SECTION 23 09 00 – CONTROL SYSTEMS (UMKC)

1.   GENERAL

1.1   RELATED DOCUMENTS

A.   The work of this Division shall be scheduled, coordinated, and interfaced with the associated work of other trades. Reference the Division 21, 22, 23 Sections for details.

B.   The work of this Division shall be as required by the Specifications, Point Schedules and Drawings.

C.   If the EMCS Contractor believes there are conflicts or missing information in the project documents, the Contractor shall promptly request clarification and instruction from the design team.

1.2   DEFINITIONS

A.   Analog: A continuously variable system or value not having discrete levels. Typically exists within a defined range of limiting values.

B.   Binary: A two-state system where an "ON" condition is represented by one discrete signal level and an "OFF" condition is represented by a second discrete signal level.

C.   Building Automation & Control System (EMCS): The total integrated system of fully operational and functional elements, including equipment, software, programming, and associated materials, to be provided by this Division EMCS Contractor and to be interfaced to the associated work of other related trades.

D.   EMCS Contractor: The EMCS Contractor to provide the work of this Division. This Contractor shall be the primary licensed dealer, installer, commissioner and ongoing service provider for the EMCS work.

E.   Control Sequence: An EMCS pre-programmed arrangement of software algorithms, logical computation, target values and limits as required to attain the defined operational control objectives.

F.   Direct Digital Control: The digital algorithms and pre-defined arrangements included in the EMCS software to provide direct closed-loop control for the designated equipment and controlled variables. Inclusive of Proportional, Derivative and Integral control algorithms together with target values, limits, logical functions, arithmetic functions, constant values, timing considerations and the like.

G.   EMCS Network: The total digital on-line real-time interconnected configuration of EMCS digital processing units, workstations, panels, sub-panels, controllers, devices and associated elements individually known as network nodes. May exist as one or more fully interfaced and integrated sub-networks, LAN, WAN or the like.

H.   EMCS Integration: The complete functional and operational interconnection and interfacing of all EMCS work elements and nodes in compliance with all applicable codes, standards and ordinances so as to provide a single coherent EMCS as required by this Division.

I.   Provide: The term "Provide" and its derivatives when used in this Division shall mean to furnish, install in place, connect, calibrate, test, commission, warrant, document and supply the associated required services ready for operation.

J.   Furnish: The term "Furnish" and its derivatives when used in this Division shall mean supply at the EMCS Contractor's cost to the designated third party trade contractor for installation. EMCS Contractor shall connect furnished items to the EMCS, calibrate, test, commission, warrant and document.

K.   Wiring: The term "Wiring" and its derivatives when used in this Division shall mean provide the EMCS wiring and terminations.

L.   Install: The term "Install" and its derivatives when used in this Division shall mean receive at the jobsite and mount.

M.   Owner: The term "Owner" shall refer to the University of Missouri.

N.   Protocol: The term "protocol" and its derivatives when used in this Division shall mean a defined set of rules and standards governing the on-line exchange of data between EMCS network nodes.

O.   Software: The term "software" and its derivatives when used in this Division shall mean all of programmed digital processor software, preprogrammed firmware and project specific digital process programming and database entries and definitions as generally understood in the EMCS industry for real-time, on-line, integrated EMCS configurations.

P.   University: The Term "University" shall mean the Curators of the University of Missouri, or any of its campuses individually.

Q.   The use of words in the singular in these Division documents shall not be considered as limiting when other indications in these documents denote that more than one such item is being referenced.

R.   Headings, paragraph numbers, titles, shading, bolding, underscores, clouds and other symbolic interpretation aids included in the Division documents are for general information only and are to assist in the reading and interpretation of these Documents.

S.   The following abbreviations and acronyms may be used in describing the work of this Division:

        1.   ADC   -   Analog to Digital Converter
        2.   AI   -   Analog Input
        3.   AN   -   Application Node
        4.   ANSI   -   American National Standards Institute
        5.   AO   -   Analog Output
        6.   ASCII   -   American Standard Code for Information Interchange
        7.   ASHRAE -   American Society of Heating, Refrigeration and Air Conditioning Engineers
        8.   AWG   -   American Wire Gauge
        9.   CPU   -   Central Processing Unit
        10. CRT   -   Cathode Ray Tube
        11. DAC   -   Digital to Analog Converter
        12. DDC   -   Direct Digital Control
        13. DI   -   Digital Input

14.	DO	-	Digital Output
15.	EEPROM	-	Electronically Erasable Programmable Read Only Memory
16.	EMI	-	Electromagnetic Interference
17.	FAS	-	Fire Alarm Detection and Annunciation System
18.	GUI	-	Graphical User Interface
19.	HOA	-	Hand-Off-Auto
20.	ID	-	Identification
21.	IEEE	-	Institute of Electrical and Electronics Engineers
22.	I/O	-	Input/Output
23.	LAN	-	Local Area Network
24.	LCD	-	Liquid Crystal Display
25.	LED	-	Light Emitting Diode
26.	MCC	-	Motor Control Center
27.	NC	-	Normally Closed
28.	NIC	-	Not In Contract
29.	NO	-	Normally Open
30.	OWS	-	Operator Workstation
31.	OAT	-	Outdoor Air Temperature
32.	PC	-	Personal Computer
33.	RAM	-	Random Access Memory
34.	RF	-	Radio Frequency
35.	RFI	-	Radio Frequency Interference
36.	RH	-	Relative Humidity
37.	ROM	-	Read Only Memory
38.	RTD	-	Resistance Temperature Device
39.	SPDT	-	Single Pole Double Throw
40.	SPST	-	Single Pole Single Throw
41.	XVGA	-	Extended Video Graphics Adapter
42.	TBA	-	To Be Advised
43.	TCP/IP	-	Transmission Control Protocol/Internet Protocol
44.	TTD	-	Thermistor Temperature Device
45.	UMKC	-	University of Missouri-Kansas City
46.	UPS	-	Uninterruptible Power Supply
47.	VAC	-	Volts, Alternating Current
48.	VAV	-	Variable Air Volume
49.	VDC	-	Volts, Direct Current
50.	WAN	-	Wide Area Network

1.3   PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION EXCEPT FOR RETROFIT CONTROL PROJECTS.

  A.   Hydronic Piping:

  1.   Control valves
  2.   Flow switches
  3.   Pressure and temperature sensor wells and sockets
  4.   Flow meters and switches

  B.   Ductwork Accessories:

  1.   Automatic dampers
  2.   Airflow stations

3. Terminal unit controls

1.4 EMCS DESCRIPTION

A. Furnish all labor, materials, equipment, and service necessary for a complete and operating temperature control system, utilizing a high- speed, peer-to-peer network of Direct Digital Controls (DDC). For retrofit projects, the new controls shall replace all existing versions of the Honeywell Campus Building Automation system. Provide all control system hardware including, routers, repeaters, and electronic interfaces and actuation devices, as shown on the drawings and as described herein. Graphics for new work is to be added to the campus operator workstations.

B. Provide monitoring and control of chillers, boilers, packaged mechanical equipment, variable frequency drives, fuel oil systems, low voltage lighting systems, electrical circuit breaker panels, utility metering, as shown on drawings, and described herein.

1.5 APPROVED SOFTWARE

A. WebCTRL

1.6 CODES AND STANDARDS

A. All work, materials, and equipment shall comply with the adopted codes of the University of Missouri listed on the drawings. Such codes, when more restrictive, shall take precedence over these drawings and specifications.

1.7 SUBMITTALS

A. Product data and shop drawings: Contractor shall provide shop drawings or other submittals on all hardware, software, and installation to be provided. [6] copies are required. All drawings shall be prepared with AutoCAD and be provided via a digital means and a full-size 11" x 17" set of drawings. Each submitted piece of literature and drawings shall clearly reference the specification and drawing that the submittal is to cover.

B. Project record documents: Upon completion of installation, submit [3] copies of 11x17 record as-built documents along with a digital copy, Contractor shall place one set of the hard copy as-builts neatly in the applicable control panel for each location. The other hard copies shall be provided to the University campus management staff for the documents of record. Documents shall be submitted for approval prior to final completion. Training Courses and Training Manuals - beginning through advance training courses shall be provided to the University staff in-person, or on-line, prior to and for up to one-year following any EMCS projects, or upon request by University at a schedule agreed upon by both Contractor and the University campus management, or campus representative. Contractor shall provide a course outline and training manuals for all training classes prior to all training events.

1.8 RECORD DOCUMENTATION

A. Operation and Maintenance Manuals

1. Three (3) copies of the Operation and Maintenance Manuals shall be provided to the Owner's Representative upon completion of the project. The entire Operation and

Maintenance Manual shall be furnished on Compact Disc media, and include the following for the EMCS provided:

    a.   Table of contents.
    b.   As-built system record drawings. Computer Aided Drawings (CAD) record drawings shall represent the as-built condition of the system and incorporate all information supplied with the approved submittal.
    c.   Manufacturers product data sheets or catalog pages for all products including software.
    d.   System Operator's manuals.
    e.   Archive copy of all site-specific databases and sequences.
    f.   EMCS network diagrams.
    g.   Interfaces to all third-party products and work by other trades.

2.   The Operation and Maintenance Manual CD shall be self-contained, and include all necessary software required to access the product data sheets. A logically organized table of contents shall provide dynamic links to view and print all product data sheets. Viewer software shall provide the ability to display, zoom, and search all documents.

1.9   WARRANTY & PROPRIETARY MATERIAL:

A.   Warrant all work as follows:

1.   Labor and materials for the control system specified shall be warranted free from defects for a period of 12 months after final completion and acceptance. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. The Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.

2.   All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up. At the end of the final start-up, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the Engineer, the Engineer shall sign certificates certifying that the control system's operation has been tested and accepted in accordance with the terms of this Specification. The contractor and engineer shall include UMKC Campus Facilities/HVAC Operations in verifying system operation. The date of acceptance shall be the start of warranty.

B.   Ownership of Proprietary Material

1.   Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

    a.   Graphics
    b.   Record drawings
    c.   Database
    d.   Application programming code
    a.   Documentation

1.10   QUALITY ASSURANCE

A.   General

1.   The Building Automation & Control System Contractor shall be a dealer authorized by the manufacturer and is regularly engaged in the engineering, programming, installation and service of total integrated Building Automation & Control Systems.

2. The EMCS Contractor shall be a recognized national manufacturer, authorized dealer, and installer and service provider of EMCS.
3. The EMCS Contractor shall have a branch facility within a 100-mile radius of the job site supplying complete maintenance and support services on a 24 hour, 7-day-a-week basis.
4. As evidence and assurance of the Contractor's ability to support the Owner's system with service and parts, the Contractor must have been in the EMCS business for at least the last ten (10) years and have successfully completed total projects of at least 10 times the value of this contract in each of the preceding five years.
5. The Building Automation & Control System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Automation & Control Systems and shall be the manufacturer's latest standard of design at the time of bid.

B. Workplace Safety And Hazardous Materials

1. Provide a safety program in compliance with the Contract Documents.
2. The EMCS Contractor shall have a corporately certified comprehensive Safety Certification Manual and a designated Safety Supervisor for the Project.
3. The Contractor and its employees and subtrades comply with federal, state and local safety regulations.
4. The Contractor shall ensure that all subcontractors and employees have written safety programs in place that covers their scope of work, and that their employees receive the training required by the OSHA have jurisdiction for at least each topic listed in the Safety Certification Manual.
5. Hazards created by the Contractor, or its subcontractors, shall be eliminated before any further work proceeds.
6. Hazards observed but not created by the Contractor or its subcontractors shall be reported to either the General Contractor or the Owner within the same day. The Contractor shall be required to avoid the hazard area until the hazard has been eliminated.
7. The Contractor shall sign and date a safety certification form prior to any work being performed, stating that the Contractors' company is in full compliance with the Project safety requirements.
8. The Contractor's safety program shall include written policy and arrangements for the handling, storage and management of all hazardous materials to be used in the work in compliance with the requirements of the AHJ at the Project site.
9. The Contractor's employees and subcontractor's staff shall have received training as applicable in the use of hazardous materials and shall govern their actions accordingly.

C. Quality Management Program

1. Designate a competent and experienced employee to provide EMCS Project Management. The designated Project Manager shall be empowered to make technical, scheduling and related decisions on behalf of the EMCS Contractor. At minimum, the Project Manager shall:

   a. Manage the scheduling of the work to ensure that adequate materials, labor and other resources are available as needed.
   b. Manage the financial aspects of the EMCS Contract.
   c. Coordinate as necessary with other trades.
   d. Be responsible for the work and actions of the EMCS workforce on site.

2. **PRODUCTS**

2.1   MATERIALS

      A.   All products used in this project installation shall be new and currently under manufacture.

2.2   COMMUNICATION

      A.   General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

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

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

      D.   System shall use the BACnet protocol for communication between the control modules and web server. Communication between the web server and the user's browser shall be HTTP or HTTPS protocol utilizing HTML5. Use of Adobe Flash technology is not acceptable.

2.3   OPERATORS INTERFACE

      A.   The web server shall reside on high-speed network with building controllers. Web pages generated by this server shall be compatible with the latest versions of Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).

      B.   Communication. Web server and controllers shall communicate using BACnet protocol, including BACnet/SC. Web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.

      C.   Hardware.

          1.   Web server and/or workstation. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The web server may also be configured in client/server fashion to accommodate a "workstation" definition. In "workstation" configuration, the workstation will also perform as a server supplying additional clients as needed. The following hardware requirements apply:

              a.   System storage shall have sufficient memory to accommodate:

                  1)   All required system software.
                  2)   A DDC database to accommodate, as a minimum, twice the size of the delivered system database.
                  3)   One year of archival trend data based on the points specified to be trended at their specified trend intervals.

b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.

c. Minimum hardware configuration shall include the following:

   1) Quad Core Processor
   2) 4-24 GB RAM (size dependent on size of system)
   3) 500 GB hard disk providing data at 3.0 Gb/sec (size dependent on historical data storage requirements)
   4) Gigabit Ethernet Network adapter
   5) 16x DVD+/-RW drive
   6) Qwerty Keyboard
   7) Optical Mouse
   8) 24-inch LED Color monitor with 75Hz refresh rate and 1080P resolution to provide a minimum screen resolution of 1920 x 1080 pixels.
   9) Serial (USB) and network communication ports, with cables as required for proper DDC system operation.

D. System Software.

1. Operating System. Web server shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the BMS manufacturer's minimum requirements for their software. The acceptable system is Microsoft Windows Server 2022.

2. Security. The web server application shall support Transport Layer Security (TLS) 1.3 capable of encryption of up to 256-bit elliptical curve for transmitting private information over the Internet using HTTPS. Additionally, the web server shall have SHA-2 certificate support capability.

3. Database. System shall support any JDBC (Java DataBase Connectivity) compliant engine. This includes - MS SQL, My SQL, Apache Derby, PostgreSQL and Oracle.

4. The BMS system shall allow an unlimited number of concurrent users.

5. The BMS manufacturer shall provide all software and tools necessary to provide the following capabilities:

   a. Create and/or edit any programming used in controllers
   b. Create and/or edit any graphics used in the system
   c. Software shall not be subscription based and be given to owner at time of turnover. If software is subscription based, manufacturer shall include 10 years of subscription service.
   d. The owner shall have the ability to install software on a minimum of five (5) additional owner furnished computers without additional licenses or fees.

6. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

   a. Minimum graphics resolution shall be 1920 x 1080 for display of detailed system graphics.
   b. Floor Plan Graphics. Floor plan graphics shall be capable of allowing the floor plan graphic to dynamically size relative to the end user's monitor resolution. The floor plan graphics shall show ductwork.
   c. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters. Graphics shall include a button that displays the

corresponding sequence of operation.

    d.   Animation. Graphics shall be able to animate by displaying different image files for changed object status.

    e.   Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.

    f.   Manual. Points moved from automation and placed in the manual setting shall be graphically represented using a color change alerting users to the change in conditions.

    g.   Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, GIF, or SVG. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in or shall only require widely available no-cost plug-ins.

7.   Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system used to create and modify graphics that are saved in the same formats as are used for system graphics.

8.   Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

E.   System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on a standard PC type personal computer with no limit on the number of copies that can be installed under the system license.

1.   Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

2.   Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.

3.   System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password.

4.   On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing 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.

5.   Video Training. Provide on-line video support to supplement on-line help assistance. Video content shall be relevant and support existing system documentation.

6.   Security. Each operator shall be required to log on to the system with username and password in order to view, edit, add, or delete data.

    a.   Operator Access. The username and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.

    b.   Password Policy Rules. System administrator shall invoke policies for minimum password strength, including number of characters, special characters and numbers, upper and lower case, etc.

    c.   Automatic Log Out. Automatically log out each operator if no keyboard or mouse

activity is detected. This auto logoff time period shall be user-adjustable.

    d.   Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

7.   System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.

8.   Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as

required by sequences of operation. Alarms shall be BACnet alarm objects and shall use BACnet alarm services. BMS system shall be capable of assigning alarm sources to categories such as HVAC Critical, or HVAC General. The BMS shall include at a minimum HVAC and FDD categories. BMS system shall allow user to create custom alarm categories.

9.   Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms or mnemonics. The message shall be sent to designated campus staff via email or text for critical alarms.

10.   Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send SMS text, and audibly annunciate.

11.   Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms and archive closed alarms to the workstation or web server hard disk.

12.   Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified by the sequences of operation. Trends shall be BACnet trend objects.

13.   Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.

14.   Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

15.   Audit and Security Detail. All users accessing the system shall have their actions recorded. Information recorded shall include:

    a.   Login/logout time and date
    b.   System modifications - with before and after values
    c.   Ability to report user activity based on individual and/or date and time.
    d.   Information shall be available for 365 days.

16.   Standard Reports. Furnish the following standard system reports:

    a.   Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
    b.   Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    c.   Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

        1)   Alarm History.
        2)   Trend Data. Operator shall be able to select trends to be logged.

17. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface. Operator shall be able to schedule reports to automatically run and be emailed to recipients on a recurring basis from the BMS system.

18. Logic Page. System shall allow operator to view all application software in real time for all controllers furnished and installed by BMS manufacturer.

19. Environmental Index. System shall monitor all occupied zones and compile an index that provides a numerical indication of the environmental comfort within the zone. As a minimum, this indication shall be based upon the deviation of the zone temperature from the heating or cooling setpoint. If humidity is being measured within the zone, then the environmental index shall be adjusted to reflect a lower comfort level for high or low humidity levels. Similarly, if carbon dioxide levels are being measured as an indication of ventilation effectiveness, then the environmental index shall be adjusted to indicate degraded comfort at high carbon dioxide levels. Other adjustments may be made to the environmental index based upon additional measurements. The system shall maintain a trend of the environmental index for each zone in the trend log. The system shall also compute an average comfort index for every building included in this contract and maintain trend logs of these building environmental indices. Similarly, the system shall compute the percentage of occupied time that comfortable conditions were maintained within the zones. Through the UI the user shall be able to add a weighting factor to adjust the contribution of each zone to the average index based upon the floor area of the zone, importance of the zone, or other static criteria.

20. Indoor Environmental Quality Index (IEQ)

    a. System shall monitor up to ten building conditions and compile an index that provides a numerical indication of the overall building environmental quality and health. A graphical dashboard indicating each measured building condition name, a description of each measured building condition, the current value of each measured building condition, and the overall building IEQ value. In addition, an historical trend graph of the IEQ Index and/or individual health components shall also be displayed The IEQ numerical value indication shall be 0-100 with 0 being the worst and 100 the best. The IEQ shall be calculated using an algorithm that aggregates all of the selected building conditions and allows the user to define the acceptable ranges for each monitored building condition. In addition, the user shall have the ability assign a weighting/importance factor to each building condition that determines the impact the monitored building condition has on the overall IEQ index calculation. The IEQ value graphical representation shall have the ability to display one of a minimum of four (4) colors based on the IEQ value and the user adjustable range for each color. The default IEQ ranges and colors shall be as follows:

        1) Less than 85 = Red
        2) 85 to 89.9 = Orange
        3) 90 to 94.9 = Yellow
        4) 95 to 100 = Green

    b. The system shall allow the user to select from one of the following ten building conditions:

        1) Temperature, average area
        2) Humidity, average area
        3) Carbon Dioxide, average area
        4) Volatile Organic Compounds, average area
        5) % Dirty Filters, % dirty filter switches
        6) % Occupied, of expected occupants
        7) Air Purifiers, Total counted purifiers
        8) % OA of Design, % Total OA cfm of buildings design

9)   CFM per Person, Average outside air flow per occupant

10)   % Time Above minimum, % of time outside air dampers are above the minimum when occupied (average of all)

21.   Time Span Graphic Replay. Operator shall be able to "replay" any graphic in the system to see how key values changed over an operator-selected period of time. Operator shall be able to select the starting date/time for this display and the end date/time or the display period. System shall then display the graphic as it would have looked at the beginning of that period, displaying key data, dynamic colors, etc. based upon values recorded at the start time. When the operator starts the replay the graphics and key values shall dynamically change to produce the effect of "fast forwarding" through the designated period of time. Once the system has been operational for at least 30 days, the Contractor shall demonstrate that up to 24 hours of data from within the last 30 days can be replayed on any graphic page. Owner's representative shall choose the graphic pages for this demonstration at the time of the demonstration.

22.   Semantic Tagging. The BMS system shall include a semantic tagging engine that uses the Project Haystack library of descriptive tagging for building equipment and systems used in the BMS. The Project Haystack naming tags used by the BMS shall be a library that includes a comprehensive list of standard tag names to address common equipment, building systems, and device types. The library of tag names shall include at a minimum the tag names listed in ASHRAE Standard 223P.

23.   Network Health Monitoring.

a.   The BAS shall allow for monitoring of the network system health through the use of a remote cloud-based analytics platform. The BAS vendor shall provide to the owner a baseline report of the building network health at project completion and then once again at the end of the warranty period. The health monitoring application provides insights into the health of the BAS system for system maintenance and usage. This application will provide at a minimum the following information for the BAS network:

1)   BAS Server
2)   Online status/availability
3)   CPU and memory usage
4)   JAVA Container Health: Memory usage patterns and allocation to overall server resources
5)   BACnet Controllers
6)   Memory usage: Controller flash and database utilization
7)   Critical errors: Controller and watchdog errors
8)   Network communications health: Transmit and receive patterns and identification of controllers that may be causing errors
9)   Network System Inventory
10)   BAS Server software version
11)   Controller driver versions
12)   Controller upgrade requirements

b.   At the completion of the warranty period, the owner shall have the option of continuing the remote network health monitoring service as part of an ongoing service contract negotiated with the BAS provider for an additional fee.

24.   Weather Data. The BMS system shall retrieve current weather conditions from a data source such as AccuWeather. This weather information shall be displayed on a graphic page and be capable for use in control logic.

25.   The Door Status Integration 17-01 (add-on). BMS shall integrate to Winpak with API v4.7 or higher to monitor and respond to door-related events by creating points that can be viewed on a graphic. System shall pull in the door status points and display colored buttons to represent and indicate status. Operator shall also be able to set up automatic log of door activities.

26.   Open ADR (add-on). Open Automated Demand Response interface shall be provided that allows electricity providers to communicate DR signals directly to the BMS. Software shall

fully support the OpenADR 2.0a and 2.0b and does not require any additional specialized hardware.

27. BACnet Scheduling Interface (add-on). The BMS system shall allow third-party devices to read and write schedules via the BACnet protocol. These exposed schedules to third- party BACnet devices are used to control when mechanical equipment runs. Resolves schedule issues with products like SchoolDude® - Operations Management Software.

28. Trend Export (add-on). The BMS shall allow user to specify, manage, and export trend source data to a .CSV file. User can export the files on-demand at any time or at scheduled intervals allowing user to process or analyze trend data outside of the building automation system. Up to two years of trend data can be exported.

29. HVAC Schedule Optimization (add-on). The BMS shall gather information from a Lenel® OnGuard® badge reader data system to track historical occupancy trend and then predict future facility occupancy levels. The system then shall automatically adjust zone and building schedules, optimizing energy usage and operational efficiency. System shall analyze each day type separately to account for daily differences, e.g. Monday vs Friday departures. The OnGuard® version 7.0 or later if using DataConduIT interface or version 7.4 or later if using OpenAccess interface.

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

1. One Ethernet Port 100 Mbps or better, RJ45
2. Three independent BACnet® MS/TP Channels.
3. Battery Backup using Gold Capacitor to avoid low battery alarms and subsequent replacement during service life of the controller.
4. 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)
5. A Reset Button
6. The NC must be capable of operation over a temperature range of 0 to 50°C
7. The NC must be capable of withstanding storage temperatures of between 5 and 70°C
8. The NC must be capable of operation over a humidity range of 5 to 93% RH, non-condensing
9. Shall include expansion for Input/Output
10. Field Bus for remote I/O

2.4   ADVANCED APPLICATION SPECIFIC CONTROLLERS (AASC)

1. All Advanced Application Controller shall be fully programmable and shall at all times maintain their BACnet® compliance. All control sequences within or programmed into the B-AAC shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained. Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of communicating actuators, communicating sensors, BACnet Smart Actuators and BACnet Smart Sensors.

2. Stand-alone, Native BACnet®, UL Listed Application Controllers shall be used to provide direct digital control of HVAC equipment. In addition to their standalone capabilities, they shall also provide the ability networked in a peer-to-peer, BACnet® MS/TP field network to other MS/TP controllers, and VAV/SPC zone controllers. These controllers may be used to optimize the energy consumption by implementing various control strategies such as temperature setup/setback etc.

3. Standard features for all Advanced Application Controllers shall include:

a. Should support BACnet® intrinsic alarm reporting

b. Should support calendar objects for scheduling

c. Flexibility to be used and connected to Network Controller to expand the I/O capacity of network controller

d. BACnet® MS/TP LAN with configurable baud rate from 9600 to 76.8k baud

2.5   AUXILIARY CONTROL DEVICES

A.   Motorized Control Dampers (Unless Specified Elsewhere):

1.   Control dampers shall be parallel or opposed airfoil type blade as below or as scheduled on drawings.

a.   Outdoor, return air mixing dampers and face and bypass (F&BP) dampers shall be parallel blade, arranged to direct air-streams toward each other.
b.   Other modulating dampers shall be opposed blade type.
c.   Two-position shutoff dampers may be parallel or opposed blade type with blade and side seals.

2.   Damper frames shall be [16] gauge galvanized steel channel or 1/8" extruded aluminum with reinforced corner bracing.
3.   Damper blades shall not exceed 8" in width or 48" in length. Blades are to be suitable for medium-velocity performance (2,000 – 3,000 fpm). Blades shall be not less than 16 gauge.
4.   Damper shaft bearings shall be as recommended by manufacturer for application, synthetic, impregnated sintered bronze or stainless steel.
5.   All blade edges and top and bottom of the frame shall be provided with vinyl or neoprene seals. Side seals shall be spring-loaded aluminum. The blade seals shall provide for a maximum leakage rate of 8 cfm per sq. ft. at 4" w.c. differential pressure. Provide airfoil blades suitable for a wide- open face velocity of 1,500 fpm.
6.   Individual damper sections shall not be larger than 48" x 48". Provide a minimum of one damper actuator per section.
7.   Modulating dampers shall provide a linear flow characteristic where possible.
8.   Dampers shall have capability for internal and external linkages. Dampers over 48" in applications where sectioning is not applicable shall be supplied with a second actuator, jackshafts shall not be installed, and the actuator shall be adequately sized to provide sufficient force throughout the intended operating range.
9.   Dampers shall be AMCA Certified Performance in accordance with AMCA Standard 511.
10.   Acceptable: Greenheck, Ruskin or approved equal.
11.   Must have an end switch for proof of open/close positions.

B.   Electric damper and valve actuators:

1.   The actuator shall have mechanical or electronic stall protection to prevent damage to the actuator through the rotation of the actuator.
2.   Where shown, for power-failure and safety applications, an internal mechanical spring-return mechanism shall be built into the actuator housing.
3.   All rotary spring-return actuators shall be capable of clockwise or counter-clockwise spring-return operation. Linear actuators shall spring-return to the retracted position.
4.   Proportional actuators shall accept a 0 to 10 VDC control signal and provide a 2 to 10 VDC operating range.
5.   All 24 VAC/VDC actuators shall operate on Class 2 wiring.
6.   All non-spring-return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring-return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.
7.   All modulating actuators shall have an external, built-in switch to allow the reversing of

rotation direction.

8. Actuators shall be provided with a raceway fitting and a minimum 1 ft electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
9. Actuators shall be UL Standard 873 Listed as meeting correct safety requirements and recognized industry standards.
10. Actuator housings shall be NEMA 2 and plenum rated.
11. Actuators shall be designed for a minimum of 60,000 full- stroke cycles at the actuator's rated torque and 1.5 million repositions.
12. Acceptable manufacturer: Belimo AFB series or approved equal.

C. Control Valves:

1. Control valves shall be two-way or three-way type for two- position or modulating service as shown.
2. Close-off (differential) pressure rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:

    a. Water valves:

        1) Two-way: 150 percent of total system (pump) head.
        2) Three-way: 300 percent of pressure differential between ports A and B at design flow or 100 percent of total system (pump) head.

    b. Steam valves: 150 percent of operating (inlet) pressure.

3. Water Valves:

    a. Standard design shall be **Ball valves for water application & Globe Valves for steam application.** Valves shall include body and trim style and materials per manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.
    b. Sizing criteria:

        1) Two-position service: Line size, unless otherwise shown.
        2) Two-way modulating service: Pressure drop shall be a maximum of 5 psi.
        3) Three-way modulating service: Pressure drop shall be a maximum of 5 psi.
        4) Valves 1/2" through 2" shall be bronze body or cast brass ANSI Class 250, O-ring seal, EPDM packing, quick opening for two- position service. Two-way valves to have replaceable composition disc, or stainless-steel ball.
        5) 2 1/2" valves and larger shall be cast iron ANSI Class 125 with guided plug and EDPM O-ring or Teflon packing, unless otherwise shown.
        6) Supply and return lines shall have valves for isolation only to allow for the coil or VAV unit to be isolated for maintenance repairs.

    c. Water valves shall fail normally open or closed as follows:

        1) Hot water heating valves in air handlers— normally open.
        2) Chilled water control valves—normally closed (typical). Certain applications may require fail-in-place.
        3) Large butterfly valves fail-in-place, unless specified otherwise.
        4) Terminal unit valves fail-in-place unless specified otherwise.
        5) Other applications—as scheduled or as required by sequences of operation.

    d. Acceptable manufacturer:

        1) Ball Valve: Belimo B series or approved equal.

    2) Globe Valve: Belimo G series or approved equal.

  4. 2-Way AHU Chilled and Hot Water Valves:

    a. All valves shall be modulating pressure independent and be provided by the same manufacturer. The flow through the valve shall not vary more than +/- 5% due to system pressure fluctuations across the valve in the selected operating range. The control valve shall accurately control the flow from 1 to 100% full rated flow. The engineer may consider using high performance energy monitoring control valves as an option, but only if the coil is designed for higher Delta T's.

    b. Balancing valves shall not be used where pressure independent valves are installed. The control valve must have the ability to limit flow to the maximum design flow specific for each coil at all valves differential pressure ranges from 5 to 70 PSID.

    c. Valve bodies 2" and smaller shall be brass. Valve bodies 8" and under shall be cast iron. All internal parts shall be brass, carbon steel, stainless steel, or Teflon. Internal plastic parts are not acceptable.

    d. Valves shall include a pressure port on each side of the valve for testing purposes. The pressure taps shall have ½" extensions for accessibility.

    e. Valve flow characteristics may be modified without removing valve from the piping system.

    f. Valve actuators shall modulate via a 2-10Vdc control signal and be sized to provide proper torque to assure proper close off.

    g. Valve Tag shall include the model number, AHU being served, design flow and maximum flow for that valve.

    h. Acceptable manufacturer: Belimo EP series or approved equal.

  5. Steam Valves:

    a. Body and trim materials shall be per manufacturer's recommendations for design conditions and service. Linear ports for modulating service.

    b. Sizing criteria:

      1) Two-position service: pressure drop 10 percent to 20 percent of inlet psig.
      2) Modulating service: 15 psig or less; pressure drop 80 percent of inlet psig.
      3) Modulating service: 16 to 50 psig; pressure drop 50 percent of inlet psig.
      4) Modulating service: over 50 psig; pressure drop as scheduled on plans.

    c. Steam valves on air handlers shall fail normally open. Steam valves on heat exchangers shall fail normally closed.

    d. Acceptable manufacturer: Belimo DN, G or B series or approved equal.

  6. Central Plant Valves:

    a. Ball valves shall be utilized for chiller & boiler isolation & control for valves under 6" and Butterfly valves shall be utilized for valves 6" and larger.

    b. Bodies shall be 2-way or 3-way as required and shall be cast iron, equal percentage flow, with lugged connections.

    c. Valves shall be rated for 50% glycol and 250psi max pressure.

    d. 2"-4" Valves shall be spring return based on design requirements.

    e. 5"-20" Valves shall fail in place unless critical design requirement or sequence states otherwise.

    f. Valve operation shall be 2-position as required per sequence of operation. Actuator NEMA rating shall meet the requirements of intended use.

    g. Acceptable manufacturer: Bray, Belimo F series or approved equal.

 D. Digital temperature devices:

  1. Line-voltage space thermostat shall be bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch type, or equivalent solid-state type, with heat anticipator, UL listed for electrical rating, concealed setpoint adjustment +35F to +95F setpoint range,

2F maximum differential, and vented ABS plastic cover. Acceptable manufacturer: ALC-TB series or approved equal.

E.   Temperature sensors:

    1.   Temperature sensors shall be resistance temperature detector (RTD) or thermistor, 20K ohm NTC type.

    2.   Duct sensors for critical control locations (ie. Mixed air, discharge air, coil air) shall be averaging sensors. Duct sensors for non-critical locations (ie. Return air) shall be rigid single- point. Averaging sensors shall be a minimum of 5 ft in length per 10 ft2 of duct cross section. Acceptable manufacturer:

        a.   Averaging Duct sensor: ALC NSB-10K-A series or approved equal

        b.   Single Point Duct sensor: ALC NSB-10K-2-D series or approved equal

    3.   Immersion sensors shall be provided with a separable stainless steel or copper well. Pressure rating of well shall be consistent with the system pressure in which it is to be installed. The well shall withstand flow velocities in the pipe. Acceptable manufacturer: NSB-10K-2-I series or approved equal

    4.   Space sensors for unitary controllers shall be equipped with set point adjustment. Acceptable manufacturer: ALC ZS-PL series or approved equal.

F.   Low limit temperature sensors:

    1.   The low limit sensor shall have an adjustable temperature range of 20-140F containing a window showing actual setpoint.

    2.   A 20' capillary sensing element shall respond to the lowest temperature sensed in a given 1' section.

    3.   Upon activation, the (2) auxiliary switches shall trip. The sensor will require a manual reset.

    4.   Sensors shall be installed after the hot water coil, just before the chilled water coil. Sensor shall be installed away from each coil and in a way that provides the best sampling of mixed air and areas stratification. Recommended coverage is (1) 20' sensor per 20 ft^2 of chilled water coil.

    5.   Acceptable manufacturer: Johnson Controls A70 or approved equal.

G.   Humidity sensors:

    1.   Duct and room sensors shall have a sensing range of 20 percent to 95 percent.

    2.   Duct sensors shall be provided with a sampling chamber.

    3.   Outdoor air humidity sensors shall have a sensing range of 20 percent to 95 percent RH. They shall be suitable for ambient conditions of -10F to +140F.

    4.   Humidity sensor accuracy shall be +/- 3%.

    5.   Humidity sensor's drift shall not exceed 1 percent of full scale per year.

    6.   Humidity sensor shall have selectable 4-20ma, 0-10 Vdc or 0-5 Vdc output.

    7.   Acceptable manufacturer:

        a.   Space Sensor: ALC ZS H series or approved equal.

        b.   Duct Sensor: NSB-10K-2-H200-D series or approved equal.

        c.   Outside Air Sensor: Belimo UT series or approved equal.

H.   Relays:

    1.   Control relays shall be UL Listed of the self-contained type. Contact rating, configuration, and coil voltage suitable for application.

    2.   Time delay relays shall be UL Listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable 200% (minimum) from set point shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.

3. Acceptable manufacturer: Senva or approved equal.

I. Current switches:

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system.
2. Current switch shall be split core & rated for usage with Variable Frequency Drives (VFD's).
3. Acceptable manufacturer: Senva or approved equal.

J. Pressure transducers:

1. Transducers shall have linear output signal. Zero and span shall be field-adjustable.
2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50 percent greater than calibrated span without damage.
3. Water pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Transducers shall be complete with 4 to 20 mA output, required mounting brackets. Acceptable manufacturer: Setra or approved equal.
4. Water differential pressure transducer shall have stainless steel diaphragm construction, proof pressure of 150 psi minimum. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall be complete with 4 to 20 mA output, required mounting brackets, and five-valve manifold. Acceptable manufacture: Setra or approved equal.
5. Air differential pressure transducers shall be duct mounted for monitoring duct pressure, and panel mounted for all other applications. The **EXACT LOCATION** of duct-mounted sensors shall be documented on engineering drawings and as-builts. Transducers shall be complete with 0-10Vdc or 4 to 20 mA output and switch selectable pressure ranges. Accuracy shall be +/-1%. Acceptable manufacturer: NSB-ZPS-SR series or approved equal.

K. Differential-pressure-type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 enclosure, with scale range and differential suitable for intended application, or as shown. Acceptable manufacturer: NSB-ZPS-SW3-A series or approved equal.

L. Liquid Flow Meters: (Chilled Water flow, Make-up Water)

1. Flow sensor shall be an ultrasonic type meter. Signal output shall be 0-10Vdc, 4-20mA or (preferred) BACnet. Wetted parts shall be stainless steel. Acceptable manufacturers: Onicon Insertion Mag Meter FT-3400 or approved equal.
2. Irrigation, cooling tower make-up and steam boiler make-up water supply shall have a Sewer Allowance Credit (SAC) meter installed. SAC meter must be purchased, inspected and commissioned by KCMO Water Dept.

M. Steam Flow Meters:

1. Flow sensor shall have a temperature range of 300F for steam applications. Signal output shall be 0-10Vdc, 4-20mA or (preferred) BACnet. Steam meter must be capable or measuring flow in pounds per hour and pressure in PSI. Wetted parts shall be stainless steel. Acceptable manufacturers: Rosemount, Onicon or approved equal.

N. Natural Gas Flow Meters:

1. Gas flow sensor shall be an insertion type or inline meter with display, accuracy of +/- 0.5% of full scale. Repeatability of 0.2% and shall be calibrated for the specific pipe size. Signal output shall be 0-10Vdc, 4-20mA or BACnet. Acceptable manufacturer: Sage SRA, Dresser Roots series or approved equal.

O.   Airflow measuring stations (electronic):

   1.   Airflow measuring devices of the vortex shedding type, capable of continuously monitoring the airflow volume of the duct served and electronically transmitting a signal linear to the airflow volume, shall be provided where indicated. Airflow measuring devices shall be of the insertion type, or built into airflow control valves, as required, with the capability of measuring velocity over the full range of 350 to 7000 FPM. Devices shall consist of multiple velocity sensors, supported on insertion probe bars. Tek-Air or approved equal
   2.   Individual airflow sensors shall be of rugged construction and shall not require special handling during installation. Sensors shall be mounted on support bars, as required to achieve an equal area traverse. Standard materials shall be aluminum bars with aluminum and ABS sensors. Support bars over one foot in length shall be supported on both ends. Where utilized in corrosive air streams, sensors and support bars shall be manufactured of corrosion resistant CPVC and ABS.
   3.   Velocity-sensing methods, other than those specified, shall be acceptable provided the basic requirements for linear electronic output, turndown, accuracy, materials of construction, and output signal are met. If differential pressure devices are used, dual differential pressure transmitters, the span of the lower transmitter being 1/10 the span of the higher, with an accuracy not less than +/- 0.5 percent, shall be utilized to provide the required turndown.
   4.   Thermal dispersion devices shall use two thermistors to determine the airflow rate and temperature at each sensing point location. Flow station shall output a 0-10Vdc or 4- 20mA signal proportional to the flow rate. Acceptable: Paragon, Ebtron, or approved equal.
   5.   Airflow Measuring Stations (pneumatic): For general airflow sensing applications (5% accuracy), provide Ebtron, Paragon, or approved equal airflow measuring stations.

P.   CO2 Carbon dioxide sensors:

   1.   Sensing of carbon dioxide shall incorporate the NDIR—non- dispersive infrared—sensing method. The sensor shall incorporate sampling tubes for duct mounting and have optional LCD readout. Range of sensing shall be 0-2000 PPM, with an accuracy of ± 75 PPM from 0 to 2000 PPM and ± 5 percent above 1500 PPM. Annual drift shall be (20PPM nominal) and have a calibration interval of five years recommended. Output shall

      be 4-20 ma and have an operating temperature range of +32F to +122F and 0 to 95 percent RH, non-condensing. Acceptable manufacturer:

      a.   Wall mount - ALC, Dwyer or approved equal.
      b.   Duct mount – ALC, Dwyer series or approved equal.

Q.   Electric Utility Meters: (Unless Provided Elsewhere):

   1.   Provide utility-grade (0.2% accuracy) 3-phase meter.

      a.   Voltage monitoring range up to 600Vac RMS
      b.   Current sensing range up to 3200 Amps RMS
      c.   Line frequency 50-60Hz
      d.   Temperature operation range -4F to 122F
      e.   Relative humidity range 0-95% non-condensing
      f.   Advanced 4-line display showing the following: kWh consumption, kW demand (with peak date & time),
      g.   Power factor per phase
      h.   On-board setup options for IP address, date/time, 100 Mbps or greater Ethernet adapter RJ45
      i.   Modbus/BACnet address
      j.   0-2Vdc split-core current sensors for safety
      k.   Onboard installation diagnostics (proper current sensor and phase error diagnostics)
      l.   2 auxiliary load inputs, readable via Modbus/BACnet register points

        m.   Built-in communications protocols BACnet

        n.   Standard NEMA 1 enclosure, NEMA 4X available

    2.   Acceptable manufacturer: Dent meter or approved other.

R.   Local control panels:

    1.   All indoor control cabinets shall be fully enclosed NEMA 1 construction with [hinged door], and removable sub-panels.

    2.   Wires shall be color-coded solid conductors neatly installed in plastic troughs and/or tie-wrapped. All wires shall terminate to panel terminal blocks. Terminals for field connections shall be UL Listed for 600-volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.

    3.   Provide on and off power switch with over-current protection for control power sources to each local panel.

    4.   Contractor shall make best efforts to locate control panels on the same floor as the equipment which it is connected to.

    5.   All control panels shall be built in accordance with UL508A standards and be labeled with separate UL label numbers. Acceptable manufacturer: Hoffman, Eaton, Hubbel/Wiegman, or approved equal.

S.   Fan and Pump Motor Control:

    1.   Where applicable motors shall be controlled by a variable frequency drive (VFD). There shall not be more than 2 motors controlled by a single VFD.

    2.   VFD shall have a digital control panel and have an electronic by-pass. In applications where there is no back-up or redundant device the VFD shall be equipped with a Manual By-Pass.

    3.   VFD shall be capable of BACnet integration.

    4.   Acceptable manufacturers: Eaton (Cutler Hammer), Toshiba or an approved equal.

2.6   WIRING AND RACEWAYS

A.   General: Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 26.

B.   All insulated wire to be copper conductors, UL labeled for 90C minimum service.

3.   EXECUTION

3.1   EMCS SPECIFIC REQUIREMENT

A.   Graphic Displays

    1.   Provide a color graphic system flow diagram display for each system with all points as indicated on the point list. All terminal unit graphic displays shall be from a standard design library.

    2.   User shall access the various system schematics via a graphical penetration scheme and/or menu selection.

    3.   PDF links to as-built drawings and sequences of operations shall be on system graphics.

B.   Custom Reports:

    1.   Provide custom reports as required for this project:

3.2   EXAMINATION

    A.   The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the Owner for resolution before rough-in work is started.

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

    C.   The Contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the Contractor's work, and the plans and the work of others—the Contractor shall report these discrepancies to the Owner.

3.3   PROTECTION

    A.   The Contractor shall protect all work and material from damage from its work or employees and shall be liable for all damages thus caused.

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

3.4   COORDINATION

    A.   Site:

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

    B.   Submittals: Refer to "Submittals" Article in Division 1 of the Project Manual for requirements.

    C.   Test and balance:

        1.   The Contractor shall furnish all tools necessary to interface to the control system for test and balance purposes.
        2.   The Contractor shall provide training in the use of these tools. This training will be for a minimum of **(4) four** hours.
        3.   In addition, the Contractor shall provide a qualified technician to assist in the test and balance process, until **the first 10 or first 10% (whichever is greater)** of terminal units are balanced.
        4.   The tools used during the test and balance process are to be returned at the completion of the testing and balancing.

3.5   GENERAL WORKMANSHIP

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

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

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

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

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

3.6 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this Specification.

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

C. Contractor shall have work inspected by local or state authorities having jurisdiction over the work.

D. After all testing is completed the critical data points (as defined by the University campus) shall be setup to trend for a minimum period of **3 months**.

3.7 WIRING

A. All control and interlock wiring shall comply with national electrical codes and Division 26 of this specification. Where the requirements of this section differ with those in Division 26, the requirements of this section shall take precedence.

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

C. All low-voltage wiring shall meet NEC Class 2 requirements. (Low- voltage power circuits shall be sub-fused when required to meet the Class 2 current limit.)

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

E. Do not install wiring in raceway containing tubing.

F. All wire-to-device connections is to be at a terminal block or terminal strip. All wire-to-wire connections is to be at a terminal block or wire nut at junction box.

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

H. All wiring is to be installed as continuous lengths, with no splices permitted between termination points.

I. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

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

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

L. The Contractor shall terminate all control and interlock wiring and shall maintain updated wiring diagrams with terminations identified at the job site.

3.8 INSTALLATION OF SENSORS

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

 1. Sensor locations are to be noted on graphics (ie. Duct pressure sensors, CO_2 sensors, building pressure sensors, etc.).
 2. Mount sensors rigidly and adequately for the environment within which the sensor operates.

3.9 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup testing: All testing listed in this Article shall be performed by the Contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the Owner's representative is notified of the system demonstration.

 1. The Contractor shall furnish all labor and test apparatus required to calibrate and prepare for service all instruments, controls, and accessory equipment furnished under this Specification.
 2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
 3. Enable the control systems and verify all input, output, safety, alarm, and interlock devices are working properly and according to the sequence of operations.

3.10 TRAINING

A. Unlimited system training for operating and maintenance staff shall be included. Training to be coordinated with the owner onsite or at a local office.

3.11 SEQUENCES OF OPERATION

A. Provide operation as shown on drawings.

B. All sequence of operations must be included in the control as-built drawings and provided to the University campus upon substantial completion of the project. Any changes following substantial completion must be captured and updated control as-built drawings shall be provided to the campus.

END OF SECTION 23 09 00