ITEM NO. 1:
CLARIFICATION:
A. Attached is the response for PreBid RFI 001 regarding miscellaneous questions.

ITEM NO. 2:
Section 23 09 00 – Instrumentation and Control For HVAC (Reissued)
A. The specification section has been updated with additional information and is being reissued in its entirety.

ITEM NO. 3:
Sheet: D201 (Not Reissued)
Change demolition note 6 to read, "Remove dock leveler and salvage for reuse. Remove hydraulic pistons from lift and rebuild. Sawcut concrete to depth of recess and remove embedded angles."

ITEM NO. 4:
Sheet: A101 - Basement & Sub-Basement Floor Plans (Not Reissued)
A. Add reference to detail 4/A402 at column 15/A.6. Flammable storage cabinet shall be moved to accommodate pilaster.
B. Revise note 14 to read, "Infill shutter opening to match existing. Tooth in CMU at jambs."

ITEM NO. 5:
Sheet: A401 - Details (Reissued)
A. Add detail 4. This detail is to be used at the top of all new full-height masonry walls.
B. Change note about parging in Details 2 and 3 to read, "Non-shrink grout for slopes less than 1/8:12."

ITEM NO. 6:
Sheet: S101 – Foundation & Partial Framing Plan (Reissued)
A. Add note about existing steam and condensate anchors in the tunnel, as indicated.

ITEM NO. 6:
Sheet: S201 - Roof Framing Plan (Not Reissued)
A. Add note to the CMU walls at the south and east side of Receiving B017 to read, "Provide bond beam with (2)#4 at first full course below top of CMU wall."
ITEM NO. 7:
Sheet: M301 – Mechanical Site Plan, Vault Plan and Sections (Reissued)
A. Changed sizes of exiting steam and condensate connections in vault to match the sizes installed by the owner.

END OF ADDENDUM
Question

1. Please provide the height of the vault in which we are installing the new steam lines in the steam tunnel. It appears the steam tunnel is 7’ per drawing C101, but it appears the vault is taller (10’ inside?) per drawing S301 section 11.
2. The column located at gridlines 14 and A.6 is not shown to be wrapped similar to the other columns on A101. If it is going to be wrapped, it will likely bump out into room B014 and affect the layout of the flammable cabinets. Please confirm it is to be wrapped similar to detail 4 on A402.
3. Please provide a spec for the cement parging shown on drawing A401.
4. Are the interior CMU walls required to be fastened to the metal deck/roof in any fashion? If so, please provide that detail.
5. Please confirm that we do not need to tooth in the CMU where we are filling in the opening currently occupied by a rolling shutter in the remodeled room B002.
6. Do we need to remove the embedded angles that are currently in the floor on the perimeter of the loading dock lift? If not, they will be exposed in the floor of the new general supplies room.
7. Key Note 22 on drawing A101 calls for wainscot on the column in the middle of the room, but it doesn’t exist anywhere else in that room. Is this correct?

GCI Proposed Solution

1. 10’ Interior height
2. Wrapped per detail 4, adjusted flammable cabinet layout to be provided
3. Provide spec for cement parging
4. Yes fasten to roof decking per detail to be provided
5. No toothing required at this location
6. Yes remove the embedded angles and fill the area with concrete
7. No wainscot required at this location

Architect/Engineer/Owner Response

1. Original tunnel construction drawings depict the vault as taller than the 7’ steam tunnel, but do not give the overall height of the vault. Section 11/S301 depicts the approximate vault height based on those construction drawings, but vault height will need to be field verified.
2. Wrap column per detail 4/A402. Move flammable storage cabinet toward the center of the room to accommodate pilaster.

3. Parging is not required if existing slope is 1/8"-.12" or steeper. If no slope exists, use non-shrink grout as specified for under base plates in Section 03 31 00, Paragraph 2.1.1.

4. Fasten to roof deck as shown in details below:
5. CMU shall be toothed in at infill location.
6. Remove embedded angles, sawcut concrete to depth of recess, and fill with new concrete.
7. Wainscot shall be provided at column.

Response by Kyle Shaver and Michelle Hoffner of FTCH on May 18, 2017
SECTION 23 09 00 – INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Furnish all labor, materials, equipment, and service necessary for the complete installation and function of new controllers, sensors, actuators, transducers and VFD’s. The Facilities Management and Control System (FMCS) shall be capable of total integration of the facility infrastructure systems with user access to all system data either locally over a secure Intranet within the building or by remote access by a standard Web Browser over the Internet. This shall include HVAC control, energy management, alarm monitoring, fire-life safety systems, and all trending, reporting and maintenance management functions related to normal building operations all as indicated on the drawings or elsewhere in this specification.

2. All labor, material, equipment and software not specifically referred to herein or on the plans, that is required to meet the functional intent of this specification, shall be provided without additional cost to the Owner.

3. Installers, support technicians and programmers shall be certified by the control system manufacturer or its exclusive factory authorized installing contracting field office or authorized manufacturer representative. The installing office shall have a minimum of five years of installation experience with the manufacturer and shall provide documentation in submittal package verifying longevity of the installing company's relationship with the manufacturer.

4. Contractor are required to have the following qualifications:

a. A minimum of 2 direct employees that are AX Certified Technicians.

b. A minimum of 5 completed FMCS projects on a Tridium system.

5. Contractor shall not employ a third party Integrators on this project

6. Contractor shall have an office within 100 miles of Houghton, Michigan for on-going support of the FMCS.

B. Major items unique to the work of this Section:

1. Direct digital control (DDC) hardware.

2. DDC software.

3. All remote sensing devices and interconnecting wiring or tubing.

4. All secondary control devices including, but not necessarily limited to, the following:

   a. Thermostats.

   b. Temperature and humidity sensors.

   c. Primary and secondary controllers.

   d. Automatic valves and dampers.

   e. Damper and valve operators.

   f. Relays.

   g. Control panels.

   h. Operator interface.

   i. Network devices.

   j. Miscellaneous sensors (CO₂ and O₂).

5. Electric power supply source.

6. Conductor and conduit.

7. Necessary appurtenances to make a complete and functional system to satisfy the functional intent.

8. Final and complete operational demonstration.

9. Mechanical testing, adjusting and balancing.

10. BMS interface, integration devices and programming.
C. Mechanical systems included in the Work of this Section:
   1. Except as specifically described below, it is the work of this Section to provide, install and integrate complete control of the HVAC systems, including, but not limited to the following:
      a. Air handling unit controls.
      b. Terminal unit controls.
      c. Ventilation system controls.
      d. Exhaust fan controls.
      e. Variable frequency drives.

D. Integration:
   1. Existing Control Equipment:
      a. Provide for interface between new controls installation and Owner's existing control and building management systems:
         1) As indicated on the Drawings.
         2) As required to satisfy the functional intent description of this Section.
      b. All existing equipment is assumed to be fully functional and in proper working order as it relates to the work of this Section for Base Bid.

1.3 SYSTEM DESCRIPTION

A. The entire Facility Management and Control System (FMCS) shall be comprised of a network of interoperable, stand-alone digital controllers communicating on an open protocol communication network to a host computer within the facility (when specified) and communicating via the internet to a host computer in a remote location. The FMCS shall communicate to third party systems such as energy metering systems, other energy management systems, access control systems, fire-life safety systems and other building management related devices with open, interoperable communication capabilities.

1.4 SOFTWARE LICENSE AGREEMENT

A. The Owner shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement, but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

1.5 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.

1.6 JOB CONDITIONS

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

B. Chemical Sciences and Engineering Building houses many class rooms that are utilized during normal working hours. Cooperate with classes and instructors that are adjacent to work areas

1.7 QUALITY ASSURANCE

A. The Manufacturer of the FMCS digital controllers shall provide documentation supporting compliance with ISO-9001 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing). Product literature provided by the FMCS digital controller manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar.
1.8 SPECIFICATION NOMENCLATURE

A. Acronyms used in this specification are as follows:
1. FMCS Facility Management and Control System.
2. NAC Network Area Controller.
3. IDC Interoperable Digital Controller.
4. IBC Interoperable BACnet Controller.
5. GUI Graphical User Interface.
6. WBI Web Browser Interface.
7. POT Portable Operator's Terminal.
8. PMI Power Measurement Interface.
9. DDC Direct Digital Controls.
10. LAN Local Area Network.
11. WAN Wide Area Network.
12. OOT Object Oriented Technology.
13. PICS Product Interoperability Compliance Statement.

1.9 DEFINITIONS

A. Where applicable, the terminology used herein uses the definitions listed in ASHRAE Standard 13.

B. Other definitions used include:
1. Low Voltage:
   a. Voltage less than 120V single phase, typically 24V AC.
   b. Low voltage is used primarily for communication and control of devices.
2. Large Valves: Valves for piping greater than 2 inches in diameter.
3. Large Dampers: Greater than 133-inch/pound torque required or 30 square feet.
4. DDC: Direct digital controls.
5. IP: Internet protocol.
6. LAN: Local area network.
7. HVAC: Heating, ventilating and air conditioning systems. Generally, the work of Division 23.
8. Control Logic Diagram: A graphical representation of control logic for the multiple processes that make up a system. Logic symbols are used to represent:
   a. Input/Output (I/O) data.
   b. Control functions such as PID, two-position control, switches, etc.
   c. Math functions such as addition, subtraction, multiplication, division, etc.
   d. Boolean functions such as greater than, less than, equal to, etc.
   e. Limit functions such as maximum, minimum, ramps, etc.

1.10 DESIGN AND PERFORMANCE REQUIREMENTS

A. System layout and design responsibility are included as Work of this Section:
1. Details of construction, quantities, components and accessories indicated on the Drawings and in the Specifications are minimum requirements.
2. Increases in system component requirements beyond these minimums that are determined by the system designer to be necessary to provide the functional intent and for a complete system shall not be a basis for an increase in cost to Owner. Refer to Sequences of Operations on the Drawings for functional intent.

B. Comply with the following performance requirements:
1. Graphic Display: Display graphic with minimum 20 dynamic points or as required to display required data.
2. Graphic Refresh: Update graphic with display with current data within 8 seconds.
3. Object Command: Reaction time of less than 2 seconds between operator command of a binary object and device reaction.
4. Object Scan: Transmit change of state and change of analog values to control units or workstation within 6 seconds.
5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within 5 seconds of each other.
6. Program Execution Frequency: Run capability of applications as often as 5 seconds, but selected consistent with mechanical process under control.

7. Performance: Programmable controllers shall execute DDC/PID control loops, and scan and update process values and outputs at least once per second.

8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
   a. Space Temperature: ±1 degree F (0.5 degree C).
   b. Ducted Air Temperature: ±1 degree F (0.5 degree C).
   c. Outside Air Temperature: ±2 degree F (1.0 degree C).
   d. Dew Point Temperature: ±1 degree F.
   e. Temperature Differential: Plus or minus 0.25 degree F (0.15 degree C).
   f. Relative Humidity: ±5%.
   g. Airflow (Pressurized Spaces): ±3% of full scale.
   h. Airflow (Measuring Stations): ±5% of full scale.
   i. Airflow (Terminal): ±10% of full scale.
   j. Air Pressure (Space): ±0.01-inch wg (2.5 Pa).
   k. Air Pressure (Ducts): ±0.1-inch wg (25 Pa).
   l. Carbon Monoxide: ±5% of reading.
   m. Carbon Dioxide: ±50 ppm.
   n. Electrical: ±5% of reading.

1.11 SUBMITTALS

A. Copies of shop drawings of the control system component shall be submitted electronically and shall consist of a complete list of equipment and materials, including manufacturers catalog data sheets and installation instructions. Shop drawings shall also contain complete wiring and schematic diagrams, software descriptions, calculations, and any other details required to demonstrate that the system has been coordinated and will properly function as a system. Terminal identification for all control wiring shall be shown on the shop drawings. An "as is" complete written Sequence of Operation will be provided and is to be updated by the contractor and included with the submittal package.

B. Submittal shall also include a trunk cable schematic diagram depicting the Graphical User Interface (GUI) computer, control panel locations and a description of the communication type, media and protocol.

C. Submittal shall also include a complete point list of all connected points to the DDC system.

D. Contractor shall submit the names of two AX Certified Technicians that are direct employees.

1.12 QUALITY ASSURANCE

A. Fabrication, Programming and Installation Personnel Qualifications:
   1. Trained and experienced in the fabrication and installation of the materials and equipment.
   2. Knowledgeable of the design and the reviewed Shop Drawings.

B. Regulatory Agencies Requirements:
   1. All temperature control wiring shall comply with NEC.
   2. All pneumatic piping installation shall comply with all state and local codes and ordinances.
   3. All smoke detectors shall bear the UL label and be FM approved.
   4. All components used for smoke control shall comply with UL864.
   5. All DDC I/O Devices (Specified and Future):
      b. Furnished with EIA (Electronic Industries Association) interface hardware.
   6. All instrumentation hardware shall be ISA (Instrument Society of America) compatible.
   7. All primary components of DDC hardware shall be UL listed (UL916).
   8. Installation shall comply with FCC (Federal Communications Commission) rules for Class A and Class B computing devices pursuant to Subpart J of Part 15.
   9. ASHRAE Standard 135, BACnet/IP.
   10. Network wiring shall comply with EIA/TIA Standards.
   11. ULC; UL - Canadian Standards Association.
1.13 **OWNERSHIP OF PROPRIETARY MATERIAL**

A. The Owner shall retain all rights to software for this project.

B. The Owner shall sign a copy of the Manufacturer’s standard software and firmware licensing agreement as a condition of this Contract. Such license shall grant use of all programs and application software to the Owner as defined by the Manufacturer’s license agreement, but shall protect the Manufacturer’s rights to disclosure of trade secrets contained within such software.

C. The licensing agreement shall not preclude the use of the software by individuals under contract to the Owner for commissioning, servicing or altering the system in the future. Use of the software by individuals under contract to the Owner shall be restricted to use only for the purpose of commissioning, servicing or altering the installed system.

D. All project developed software, files and documentation shall become the property of the Owner. These include but are not limited to:
   1. Server and workstation software.
   2. Application programming tools.
   3. Configuration tools.
   4. Addressing tools.
   5. Application files.
   6. Configuration files.
   7. Graphic files.
   9. Graphic symbol libraries.
  10. All documentation.

**PART 2 - PRODUCTS**

2.1 **GENERAL**

A. The Facility Management Control System (FMCS) shall be comprised of a network of interoperable, stand-alone digital controllers, a computer system, graphical user interface software, portable operator terminals, printers, network devices and other devices as specified herein. All controllers and software within FMCS shall be supported by compliance documentation from the manufacturer.

B. The installed system shall provide secure password access to all features, functions and data contained in the overall FMCS.

2.2 **OPEN, INTEROPERABLE, INTEGRATED ARCHITECTURES**

A. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate both the ANSI/ASHRAE Standard 135-1995 BACnet and BACnet technology communication protocols in one open, interoperable system.

B. The supplied computer software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. In addition, adherence to industry standards including ANSI/ASHRAE Standard 135-1995, BACnet required to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a PICS document showing the installed device’s compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet.

C. All components and controllers supplied under this contract shall be true “peer-to-peer” communicating devices. Components or controllers requiring “polling” by a host to pass data shall not be acceptable.
D. The supplied system must incorporate the ability to access all data using Java enabled browsers without requiring proprietary operator interface and configuration programs. 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.

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

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

2.3 NETWORKS

A. The Local Area Network (LAN) shall be either a 10 or 100 Megabits/sec Ethernet network supporting BACnet.

2.4 NETWORK ACCESS

A. Communicate with existing building management system.

2.5 NETWORK AREA CONTROLLER (NAC)

A. The Network Area Controller (NAC) 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 NAC. It shall be capable of executing application control programs to provide:

1. Calendar functions.
2. Scheduling.
3. Trending.
5. Time synchronization.
6. Integration of BACnet controller data.
7. Network Management functions for all BACnet based devices.

B. The Network Area Controller must provide the following hardware features as a minimum:

1. One Ethernet Port -10 / 100 Mbps.
2. One RS-232 port.
3. BACnet Interface Port - 78KB FTT-10A.
4. Battery Backup.
5. Flash memory for long term data backup (If battery backup or flash memory is not supplied, the controller must contain a hard disk with at least 1 gigabyte storage capacity).
6. The NAC must be capable of operation over a temperature range of 0 to 55 degrees C.
7. The NAC must be capable of withstanding storage temperatures of between 0 and 70 degrees C.
8. The NAC must be capable of operation over a humidity range of 5 to 95% RH, non-condensing.

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

D. The NAC shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 16 simultaneous users.

E. Event Alarm Notification and Actions:

1. The NAC shall provide alarm recognition, storage; routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers.
2. The NAC 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.
3. 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.
4. Provide for the creation of an unlimited number of alarm classes for the purpose of routing types and or classes of alarms, i.e.: security, HVAC, Fire, etc.
5. Provide timed (schedule) routing of alarms by class, object, group, or node.
6. 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.

F. Control equipment and network failures shall be treated as alarms and annunciated.

G. Alarms shall be annunciated in any of the following manners as defined by the user:
   1. Screen message text.
   2. Email of the complete alarm message to multiple recipients. Provide the ability to route and email alarms based on:
      a. Day of week.
      b. Time of day.
      c. Recipient.
   3. Pagers via paging services that initiate a page on receipt of email message.
   4. Graphic with flashing alarm object(s).
   5. Printed message, routed directly to a dedicated alarm printer.

H. The following shall be recorded by the NAC for each alarm (at a minimum):
   1. Time and date.
   2. Location (building, floor, zone, office number, etc.).
   3. Equipment (air handler #, accessway, etc.).
   4. Acknowledge time, date, and user who issued acknowledgement.
   5. Number of occurrences since last acknowledgement.

I. Alarm actions may be initiated by user defined programmable objects created for that purpose.

J. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user.

K. A log of all alarms shall be maintained by the NAC and/or a server (if configured in the system) and shall be available for review by the user.

L. Provide a "query" feature to allow review of specific alarms by user defined parameters.

M. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.

N. An Error Log to record invalid property changes or commands shall be provided and available for review by the user.

2.6 DATA COLLECTION AND STORAGE

A. The NAC 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 NAC 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 NAC and the data shall be accessed from a server (if the system is so configured) or a standard Web Browser.

D. All log data, when accessed from a server, shall be capable of being manipulated using standard SQL statements.

E. 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.

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

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

2.7 AUDIT LOG
A. Provide and maintain an Audit Log that tracks all activities performed on the NAC. 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 the user-defined buffer size. Provide the ability to archive the log locally (to the NAC), to another NAC 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.

2.8 DATABASE BACKUP AND STORAGE
A. The NAC shall have the ability to automatically backup its database. The database shall be backed up based on a user-defined time interval.

B. Copies of the current database and, at the most recently saved database shall be stored in the NAC. The age of the most recently saved database is dependent on the user-defined database save interval.

C. The NAC 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.

D. Controls shall be microprocessor based Interoperable BACnet Controllers.

E. HVAC control shall be accomplished using BACnet based devices. For each device that does not have BACnet certification, the device supplier must provide an XIF file for the device. Publicly available specifications for the Applications Programming Interface (API) must be provided for each BACnet controller defining the programming or setup of each device. All programming, documentation and programming tools necessary to set up and configure the supplied devices per the specified sequences of operation shall be provided.
F. The BACnet network trunk shall be run to the nearest Network Area Controller (NAC). A maximum of 126 devices may occupy any one BACnet trunk and must be installed using the appropriate trunk termination device. All BACnet and devices must be supplied using FTT-10A BACnet communications transceivers.

G. The Network Area Controller will provide all scheduling, alarming, trending, and network management for the BACnet based devices.

H. The IDCs shall communicate with the NAC at a baud rate of not less than 78.8K baud. The IDC shall provide LED indication of communication and controller performance to the technician, without cover removal.

I. All IDCs shall be fully application programmable and shall at all times maintain their BACnet certification. Controllers offering application selection only (non-programmable), require a 10% spare point capacity to be provided for all applications. All control sequences within or programmed into the IDC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.

J. The supplier of any programmable IDC shall provide one copy of the manufacturer's programming tool, with documentation, to the Owner.

2.9 INTEROPERABLE BACnet CONTROLLER (IBC)

A. Controls shall be microprocessor based Interoperable BACnet Controllers (IBC) in accordance with the ANSI/ASHRAE Standard 135-2012. IBCs shall be provided for Unit Ventilators, Fan Coils, Heat Pumps, 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. The system supplier must provide a PICS document showing the installed systems compliance level to the ANSI/ASHRAE Standard 135-2012. Minimum compliance is Level 3.

B. The IBCs shall communicate with the NAC via an Ethernet connection at a baud rate of not less than 10 Mbps.

C. The IBC Sensor shall connect directly to the IBC and shall not utilize any of the I/O points of the controller. The IBC Sensor shall provide a two-wire connection to the controller that is polarity and wire type insensitive. The IBC Sensor shall provide a communications jack for connection to the BACnet communication trunk to which the IBC controller is connected. The IBC Sensor, the connected controller, and all other devices on the BACnet bus shall be accessible by the POT.

D. All IBCs shall be fully application programmable and shall at all times maintain their BACnet Level 3 compliance. Controllers offering application selection only (non-programmable), require a 10% spare point capacity to be provided for all applications. All control sequences within or programmed into the IBC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.

2.10 GRAPHICAL USER INTERFACE SOFTWARE

A. Operating System: The GUI shall run on Microsoft Windows NT Workstation 4.0, Service Pack 4 or later.

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

C. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:
   1. Graphic screens shall be developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.
   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 other graphic screens.
3. Graphics shall support layering and each graphic object shall be configurable for assignment to a layer. A minimum of six layers shall be supported.

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.

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

E. 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.

F. 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.

G. 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.

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

2.11 SERVER FUNCTIONS AND HARDWARE

A. A central server is located at Michigan Tech's Central Energy Plant. The server supports all Network Area Controllers (NAC) connected to the customer's network whether local or remote.

B. Local connections shall be via an Ethernet LAN. Remote connections can be via ISDN, ADSL, T1 or dial-up connection.
C. It shall be possible to provide access to all Network Area Controllers via a single connection to the server. In this configuration, each Network Area Controller can be accessed from the Graphical User Interface (GUI) or from a standard Web browser (WBI) by connecting to the server.

D. The server shall provide the following functions, at a minimum:
   1. Global Data Access: The server shall provide complete access to distributed data defined anywhere in the system.
   2. Distributed Control: The server shall provide the ability to execute global control strategies based on control and data objects in any NAC in the network, local or remote.
   3. The server shall include a master clock service for its subsystems and provide time synchronization for all Network Area Controllers (NAC).
   4. The server shall accept time synchronization messages from trusted precision Atomic Clock Internet sites and update its master clock based on this data.
   5. The server shall provide scheduling for all Network Area Controllers and their underlying field control devices.
   6. The server shall provide demand limiting that operates across all Network Area Controllers. The server must be capable of multiple demand programs for sites with multiple meters and or multiple sources of energy. Each demand program shall be capable of supporting separate demand shed lists for effective demand control.
   7. The server shall implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of all commands issued to Network Area Controllers. Systems not employing this prioritization shall not be accepted.
   8. Each Network Area Controller supported by the server shall have the ability to archive its log data, alarm data and database to the server, automatically. Archiving options shall be user-defined including archive time and archive frequency.
   9. The server shall provide central alarm management for all Network Area Controllers supported by the server. Alarm management shall include:
      a. Routing of alarms to display, printer, email and pagers.
      b. View and acknowledge of alarms.
      c. Query alarm logs based on user-defined parameters.
   10. The server shall provide central management of log data for all Network Area Controllers supported by the server. Log data shall include process logs, runtime and event counter logs, audit logs and error logs. Log data management shall include:
       a. Viewing and printing log data.
       b. Exporting log data to other software applications.
       c. Query log data based on user-defined parameters.

E. Server Hardware Requirements: The server hardware platform shall have the following requirements:
   1. The computer shall be an Intel Pentium based computer (minimum processing speed of 400 MHz with 256 MB RAM and a 10-gigabyte minimum hard drive). It shall include a 32X CD-ROM drive, 3.5-inch floppy drive, a 100 MB Zip drive, 2-parallel ports, 2-asyncronous serial ports and 2-USB ports. A minimum 17-inch, 28-dot pitch SVGA (1024 x 768) color monitor with a minimum 80 Hz refresh rate shall also be included.
   2. The server operating system shall be Microsoft Windows NT Workstation 4.0, with Service Pack 4 or higher. Include Microsoft Internet Explorer 4.0 or later or Netscape Navigator 4.5 or later.
   3. Connection to the FMCS network shall be via an Ethernet network interface card, 10 or 100 Mbps.
   4. A system printer shall be provided. Printer shall be laser type with a minimum 600 x 600-dpi resolution and rated for 8-PPM print speed minimum.
   5. For dedicated alarm printing, provide a dot matrix printer, either 80 or 132 column width. The printer shall have a parallel port interface.

2.12 SYSTEM PROGRAMMING

A. The Graphical User Interface software (GUI) shall provide the ability to perform system programming and graphic display engineering as part of a complete software package. Access to the programming functions and features of the GUI shall be through password access as assigned by the system administrator.
B. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. 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 display shall not be acceptable.

C. Programming Methods:
1. 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.
2. 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.
3. The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real time for easy diagnosis of the logic execution. When 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.
4. All programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects shall not be allowed.
5. 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.

2.13 BACnet NETWORK MANAGEMENT

A. The Graphical User Interface software (GUI) shall provide a complete set of integrated BACnet network management tools for working with BACnet 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. These tools shall also be capable of defining network data connections between BACnet devices, known as "binding". Systems requiring the use of third party BACnet network management tools shall not be accepted.

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

C. 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.

D. These tools shall provide the ability to "learn" an existing BACnet network, 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.

E. The network management database shall be resident in the Network Area Controller (NAC), ensuring that anyone 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.

2.14 OBJECT LIBRARIES

A. A standard library of objects shall be included for development and setup of application logic, user interface displays, system services, and communication networks.
B. 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.

C. 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.

D. All control objects shall conform to the control objects specified in the BACnet specification.

E. 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.

6. Demand Limiting Object. Provide a comprehensive demand-limiting object that is capable of controlling demand for any selected energy utility (electric, oil, and gas). The object shall provide the capability of monitoring a demand value and predicting (by use of a sliding window prediction algorithm) the demand at the end of the user defined interval period (1-60 minutes). This object shall also accommodate a utility meter time sync pulse for fixed interval demand control. Upon a prediction that will exceed the user defined demand limit (supply a minimum of 6 per day), the demand limiting object shall issue shed commands to either turn off user specified loads or modify equipment set points to effect the desired energy reduction. If the list of sheddable equipment is not enough to reduce the demand to below the set point, a message shall be displayed on the users screen (as an alarm) instructing the user to take manual actions to maintain the desired demand. The shed lists are specified by the user and shall be selectable to be shed in either a fixed or rotating order to control which equipment is shed the most often. Upon suitable reductions in demand, the demand-limiting object shall restore the equipment that was shed in the reverse order in which it was shed. Each sheddable object shall have a minimum and maximum shed time property to effect both equipment protection and occupant comfort.

F. 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.

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. This object must also include the capability to record equipment run-time by counting the amount of time the hardware input is in an "on" condition. The user must be able to specify either input condition as the "on" condition.
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 interstart 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. 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.

6. 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. Also, allow limits to be applied to the output value for alarm generation.

7. 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.

8. 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 simple BASIC-like 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.

9. 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.

10. Temperature Override Object - Provide an object whose purpose is to provide the capability of overriding a binary output to an "On" state in the event a user specified high or low limit value is exceeded. This object is to be linked to the desired binary output object as well as to an analog object for temperature monitoring, to cause the override to be enabled. This object will execute a Start command at the Temperature Override level of start/stop command priority unless changed by the user.

11. Composite Object - Provide a container object that allows a collection of objects representing an application to be encapsulated to protect the application from tampering, or to more easily represent large applications. This object must have the ability to allow the user to select the appropriate parameters of the "contained" application that are represented on the graphical shell of this container.

G. The object library shall include objects to support the integration of devices connected to the Network Area Controller (NAC). At a minimum, provide the following as part of the standard library included with the programming software:

1. BACnet devices. These devices shall include, but not be limited to, devices for control of HVAC, lighting, access, and metering.

2. For BACnet devices, provide the following objects at a minimum:
   a. BACnet AI.
   b. BACnet AO.
   c. BACnet BI.
   d. BACnet BO.
   e. BACnet Device.

3. For each BACnet object, provide the ability to assign the object to a BACnet device and object's instance number.

2.15 DDE DEVICE INTEGRATION

A. The Network Area Controller shall support the integration of device data via Dynamic Data Exchange (DDE), over the Ethernet Network. The Network Area Controller shall act as a DDE client to another software application that functions as a DDE server.
B. Provide the required objects in the library, included with the Graphical User Interface programming software, to support the integration of these devices into the FMCS. Objects provided shall include at a minimum:
1. DDE Generic AI Object.
2. DDE Generic AO Object.
3. DDE Generic BO Object.
4. DDE Generic BI Object.

2.16 ELECTRICAL DEVICES AND WIRING

A. Comply with all local codes and applicable Sections in Division 26 of these Specifications.

B. Low Voltage Wiring (24V or Less):
1. Installed in a ceiling plenum used for return air shall be plenum rated wire securely fastened in accordance with the requirements of Division 26.
2. Exposed wiring shall be installed in accordance with the requirements of Division 26.

C. Approved Manufacturers:
1. Honeywell.
2. Siemens.
3. Allen-Bradley.
4. GE.
5. Square D.

D. Limit Switches: Limit switches shall be oil tight type with appropriate operator to provide required function. Limit switches used on dampers should be set at approximately 75% of full stroke.

E. Control Relays and Contactors:
1. Relays shall be a minimum DPDT, of proper coil voltage, with indicator light, and of sufficient rating for specified purpose. Relay base shall be of the screwed terminal type.
2. Contactors shall be definite purpose type, have adequate number of poles, of proper coil voltage, and of sufficient rating for specified purpose.

F. Selector Switches:
1. Switches shall be multiple position type, oil-tight, watertight, dust-tight, have the adequate number of contact blocks, capable of additional contact blocks, and of sufficient rating for specified purpose.
2. Nomenclature plate shall be provided with appropriate wording, units, etc.

G. Push Buttons and Pilot Lights:
1. Push button switches and pilot lights shall be, oil-tight, watertight, dust-tight, have the adequate number of contact blocks, capable of additional contact blocks, and of sufficient rating for specified purpose.
2. Nomenclature plate shall be provided with appropriate wording, units, etc.
3. Pilot lights shall be LED, push-to-test type with replaceable lamps and lens. Lens shall be of the appropriate color for application served.

H. Environment:
1. All devices shall be of the correct NEMA rating for the environment in which it is installed.
2. Refer to Electrical Drawings for area classifications.

I. Current Sensitive Switches: Solid state, split core current switch that operates when the current level (sensed by the internal current transformer) exceeds the adjustable trip point. Current switch to include an integral LED for indication of trip condition and a current level below trip set point.

2.17 ELECTRIC INSTRUMENTS

A. Thermistor Temperature Sensors and Transmitters:
1. Accuracy: ±0.5 degrees F (0.3 degrees C) at calibration point.
2. Wire: Twisted, shielded pair cable.
3. Insertion Elements in Ducts: Single point, 8 inches (200 mm) long; use where not affected by temperature stratification or where ducts are smaller than 9 sf (0.84 sq. m).
4. Averaging Elements in Ducts: 36 inches (915 mm) long, flexible long, flexible, rigid; use where prone to temperature stratification or where ducts are larger than 10 sq. ft. (1 sq. m).
5. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches (64 mm).
6. Wall Mount Room Thermostats: Each room thermostat shall provide temperature indication to the digital controller, provide the capability for a software-limited set point adjustment and operation override capability. An integral LCD shall annunciate current room temperature and set point as well as override status indication. In addition, the thermostat shall include a port for connection of the portable operator's terminal described elsewhere in this specification.
7. Outside Air Sensors: Watertight inlet fitting, shielded from direct sunlight. Provide vandal resistant enclosures where accessible to the public.

B. Low Temperature Detection:
1. Provide Electric Thermostat:
   a. With 20-foot sensing element installed in a serpentine manner across the coil face area.
   b. 2-position manual reset type with adjustable differential and of range to match the application.
2. Provide multiple thermostats wired in series as required to provide complete coil area coverage.
3. Shut down the unit supply fan upon detection of a low temperature along any 1-foot length of its sensing element.

C. Static Pressure Transducer:
1. Factory installed and wired in the control box.
2. The transducer shall have a range of 0 to 5-inch W.G. and shall have an accuracy of ±2% of the range, including nonlinearity and hysteresis.
3. The static pressure probe shall be field installed 2/3 down the duct or as indicated on the Drawings.

D. Differential Air Pressure Switch:
1. The differential air pressure switch shall be factory installed across the supply fan inlet and discharge and field wired to the fan relay.
2. The switch shall be SPDT and shall include a manual reset button.
3. The switch shall be factory set at 3.0-inch W.G. and shall have the ability of being field adjusted over a range of 1.4-inch to 6.0-inch W.G.

E. Relative Humidity Transmitter:
1. Polymer film capacitance change type.
2. Temperature compensated.
3. Accuracy: ± 2%.
4. Range: 0 - 100% relative humidity.
5. Ambient Temperature: 0 - 120 degrees F.
6. Output Signal: 4 to 20 mA or 0 to 10 VDC, as required.
7. Manufacturers:
   a. General Eastern Instruments Corporation.
   b. Vaisala, Inc.

F. Dew Point Transmitter:
1. Saturated salt lithium chloride type.
2. Accuracy: ±1 degree F.
3. Range: 12 to 99% relative humidity.
4. Ambient Temperature: -40 to 140 degrees F.
5. Input Power: 24 VDC or 115 VAC, as required.
6. Manufacturers:
   a. General Eastern Instruments Corporation.
   b. Vaisala, Inc.
G. Carbon Dioxide Sensor:
   1. Manufacturer and Model: Johnson Controls, CDS-2000-2; or approved equal.
   2. Description: Carbon dioxide sensor using non-dispersive infrared (NDIR) sensing technology to measure carbon dioxide and provide a 1-10 VDC output signal corresponding to 2-2000 parts per million (ppm) concentration of carbon dioxide.
   3. Components:
      a. Carbon dioxide sensor capable of measuring carbon dioxide concentration in air from 0-2000 ppm.
      b. 24V AC transformer to power carbon dioxide sensor.
      c. Supply air flow filter which inhibits sensing chamber contamination.
      d. 2 front-mount wiring terminal blocks.
   4. Performance Requirements:
      a. Accuracy: ±100 ppm carbon dioxide.
      b. Repeatability: ±20 ppm carbon dioxide.
      c. Drift: ±100 ppm carbon dioxide per year.
      d. Response Time: Less than, or equal to 30 seconds maximum.
      e. Airflow Rate: 500 milliliters per minute at 1.4 psi ±10% through 1/4-inch O.D. tubing.

H. Oxygen Sensor:
   1. Manufacturer and Model: Kele, OS-1; or approved equal.
   2. Description:
      a. 4-20 mA, 0-5VDC, 0-10 VDC output, jumper-selectable.
      b. SPDT alarm relay.
      c. 24VAC/VDC power.
      d. Galvanic cell sensing technology.
   3. Components:
      a. Oxygen sensor capable of measuring oxygen in air from 0% to 25% oxygen.
      b. 24V AC transformer to power oxygen sensor.
      c. Wiring terminal blocks.
      d. Enclosure for dust and moisture protection.
   4. Performance Requirements:
      a. Accuracy: +1%.
      b. Measurement Range: 0% to 25% oxygen.
      c. Response Time: 12 seconds.
      d. Ambient Temperature: 40 degrees F to 104 Degrees F.
      e. Ambient Humidity: 10% to 95% non-condensing.

2.18 GAGES

A. Comply with the requirements of Division 23 Section "Meters and Gages for HVAC Piping."

B. Air Pressure Gages:
   1. Provide 1-1/2-inch diameter gages at all input sensor lines, switch lines, branch side of each controller and at each controlled device.
   2. Stem or surface mounted as required.
   3. Compatible with tubing size.

C. Temperature, Humidity and Pressure Indicators:
   1. Dial type having a minimum diameter of 3-1/2 inches, adjustable calibration, and accuracy of ±1/4% of dial range.
   2. Thermometer ranges to match the range of the transmitter with which used.
   3. Furnish for all transmitters as described in the Functional Intent article of this Section.

D. Alternate Manufacturers: As listed in Division 23 Section "Meters and Gages for HVAC Piping."
2.19 AIRFLOW MEASURING STATIONS

A. Electronic Thermister Type:
   1. Manufacturer: Ebtron.
   2. Hermetically sealed bead in glass thermisters.
   3. 304 stainless steel mounting brackets.
   4. Plenum rated cabling.
   5. Accuracy: ±2% of reading at 0-5000 fpm.
   6. Repeatability: ±0.25% of reading.
   7. 16 character LED display.
   8. Fully temperature compensated.
   10. Interface with central building automation system.
   11. Device shall include necessary velocity treatment and flow straightening devices to achieve stated accuracy.

B. Provide as indicated on the Drawings.

2.20 AUTOMATIC CONTROL VALVES AND ACTUATORS

A. Furnish valves in accordance with the requirements of Division 23 Section “General Duty Valves for HVAC.”

B. Control Valve Actuators:
   1. Size to operate with sufficient reserve power to provide smooth modulating action or 2-position action.
   2. Close-off (differential) pressure rating.
   3. Hydronic Systems: Combination of actuator and trim shall provide minimum close-off pressure rating of 150% of total system (pump) head for 2-way valves and 100% of pressure differential across valve or 100% of total system (pump) head.
   4. Steam Systems: Combination of actuator and trim shall provide minimum close-off pressure rating of 150% of operating (inlet) pressure.
   5. Provide with neck extension on insulated service
   6. Pneumatic Valve Operators:
      a. Cast iron yoke with steel or cast aluminum bolted diaphragm enclosure.
      b. Buna N or Neoprene diaphragm designed for 30 psig maximum pressure.
      c. 3 to 14 psig input signal.
      d. Rolling neoprene diaphragm style, either normally open or normally closed as required.
      e. Pilot Positioner:
         1) Provide for:
            a) All valves 1-1/2 inches and larger.
            b) As required for proper sequencing.
            c) As indicated.
         2) Three-Pipe Relay Device With Position Indicator: 3 to 13 psig operating range.
   7. Electric Actuators and Motors:
      a. Manufacturers: Subject to compliance with the requirements, provide products by one of the following:
         1) Johnson.
         2) Honeywell.
         3) Belimo Aircontrols (USA), Inc.
         4) Siemens.
      b. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
      c. Serviceable and rebuildable.
      d. Coupling: V-bolt and V-shaped, toothed cradle.
      e. Overload Protection: Electronic overload or digital rotation-sensing circuitry.

2.21 AUTOMATIC CONTROL DAMPERS AND OPERATORS

A. Furnish dampers in accordance with the requirements of Division 23 Section “Dampers.”
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B. Damper Operators:
   1. General:
      a. Sized for ample power to overcome friction of damper linkage and air pressure acting on the blades.
      b. Capable of operating at varying rates of speed to correspond to the dictates of the controllers and variable load requirements.
      c. The operator linkage arrangement shall be such as to permit normally open or normally closed positions of the dampers as required.
   2. Electronic Damper Actuators:
      a. Direct coupled type designed for minimum 60,000 full stroke cycles at rated torque.
      b. Coupling: V-belt and V-shaped, toothed cradle.
      c. Overload Protection: Electronic overload or digital rotation sensing circuitry.
      d. Fail Safe Operation: Mechanical, spring return mechanism. Provide external, manual gear release on non-spring return actuators.
      e. Temperature Rating: -22 to +122 degrees F.

2.22 CONTROL PANELS

   A. Temperature Control Panels: Furnish temperature control panels of code gauge steel with locking doors for mounting all devices as shown. Control panels shall meet all requirements of Title 24, California Administrative Code. All electrical devices within a control panel shall be factory wired. All external wiring shall be connected to terminal strips mounted within the panel. Provide engraved phenolic nameplates identifying all devices mounted on the face of control panels. A complete set of 'as-built' control drawings (relating to the controls within that panel) shall be furnished within each control panel.

PART 3 - EXECUTION

3.1 INSTALLATION

   A. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the temperature control system manufacturer or its exclusive factory authorized installing contracting field office or authorized manufacturer representative. The installing office shall have a minimum of five years of installation experience with the manufacturer and shall provide documentation in submittal package verifying longevity of the installing company's relationship with the manufacturer. Supervision, calibration and checkout of the system shall be by the employees of the local exclusive factory authorized temperature control contracting field office (branch or representative).

   B. Install system and materials in accordance with manufacturer's instructions, and as detailed on the project drawing set.

   C. Drawings of temperature control systems are diagrammatic only and any apparatus not shown, such as relays, accessories, etc., but required to make the system operative to the complete satisfaction of the Architect shall be furnished and installed without additional cost.

   D. Line and low voltage electrical connections to control equipment shown specified or shown on the control diagrams shall be furnished and installed by the Temperature Control sub-contractor in accordance with these specifications.

   E. Equipment furnished by the HVAC Contractor that is normally wired before installation shall be furnished completely wired. Control wiring normally performed in the field will be furnished and installed by the Temperature Control sub-contractor.

   F. All control devices mounted on the face of control panels shall be clearly identified as to function and system served with permanently engraved phenolic labels.

3.2 WIRING

/1
A. All electrical control wiring and power wiring to the control panels shall be the responsibility of the FMCS contractor.

B. All electrical power connections shall be made by qualified electricians.

C. All wiring shall be in accordance with the National Electrical Code and any applicable local codes. All FMCS wiring shall be installed in the conduit types specified in the National Electrical Code or applicable local codes. Where FMCS plenum rated cable wiring is allowed it shall be run parallel to or at right angles to the structure, properly supported and installed in a neat and workmanlike manner.

3.3 WARRANTY

A. Equipment, materials and workmanship incorporated into the work shall be warranted for a period of one year from the time of system acceptance.

B. Within this period, upon notice by the Owner, any defects in the FMCS due to faulty materials, methods of installation or workmanship shall be promptly (within 48 hours after receipt of notice) repaired or replaced by the Temperature Control sub-contractor at no expense to the Owner.

3.4 WARRANTY ACCESS

A. The Owner shall grant to the Temperature Control sub-contractor, reasonable access to the FMCS during the warranty period. The Owner shall allow the contractor to access the FMCS from a remote location for the purpose of diagnostics and troubleshooting, via the Internet, during the warranty period.

3.5 ACCEPTANCE TESTING

A. Upon completion of the installation, the Temperature Control sub-contractor shall load all system software and start-up the system. The Temperature Control sub-contractor shall perform all necessary calibration, testing and de-bugging and perform all required operational checks to insure that the system is functioning in full accordance with these specifications.

B. The Temperature Control sub-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 DDC system operation.

C. Upon completion of the performance tests described above, repeat these tests, point by point as described in the validation log above in 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.

D. System Acceptance: Satisfactory completion is when the Temperature Control sub-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 OPERATOR INSTRUCTION, TRAINING

A. During system commissioning and at such time acceptable performance of the FMCS hardware and software has been established the Temperature Control sub-contractor shall provide on-site operator instruction to the Owner's operating personnel. Operator instruction shall be done during normal working hours and shall be performed by a competent representative familiar with the system hardware, software and accessories.

B. The Temperature Control sub-contractor shall provide 40 hours of instruction to the Owner's designated personnel on the operation of the FMCS and describe its intended use with respect to the programmed functions specified. Operator orientation of the FMCS shall include, but not be limited to; the overall operation program, equipment functions (both individually and as part of the total integrated system), commands,
systems generation, advisories, and appropriate operator intervention required in responding to the System's operation.

C. The training shall be in three sessions as follows:
   1. Initial Training: One day session (8 hours) after system is started up and at least one week before first acceptance test. Manual shall have been submitted at least two weeks prior to training so that the Owners' personnel can start to familiarize themselves with the system before classroom instruction begins.
   2. First Follow-Up Training: Two days (16 hours total) approximately two weeks after initial training, and before Formal Acceptance. These sessions will deal with more advanced topics and answer questions.
   3. Warranty Follow Up: Two days (16 hours total) in no less than 4 hour increments, to be scheduled at the request of the Owner during the one year warranty period. These sessions shall cover topics as requested by the Owner such as; how to add additional points, create and gather data for trends, graphic screen generation or modification of control routines.

END OF SECTION 23 09 00