FMCS software upgrades issued by the manufacturer during the one-year warranty period.

D. Update all software and back-ups during warranty period and all user documentation on the Owner's archived software disks.

1.15 WARRANTY ACCESS

A. The Owner shall grant to this Contractor reasonable access to the TCS and FMCS during the warranty period.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Provide a building automation system consisting of Distech EC-NET Tridium Niagara AX platform with EC-BOS or ECLPYSE line of field controllers supplied by a company regularly engaged in the manufacturing and distribution of building automation systems. The BAS Manufacturer shall meet the following qualifications as a minimum:
   1. The manufacturer of the hardware and software components must be primarily engaged in the manufacture of building automation systems as specified herein, and must have been so for a minimum of five (5) years.
   2. The manufacturer of the hardware and software components as well as its subsidiaries must be a member in good standing of BACnet International.
   3. At least 75% of the manufacture product line shall be produced under their own direction, including R&D and assembly. Rebranding of another manufacture product shall not qualify.
   4. The manufacturer of the hardware and software components shall have a technical support group accessible via a toll free number that is staffed with qualified personnel, capable of providing instruction and technical support service for networked control systems.
   5. THIS CONTRACTOR MUST HAVE A DIRECT FACTORY RELATIONSHIP WITH DISTECH CONTROLS

2.2 SYSTEM ARCHITECTURE

A. The Building Automation System (BAS) shall be comprised of Network Control Units (NCU) connected to the Building Automation System local area network (BAS LAN). Access to the BAS, either through a Workstation on the BAS LAN, within the building or remotely through the Internet, shall be accomplished through a standard Web browser. Each NCU shall communicate to BTL Listed BACnet controllers provided under the Programmable Controllers section. The system includes Network Control Unit(s) (NCU), software and programming of the NCU, development of

all graphical screens, setup of schedules, trends, logs and alarms, network management and connection of the NCU to the local area network.

B. The system shall consist of a network of Network Control Units (NCUs), interoperable Local Control Units (LCUs) and Terminal Control Units (TCUs) (VAV Box Controllers, Fan Coil Unit Controllers, etc.). All controllers for terminal units, air handling units (AHU) and controllers shall communicate and share data, utilizing BACnet MS/TP communications protocol only and be provided by the DDC contractor. No packaged controllers that need integrated to the BAS will be allowed. Also no IP based point or field controllers will be allowed.

C. The intent of this specification is to provide a distributed and networked open Building Automation System, the capability to integrate ANSI/ASHRAE Standard 135, BACnet and ISO/IEC 14908-1: Open Data Communication in Building Automation, Controls and Building Management – Control Network Protocol into a unified system in order to provide flexibility for expansion, maintenance, and service of the system.

D. BACnet system must be tested and listed on BACnet Testing Laboratory (BTL) web site. Systems based on vendor specific proprietary hardware or software will not be considered for this project.

E. Systems utilizing gateways will not be considered for this project. A gateway is considered to be a device or controller where the sole function is mapping of data points from one protocol to another.

F. The BAS shall utilize BACnet/IP (ASHRAE Standard 135, Annex J) for communication between NCUs. Manufacturer specific proprietary protocols, gateways, or protocol converters are not acceptable for this project. The Server shall communicate to the NCUs utilizing standard Ethernet to IEEE 802.3 Standards. Any break in the BAS LAN between NCU and Server shall result in an alarm notification at the Server.

G. The supplied system 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, BACnet to assure interoperability between all system components is required.

H. 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. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 10 seconds for network connected user interfaces. 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.

I. 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.

J. An Open DataBase Connectivity (ODBC) 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.

K. 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 to the completion of the warranty period, 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.

2.3 DYNAMIC DATA ACCESS

A. All operator devices shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network. Access to data shall be based upon logical identification of building equipment.

2.4 NETWORKS

A. Design for the Network LAN (NCU LAN) shall include the following provisions:
   1. The network LAN shall utilize BACnet/IP (ASHRAE Standard 135, Annex J) for communication between NCUs. Manufacturer specific proprietary protocols, gateways, or protocol converters are not acceptable for this project. The Server shall communicate to the NCUs utilizing standard Ethernet to IEEE 802.3 Standards. Products utilizing BACnet over ARCnet technology are not acceptable for this project.
   2. High-speed data transfer rates for alarm reporting, quick report generation form multiple controllers and upload/download efficiency between network devices.
   3. Support of any combination of controllers directly connected to the local area network. A minimum of 50 devices shall be supported on a single local area network.
   4. Detection and accommodation of single or multiple failures of workstations, controller panels and the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures.
   5. Message and alarm buffering to prevent information from being lost.
   6. Error detection, correction, and retransmission to guarantee data integrity.
   7. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.
   8. Commonly available, multiple sourced, networking components shall be used to allow the system to coexist with other networking applications such as office automation. ETHERNET to IEEE 802.3 standard is the only acceptable technology.
   9. Synchronization of the real-time clocks in all NCU panels shall be provided.
   10. The NCU LAN shall be a 100 Megabits/sec Ethernet network supporting BACnet for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Network Control Units (NCUs), user workstations and where specified, a local server. Local area network minimum physical and media access requirements:
       a. Ethernet; IEEE standard 802.3
       b. Cable; 100 Base-T, UTP-8 wire, category 5
       c. Minimum throughput; 100 Mbps
   11. Provide access to the NCU LAN from a remote location, via the Intranet or Internet. The owner shall provide (in future) a connection to the Internet to enable access via high-speed cable modem, asynchronous digital subscriber line (ADSL) modem, ISDN line, T1 Line or access to an Internet Service Provider (ISP). If required, the owner will provide a switch/firewall between the building LAN and the NCU LAN. Through this connection the NCU LAN will provide authorized staff with the ability to monitor and control the BAS from a remote location through a web browser, cellular phone, pager, web-enabled media players, or PDA. (Pocket Computer).

B. Design for the Building Automation System LAN (LCU and TCU LAN) shall include either or both of the following BACnet architecture provisions:
   1. The BAS must be based on Open Systems. BAS shall employ the BACnet protocol for communication between controllers. BACnet protocol implementation shall adhere to the ANSI/ASHRAE Standard 135. Communications between BACnet devices shall be 38.4 kbps over approved twisted shielded pair cabling utilizing Master/Slave Toke Passing BACnet protocol. BACnet defines a comprehensive set of object types and application services for communication requirements among all levels of control in a distributed, hierarchical Building Automation System. BACnet is intended to provide a single, uniform standard for the BAS to provide the required interoperability.

2.5 UNINTERRUPTABLE POWER SUPPLIES

A. Provide each NCU with individual UPS to provide clean, reliable, noise-filtered power at all times and to protect and maintain systems operation throughout short term power interruptions of up to 15 minutes duration. Approved UPS manufacturer: APC.

2.6 UTILITY SOFTWARE

A. Supply and install software products to allow the owner to access and manipulate the control schematic diagrams, and to access product data sheets in an electronic format.

B. Enter all soft copy submissions; including "Record" drawings as specified herein [Shop Drawings, Product Data and Review Process] in OWS.

2.7 GRAPHICAL USER INTERFACE (GUI) SOFTWARE AND WEB BROWSER CLIENTS

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. All Distech EC-NET Tridium Niagara AX JACE products installed must incorporate the embedded workbench toolset and open licenses.

B. The GUI shall employ browser-like functionality for ease of control system navigation and operation. 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. The GUI shall allow configuration of system-wide controllers, including management and display of the controller programming. This GUI software system shall provide the capability to configure controller binary and analog inputs/outputs.

C. The GUI shall be capable of using third-party Windows-based programs for such things as spreadsheet analysis, graphing, charting, custom report generation, and graphics design packages. Provide software features which enables the non-programmer skill level operator to easily perform tasks which are likely to be part of his daily routine.

D. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:
   1. Graphic screens shall be developed using any Windows-based drawing package capable of generating or assembling objects from a GIF, JPG, PNG or ICO file formats. 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.
   2. 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 and from other graphic screens.
   3. The GUI software shall provide facilities for manual entries and visual displays enabling an operator to enter information into the system and obtain displays and logs of system information. All requests for status, analog, graphic displays, logs, and control shall be selected from the GUI. The operator interface shall minimize the use of typewriter style keyboard by implementing a mouse or similar pointing device and "point and click" approach to command selection. A robust full-featured GUI shall be provided to permit the system Operator to perform the following tasks:
      a. Automatic logging of digital alarms and change of status message.
      b. Automatic logging of all analog alarms.
      c. System changes (alarm limits, set-points, alarm lock-outs, etc.).
      d. Display specific points as requested by the operator.
      e. Provide reports as requested by the operator and on Scheduled basis where so required.
      f. Display graphics as requested by the system Operator.

g. Display help information.
h. Provide trend logs as required by the system Operator.
i. Provide manual control of digital and analog outputs as required by the system Operator.
j. Direct the hard copy output of information to the device selected by the system user operator.
k. Data displayed on monitor must cyclically update as appropriate.
l. Operator shall be able to revise or override via the GUI:
    1) Alarm limits
    2) Set-points
    3) Dead-bands
    4) Deletions/additions of analog or digital points.
    5) Times of day, day, month, year.
    6) Control loop tuning through the adjustment of control loop parameters.
    7) Additions/deletions to system graphics
    8) Schedules, times of day, day, month, year

4. Modifying common application objects, such as schedules, calendars, and set points shall be accomplished 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.
5. 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.
6. 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.
7. It shall be possible for the Operator to initiate analog and digital output commands via the GUI. Where the BAS software normally originates these outputs, the provision shall exist for the Operator to terminate automatic BAS control of any particular output and to originate a manual analog or digital output command. The provision shall exist for the Operator to return analog or digital output command functions back to automatic BAS software control.
8.

E. 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. Enable or disable control strategies.
    4. Control loop tuning through the adjustment of control loop parameters.
    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.

F. Password Protection:
    1. Provide security system that prevents unauthorized use unless Operator is logged on. Access shall be limited to Operator's terminal functions unless user is logged on. This includes displays as outlined above.
    2. GUI software shall provide security for 100 users minimum. Each user shall have an individual User ID, User Name and Password. Entries are alphanumeric characters only and are case sensitive (except for User ID). User ID shall be 8 characters, User Name shall be 29 characters, and Password shall be 8 characters long. Each system user shall be allowed individual assignment of only those control functions and menu items to which that user requires access. All passwords, user names, and access assignments shall be adjustable online at the operator's terminal. Each user shall also have a set security level, which defines

access to displays and individual objects the user may control. System shall include 10 separate and distinct security levels for assignment to users.

3. All above functions shall operate under the password protection system.

G. 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.

H. Trend Data:
   1. System shall periodically gather historically recorded selected samples of object data stored in the field equipment (global controllers, field controllers) and archive the information where specified. Archived files shall be appended with new sample data, allowing samples to be accumulated over several years. Systems that write over archived data shall not be allowed, unless limited file size is specified. Samples may be viewed at the GUI in a trend log. Logged data shall be stored in spreadsheet format. Operator shall be able to scroll through all trend log data. System shall automatically open archive files as needed to display archived data when Operator scrolls through the data vertically. All trend log information shall be displayed in standard engineering units.
   2. Secondary software shall be included that is capable of graphing the trend logged object data. Software shall be capable of creating two-axis (x, y) graphs that display up to six object types at the same time in different colors. Graphs shall show object type value relative to time.
   3. Operator shall be able to change trend log setup information as needed. This includes the information to be logged as well as the interval at which it is to be logged. All input, output, and value object types in the system shall be able to be logged. Setup and viewing may be accessed directly from any and all graphics object is displayed on.
   4. Trend Reports: To permit the trending of points selected by the Operator, including as a minimum digital input and output, analog input and output, set points, and calculated values.
   5. Historical Data Collection: Provision shall be made to ensure historical data is not lost. The ability to off-load historical data to removable media, and to later load data previously backed-up, will be provided. Historical data values, for an Operator specified time range and for Operator specified points, may be output the same as for trend data.
   6. Disable Point Summary: Provide a summary of all points in the disabled state and include as a minimum point acronym and point description.
   7. Run Time Summary: Provide a summary of the accumulated running time of selected pieces of equipment with point acronym and description, run time to date, alarm limit setting. The run time shall continue to accumulate until reset individually by means of suitable Operator selection.
   8. User Record Summary: Provide a summary of all user records to include as a minimum; user name, password, initials, command access level and point groups assigned.

I. Reports:
   1. Provide a report facility to generate and format for display, printing, or permanent storage, as selected by the Operator, the reports as specified in this section. If display output is requested, it shall be scrollable; scroll bars will be used to allow easy and flexible movement within the report. Output to be sorted by area, system point.
   2. Periodic/Automatic Report: Provide the software to automatically generate any report specified, the User/Operator will be able to specify the type of report, start time and date, interval between reports (hourly, daily, weekly, monthly) and output device. The software will allow the operator to modify the periodic/automatic reporting profile at any time.

J. Archiving:
   1. Store backup copies of all controller databases in at least one OWS and the server.

2. Provide continuous supervision of integrity of all controller databases. If controller loses database, system to automatically download new copy of database to restore proper operation.
3. Data base back up and downloading to occur over LAN without operator intervention. Operator to be able to manually download entire controller database or parts thereof.

K. 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.

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 and Alarms:
1. Operator's terminal shall provide audible, visual, and printed means of alarm indication. The alarm dialog box shall always become the top dialog box regardless of the application(s), currently running (such as a word processor). Printout of alarms shall be sent to the assigned terminal and port.
2. System shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the system operator's terminal. Each entry shall include a description of the event-initiating object generating the alarm, time and date of alarm occurrence, time and date of object state return to normal, and time and date of alarm acknowledgement.
3. Alarm messages shall be in user-definable text English or other specified language) and shall be entered either at the operator's terminal or via remote communication.
4. The system will be provided with a dedicated alarm window or console. This window will notify the Operator(s) 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.
5. 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.
6. Critical Alarm Summary: Provide a summary of those points in the critical alarm state and include as a minimum; point acronym, point description, alarm type, limit exceed, current value, alarm type, time and date of occurrence.
7. Alarm Summary: Provide a summary of all points in alarm and include as a minimum; point acronym, point description, current value, alarm type, limit exceeded, and time and date of occurrence.
8. Maintenance Alarm Summary: Provide a summary of those points in maintenance alarm and include as a minimum; point acronym, point description, current value, alarm type, limit exceed, time and date of occurrence.

2.8 WEB BROWSER CLIENTS

A. 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.
1. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Internet Explorer™ or Mozilla Firefox™. 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. As a minimum provide the capability of 32 web browser clients that can simultaneously access the system.
2. 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.

3. 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.
4. The Web browser client shall support at a minimum, the following functions:
   a. 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.
   b. 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.
   c. HTML programming shall not be required to display system graphics or data on a Web page
   d. Storage of the graphical screens shall be in the Network Control Unit (NCU), without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.
   e. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.
   f. 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.
      2) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
      3) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
      4) 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.
      5) View logs and charts
      6) View and acknowledge alarms
   g. 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.
   h. 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.

2.9 BUILDING AUTOMATION SYSTEM CONTROLLERS - NETWORK CONTROL UNIT (NCU)

A. The Network Control Unit (NCU) shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control functions over the control devices connected to the NCU.

B. The NCU shall be capable of executing application control programs to provide:
   1. Calendar functions
   2. Scheduling
   3. Trending
   4. Alarm monitoring and routing
   5. Time synchronization
   6. Integration of BACnet MS/TP and BACnet/IP controllers as well as their BACnet objects
   7. Network Management functions for all BACnet MS/TP and BACnet/IP based devices
   8. Host graphics

C. The Network Control Unit must provide the following hardware features as a minimum:
   1. One Ethernet Port -10 / 100 Mbps
   2. One RS-485 port
   3. Battery Backup
   4. Flash memory for long term data backup (If battery backup or flash memory is not supplied, the controller must contain a Type SSD (Solid State Drive) hard disk with at least 1 terabyte (TB) storage capacity)
   5. The NCU must be capable of operation over a temperature range of 32 to 122°F
   6. The NCU must be capable of withstanding storage temperatures of between 32 to 140°F and a humidity range of 5 to 95% RH, non-condensing
   7. A modem port and 56K modem. Exempt if remote access is provided via the Internet

D. The NCU shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the NCU shall be an ODBC-compliant database or must provide an ODBC data access mechanism to read and write data stored within it.

E. Provide multiple Network Control Units as necessary. The NCU shall support a minimum of 128 BACnet controllers. In order to maintain peak performance of the network, no more than 110 BACNet controllers may be connected to a single NCU. In any event no more than 80% of the available resources of the NCU (as indicated by the resource meter of the programming tools for the NCU) shall be committed. In the event that the available resources are less than 20%, the number of nodes connected to the NCU shall be reduced in order to maintain a 20% or greater buffer of resources within the NCU.

F. The NCU shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 32 simultaneous users.

G. Event Alarm Notification and actions - The NCU shall provide alarm recognition, storage; routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers. The NCU shall be able to route any alarm condition to any defined user location whether connected to a local network or remote via dial-up, telephone connection, or wide-area network.
   1. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including but limited to:
      a. To alarm
      b. Return to normal
      c. To fault
   2. Provide for the creation of a minimum of eight of alarm classes for the purpose of routing types and or classes of alarms, i.e.: security, HVAC, Fire, etc.
   3. Provide timed (schedule) routing of alarms by class, object, group, or node.
   4. Provide alarm generation from binary object “runtime” and /or event counts for equipment maintenance. The user shall be able to reset runtime or event count values with appropriate password control. Control equipment and network failures shall be treated as alarms and annunciated.
   5. Alarms shall be annunciated in any of the following manners as defined by the user:
      a. Screen message text
      b. Email of the complete alarm message to multiple recipients. Provide the ability to route and email alarms based on:
         1) Day of week
         2) Time of day
         3) Recipient
      c. Pagers via paging services that initiate a page on receipt of email message
      d. Graphic with flashing alarm object(s)
      e. Printed message, routed directly to a dedicated alarm printer
   6. The following shall be recorded by the NCU for each alarm (at a minimum):
      a. Time and date
      b. Location (building, floor, zone, office number, etc.)

c. Equipment (air handler #, access way, etc.)
d. Acknowledge time, date, and user who issued acknowledgement.
e. Number of occurrences since last acknowledgement.

7. Alarm actions may be initiated by user defined programmable objects created for that purpose.
8. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user.
9. A log of all alarms shall be maintained by the NCU and/or a server (if configured in the system) and shall be available for review by the user.
10. Provide a "query" feature to allow review of specific alarms by user defined parameters.
11. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.
12. An Error Log to record invalid property changes or commands shall be provided and available for review by the user.

2.10 DATA COLLECTION AND STORAGE

A. The NCU shall have the ability to collect data for any property of any object and store this data for future use.

B. The data collection shall be performed by log objects, resident in the NCU that shall have, at a minimum, the following configurable properties:
1. Designating the log as interval or deviation.
2. For interval logs, the object shall be configured for time of day, day of week and the sample collection interval.
3. For deviation logs, the object shall be configured for the deviation of a variable to a fixed value. This value, when reached, will initiate logging of the object.
4. For all logs, provide the ability to set the maximum number of data stores for the log and to set whether the log will stop collecting when full, or rollover the data on a first-in, first-out basis.
5. Each log shall have the ability to have its data cleared on a time-based event or by a user-defined event or action.

C. All log data shall be stored in a relational database in the NCU and the data shall be accessed from a server (if the system is so configured) or a standard Web Browser. All log data, when accessed from a server, shall be capable of being manipulated using standard SQL statements. All log data shall be available to the user in the following data formats:
1. HTML
2. XML
3. Plain Text
4. Comma or tab separated values

D. Systems that do not provide log data in HTML and XML formats at a minimum shall not be acceptable.

E. The NCU shall have the ability to archive its log data either locally (to itself), or remotely to a server or other NCU on the network. Provide the ability to configure the following archiving properties, at a minimum:
1. Archive when the log has reached its user-defined capacity of data stores
2. Archive on time of day
3. Archive on user-defined number of data stores in the log (buffer size)
4. Provide ability to clear logs once archived

F. Audit Log - Provide and maintain an Audit Log that tracks all activities performed on the NCU. Provide the ability to specify a buffer size for the log and the ability to archive log based on time or when the log has reached its user-defined buffer size. Provide the ability to archive the log locally (to the NCU), to another NCU on the network, or to a server. For each log entry, provide the following data:

1. Time and date
2. User ID
3. Change or activity: i.e., Change setpoint, add or delete objects, commands, etc.

2.11 DATABASE BACKUP AND STORAGE

A. The NCU shall have the ability to automatically backup its database. The database shall be backed up based on a user-defined time interval. Copies of the current database and, at the most recently saved database shall be stored in the NCU. The age of the most recently saved database is dependent on the user-defined database save interval. The NCU database shall be stored, at a minimum, in XML format to allow for user viewing and editing, if desired. Other formats are acceptable as well, as long as XML format is supported.

B. Provide three (3) copies of all tools necessary for the development, maintenance, expansion and use of the BAS described within these specifications. All software tools shall be compatible with Microsoft Windows 7 or XP Professional. For the purpose of this specification software tools shall be divided into the following categories and meet these specified requirements.

2.12 NCU PROGRAMMING WIZARDS FOR LCU/TCU CONTROLLERS

A. Provide Wizards or objects that facilitate the programming and configuration of the Local Control Unit (LCU) and Terminal Control Unit (TCU) Controllers sequence of operation through a menu driven wizard. The programming and configuration tools shall perform the following functions:
   1. LCU Controllers programming shall be accomplished by Graphical Programming Language (GPL) where objects are used to define different portions of the control sequence. All control sequences programmed into the controller shall be stored in non-volatile memory. Systems that only allow selection of sequences from a library or table are not acceptable. All code must be exportable to a library for future use.
   2. TCU Controllers – Provide for the programming of the required sequence of operation through an intuitive menu driven selection process. The configuration tools menu shall define items such as I/O configurations, set point, delays, PID loops, optimum start stops, and network variables settings. The configuration tool must indicate the device status and allow system override. Or, provide for the programming of the required sequence of operation through Graphical Programming Language (GPL) where objects are used to define different portions of the control sequence. All control sequences programmed into the controller shall be stored in non-volatile memory. Systems that only allow selection of sequences from a library or table are not acceptable. All code must be exportable to a library for future use.
   3. Wizards shall be openly available and be compatible with the current published versions of the network management tool that is provided as part of this project. The wizard software shall be available for public access from the manufacturer's web site. These wizard programming or configuration tools shall be compatible with at least 3 other manufactures Building Automation System (BAS). The System Integrator shall demonstrate as part of their prequalification as to how they intend to comply with these requirements. Should wizards as specified herein not be available then the System Integrator shall provide the following:
   4. Provide three copies of the programming or configuration tools along with any manufacture specific software tools required to operate the programming or configuration tools. Such tools shall be provided with a permanent and operating system transferable license.
   5. Provided free of charge to the owner or his designated agent for a period of 10 years the latest manufacturer's updates to the software described herein.

2.13 NCU NETWORK MANAGEMENT SOFTWARE TOOLS

A. Provide a complete set of Network Management tools that provides for the development and management of BACnet networks.

B. Provide a complete set of integrated BACnet network management tools for working with these networks. These tools shall manage a database for all BACnet devices by type and revision, and shall provide a software mechanism for identifying each device on the network. Systems requiring the use of third party BACnet network management tools shall not be accepted.

C. Network management shall include the following services: device identification, device installation, device configuration, device diagnostics, device maintenance and network variable binding.

D. The network configuration tool shall also provide diagnostics to identify devices on the network, to reset devices, and to view health and status counters within devices.

E. These tools shall provide the ability to “discover” existing BACnet networks, regardless of what network management tool(s) were used to install the existing network, so that existing BACnet devices and newly added devices are part of a single network management database.

F. The network management database shall be resident in the NCU with proper authorization has access to the network management database at all times. Systems employing network management databases that are not resident, at all times, within the control system, shall not be accepted.

G. Provide for the ability to access all of the Network Management tool functions including controller programming from a Web Browser.

2.14 NCU PROGRAMMING SOFTWARE

A. Provide programming software for the Network Control Unit that allows for the development of the NCU control logic, point management, global properties such as alarm, trend and scheduling.

B. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. Access to these functions shall be provided through Graphical User Interface software (GUI). Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide “real-time” data updates. Any real-time data value or object property may be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.

C. Programming Methods - Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user’s application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification. Links will vary in color depending on the type of link; i.e., internal, external, hardware, etc.
   1. Configuration of each object will be done through the object’s property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.
   2. The software shall provide the ability to view the logic in an off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system.
   3. All programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects shall not be allowed.
   4. The system shall support object duplication within a customer’s database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

D. NCU Object Library:
   1. A standard library of software objects that represent functions and applications for the development and setup of application logic, user interface displays, system services, and communication networks.

2. The objects in this library shall be capable of being copied and pasted into the user's database and shall be organized according to their function. In addition, the user shall have the capability to group objects created in their application and store the new instances of these objects in a user-defined library.
3. In addition to the standard libraries specified here, the supplier of the system shall maintain an on-line accessible (over the Internet) library, available to all registered users to provide new or updated objects and applications as they are developed.
    a. All control objects shall conform to the control objects specified in the ANSI/ASHRAE Standard 135-2008 BACnet specification.
    b. The library shall include applications or objects for the following functions, at a minimum:
        1) Scheduling Object. The schedule must conform to the schedule object as defined in the BACnet specification, providing 7-day plus holiday & temporary scheduling features and a minimum of 10 on/off events per day. Data entry to be by graphical sliders to speed creation and selection of on-off events.
        2) Calendar Object. The calendar must conform to the calendar object as defined in the BACnet specification, providing 12-month calendar features to allow for holiday or special event data entry. Data entry to be by graphical "point-and-click" selection. This object must be "linkable" to any or all scheduling objects for effective event control.
        3) Duty Cycling Object. Provide a universal duty cycle object to allow repetitive on/off time control of equipment as an energy conserving measure. Any number of these objects may be created to control equipment at varying intervals
        4) Temperature Override Object. Provide a temperature override object that is capable of overriding equipment turned off by other energy saving programs (scheduling, duty cycling etc.) to maintain occupant comfort or for equipment freeze protection.
        5) Start-Stop Time Optimization Object. Provide a start-stop time optimization object to provide the capability of starting equipment just early enough to bring space conditions to desired conditions by the scheduled occupancy time. Also, allow equipment to be stopped before the scheduled un-occupancy time just far enough ahead to take advantage of the building's "flywheel" effect for energy savings. Provide automatic tuning of all start / stop time object properties based on the previous day's performance.
    c. The library shall include control objects for the following functions. All control objects shall conform to the objects as specified in the BACnet specification.
        1) Analog Input Object - Minimum requirement is to comply with the BACnet standard for data sharing. Allow high, low and failure limits to be assigned for alarming. Also, provide a time delay filter property to prevent nuisance alarms caused by temporary excursions above or below the user defined alarm limits.
        2) Analog Output Object - Minimum requirement is to comply with the BACnet standard for data sharing. The BACnet Command Prioritization priority scheme shall be incorporated to allow multiple control applications to execute commands on this object with the highest priority command being invoked. Provide sixteen levels of priority as a minimum. Systems not employing the BACnet method of contention resolution shall not be acceptable.
        3) Binary Input Object - Minimum requirement is to comply with the BACnet standard for data sharing. The user must be able to specify either input condition for alarming.
        4) Binary Output Object - Minimum requirement is to comply with the BACnet standard for data sharing. Properties to enable minimum on and off times for equipment protection as well as inter-start delay must be provided. The BACnet Command Prioritization priority scheme shall be incorporated to allow multiple control applications to execute commands on this object with the highest priority command being invoked. Provide sixteen levels of priority as a minimum. Systems not employing the BACnet method of contention resolution shall not be acceptable.
        5) Multi-State Input Object - Minimum requirement is to comply with the BACnet standard for data sharing.

6) Multi-State Output Object - Minimum requirement is to comply with the BACnet standard for data sharing. The BACnet Command Prioritization priority scheme shall be incorporated to allow multiple control applications to execute commands on this object with the highest priority command being invoked. Provide sixteen levels of priority as a minimum. Systems not employing the BACnet method of contention resolution shall not be acceptable.
7) PID Control Loop Object - Minimum requirement is to comply with the BACnet standard for data sharing. Each individual property must be adjustable as well as to be disabled to allow proportional control only, or proportional with integral control, as well as proportional, integral and derivative control.
8) Comparison Object - Allow a minimum of two analog objects to be compared to select either the highest, lowest, or equality between the two linked inputs. Allow a minimum of two analog objects to be compared using comparators and return a True/False value. The following comparators shall be supported as a minimum: equal, not equal, greater than, less than, greater or equal, less or equal. Also, allow limits to be applied to the output value for alarm generation.
9) Math Object - Allow a minimum of four analog objects to be tested for the minimum or maximum, or the sum, difference, or average of linked objects. Also, allow limits to be applied to the output value for alarm generation. Allow mathematical operation on a minimum of two analog objects. The following mathematical operators shall be supported as a minimum: add, subtract, multiply, divide, sine, cosine, tangent, logarithm, natural logarithm, square root, power and absolute value.
10) Logic Object - Allow a minimum of two binary objects to be compared using Boolean comparator. The following comparators shall be supported as a minimum: And, Or, X or and Not.
11) Custom Programming Objects - Provide a blank object template for the creation of new custom objects to meet specific user application requirements. This object must provide a standard programming language that is used to define object behavior. Provide a library of functions including math and logic functions, string manipulation, and e-mail as a minimum. Also, provide a comprehensive on-line debug tool to allow complete testing of the new object. Allow new objects to be stored in the library for re-use.
12) Interlock Object - Provide an interlock object that provides a means of coordination of objects within a piece of equipment such as an Air Handler or other similar types of equipment. An example is to link the return fan to the supply fan such that when the supply fan is started, the return fan object is also started automatically without the user having to issue separate commands or to link each object to a schedule object. In addition, the control loops, damper objects, and alarm monitoring (such as return air, supply air, and mixed air temperature objects) will be inhibited from alarming during a user-defined period after startup to allow for stabilization. When the air handler is stopped, the interlocked return fan is also stopped, the outside air damper is closed, and other related objects within the air handler unit are inhibited from alarming thereby eliminating nuisance alarms during the off period.
13) The object library shall include objects to support the integration of devices connected to the Network Control Unit (NCU). At a minimum, provide the following as part of the standard library included with the programming software:
    a) For BACnet devices, provide the following objects at a minimum:
        (1) Analog Input
        (2) Analog Output
        (3) Analog Value
        (4) Binary Input
        (5) Binary Output
        (6) Binary Value
        (7) Multi-State Input
        (8) Multi-State Output

(9) Multi-State Value
(10) Schedule Export
(11) Calendar Export
(12) Trend Export
(13) Device
(14) Loop

b) For each BACnet object, provide the ability to assign the object a BACnet device and object instance number.

c) For BACnet devices, provide the following services at a minimum
(1) Segmentation
(2) Segmented Request
(3) Segmented Response
(4) Application Services
(5) Read Property
(6) Read Property Multiple
(7) Write Property
(8) Write Property Multiple
(9) Confirmed Event Notification
(10) Unconfirmed Event Notification
(11) Acknowledge Alarm
(12) Get Alarm Summary
(13) Who-has
(14) I-have
(15) Who-is
(16) I-am
(17) Subscribe COV
(18) Confirmed COV notification
(19) Unconfirmed COV notification
(20) Media Types
(21) Ethernet
(22) BACnet IP Annex J
(23) MSTP
(24) BACnet Broadcast Management Device (BBMD) function Routing

2.15 BUILDING AUTOMATION SYSTEM CONTROLLERS - LOCAL CONTROL UNITS (LCU), TERMINAL CONTROL UNITS (TCU)

A. GENERAL

1. Refer to Building Automation System PART 1 – GENERAL REQUIREMENTS with the following clarifications and additions.
2. Performance requirements of the Programmable Controllers are specified in this section.
3. All controllers provided as part of this system and used for indoor applications shall operate under ambient environmental conditions of 32°F to 122°F dry bulb and 5% to 90% relative humidity, non-condensing as a minimum.
4. All controllers provided as part of this system and used for outdoor applications shall operate under ambient environmental conditions of -40°F to 158°F dry bulb and 5% to 90% relative humidity, non-condensing as a minimum.

B. SYSTEM DESIGN

1. Local Control Units (LCU) shall be utilized for primary mechanical and electrical systems such as Air handling equipment, Make-up Air Unit, Boiler System Control, and Chiller System Control type of applications.
2. Terminal Control Units (TCU) shall be utilized for terminal equipment, such as Variable Air

Volume, Fan Coil, and Rooftop Units, etc.

3. Each LCU and TCU controller shall have a minimum of 10% spare capacity of each point type for future points. As a minimum, each controller shall have one spare of each point type available on the controller.
4. Each NCU and each LAN shall have the capability of accepting 20% additional LCU/TCU(s) without the necessity of adding additional LAN controllers or LAN wiring.
5. The LCU and TCU controller programming or configuration tools shall be fully accessible through the Web Browser Client through the use of Wizards.
   a. Provide Wizards or objects as specified in NCU section, which facilitate the programming and configuration of the LCU and TCU through a menu driven wizard.

2.16 CONTROLLER LOCAL AREA NETWORK (BAS SUB LAN)

A. Provide a network of stand-alone, distributed direct digital controllers that operate on the following protocol using the specified physical layers:
   1. ANSI/ASHRAE Standard 135 BACnet Master/Slave Token Passing (MS/TP) at 76.8 kbps.
   2. BACnet IP devices will be allowed.

B. Strict adherence to industry standards including ANSI/ASHRAE Standard 135, BACnet, certified by BACnet Testing Laboratory (BTL listed) to assure interoperability between all system components. Controllers that are not BTL listed are unacceptable.

C. Provide BAS Controllers that conform to ANSI/ASHRAE Standard 135, BACnet. Controllers using proprietary protocols or protocols other than the two listed herein are unacceptable.

D. The design of the BAS sub LAN shall network Local Control Unit (LCU) and Terminal Control Unit (TCU) to a Network Control Unit (NCU).

E. This level of communication shall support a family of application specific controllers and shall communicate bi-directionally with the network through DDC Controllers for transmission of global data.

F. Terminal Control Unit (TCU) shall be arranged on the BAS sub LAN's in a functional relationship manner with Local Control Unit (LCU). Ensure that a Variable Air Volume (VAV) Terminal Control Unit (TCU) is logically on the same LAN or segment as the Local Control Unit (LCU) that is controlling its corresponding Air Handling Unit (AHU).

2.17 LOCAL CONTROL UNITS (LCU) (PRIMARY SYSTEMS SUCH AS AHU, MAU, CHILLER, BOILER, WATER SYSTEM)

A. The Local Control Units (LCU) shall be 32 bits microprocessor-based. They shall also be multi-tasking, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification and the attached point list.

B. Each LCU shall have sufficient memory, to support its own operating system and databases, including:
   1. Control processes
   2. Energy management applications
   3. Alarm management applications
   4. Historical/trend data for points specified
   5. Maintenance support applications
   6. Custom processes
   7. Manual override monitoring

C. Each LCU shall support:

1. Monitoring of the following types of inputs, without the addition of equipment outside the DDC Controller cabinet:
   a. Analog inputs of 4-20 mA, 0-10 Vdc, 10,000 ohm thermistor or 1000 ohm RTD.
   b. Digital inputs from dry contact closure, pulse accumulators, voltage sensing.
2. Each LCU shall be capable of providing the following control outputs without the addition of equipment outside the DDC controller cabinet:
   a. Digital outputs (contact closure for motor starters up to size 4).
   b. Analog outputs of 4-20 mA or 0-10 Vdc.

D. The LCU analog or universal input shall use a 16 bit A/D converter.

E. The LCU analog or universal output shall use a 10 bit D/A converter. Each output shall have supervised manual override switch and a potentiometer.

F. Each LCU shall have a minimum of 10% spare capacity for each point type for future point connection. Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring. As a minimum, provide one of each type of point available on the controller.

G. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

H. The LCU shall provide local LED status indication for each output for constant, up-to-date verification of all point conditions without the need for an operator output device. Graduated intensity LEDs or analog indication of value shall also be provided for each analog output. Status indication shall be visible without opening the panel door.

I. The LCU shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The controller shall provide both local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication.

J. Should the LCU memory be lost for any reason, the user shall have the capability of reloading the controller software via the BAS LAN or Server. Controller requiring a local port to reload the controller software is not acceptable.

K. Provide an onboard network communication jack for connection to the BACnet Network.

2.18 LCU PROGRAMMING SOFTWARE

A. Provide programming software for the Local Control Unit (LCU) that allows for the development of the LCU control logic and point management.

B. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. Access to these functions shall be provided through Graphical User Interface software (GUI). Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide “real-time” data updates. Any real-time data value or object property may be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.

C. Programming Methods - Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user’s application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall

show link identification for links to objects on other pages for easy identification.

1. Configuration of each object will be done through the object's property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.
2. The software shall provide the ability to view the logic with value being inputted/outputted of the graphical blocks (debug mode),
3. The system shall support object duplication within a customer's database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

D. Provides function to compare and calculate from multiple values from networked controllers (NCU, TCU and/or LCU). As a minimum, the function shall calculate and compared the values and return the average, sum, highest, lowest, 3 highest and 3 lowest values.

2.19 TERMINAL CONTROL UNITS (TCU) (SECONDARY SYSTEMS SUCH AS VAV, FAN POWERED VAV, FAN COIL, RADIATION, REHEAT)

A. Provide Terminal Control Units (TCU) for control of each piece of terminal equipment.

B. The Terminal Control Units (TCU) shall be 8 bits microprocessor-based. They shall also be multi-tasking, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification and the attached point list.

C. Each TCU shall have sufficient memory, to support its own operating system and databases, including:

1. Control processes
2. Maintenance support applications
3. Custom processes
4. Manual override monitoring

D. Each TCU shall support:

1. Monitoring of the following types of inputs, without the addition of equipment:
   a. Analog inputs of 4-20 mA, 0-10 Vdc, 10,000 ohm thermistor or 1000 ohm RTD.
   b. Digital inputs from dry contact closure, pulse accumulators, voltage sensing.
2. Each TCU shall be capable of providing the following control outputs without the addition of equipment:
   a. Digital outputs (contact closure for motor starters up to size 4).
   b. Analog outputs of 4-20 mA or 0-10 Vdc.

E. The TCU analog or universal input shall use a 16 bit A/D converter.

F. The TCU analog or universal output shall use a 10 bit D/A converter.

G. Controllers shall include all point inputs and outputs necessary to perform the specific control sequences. As a minimum, 25% of the point outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. Analog outputs shall be industry standard signals such as 24V floating control, allowing for interface to a variety of modulating actuators.

H. Each TCU controller performing space temperature control shall be provided with a matching room temperature sensor. Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with all controllers on the Network.

I. Each room sensor shall also include the following auxiliary devices:

1. Setpoint Adjustment: The setpoint adjustment dial shall allow for modification of the temperature by the occupant. Setpoint adjustment may be locked out, overridden or limited as to time or temperature through software by an authorized operator at the central workstation, DDC controller, or via the portable operator's terminal.
2. Temperature Indicator: Required
3. Override Switch: None required

J. Each controller shall perform its primary control function independent of other NCU controller LAN communication, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the NCU controller time clock to insure LAN continuity. Each controller shall include algorithms incorporating proportional, integral, and derivative (PID) gains for all applications. All PID gains and biases shall be field-adjustable by the user via terminals as specified herein. This functionality shall allow for tighter control of space conditions and shall facilitate optimal occupant comfort and energy savings.

K. Provide each TCU with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Operating programs shall be field selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of all applications are not acceptable.

L. Variable Air Volume (VAV) Terminal Control Units (TCU):
1. The VAV box TCU controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC (±15%), allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32°F to 122°F and 5% to 90% RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.
2. The Variable Air Volume (VAV) Terminal Control Unit (TCU) shall include a built-in differential pressure transducer that shall connect to the VAV terminal unit manufacturer's standard differential pressure sensor to measure the average and amplify differential pressure in the duct. The controller shall convert this value to actual air flow. Single point differential pressure sensing device is not acceptable. The VAV TCU differential pressure transducer shall have a measurement range of 0 to 1 in. W.C. and measurement accuracy of ±5% at 0.1 to 1 in. W.C. and a minimum resolution of 0.0001 in. W.C., ensuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified minimum and maximum air flow parameters. The VAV TCU differential pressure transducer shall have a zero value air flow measurement repeatability of 0.001 in. W.C., VAV TCU differential pressure transducer requiring periodic zero value air flow calibration is not acceptable. The BAS contractor shall verify the type of differential pressure sensors used in the existing boxes, and ensure compatibility with the VAV TCU controllers.
3. The Variable Air Volume (VAV) Terminal Control Unit (TCU) shall include provision for air flow balancing using a local air flow balancing interface. A portable air flow balancing interface or an Intelligent Space Sensor (ISS) capable of balancing air flow is acceptable. The portable air flow balancing interface shall connect to the VAV TCU or the matching room temperature sensor.
4. The Variable Air Volume (VAV) Terminal Control Unit (TCU) shall also provide a web browser based air flow balancing tool. This tool shall allow the air balancer to manually

control the action of the actuator including the following function: open VAV damper, close VAV damper, open all VAV dampers, and close all VAV dampers.

5. Systems not able to provide a web based air balance tool or a portable air flow balancing interface or an Intelligent Space Sensor (ISS) capable of balancing air flow as part of the VAV TCU controller shall provide an individual full time technician during the air flow balancing process to assure full balance compliance.
6. The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F of setpoint at the room sensor location. Each controller shall also incorporate an algorithm that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space requirements. This algorithm shall function to signal the respective DDC controller to perform the required discharge temperature reset in order to maintain space temperature setpoint.
7. It shall be possible to view and reset the space temperature, temperature setpoint, maximum airflow setting, minimum airflow setting, and actual airflow, through the BAS LAN.

2.20 TCU PROGRAMMING SOFTWARE

A. Provide programming software for the Terminal Control Unit (TCU) that allows for the development of the TCU control logic and point management.

B. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. Access to these functions shall be provided through Graphical User Interface software (GUI). Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide “real-time” data updates. Any real-time data value or object property may be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.

C. Programming Methods - Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user’s application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification.
   1. Configuration of each object will be done through the object’s property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.
   2. The software shall provide the ability to view the logic with value being inputted/outputted of the graphical blocks (debug mode),
   3. The system shall support object duplication within a customer’s database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

D. Provides function to compare and calculate from multiple values from networked controllers (NCU, TCU and/or LCU). As a minimum, the function shall calculate and compared the values and return the average, sum, highest and lowest values.

2.21 TCU CONFIGURATION SOFTWARE

A. Configuration of the TCU controller shall be done through the configuration tool using fill-in the blank fields, list boxes, and selection buttons.

B. The configuration tool menu shall define items such as I/O configurations, set point, delays, PID loops, optimum start stops, and network variables/object settings. The configuration tool shall indicate the device status and allows system override.

C. The Configurable Controller shall allow the use of its spare I/O as dumb I/O to be shared over the network to other Controllers such as Programmable Controllers, where a sequence of operation can be applied to the I/O. Such applications shall include but not be limited to exhaust fan control, heaters, etc.

2.22 CONTROLLERS – BACNET PROTOCOL

A. Provide BACnet Controllers that BACnet Testing Laboratory listed as specified herein:
   1. BACnet Building Controller (B-BC)
   2. BACnet Advanced Application Controller (B-AAC)
   3. BACnet Application Specific Controller (B-ASC)

B. All BACnet Controllers shall use the following communication specifications and achieve performance as specified herein:
   1. All controllers shall be able to communicate peer-to-peer without the need for a Network Control Unit (NCU). Any controller on the MS/TP Data Link/Physical layer shall be able to act as a Master to allow for the exchange and sharing of data variables and messages with any other controller connected on the same communication cabling. Slave controllers are not acceptable.
   2. Performance – Each BACnet controller shall have a minimum of 64Kb of RAM and 384Kb of non-volatile flash memory. Each controller shall have a 32-bit microprocessor operating at 68 MHz and support a BACnet protocol stack in accordance with the ANSI/ASHRAE Standard 135-2008 and the BACnet Device Profile supported. Each BACnet controller shall provide a loading characteristic of minimum 1/4th Load on the BACnet MS/TP communications trunk. Manufacturers, who wish to supply LCU and TCU controllers with less than a 32-bit microprocessor and/or a MS/TP loading characteristic of greater than 1/4th Load, may do so as long as only they provide a maximum of 32 controllers on a single bus segment per NCU.
   3. BACnet Controllers shall be provided for Fan Coils, Variable Air Volume (VAV) Terminals and other applications as shown on the drawings. The application control program shall be resident within the same enclosure as the input/output circuitry, which translates the sensor signals.
   4. All Local Control Unit (LCU) and Terminal Control Units (TCUs) shall be fully programmable and the programming software shall have a library of pre-built, tested, and user re-definable control sequences for a wide range of typical HVAC applications. LCU and TCU controllers that are not fully programmable are not acceptable.
   5. BACnet Controllers shall communicate with the Network Control Unit (NCU) via a BACnet/IP connection at a baud rate of not less than 100 Mbps or via the RS485 MS/TP connection at a baud rate of not less than 76.8 kbps.
   6. BACnet TCU matching room temperature and/or humidity sensor shall connect directly to the TCU and shall not utilize any of the I/O points of the Controller. The TCU matching room temperature sensor shall provide a communications jack for connection to the BACnet communication trunk to which the TCU is connected. The TCU matching room temperature sensor, the connected TCU, and all other devices on the BACnet bus shall be accessible from this communications jack.

C. ALL BACNET LCU AND TCU SHALL BE FULLY APPLICATION PROGRAMMABLE. ALL CONTROL SEQUENCES PROGRAMMED INTO THE LCU AND TCU SHALL BE STORED IN NON-VOLATILE memory, which is not dependent upon the presence of a battery, to be retained.

D. The network router shall be used to route messages from a segment, sub-net, or domain in full duplex communication mode. Routers shall utilize BACnet protocol transport, network, and session layers to transparently route messages bound for a device instance in another

network. The routers, shall be capable of DIN rail or panel mounting and be equipped with status LED lights for Network traffic and power. A router may not manage more than 60 nodes on any single channel so as to allow for future expansion. Equip each router with a network transceiver on each network port (inbound and outbound) as dictated by the network type

E. A repeater or signal booster may only be used to increase the signal strength of the communications. Under no circumstances may it be used in the place of a router.

F. The System Integrator supplying the BACnet Controllers shall provide documentation for each device, with the following information at a minimum:
   1. BACnet Device; MAC address, name, type and instance number
   2. BACnet Objects; name, type and instance number

G. It is the responsibility of the System Integrator to ensure that the proper BACnet objects are provided in each BACnet controller, as required by the Point List located in the POINTS LIST section of this specification.

2.23 CONTROL PANELS, ENCLOSURES & SUB-PANELS

A. Provide wall or base mounted enclosures to house all controllers, transformers, relays, etc… associated with system, mechanical room or area. Enclosures shall conform to the following requirements:

1. Minimum 16 gauge steel or aluminum, totally enclosed on all sides and painted with a baked enamel finish.

2. Enclosures located outdoors shall meet NEMA 4X.

3. Enclosures located in all other locations including but not limited to mechanical or electrical rooms not requiring NEMA 2, occupied spaces, above ceilings and plenums shall be the same NEMA classification as all other enclosures located in the same environment, except if location requires additional protection due to potential vandalism or environmental conditions and shall at a minimum meet NEMA 1 requirements.

4. Provide a hinged door, keyed locking latch and removable sub-panel. A single key shall be common to all control enclosures.

5. Provide each DDC panel with on/off control, 120VAC convenience outlet, high/low voltage separation, control fuse(s), control transformer(s), terminal blocks and DC power supplies as necessary.

2.24 FIELD DEVICES

A. CONTROL DAMPERS

1. Rectangular Control Dampers - Standard Construction:
   a. Shall be licensed to bear the AMCA Certified Rating Seal.
   b. Test leakage and pressure drop per AMCA 500.
   c. Frame: Hat-shaped channel, minimum 12 gauge extruded aluminum, and minimum 4” deep. Caulk or weld seams to prevent leakage.
   d. Blades: Minimum 12 gauge extruded aluminum airfoil design, minimum 6” wide, and overlapping blades and blade seals (overlapping blade seals only is unacceptable).
   e. Shaft: Non-cylindrical, solid aluminum shaft with opening in blade to match profile of shaft. Shaft shall be securely fastened to the blade and of sufficient length to mount direct-coupled actuator. Damper manufacturer shall provide drive pin extensions and outboard bearing support brackets as required.
   f. Bearings: Acetal (Delrin/Celcon) inner bearing fixed to an aluminum shaft, rotating within a polycarbonate outer bearing inserted in the frame. Provide thrust bearings for vertical damper applications.
   g. Blade Seals: Extruded silicone gaskets secured in an integral slot within the blade.

h. Side Seals: Stainless steel compression type or extruded silicone gasket secured in an integral slot within the frame.
i. Linkage: Shall be concealed in the frame, constructed of aluminum or corrosion-resistant zinc plated steel, and securely fastened to shaft. Blades linked for opposed operation, unless noted otherwise on the drawings. Blades shall close evenly. Use one direct-coupled actuator per damper section. Jack-shafting is not acceptable.
j. Size Limits: 48" maximum horizontal blade length, 24 square foot maximum area per damper. Total cross-sectional area of dampers in ducts shall be at least as large as the duct without the use of blank-off sections.
k. Maximum Leakage: 9 cfm at 1" w.c. pressure differential for a 24"x 24" damper.
l. Maximum Pressure Drop for Opposed Blade Damper: 0.15" for 8,000 cfm through a 24"x24" damper (2000 fpm).
m. Maximum Pressure Drop for Parallel Blade Damper: 0.08" for 8,000 cfm through a 24"x24" damper (2000 fpm).

B. DAMPER ACTUATORS

1. Damper Actuators - Electronic - Spring Return:
   a. Damper actuators shall be UL listed, electronic direct coupled with spring return to normal position for modulating or two-position control as noted in the sequence of control. Actuator shall be 24 VAC with proportional control, electronic overload protection to prevent actuator damage due to over-rotation and "V" bolt clamp with matching "V" toothed cradle (single bolt or setscrew fasteners not acceptable).
   b. Following power interruption, spring return mechanism shall close the damper. Mechanical spring shall be rated for a minimum of 60,000 full cycles. Provide breathable membrane in actuator housing to compensate for pressure differential and allow for 95% non-condensing relative humidity in the airstream.
   c. Mount actuators with motor outside of airstream whenever possible. Unit casings shall have housing with proper weather, corrosive, or explosion-proof construction as required by application.
   d. Actuators shall be rated for 60,000 full cycles at rated torque with 2-year unconditional warranty. Size actuators per damper manufacturer's recommendations.
   e. Provide end switches as required for the sequence of operation.
   f. Provide analog feedback signal for positive position indication. Refer to FMCS points list.

C. HYDRONIC CONTROL VALVES

1. General:
   a. Two-position valves shall be a minimum of line size with a maximum allowable pressure drop of 2 psi.
   b. Size two-way and three-way modulating valves to provide a pressure drop at full flow of 1 to 4 psi, except boiler three-way and cooling tower bypass valves shall not have a pressure drop over 2 psi.
   c. Two-way valves shall be 100% tight-closing. Three-way valves shall be 100% tight-closing in both extreme positions.
   d. Modulating two-way valves shall have equal percentage flow characteristics.
   e. Modulating three-way valves shall have linear flow characteristics.
   f. Piping geometry correction factors for Cv ratings shall be used and stated for ball valves, butterfly valves, or non-characterized valves.
2. Two-position:
   a. Ball 2" and under:
      1) Design Pressure: 400 psi
      2) Design Temperature:212ºF
      3) Design Flow Differential Pressure Rating: 150 psi
      4) Bronze or brass body, stainless steel stem, chrome plated brass or stainless steel full port ball, PTFE or RTFE seats and seals, screwed ends (solder ends are acceptable

only if rated for soldering in line with 470ºF melting point of 95-5 solder).

b. Ball 3” to 6”:
   1) Design Pressure: 200 psi
   2) Design Temperature: 212ºF
   3) Design Flow Differential Pressure Rating: 35 psi
   4) Cast iron body, stainless steel stem, stainless steel full port ball, PTFE or RTFE seats and seals, flanged ends.

c. Butterfly 2-1/2” to 12”:
   1) Design Pressure: 125 psi
   2) Design Temperature: -20 to 212ºF
   3) Design Flow Differential Pressure Rating: 50 psi
   4) Cast iron body, stainless steel stem with extended neck, aluminum-bronze or nickel-plated iron disc, EPDM seats and seals, fully lugged ends.

3. Modulating:
   a. Globe 1/2" to 2”:
      1) Design Pressure: 250 psi
      2) Design Temperature: 212ºF
      3) Design Flow Differential Pressure Rating: 35 psi
      4) Bronze or brass body, trim and plug; stainless steel stem; stainless steel or bronze seat; EPDM or PTFE packing; threaded ends.

   b. Globe 2-1/2” to 6”:
      1) Design Pressure: 125 psi
      2) Design Temperature: 250ºF
      3) Design Flow Differential Pressure Rating: 25 psi
      4) Cast iron body, bronze or brass trim and plug; stainless steel stem; bronze seat; EPDM or PTFE packing; flanged ends.

   c. Ball 2” and under:
      1) Design Pressure: 400 psi
      2) Design Temperature: 212ºF
      3) Design Flow Differential Pressure Rating: 35 psi
      4) Bronze or brass body, stainless steel stem, chrome plated brass or stainless steel full port ball, PTFE or RTFE seats and seals, screwed ends (solder ends are acceptable only if rated for soldering in line with 470ºF melting point of 95-5 solder).

   d. Ball 3” to 6”:
      1) Design Pressure: 200 psi
      2) Design Temperature: 212ºF
      3) Design Flow Differential Pressure Rating: 35 psi
      4) Cast iron body, stainless steel stem, stainless steel full port ball, PTFE or RTFE seats and seals, flanged ends.

   e. Butterfly 2-1/2” to 12”:
      1) Design Pressure: 125 psi
      2) Design Temperature: -20 to 212ºF
      3) Design Flow Differential Pressure Rating: 50 psi
      4) Cast iron body, stainless steel stem with extended neck, aluminum-bronze or nickel-plated iron disc, EPDM seats and seals, fully lugged ends.

D. STEAM CONTROL VALVES

1. General:
   a. Two-position valves shall have a maximum pressure drop equal to 10% of the inlet pressure.
   b. Modulating control valves shall have modified linear characteristics.

c. Two modulating control valves in parallel shall have 1/3 – 2/3 capacities sequenced so that the smaller valve opens first.
d. The pressure drop through a modulating control valve with an inlet pressure less than or equal to 15 psig shall be equal to 80% of the inlet pressure. In no case shall the inlet pressure of the equipment after the valve be less than 2 psig, except for integral face and bypass coils where the inlet pressure after the valve shall not be less than 5 psig.
e. The pressure drop through modulating control valves with inlet pressures greater than 15 psig shall be required to provide outlet pressure of 1 psi above the scheduled or specified inlet pressure of the equipment served.
f. Piping geometry correction factors for Cv ratings shall be used and stated for ball valves, butterfly valves, or non-characterized valves.

2. Two-Position or Modulating (Low Pressure: 15 psi or below):
a. Globe 1/2" to 2":
1) Design Pressure: 100 psi
2) Design Temperature: 337ºF
3) Bronze body; stainless steel trim, plug, stem and seat; EPDM or PTFE packing; threaded ends.
b. Globe 2-1/2" to 6":
1) Design Pressure: 100 psi
2) Design Temperature: 337ºF
3) Cast iron body; stainless steel trim, plug, stem and seat; EPDM or PTFE packing; flanged ends.

E. VALVE ACTUATORS

1. General:
a. Actuators shall be sized to operate the valve through its full range of motion and shall close against pump shutoff pressure without producing audible noise at any valve position.
b. Provide visual position indication.
c. Mount actuator directly on valve or provide linear motion assembly as required for valve type.

2. Valve Actuators - Electronic:
a. Actuator shall be UL listed and provided with NEMA housing for applicable environment, electronic overload protection to prevent actuator damage due to over-rotation, and "V" bolt clamp with matching "V" toothed cradle (single bolt or setscrew fasteners not acceptable).
b. Actuators shall be rated for 60,000 full stroke cycles at rated torque. Stall motor not acceptable.
c. Tri-state/floating actuators shall have auto-zeroing function for realigning valve position.
d. Proportional actuator position shall be proportional to analog or pulse width modulating signal from electronic control system.
e. Spring return actuators shall have an internal spring return mechanism. Non-mechanical forms of fail-safe operation are not acceptable.
f. Provide analog feedback signal for positive position indication. Refer to Valve Schedule and FMCS points list.

F. VALVE SCHEDULE

Equipment Type		**Power Failure Position**	**Positive Position Feedback Required**
AHU Steam Coil	Proportional	N.O.	No
AHU Chilled Water Coil	Proportional	N.C.	No
Convector (Hot Water)	Floating	Last Position	No
Cabinet Heater (Hot Water)	Proportional	N.O.	No
Unit Heater (Hot Water)	Proportional	N.O.	No

Unit Heater (Steam)	Proportional	N.O.	No
Heat Exchanger (Steam)	Proportional	N.C.	No
Cooling Tower Bypass	Proportional	N.O. to Chiller	No
Humidifier Steam Control Valve	Proportional	N.C.	No
Radiation (Hot Water)	Proportional	N.O.	No
Evaporator Cooler Bypass	Proportional	N.O. to Cooler	No
Chiller 4 Changeover	Proportional	N.O. to Chiller 4	No

2.25 CONTROL INSTRUMENTATION

A. Temperature Measuring Devices:
   1. Low Limit Switch:
      a. Provide one foot of sensing element for each one square foot of coil area, maximum element length 25 feet, of the vapor tension type, so that any point along the entire length of measuring element is capable of triggering the switch.
      b. Provide 3” minimum radius capillary support clips at each turn.
      c. Furnish each thermostat with one single pole, single throw normally-opened switch and one single pole, single throw normally-closed auxiliary switch.
      d. Setpoint range shall be 15ºF to 55ºF with a permanent stop at 35ºF.
      e. Differential shall be fixed at approximately 5ºF and supplied with manual reset.

B. Temperature Sensors:
   1. Room Temperature Sensor:
      a. Sensor with Setpoint Adjustment and Override: Two-piece construction, ventilated plastic enclosure, off-white color, thermistor sensing element or resistance temperature device (RTD), 45°F to 90°F operating range, ± 0.50°F accuracy, with exposed single setpoint adjustment (no numeric temperature scale – provide with a warmer/cooler or red/blue visual scale), occupied/unoccupied override button with LED.
   2. Duct Temperature Sensor:
      a. Thermistor or RTD type. Pneumatic transmitters with transducers are not acceptable.
   3. Water Temperature Sensor:
      a. Install in immersion wells. Separate thermometers as specified elsewhere, also of the immersion well type, shall be installed within 2 feet of each temperature sensor.

C. Humidity Measuring Devices:
   1. Humidity Sensors:
      a. Humidity Sensors: Fully electronic with no moving parts or parts requiring periodic service. Accuracy shall be ± 2% of reading.

D. Pressure Measuring Devices
   1. Differential Pressure Switches:
      a. Standard Pressure Switches:
         1) Diaphragm-activated gauge with 4-3/4" dial, cast aluminum case, sealed interior, designed to resist shock and vibration, and rated for 15 psig.
         2) Accuracy shall be ± 3% of full scale maximum throughout entire range at 70ºF.
         3) Provide mounting brackets, probes, and shut-off valves required for proper installation.
         4) The range and service shall be as required for application or as noted on the drawings.
         5) Provide two (2) photo-transistor-activated circuits and two (2) DPDT relays for both high or low limit alarms or controls.
         6) Provide latching relays that require manual reset once activated.
         7) Acceptable Manufacturer: Dwyer Photohelic Series 3000.
      b. High Pressure Switches (Manual Reset):
         1) Differential pressure switch with single pole, double-throw snap switch and enclosure.
         2) Rated for pressure specified in sequence of control.
         3) Electrical rating shall be 15 amps at 120-480 volts.

4) Setpoint adjustment shall be screw type located inside enclosure.
5) Provide optional manual reset for overpressure protection with all tubing, brackets, and adapters.
6) Repeatability: ± 3%.

2. Pressure Transmitters/Transducer:
   a. Select device suitable for intended application; water or air, static or differential.
   b. Select for appropriate range, including negative if applicable.
   c. 100% solid state device, temperature compensated, suitable for pressures of 200% rated range with averaging to stabilize output, accuracy of ± 1% full scale, and a 4-20 mA output.
   d. Provide a NEMA 4 enclosure unless panel mounted.
   e. Air service shall have a minimum of three field selectable ranges.
   f. When used for room pressure control, the transducer shall be bidirectional with a range of ± 0.1" W.C.
   g. Provide pressure line outlet cover on both sides of the wall when used for room pressure control.
   h. Furnish with integral LED's to indicate Zero Pressure, Pressure In Range, and Pressure Out Of Range as a diagnostic aid.

E. Current Measuring Devices:
   1. Current Switches for Constant Speed Motors:
      a. Digital device rated for amperage load of motor or device with split core design, adjustable high and low trip points, 600 VAC rms isolation, induced power from the monitored load, LED indicator lamps for output status and sensor power. The device shall sense overloading, belt-loss, and power failure with a single signal.
   2. Current Switches for Motors Controlled by VFD:
      a. Digital device rated for amperage load of motor or device with split core design, factory programmed to detect motor under current conditions on variable or constant volume loads, self-calibrating, positive status indication, LED indicator lamps, 600 VAC rms isolation, and induced power from the monitored load with N.O. output. The current sensor shall store the motor current operating parameters in non-volatile memory and have a pushbutton reset to clear the memory if the operating parameters change or the sensor is moved to another load. The device shall sense overloading, belt-loss, and power failure with a single signal. The sensor shall be mounted on the load side of variable frequency drives.

2.26 MISCELLANEOUS DEVICES:

A. Control Relays:
   1. Form "C" contacts rated for the application with "push-to-test" contact transfer feature and an integral LED to indicate coil energization.
   2. Mount all relays and power supplies in a NEMA 1 enclosure beside the FMCS panel or controlled device and clearly label their functions.

B. Thermostat and Sensor Enclosures:
   1. Clear plastic guard with lock. Wire guard with tamperproof screws. Setpoint shall be adjustable with cover in place. Fasten to wall separately from thermostat. Provide guards in all corridors, gymnasiums, locker rooms, toilet rooms, assembly halls and as noted on the drawings. Coordinate locations with Owner prior to install.
   2. Heavy Duty Enclosure:
      a. Perforated steel, tamperproof locking thermostat and control device enclosure.
      b. Box shall be nominally 8"x6"x2" deep or sized as required to fit devices to be enclosed.
      c. Perforated cover shall be 16 gauge steel with maximum 3/16" perforations on maximum 1/4" staggered centers for a 55% free area.
      d. Secure to wall from inside of box. Cover shall be secured by tamperproof screws to frame.
      e. Color shall match electrical devices. Verify color with the Electrical Contractor.

C. Twist Timers:
   1. Wall-mounted heavy duty, with rotary dial and face graduated in minutes or hours as noted. Unit shall fit behind standard "decorator" wall plate. Color of timer and face plate shall match

remainder of project. Verify with Electrical Contractor. Provide wall plate and engraved plastic label indicating service.
2. Switch shall be rated for 20 amps at 125 volts (10 amps at 277 volts) and fit standard 2-1/2" deep electrical box.
3. Provide time cycle noted on the drawings or in the specifications; up to 12 hours.
4. Acceptable Manufacturers: Paragon SWD Series, Tork A500 Series, Intermatic FD Series, or Marktime Series 93.

D. Drip Pan Water Detector
1. 1” wide sensing type, installed entire length of pan.
2. Dwyer WD or equal.

2.27 WIRING, CABLE, AND RACEWAYS

A. CONDUIT TYPES:
1. Electrical Metallic Tubing (EMT) and Fittings: ANSI C80.3
   a. Fittings and conduit bodies: Compression or steel set screw type of steel or malleable iron design for their specific application.
2. Flexible Metallic Conduit (FMC) and Fittings: FS-WW-C-566
   a. Construction: Flexible steel, approved for conduit ground, zinc coated, threadless type formed from a continuous length of spirally wound, interlocked zinc coated strip steel.
   b. Fittings and conduit bodies: Threadless hinged clamp type, galvanized zinc coated cadmium plated malleable cast iron that shall include plastic or cast metal inserts supplied by the manufacturer to protect conductors from sharp edges.
   c. Maximum allowable length 6'-0".

B. WIRE AND CABLE TYPES:
1. Building Wire:
   a. Control Circuits: Copper, stranded conductor 600 volt insulation, THHN/THWN.
2. Remote Control and Signal Cable:
   a. Control Cable for Class 1 Remote Control and Signal Circuits: Copper conductor, 600 volt insulation, rated 60°C, individual conductors twisted together, shielded, and covered with a PVC jacket.
   b. Control Cable for Class 2 or Class 3 Remote Control and Signal Circuits: Copper conductor, 300 volt insulation, rated 60°C, individual conductors twisted together, shielded, and covered with a PVC jacket; UL listed.
   c. Plenum Cable for Class 2 or Class 3 Remote Control and Signal Circuits: Copper conductor, 300 volt insulation, rated 60°C, individual conductors twisted together, shielded, and covered with a nonmetallic jacket; UL listed for use in air handling ducts, hollow spaces used as ducts, and plenums.

PART 3 - EXECUTION

3.1 GENERAL INSTALLATION

A. Verify that systems are ready to receive work. Beginning of installation means installer accepts existing conditions.

B. Install system and materials in accordance with manufacturer's instructions.

C. Drawings of the TCS and FMCS network are diagrammatic only. Any apparatus not shown but required to meet the intent of the project documents shall be furnished and installed without additional cost.

D. Install all operators, sensors, and control devices where accessible for service, adjustment, calibration, and repair. Do not install devices where blocked by piping or ductwork. Devices with manual reset or limit adjustments shall be installed below 6'-0" if practical to allow inspection without using a ladder.

E. Verify locations of wall-mounted devices (such as thermostats, temperature and humidity sensors, and other exposed sensors) with drawings and room details before installation.

Coordinate mounting heights to be consistent with other wall-mounted devices. Maximum height above finished floor shall not exceed 48”.

F. Provide valves over 3/4" size with position indicators and pilot positioners where sequenced with other controls.

G. Mount control panels adjacent to associated equipment on vibration-free walls or freestanding angle iron supports. One cabinet may accommodate more than one system in same equipment room.

H. After completion of installation, test, calibrate and adjust as required all control equipment including sensors. This includes but is not limited to factory installed sensors which may be part of any HVAC equipment served by factory furnished unitary controllers.

I. Check calibration of instruments. Recalibrate or replace.

J. Furnish and install conduit, wire, and cable per the National Electric Code, unless noted otherwise in this section.

K. All controls associated with the proper operation of air handling units, pumps, or other mechanical equipment served by emergency power shall be connected to the emergency power system. Control components shall not be powered from the life safety branch of the emergency power system. Coordinate emergency power source connections with the Engineer.

L. All hardware, software, equipment, accessories, wiring (power and sensor), piping, relays, sensors, power supplies, transformers, and instrumentation required for a complete and operational FMCS system, but not shown on the electrical drawings, are the responsibility of the TCC.

M. Remodeling:
   1. All room devices as indicated on the drawings shall be removed by this Contractor. The Contractor shall also prepare the wall for finishes. Preparing the wall shall include patching old anchor holes (after the anchoring device has been removed) and sanding the wall to remove old paint outlines remaining from original devices. The wall shall be painted to match the existing wall prior to the installation of the new room device. In the event that wall covering requires patching, the Contractor shall furnish new wall covering to match existing. If new wall covering is not available to match existing, the Contractor shall furnish a white acrylic or Plexiglas plate, 1/4” thick and sized to cover the void.

N. Labels For Control Devices:
   1. Provide labels indicating service of all control devices in panels and other locations.
   2. Labels may be made with permanent marking pen in the control panels if clearly legible.
   3. Use engraved labels for items outside panel such as outside air thermostats.
   4. Labels are not required for room thermostats, damper actuators and other items where their function is obvious.

O. VFD’s:
   1. This project includes several variable frequency drives to control the flow of fans and/or pumps based on a control variable.
   2. Verify output signal required, 4-20 mA or 0-10V dc, with the EC.
   3. If VFD has a bypass feature, auxiliary contacts on the drive may not be used for motor status. A separate relay must be used to indicate motor rotation in either hand or auto positions.
   4. If a separate current transmitter or switch is indicated for status, install this device between the VFD and the motor. In this case, the drive status may be connected to the auxiliary contacts in the VFD.
   5. Some devices, such as low limits and fire alarm shutdown relays, must be hardwired to the fan motor. Make connections such that fan will shut down whether in hand or auto position if the unit has a bypass feature.

3.2 GRAPHIC DISPLAY

A. Create a customized graphic for each piece of equipment indicated on the itemized points list.

B. Components shall be arranged on graphic as installed in the field.

C. Include each graphic point listed in the itemized points list using real time data.

D. Provide a graphic representation of the following:
   1. Where there are multiple buildings, color code the campus map by the systems serving that building. The building graphic shall be linked to the graphic for that building's systems.
   2. Where there are multiple floors, provide color codes/designations for the areas served by each AHU and TAB by floor.
   3. Where multiple AHUs serve one floor, color code the areas served by each AHU. The area shall be linked to the graphic for that area's AHU.
   4. Provide an overall floor plan of each floor of the building color coded by zone linked to the TAB for that zone. The zone shall be linked to the graphic for that zone's TAB graphic.
   5. Show the location of each thermostat on the floor plan.
   6. Provide separate graphics showing the chilled and heating water system flow diagram. Show temperatures and flows on the flow diagram. Each piece of equipment shown on the flow diagram shall be linked to the graphic for that piece of equipment.
   7. Provide a graphic showing the steam system flow diagram. Show pressures and flows on the flow diagram. Each piece of equipment shown on the flow diagram shall be linked to the graphic for that piece of equipment.

E. The FMCS shall include full graphic operator interface to display the following graphics as a minimum:
   1. Home page to include a minimum of six critical points: Outside Air Temperature, Outside Air Relative Humidity, Enthalpy, KWH, KW, etc.
   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 including AHUs, ERUs, EFs, chillers, and boilers, as a minimum.
   4. Access corresponding system drawings, technical literature, and sequences of operations directly from each system graphic.

F. The FMCS shall include individual graphical buttons to access the following data stored in PDF format:
   1. Project control as-built documentation including all TCS drawings, diagrams and sequences of operation.
   2. TCS Bill of Material for each system, e.g. AHU, RTU, FCU, boiler, etc.
   3. Technical literature specification data sheets for all components listed in the TCS Bill of Material.

G. The operator's workstation shall display all data associated with the project. The operator's terminal software shall accept, GIF, PNG, JPG and ICO format graphic files for display purposes. Graphic files shall be created using scanned, full color photographs of system installation, AutoCAD or Visio drawing files of field installation drawings and wiring diagrams from as-built drawings. Operator's terminal shall display all data using 3-D graphic representations of all mechanical equipment.

H. System shall be capable of displaying graphic file, text, and dynamic object data together on each display. Information shall be labelled with descriptors and shall be shown with the appropriate engineering units. All information on any display shall be dynamically updated without any action by the user. Terminal shall allow user to change all field-resident BAS functions associated with the project, such as setpoints, weekly schedules, exception schedules, etc. from any screen no matter if that screen shows all text or a complete graphic display. This shall be done without any reference to object addresses or other numeric/mnemonic indications.

I. All displays shall be generated and customized in such a manner by the local DDC system supplier that they fit the project as specified. Canned displays shall not be acceptable. Displays

shall use standard English for labelling and readout. Systems requiring factory programming for graphics or DDC logic are specifically prohibited. The installing contractor without factory dependency or assistance shall support all graphics and DDC programming locally.

J. Binary objects shall be displayed as ON/OFF/NULL or with customized text. Text shall be justified left, right or center as selected by the user. Also, allow binary objects to be displayed as individual change-of-state bitmap objects on the display screen such that they overlay the system graphic. Each binary object displayed in this manner shall be assigned up to three bitmap files for display when the point is ON, OFF or in alarm. For binary outputs, toggle the objects commanded status when the bitmap is selected with the system digitizer (mouse). Similarly, allow the terminal operator to toggle the object's status by selecting (with the mouse) a picture of a switch or light, for example, which then displays a different picture (such as an ON switch or lighted lamp). Additionally, allow binary objects to be displayed as an animated graphic.

K. Animated graphic objects shall be displayed as a sequence of multiple bitmaps to simulate motion. For example: when a pump is in the OFF condition, display a stationary picture of the pump. When the operator selects the pump picture with the mouse, the represented objects status is toggled and the picture of the pumps impeller rotates in a time-based animation. The operator shall be able to click on an animated graphical object or switch it from the OFF position to ON, or ON to OFF. Allow operator to change bitmap file assignment and also create new and original bitmaps online. System shall be supplied with a library of standard bitmaps, which may be used unaltered or modified by the operator. Systems that do not allow customization or creation of new bitmap objects by the operator (or with third-party software) shall not be allowed.

L. Analog objects shall be displayed with operator modifiable units. Analog input objects may also be displayed as individual bitmap items on the display screen as an overlay to the system graphic. Each analog input object may be assigned to a minimum of five bitmap files, each with high/low limits for automatic selection and display of the bitmaps. As an example, a graphic representation of a thermometer would rise and fall in response to either the room temperature or its deviation from the controlling setpoint. Analog output objects, when selected with the mouse, shall be displayed as a prompted dialog (text only) box. Selection for display type shall be individual for each object. Analog object values may be changed by selecting either the increase or decrease arrow in the analog object spinner box without using the keypad. Pressing the button on the right side of the analog object spinner box allows direct entry of an analog value and accesses various menus where the analog value may be used, such as trend logs.

M. Analog objects may also be assigned to an area of a system graphic, where the color of the defined area would change based on the analog objects value. For example, an area of a floor-plan graphic served by a single control zone would change color with respect to the temperature of the zone or its deviation from setpoint. All editing and area assignment shall be created or modified online using simple icon tools.

N. A customized menu label (push-button) shall be used for display selection. Menu items on a display shall allow penetration to lower level displays or additional menus. Dynamic point information and menu label push buttons may be mixed on the same display to allow sub-displays to exist for each item. Each display may be protected from viewing unless operator has appropriate security level. A separate security level may be assigned to each display and system object.

O. A mouse, or other form of digitizer, shall be used to move the pointer arrow to the desired item for selection of new display or to allow the operator to make changes to object data.

P. Displays may be modified on site or via remote communications.

Q. Entire system shall operate without dependency on the operator's terminal. Provide graphic generation software at each workstation.

3.3 CONDUIT, WIRING, AND CABLE INSTALLATION

A. Conduit Sizing and Installation:

1. Conduit and conductor sizing shall be coordinated to limit conductor fill to less than 40%. Maintain conductor ampere capacity as required by the National Electrical Code (to include enlarged conductors due to temperature and quantity derating values) and to prevent excessive voltage drop and pulling tension due to long conduit/conductor lengths.
2. Minimum conduit size shall be 1/2" above grade, 3/4" below grade less than 5 feet from building foundation, and 1-1/4" below grade more than 5 feet from building foundation, unless noted otherwise.
3. Supports for metallic conduit shall be as near to 5 feet intervals as possible. A greater interval may be used if convenient because of building construction, but in no event shall support spans exceed the National Electric Code requirements.
4. Conduit runs installed above ceilings shall be properly supported. In no case shall conduit rest on the ceiling construction or the ceiling support system be used for conduit support.
5. Conduit shall not be supported from ductwork, water or sprinkler piping, etc., unless approved by the Engineer. All supports shall be from the building structure, unless noted otherwise and coordinated with all other applicable contractors.
6. Install expansion/deflection joints where conduit crosses structure expansion/seismic joints.
7. Conduit shall be mechanically continuous from source of current to all outlets. Conduit shall be electrically continuous from source of current to all outlets, unless a properly sized bonding conductor is routed within the conduit. All metallic conduit shall be grounded per the National Electrical Code.
8. Thermostats/temperature sensors shall be installed in junction boxes, flush with the wall, and shall be coordinated for orientation with Engineer.
9. All conduit shall be concealed in walls and above ceilings unless noted otherwise.

B. Wire Installation Methods:
1. Use no wire smaller than 14 AWG for line voltage (120V) wiring.
2. Use no wire smaller than 18 AWG for low voltage (24V) control wiring.
3. Splice and tap only in accessible junction or outlet boxes.
4. Neatly train and lace wiring inside boxes, equipment, and panelboards.
5. All conductors shall be continuous from device to their termination.
6. Install wire in conduit after interior of building has been physically protected from the weather and all mechanical work likely to damage conductors has been completed.
7. Thoroughly clean wires before installing lugs and connectors.
8. Make splices, taps and terminations to carry full ampacity of conductors without perceptible temperature rise.
9. Terminate spare conductors with electrical tape, unless otherwise indicated on the drawings.

C. Cable Installation Methods:
1. Provide protection for exposed cables where subject to damage.
2. Use suitable cable fittings and connectors.
3. Run all open cable in a neat and symmetrical manner.
4. Open cable shall be supported by the appropriate size bridle rings. Wire and cable from different systems shall not be installed in the same bridle rings.
5. Open cable installed above suspended ceilings shall not rest on the suspended ceiling construction or use the ceiling support system for wire and cable support.
6. Where open cables are grouped, they shall be neatly bundled and held together with nylon tie wraps placed every 2.5 feet on the bundle. Where tie bundle passes through a bridle ring, it shall be fastened to the ring with a tie wrap.
7. Bridle ring supports shall be installed at five-foot intervals. All rings shall be installed where completely accessible and not blocked by piping, ductwork, inaccessible ceilings, etc.
8. Open cable shall only be installed where specifically identified in these specifications.

D. Wire and Cable Installation in Conduit:
1. Pulling shall be continuous without unnecessary stops and starts with wire or cable only partially through conduit.

2. Reels of cable or wire shall be set up close to the point where the wire or cable enters the conduit so that the cable or wire may be unreeled and run into the conduit with a minimum of change in the direction of the bend.
3. Cables or wires shall not be laid out on the ground before pulling.
4. Cables or wires shall not be dragged over earth or paving.
5. Care shall be taken so as not to subject the cable or wire to high mechanical stresses that would cause damage to the wire and cable.
6. Conductors shall not be pulled through conduits until plastering or masonry work is completed and conduits are free from moisture. Care shall be taken so that long pulls of wire or pulls around several bends are not made where the wire may be permanently stretched and the insulation damaged.
7. At least six (6) inch loops or ends shall be left at each device for installation connection.
8. Completely and thoroughly swab conduit system before installing conductors.

E. Field Quality Control:
1. Inspect wire and cable for physical damage and proper connection.
2. Torque test conductor connections and terminations to manufacturer's recommended values.
3. Perform continuity test on all conductors.
4. Protection of cable from foreign materials:
   a. It is the Contractor's responsibility to provide adequate physical protection to prevent foreign material application or contact with any cable type. Foreign material is defined as any material that would negatively impact the validity of the manufacturer's performance warranty. This includes, but is not limited, to overspray of paint (accidental or otherwise), drywall compound, or any other surface chemical, liquid or compound that could come in contact with the cable, cable jacket or cable termination components.
   b. Overspray of paint on any cable, cable jacket or cable termination component will not be accepted. It shall be the Contractor's responsibility to replace any component containing overspray, in its entirety, at no additional cost to the project. Cleaning of the cables with harsh chemicals is not allowed. This requirement is regardless of the PASS/FAIL test results of the cable containing overspray. Should the manufacturer and warrantor of the structured cabling system desire to physically inspect the installed condition and certify the validity of the structured cabling system (via a signed and dated statement by an authorized representative of the structured cabling manufacturer), the Owner may, at their sole discretion, agree to accept said warranty in lieu of having the affected cables replaced. In the case of plenum cabling, in addition to the statement from the manufacturer, the Contractor shall also present to the Owner a letter from the local Authority Having Jurisdiction stating that they consider the plenum rating of the cable to be intact and acceptable.

F. Installation Schedule:
1. Conduit terminations to all devices installed in applications with rotating equipment, expansion/contraction or vibration shall be made with flexible metallic conduit, unless noted otherwise. Final terminations to exterior devices installed in damp or wet locations shall be made with liquid tight flexible metallic conduit. Terminations in hazardous areas, as defined in the National Electrical Code, shall be connected using flexible conduit rated for the environment.

Location	Conduit Type Required for Building Wire and Cable
Dry Mechanical Spaces	EMT, FMC, or Cable Tray
Wet or Damp Locations	RGS or LFMC
Interior Locations Below Accessible Ceilings	EMT
Above Non-Accessible Ceilings	EMT
Above Accessible Ceilings	None, Plenum Cable Required
Exterior Locations	RGS or LFMC

Below Accessible Floor	EMT
Hazardous Locations as Defined by the National Electric Code	RGS conduit complete with screwed fittings and conduit seals
In Walls, Bulkheads, Soffits, or other enclosed areas	EMT

3.4 FMCS INSTALLATION

A. Coordinate voltage and ampacity of all contacts, relays, and terminal connections of equipment being monitored or controlled. Voltage and ampacity shall be compatible with equipment voltage and be rated for full ampacity of wiring or overcurrent protection of circuit controlled.

B. Naming Conventions: Coordinate all point naming conventions with Owner standards. In the absence of Owner standards, naming conventions shall use equipment designations shown on plans.

3.5 CONTROL SYSTEM TESTING, COMMISSIONING, DEMONSTRATION AND ACCEPTANCE

A. The Contractor shall furnish all labor, tooling and test equipment as needed to fully test, calibrate and commission all controls, sensors, instruments, hardware, wiring, software, equipment and related accessories. Testing and Commissioning including furnish required documentation thereof shall be completed prior to Demonstration and Acceptance.

B. Verify that all control wiring is properly terminated, connected and free of shorts and ground faults. Verify all terminal connections are secure and tight.

C. Upon completion of the installation, this Contractor shall load all system software and start up the system. This Contractor shall perform all necessary calibration, testing and de-bugging and perform all required operational checks to ensure that the system is functioning in full accordance with these specifications.

D. This Contractor shall perform tests to verify proper performance of components, routines, and points. Repeat tests until proper performance results. This testing shall include a point-by-point log to validate 100% of the input and output points of the FMCS system operation.

E. Contractor shall verify the system operation achieves the sequences of operation. Simulate all modes of operation by overriding and varying input set-points and schedules. Tune all DDC algorithms and control loops as needed to optimize start/stop routines and minimize energy consumption.

F. Contractor shall test all alarms, safeties and interlocks. Simulate each alarm condition and test alarm activation thresholds and reactions by using a simulation signal which will activate the alarm condition. Once alarm conditions are activated test acknowledgment, communication and remediation steps and features.

G. This Contractor shall prove that the controls network is functioning correctly and within acceptable bandwidth criteria and shall test the system with an approved protocol analysis tool. Provide a log and statistics summary showing that each channel is within acceptable parameters. Each channel shall be shown to have at least 25% spare capacity for future expansion.

H. Upon completion of the performance tests described above, repeat these tests, point by point, as described in the validation log above in the presence of Owner's Representative, as required. Properly schedule these tests so testing is complete at a time directed by the Owner's Representative. Do not delay tests so as to prevent delay of occupancy permits or building occupancy.

I. System Acceptance: Satisfactory completion is when this Contractor has performed successfully all the required testing to show performance compliance with the requirements of the Contract Documents to the satisfaction of the Owner’s Representative. System acceptance shall be contingent upon completion and review of all corrected deficiencies.

3.6 PREPARATION FOR BALANCING

A. Verify that all dampers are in the position indicated by the controller (e.g., open, closed or modulating).

B. Check the calibration and setpoints of all controllers.

C. Check the locations of all thermostats and humidistats for potential erratic operation from outside influences such as sunlight, drafts, or cold walls.

D. Check that all sequences operate as specified. Verify that no simultaneous heating and cooling occurs, unless specified. Observe that heating cannot begin at TAB reheat terminals until the unit is at the minimum cfm.

E. Verify the operation of all interlock systems.

3.7 TESTING AND BALANCING COORDINATION

A. The Contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.

B. The Contractor shall provide a minimum of four (4) hours training for the Balancing Contractor in the use of these tools.

C. The Contractor shall provide a qualified technician to assist with the Testing, Adjusting and Balancing processes.

D. The tools used during the test and balance process shall be returned at the completion of the testing and balancing.

3.8 DEMONSTRATION AND ACCEPTANCE

A. Demonstration:
   1. Prior to acceptance, the controls system installing Contractor shall satisfactorily complete a series of performance tests to demonstrate and verify proper operation. Said performance demonstration tests shall be conducted only after said Contractor has completed their installation, system start-up, testing procedures, debugging and commissioning process as required by these Specifications.
   2. The demonstration processes shall conform with those approved under Part 1.08 – Submittals, including but not limited to utilizing all approved checklists and forms for all controlled systems. The Owner's designated representatives shall be present to observe and review the demonstration. Attendees shall be extended advanced notification of at least 10 business days prior to start of testing demonstration.
   3. The Contractor shall provide at least two qualified staff equipped with two-way communications who shall demonstrate to Owner's designated representatives actual field operation of each control point under all modes of operating conditions including occupied, unoccupied, transitional periods such as optimized start/stop warm up and cool down, temporary occupant override, seasonal changeovers, fire/smoke alarm, emergency switch activation, communication failure and power failure. The sequences of operation for all modes of operation shall be demonstrated to satisfactorily function as intended. A complete demonstration of the controls operator interface must also be provided as part of this procedure.
   4. As each control input and output point is functionally demonstrated for each mode of operation, a certified log or checklist shall be completed by Contractor's staff showing the date and times, any corrective actions taken or needed along with technician's initials. Any tests which fail to demonstrate proper operation of the system shall be repeated at a later date. The Contractor shall be responsible for any repairs, modifications, revisions to the hardware, software or programming as needed to successfully complete all tests.
   5. Demonstration testing of the DDC loops responses shall be provided. The tests shall demonstrate the loop's response to changes in set-points. Sampling rates shall vary from 10 seconds up to 3 minutes, dependent on the speed of the DDC loop. Documentation of testing

results shall be provided by Contractor in the form of trend data using a graphical format. Trend data shall show for each test sample, set-points, controlled device positions and controlled variable values. DDC loops which yield unreasonably over-damped or under-damped control responses shall require further tuning and re-testing by the Contractor.

6. Contractor shall submit Operational Logs in electronic format and printed if requested, for each system which indicate all modes of operation, set-points, operating points, control actuator positions, equipment status and alarms to the Engineer and Owner. Logs shall extend to cover three 48-hour periods using a sampling frequency of not more than 10 minutes.

B. Acceptance:
   1. The system shall not be considered accepted until which time that all forms, checklists, trends and logs completed as part of the demonstration are submitted and approved by the Engineer and Owner's designated representative.
   2. Acceptance that the control system meets the requirements of the project will be awarded only after all tests and demonstrations included in this Specification Section, related Sections or as notified in writing, have been satisfactorily performed and completed to the satisfaction of both the Engineer and Owner's representative.
   3. Any tests or demonstrations which cannot be performed due to circumstances or conditions determined to be beyond the control of the Contractor may be exempted from compliance requirements if proposed in writing to the Engineer and Owner's representative for consideration. Such tests and demonstrations, if exempted, shall be expeditiously performed by Contractor and at no additional cost as part of the system warranty.

3.9 TRAINING

A. On-Site:
   1. After completion of Demonstration testing, the Contractor shall provide a minimum of 8 hours total of on-site or at the Owner's discretion, classroom training for personnel designated by the Owner or their representative. The training course shall enable the Owner's staff representatives to perform Day-to-Day Operations as defined herein.
   2. A factory trained and certified instructor with experience in both presenting the training material and system programming for this specific project shall perform the training.
   3. Classroom training, if approved, shall be conducted using network controllers, graphics, routines, and programming representative of the actual installed system.

B. Day-to-Day Operations - Training Description:
   1. Proficiently operate the system.
   2. Understand control system architecture and configuration.
   3. Understand FMCS systems components.
   4. Understand system operation, including FMCS system control and optimizing routines (algorithms).
   5. Operate the workstation and peripherals.
   6. Log-on and off the system.
   7. Access graphics, point reports, and logs, including set-up of: custom trending reports, points to be trended, sample intervals, formats, start/stop dates/times and transmission of custom trending reports.
   8. Adjust and change system setpoints, time schedules, and holiday schedules.
   9. Alarms and procedures: alarm classes, criticality, latching enabling and disabling, acknowledgements, silencing, status and notifications.
   10. Recognize malfunctions of the system by observation of the printed copy and graphic visual signals.
   11. Understand system drawings and Operation and Maintenance manual.
   12. Understand the job layout and location of control components.
   13. Access data from FMCS controllers and ASC's.
   14. Operate portable operator's terminals.

C. Provide course outline and materials in accordance with the “SUBMITTALS” article in Part 1 of this section. The instructor(s) shall provide one copy of training material per student.

3.10 INSTALLATION OF SENSORS

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

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

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

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

E. Averaging sensors and low limits shall be installed at the top of the assembly with the element on a slight downward incline away from the sensor making a serpentine pattern over the cross-sectional area with elements spaced not over 12” apart and within 6” of the top and bottom of the area.

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

G. Install outdoor air temperature sensors on exterior of north wall, complete with sun shield at designated location approved by Engineer. TCC shall prime and paint the device enclosure. Color selection by Owner.

END OF SECTION