SECTION 23 0923
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Operator interface.

B. System software.

C. Controller software.

D. HVAC control programs.

E. Digital control equipment.

F. Software.

G. Software set-up and application programming.

1.02 RELATED REQUIREMENTS

A. Section 23 0510 -General HVAC Requirements-Demonstration, Training and Instructions.

B. Section 23 0913 - Instrumentation and Control Devices for HVAC.

C. Section 23 0993 - Sequence of Operations for HVAC Controls.

D. Section 23 0810 - Mechanical Commissioning.

E. Section 26 2717 - Equipment Wiring: Electrical characteristics and wiring connections.

1.03 REFERENCE STANDARDS

A. ANSI/CEA 709.1.D - Control Network Protocol Specification; 2014.

B. ASHRAE Std 135 - BACnet - A Data Communication Protocol for Building Automation and Control Networks; 2012.

C. ASHRAE Std 147 - Reducing the Release of Halogenated Refrigerants From Refrigerating and Air-Conditioning Equipment and Systems; 2002.

D. ASHRAE Std 147 - Reducing the Release of Halogenated Refrigerants From Refrigerating and Air-Conditioning Equipment and Systems; 2002.

E. NFPA 70 - National Electrical Code; 2020 Edition, Including All Applicable Amendments and Supplements.

F. KSU Metering Standard - 2016

1.04 SYSTEM DESCRIPTION

A. Automatic temperature control field monitoring and control system using field programmable micro-processor based units .

B. Base system on distributed system of fully intelligent, stand-alone controllers, operating in a multi-tasking, multi-user environment on token passing network, with central and remote hardware, software, and interconnecting wire and conduit. Provide Building Controllers (BC), Advanced Application Controllers (AAC), and Application Specific Controllers (ASC) as required to achieve specified sequences and performance.

C. Include computer software and hardware, operator input/output devices, control units, local area networks (LAN), sensors, control devices, actuators.

D. Controls for variable air volume terminals, radiation, reheat coils, unit heaters, fan coils, and the like when directly connected to the control units. Individual terminal unit control is specified in Section 23 0913.

E. Provide control systems consisting of thermostats, control valves, dampers and operators, indicating devices, interface equipment and other apparatus and accessories required to operate mechanical systems, and to perform functions specified.

F. Provide an interface location to accept a fiber optics connection and interface fully between the control system's local area network and the operator station to be located at the Plant Operations offices via the fiber optics cable. Owner will provide the cabling between the interface location and the building housing the operator station.

G. Update the Graphics operator station at Plant Operations to display the features specified herein.

H. The Contractor shall be responsible for all equipment, cables, installation, and programming to implement the required interface with the campus network.

I. Include installation and calibration, supervision, adjustments, and fine tuning necessary for complete and fully operational system.

1.05 SUBMITTALS

A. Refer to Section 23 0510 - General HVAC Requirements for submittal procedures.

B. Product Data: Provide data for each system component and software module.

C. Shop Drawings:
1. Indicate trunk cable schematic showing programmable control unit locations, and trunk data conductors.
2. Provide electronic pictures of proposed system graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
3. Show system configuration with peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
4. Indicate description and sequence of operation of operating, user, and application software.
5. Proposed Graphics.

D. Points List: Provide a full points list with at least the following included for each point:
1. Controlled system
2. Point abbreviation/acronym
3. Point description
4. Engineering unit to be displayed with the point
5. Control point or set-point (Yes / No)
6. Monitoring point (Yes / No)
7. Intermediate point (Yes / No)
8. Calculated point (Yes / No)

E. Sequences of operation: Complete detailed sequences of operation, including a narrative of the system operation and interactions and interlocks with other systems written by the control vendor; notations indicating whether interlock or interaction is accomplished through software or hard-wired connections; detailed delineation of control between packaged controls and the DDC system; and sequences of operation for packaged controlled equipment that interfaces with the DDC system describing what points the DDC system monitors only and what points are control points and are adjustable. Sequence shall include:
1. Equipment start-up sequences.
2. Warm-up mode sequences.
3. Normal operating mode sequences.
4. Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, capacity control, staging, optimization, etc.
5. Temperature and pressure control: setbacks, setups, resets, etc.
6. Shutdown sequences.
7. Unoccupied mode sequences.
8. Sequences for all alarms and emergency shut downs.
9. Effects of power or equipment failure with all standby component functions.
10. Seasonal operational differences and recommendations.

11. Initial and recommended values for all adjustable settings, set-points and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
12. Schedules, if known.
13. All sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered

F. Proposed Graphics: Contractor proposed graphic displays are to be submitted for KSU's review and approval with controls shop drawings. Submittal shall include all proposed displays as required by the project documents and specifications. Provide demonstration disk containing graphics. Manufacturer's Instructions: Indicate manufacturer's installation instructions for all manufactured components.

G. Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors.
1. Revise shop drawings to reflect actual installation and operating sequences.
2. Include submittals data in final "Record Documents" form.

H. Operation and Maintenance Data:
1. Include interconnection wiring diagrams complete field installed systems with identified and numbered, system components and devices.
2. Include keyboard illustrations and step-by-step procedures indexed for each operator function.
3. Include inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.

I. Observation by the Design Professional: Provide an affidavit to the Design Professional stating the Controls Systems are performing in accordance with the contract documents prior to Request for Material Completion.

J. Certificate: Provide Manufacturer's Certificate complying with the requirements of the General Conditions.

1.06 QUALITY ASSURANCE

A. Installer Qualifications: Company specializing in performing the work of this section with minimum 5 years' experience in the direct employ of the equipment manufacturer.

B. Personnel: Mechanics and electricians performing this work shall be regularly engaged in the installation of automatic temperature controls and be in the direct employ of the installing company and shall have a copy of the approved submittal data in immediate possession when performing work.

C. Products Requiring Electrical Connection: Listed and classified by Underwriters Laboratories Inc., as suitable for the purpose specified and indicated.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Automated Logic Corporation .

2.02 OPERATOR INTERFACE

A. Workstation, controllers, and control backbone to communicate using BACnet protocol and addressing.

B. BACnet protocol to comply with ASHRAE Std 135.

2.03 CONTROLLERS

A. Arrange Controllers and Unit I/O so that control unit functions continue if communications over network are lost.

B. Each DDC controller including associated input/output modules, shall be provided with a minimum of 10% spare input and output points of each type installed, but no less than one point of each type.

C. BUILDING CONTROLLERS
   1. General:
      a. Manage global strategies by one or more, independent, standalone, microprocessor based controllers.
      b. Provide sufficient memory to support controller's operating system, database, and programming requirements.
      c. Share data between networked controllers.
      d. Controller operating system manages input and output communication signals allowing distributed controllers to share real and virtual object information and allowing for central monitoring and alarms.
      e. Utilize real-time clock for scheduling.
      f. Continuously check processor status and memory circuits for abnormal operation.
      g. Controller to assume predetermined failure mode and generate alarm notification upon detection of abnormal operation.
      h. Communication with other network devices to be based on assigned protocol.
   2. Communication:
      a. Controller to reside on a BACnet network using ISO 8802-3 (ETHERNET) Data Link/Physical layer protocol.
      b. Perform routing when connected to a network of custom application and application specific controllers.
      c. Provide service communication port for connection to a portable operator's terminal or hand held device with compatible protocol.
   3. Anticipated Environmental Ambient Conditions:
      a. Outdoors and/or in Wet Ambient Conditions:
         1) Mount within waterproof enclosures.
         2) Rated for operation at 40 to 150 degrees F.
      b. Conditioned Space:
         1) Mount within dustproof enclosures.
         2) Rated for operation at 32 to 120 degrees F.
   4. Provisions for Serviceability:
      a. Diagnostic LEDs for power, communication, and processor.
      b. Make all wiring connections to field removable, modular terminal strips, or to a termination card connected by a ribbon cable.
   5. Memory: In the event of a power loss, maintain all BIOS and programming information for a minimum of 72 hours.
   6. Power and Noise Immunity:
      a. Maintain operation at 90 to 110 percent of nominal voltage rating.
      b. Perform orderly shutdown below 80 percent of nominal voltage.
      c. Operation protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W. at 3 feet.

D. APPLICATION SPECIFIC CONTROLLERS
   1. General:
      a. Not fully user programmable, microprocessor based controllers dedicated to control specific equipment.
      b. Customized for operation within the confines of equipment served.
      c. Communication with other network devices to be based on assigned protocol.
   2. Communication:
      a. Controller to reside on a BACnet network using MS/TP Data Link/Physical layer protocol.
      b. Provide service communication port for connection to a portable operator's terminal or hand held device with compatible protocol.

3. Anticipated Environmental Ambient Conditions:
    a. Outdoors and/or in Wet Ambient Conditions:
        1) Mount within waterproof enclosures.
        2) Rated for operation at 40 to 150 degrees F.
    b. Conditioned Space:
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E. INPUT/OUTPUT INTERFACE
1. Hardwired inputs and outputs tie into the DDC system through building, custom application, or application specific controllers.
2. All Input/Output Points:
    a. Protect controller from damage resulting from any point short-circuiting or grounding and from voltage up to 24 volts of any duration.
    b. Provide universal type for building and custom application controllers where input or output is software designated as either binary or analog type with appropriate properties.
3. Binary Inputs:
    a. Allow monitoring of On/Off signals from remote devices.
    b. Provide wetting current of 12 mA minimum, compatible with commonly available control devices and protected against the effects of contact bounce and noise.
    c. Sense dry contact closure with power provided only by the controller.
4. Pulse Accumulation Input Objects: Conform to all requirements of binary input objects and accept up to 10 pulses per second.
5. Analog Inputs:
    a. Allow for monitoring of low voltage 0 to 10 VDC, 4 to 20 mA current, or resistance signals (thermistor, RTD).
    b. Compatible with and field configurable to commonly available sensing devices.
6. Binary Outputs:
    a. Used for On/Off operation or a pulsed low-voltage signal for pulse width modulation control.
    b. Outputs provided with three position (On/Off/Auto) override switches.
    c. Status lights for building and custom application controllers to be selectable for normally open or normally closed operation.
7. Analog Outputs:
    a. Monitoring signal provides a 0 to 10 VDC or a 4 to 20 mA output signal for end device control.
    b. Provide status lights and two position (AUTO/MANUAL) switch for building and custom application controllers with manually adjustable potentiometer for manual override on building and custom application controllers.
    c. Drift to not exceed 0.4 percent of range per year.
8. Tri State Outputs:
    a. Coordinate two binary outputs to control three point, floating type, electronic actuators without feedback.

b. Limit the use of three point, floating devices to the following zone and terminal unit control applications:
   1) VAV terminal units.
   2) Duct mounted heating coils.
c. Control algorithms run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

9. System Object Capacity:
   a. System size to be expandable to twice the number of input output objects required by providing additional controllers, including associated devices and wiring.
   b. Hardware additions or software revisions for the installed operator interfaces are not to be required for future, system expansions.

2.04 LOCAL AREA NETWORK (LAN)

A. Provide communication between control units and operator station(s) over local area network (LAN).

B. LAN Capacity: Not less than 60 stations or nodes.

C. Break in Communication Path: Alarm and automatically initiate LAN reconfiguration.

D. LAN Data Speed: Minimum 2500 Kb.

E. Communication Techniques: Allow interface into network by multiple operation stations and by auto-answer/auto-dial modems. Support communication over telephone lines utilizing modems.

F. Transmission Median: Fiber optic or single pair of solid 24 gauge twisted, shielded copper cable.

G. Network Support: Time for global point to be received by any station, shall be less than 3 seconds. Provide automatic reconfiguration if any station is added or lost. If transmission cable is cut, reconfigure two sections with no disruption to system's operation, without operator intervention.

2.05 SYSTEM SOFTWARE

A. Operating System:
   1. Concurrent, multi-tasking capability.
      a. Common Software Applications Supported: Microsoft Excel and Microsoft Access.
   2. System Graphics:
      a. Allow up to 10 graphic screens, simultaneously displayed for comparison and monitoring of system status.
      b. Animation displayed by shifting image files based on object status.
      c. Provide method for operator with password to perform the following:
         1) Move between, change size, and change location of graphic displays.
         2) Modify on-line.
         3) Add, delete, or change dynamic objects consisting of:
            (a) Analog and binary values.
            (b) Dynamic text.
            (c) Static text.
            (d) Animation files.
   3. Custom Graphics Generation Package:
      a. Create, modify, and save graphic files and visio format graphics in PCX formats.
      b. HTML graphics to support web browser compatible formats.
   4. Standard HVAC Graphics Library:
      a. HVAC Equipment:
         1) Boilers.
         2) Rooftop Air Handlers.
         3) Terminal HVAC Units.
         4) Fan Coil Units.
         5) Lab Exhaust Air Valves

b. Ancillary Equipment:
1) Fans.
2) Pumps.
3) Coils.
4) Valves.
5) Piping.
6) Dampers.
7) Ductwork.

B. Workstation System Applications:
1. Automatic System Database Save and Restore Functions:
a. Current database copy of each Building Controller is automatically stored on hard disk.
b. Automatic update occurs upon change in any system panel.
c. In the event of database loss in any system panel, the first workstation to detect the loss automatically restores the database for that panel unless disabled by the operator.
2. Manual System Database Save and Restore Functions by Operator with Password Clearance:
a. Save database from any system panel.
b. Clear a panel database.
c. Initiate a download of a specified database to any system panel.
3. Software provided allows system configuration and future changes or additions by operators under proper password protection.
4. On-line Help:
a. Context-sensitive system assists operator in operation and editing.
b. Available for all applications.
c. Relevant screen data provided for particular screen display.
d. Additional help available via hypertext.
5. Security:
a. Operator log-on requires user name and password to view, edit, add, or delete data.
b. System security selectable for each operator.
c. System supervisor sets passwords and security levels for all other operators.
d. Operator passwords to restrict functions accessible to viewing and/or changing system applications, editor, and object.
e. Automatic, operator log-off results from keyboard or mouse inactivity during user-adjustable, time period.
f. All system security data stored in encrypted format.
6. System Diagnostics:
a. Operations Automatically Monitored:
1) Workstations.
2) Printers.
3) Modems.
4) Network connections.
5) Building management panels.
6) Controllers.
b. Device failure is annunciated to the operator.
7. Alarm Processing:
a. All system objects are configurable to "alarm in" and "alarm out" of normal state.
b. Configurable Objects:
1) Alarm limits.
2) Alarm limit differentials.
3) States.
4) Reactions for each object.
8. Alarm Messages:

a. Descriptor: English language.
b. Recognizable Features:
1) Source.
2) Location.
3) Nature.

9. Configurable Alarm Reactions by Workstation and Time of Day:
a. Logging.
b. Printing.
c. Starting programs.
d. Displaying messages.
e. Dialing out to remote locations.
f. Paging.
g. Providing audible annunciation.
h. Displaying specific system graphics.

10. Custom Trend Logs:
a. Definable for any data object in the system including interval, start time, and stop time.
b. Trend Data:
1) Sampled and stored on the building controller panel.
2) Archivable on hard disk.
3) Retrievable for use in reports, spreadsheets and standard database programs.
4) Archival on LAN accessible storage media including hard disk, tape, Raid array drive, and virtual cloud environment.
5) Protected and encrypted format to prevent manipulation, or editing of historical data and event logs.

11. Alarm and Event Log:
a. View all system alarms and change of states from any system location.
b. Events listed chronologically.
c. Operator with proper security acknowledges and clears alarms.
d. Alarms not cleared by operator are archived to the workstation hard disk.

12. Object, Property Status and Control:
a. Provide a method to view, edit if applicable, the status of any object and property in the system.
b. Status Available by the Following Methods:
1) Menu.
2) Graphics.
3) Custom Programs.

13. Reports and Logs:
a. Reporting Package:
1) Allows operator to select, modify, or create reports.
2) Definable as to data content, format, interval, and date.
3) Archivable to hard disk.
b. Real-time logs available by type or status such as alarm, lockout, normal, etc.
c. Stored on hard disk and readily accessible by standard software applications, including spreadsheets and word processing.
d. Set to be printed on operator command or specific time(s).

14. Reports:
a. Standard:
1) Objects with current values.
2) Current alarms not locked out.
3) Disabled and overridden objects, points and SNVTs.
4) Objects in manual or automatic alarm lockout.
5) Objects in alarm lockout currently in alarm.
6) Logs:

(a) Alarm History.
(b) System messages.
(c) System events.
(d) Trends.

b. Custom:
1) Daily.
2) Weekly.
3) Monthly.
4) Annual.
5) Time and date stamped.
6) Title.
7) Facility name.

c. Tenant Override:
1) Monthly report showing total, requested, after-hours HVAC and lighting services on a daily basis for each tenant.
2) Annual report showing override usage on a monthly basis.

d. Electrical, Fuel, and Weather:
1) Electrical Meter(s):
(a) Monthly showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
(b) Annual summary showing monthly electrical consumption and peak demand with time and date stamp for each meter.
2) Fuel Meter(s):
(a) Monthly showing daily natural gas consumption for each meter.
(b) Annual summary showing monthly consumption for each meter.
3) Weather:
(a) Monthly showing minimum, maximum, average outdoor air temperature and heating/cooling degree-days for the month.

e. Daily Operating Condition of Chiller(s) Based on ASHRAE Std 147:
1) Chilled water inlet and outlet temperature.
2) Chilled water flow.
3) Chilled water inlet and outlet pressure.
4) Evaporator refrigerant pressure and temperature.
5) Condenser refrigerant pressure and temperature.
6) Condenser refrigerant pressure and liquid temperature.
7) Refrigerant levels.
8) Oil pressure and temperature.
9) Oil level.
10) Compressor refrigerant discharge temperature.
11) Refrigerant suction temperature.
12) Addition of refrigerant.
13) Addition of oil.
14) Motor amperes per phase.
15) Motor volts per phase.
16) Ambient temperature (dry-bulb and wet-bulb).
17) Date and time logged.

C. Workstation Applications Editors:
1. Provide editing software for each system application at PC workstation.
2. Downloaded application is executed at controller panel.
3. Full screen editor for each application allows operator to view and change:
a. Configuration.
b. Name.
c. Control parameters.

d. Set-points.

4. Scheduling:
   a. Monthly calendar indicates schedules, holidays, and exceptions.
   b. Allows several related objects to be scheduled and copied to other objects or dates.
   c. Start and stop times adjustable from master schedule.
5. Custom Application Programming:
   a. Create, modify, debug, edit, compile, and download custom application programming during operation and without disruption of all other system applications.
   b. Programming Features:
      1) English oriented language, based on BASIC, FORTRAN, C, or PASCAL syntax allowing for free form programming.
      2) Alternative language graphically based using appropriate function blocks suitable for all required functions and amenable to customizing or compounding.
      3) Insert, add, modify, and delete custom programming code that incorporates word processing features such as cut/paste and find/replace.
      4) Allows the development of independently, executing, program modules designed to enable and disable other modules.
      5) Debugging/simulation capability that displays intermediate values and/or results including syntax/execution error messages.
      6) Support for conditional statements (IF/THEN/ELSE/ELSE-F) using compound Boolean (AND, OR, and NOT) and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
      7) Support for floating-point arithmetic utilizing plus, minus, divide, times, square root operators; including absolute value; minimum/maximum value from a list of values for mathematical functions.
      8) Language consisting of resettable, predefined, variables representing time of day, day of the week, month of the year, date; and elapsed time in seconds, minutes, hours, and days where the variable values cab be used in IF/THEN comparisons, calculations, programming statement logic, etc.
      9) Language having predefined variables representing status and results of the system software enables, disables, and changes the set points of the controller software.

2.06 CONTROLLER SOFTWARE

A. All applications reside and operate in the system controllers and editing of all applications occurs at the operator workstation.

B. System Security:
   1. User access secured via user passwords and user names.
   2. Passwords restrict user to the objects, applications, and system functions as assigned by the system manager.
   3. User Log On/Log Off attempts are recorded.
   4. Automatic Log Off occurs following the last keystroke after a user defined delay time.

C. Object or Object Group Scheduling:
   1. Weekly Schedules Based on Separate, Daily Schedules:
      a. Include start, stop, optimal stop, and night economizer.
      b. 10 events maximum per schedule.
      c. Start/stop times adjustable for each group object.

D. Provide standard application for equipment coordination and grouping based on function and location to be used for scheduling and other applications.

E. Alarms:
   1. Binary object is set to alarm based on the operator specified state.
   2. Analog object to have high/low alarm limits.
   3. All alarming is capable of being automatically and manually disabled.
   4. Alarm Reporting:

a. Operator determines action to be taken for alarm event.
b. Alarms to be routed to appropriate workstation.
c. Reporting Options:

F. Maintenance Management: System monitors equipment status and generates maintenance messages based upon user-designated run-time limits.

G. Sequencing: Application software based upon specified sequences of operation in Section 23 0993.

H. PID Control Characteristics:
1. Direct or reverse action.
2. Anti-windup.
3. Calculated, time-varying, analog value, positions an output or stages a series of outputs.
4. User selectable controlled variable, set-point, and PED gains.

I. Staggered Start Application:
1. Prevents all controlled equipment from simultaneously restarting after power outage.
2. Order of equipment startup is user selectable.

J. Energy Calculations:
1. Accumulated instantaneous power or flow rates are converted to energy use data.
2. Algorithm calculates a rolling average and allows window of time to be user specified in minute intervals.
3. Algorithm calculates a fixed window average with a digital input signal from a utility meter defining the start of the window period that in turn synchronizes the fixed-window average with that used by the power company.

K. Anti-Short Cycling:
1. All binary output objects protected from short-cycling.
2. Allows minimum on-time and off-time to be selected.

L. On-Off Control with Differential:
1. Algorithm allows binary output to be cycled based on a controlled variable and set-point.
2. Algorithm to be direct-acting or reverse-acting incorporating an adjustable differential.

M. Run-Time Totalization:
1. Totalize run-times for all binary input objects.
2. Provides operator with capability to assign high run-time alarm.

2.07 OPERATING SYSTEM SOFTWARE

A. Operator System Access: Via software password with minimum 30 access levels at work station and minimum 3 access levels at each control unit.

B. Web Based Operator System Access: Via software password with minimum 30 access levels at work station and minimum 3 access levels at each control unit.

2.08 LOAD CONTROL PROGRAMS

A. Automatic Time Scheduling:
1. Self-contained programs for automatic start/stop/scheduling of building loads.
2. Support up to seven (7) normal day schedules, seven (7) "special day" schedules and two (2) temporary day schedules.
3. Special days schedule shall support up to 30 unique date/duration combinations.
4. Any number of loads assigned to any time program; each load can have individual time program.
5. Each load assigned at least 16 control actions per day with 1 minute resolution.
6. Sequence starting of equipment with motors 3 KW or larger with adjustable time delay.
7. Minimum of 30 holiday periods up to 100 days in length may be specified for the year.
8. Create temporary schedules.

B. Start/Stop Time Optimization:
1. Perform optimized start/stop as function of outside conditions, inside conditions, or both.

2. Adaptive and self-tuning, adjusting to changing conditions unattended.
3. For each point under control, establish occupancy period, desired temperature at beginning and end of occupancy period and modify start/stop times, operation of ventilation dampers & toilet exhaust fans.

C. Night Setback/Setup Program: Reduce heating space temperature setpoint or raise cooling space temperature setpoint during unoccupied hours; in conjunction with scheduled start/stop and optimum start/stop programs.

D. Calculated Points: Define calculations and totalization computed from monitored points (analog/digital points), constants, or other calculated points.
1. Employ arithmetic, algebraic, Boolean, and special function operations.
2. Treat calculated values like any other analog value, use for any function that a "hard wired point" might be used.

E. Event Initiated Programming: Event may be initiated by any data point, causing series of controls in a sequence.
1. Define time interval between each control action between 0 to 3600 seconds.
2. Output may be analog value.
3. Provide for "skip" logic.
4. Verify completion of one action before proceeding to next. If not verified, program shall be able to skip to next action.

F. Trend logging:
1. Automatically initiate upload request and then store data on hard disk.
2. Time synchronize sampling at operator specified times and intervals with sample resolution of one minute.
3. Display trend samples on work station in graphic format. Automatically scale trend graph with minimum 60 samples of data in plot of time vs data.

2.09 HVAC CONTROL PROGRAMS

A. General:
1. Support Inch-pounds and SI (metric) units of measurement.
2. Identify each HVAC Control system.

B. Optimal Run Time:
1. Control start-up and shutdown times of HVAC equipment for both heating and cooling.
2. Base on occupancy schedules, outside air temperature, seasonal requirements, and interior room mass temperature.
3. Start-up systems by using outside air temperature, room mass temperatures, and adaptive model prediction for how long building takes to warm up or cool down under different conditions.
4. Use outside air temperature to determine early shut down with ventilation override.

2.10 UTILITY METERING

A. Refer to 230994; HVAC SEQUENCE OF OPERATIONS.

2.11 PROGRAMMING APPLICATION FEATURES

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify existing conditions before starting work.

B. Verify that conditioned power supply is available to the control units and to the operator work station.

C. Verify that field end devices, wiring, and pneumatic tubing is installed prior to installation proceeding.

3.02 PROGRAMING

A. Include operating system programming of software capability specified to provide:

1. Set-up of system I/O capability, operator access as defined by the User, database creation and support.
2. Graphic Display-Systems:
    a. Provide and generate dynamic color graphics providing menu-generated flow charting of each building process using background graphics, standard and user defined symbols and dynamic variables.
    b. Provide flow charting for each system indicating all available points.
    c. Indicate setpoint condition status by changing color, flashing. Provide flow charting for each system indicating all available points.
3. Graphic Displays- Floor Plans:
    a. Provide building floor plan graphics with thermographics or temperature readouts and a change in color during alarms.
    b. Show actual locations of equipment, and thermostats on the graphics.
4. Equipment Runtime monitoring.

B. Include Load Control and HVAC programming of software to provide:
1. System and equipment operating to specified Sequence of Operation:
2. Start-stop Optimization.
3. Night set-up/set-back of temperature set-points as directed by User.

C. Include Application system programming of software capability specified to provide:
1. Trend logging:
    a. Logging, reporting and graphing of user defined system trends on disk file and printer as directed by user.
    b. Organize data in each trend logs to facilitate documenting system operation in compliance with Sequence of Operation.
2. Alarms: Logging, reporting and printing of user defined system alarms on disk file and printer as directed by user.
3. Scheduling:
    a. Program user defined system scheduling of occupied times as directed by user.
    b. Implement optimized starting and stopping for building warm-up/cool-down before occupancy.
    c. Program user defined system scheduling as directed by user.

3.03 INSTALLATION

A. Install control units and other hardware in position on permanent walls where accessible for inspection, maintenance and repair and not subject to excessive vibration.

B. Identification:
1. Nameplates: Identify all sensors mounted in mechanical rooms using device ID and number from control drawings with permanent label mounted adjacent to device. Nameplates shall be engraved plastic laminate with uppercase black letters on a white field, 1/4 inch minimum height.
    a. Mounting: Attach nameplates with epoxy cement or non-ferrous screws after final painting.
2. Conduit/Cable Markers:
    a. Color coded, sunlight resistant cable ties.
    b. Location: Install on all conduit and raceways exposed or above ceilings in a visible location at:
        1) Connections to junction, pull boxes, or manholes. Label box cover with nominal system voltage, circuit number and panel identification legibly written with permanent marker.
        2) Connections to equipment.
        3) Each side of a wall, roof or floor penetration.
        4) Along straight runs at 50 feet intervals.
        5) At changes of direction.

6) Parallel Conduits: Group markers on each conduit in-line with the adjacent marker.

c. Color: Baby Blue.

3. Color code cable with both ends identified with manufactured alpha-numeric self-adhesive vinyl tags, 3 mils thick, minimum, keyed to termination points.

C. Electrical wiring:
1. No splices between control panels are permitted.
2. All terminations of field wiring shall be to terminal strips.
3. Power wiring to control units shown on drawings is provided under Division 26. Provide conduit and conductors and power supplies and transformers to extend power to all supplemental control units.
4. Analog input and output cable shall be shielded with panel connection grounded to comply with Part 15, Sub-part J of FCC Rules and Regulations.
5. All Wiring materials and methods shall comply with Division 26 except:
a. Minimum wire size shall be 18 AWG(copper).
b. Conduit for concealed low voltage wiring above accessible ceilings may be omitted and plenum rated cable substituted.

D. Provide conduit and electrical wiring in accordance with Section 26 2717. Electrical material and installation shall be in accordance with appropriate requirements of .

3.04 MANUFACTURER'S FIELD SERVICES

A. Start and commission systems. Allow sufficient time for start-up and commissioning prior to placing control systems in permanent operation.

B. Provide start-up certificate in the format prescribed by the General Conditions.

3.05 DEMONSTRATION, TRAINING AND INSTRUCTIONS

A. Refer to Section 23 051023 0510- Demonstration, Training and Instructions for additional requirements.

B. All training sessions may be attended by the Commissioning Agent.

C. Demonstrate a complete and operating system to Owner.

3.06 COMMISSIONING SUPPORT REQUIREMENTS:

A. The Contractor shall attend a preliminary commissioning scoping meeting and other commissioning coordination meetings during the construction process as necessary to facilitate the commissioning process. Contractor is to keep the Commissioning Authority and mechanical Commissioning Supervisor informed of progress with the Project and of changes to the proposed installation, programming and test plan.

B. The Contractor shall provide assistance to the Commissioning Authority (CxA) for scheduling and witnessing of testing. Review the Prefunctional and Functional test procedures to ensure feasibility, safety, and equipment protection.

C. Preparation of a written start-up and initial checkout plan indicating in a step-by-step manner the procedures that will be followed to test, check-out, and adjust the control system prior to beginning functional testing. Submit the proposed plan to the Commissioning Authority and mechanical Commissioning Supervisor for review and approval prior to startup. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:
1. Step-by-step procedures for testing each type controller after installation, including:
a. Process of verifying proper hardware and wiring installation.
b. Process of downloading programs to load controllers and verifying that they are addressed correctly.
c. Process of verifying proper hardware and wiring installation.
d. Process of performing operational checks of each controlled component.
e. Plan and process for calibrating valve and damper actuators and sensors.
f. A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.

g. A copy of the log and field check-out sheets that will document the process. This log shall include a place for initial and final values read during calibration of each point and clearly indicate when a sensor or controller has passed and is operating within the contract parameters. Notification of any equipment failures shall be documented.
h. A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
i. A description of the instrumentation required for testing, including a certification of calibration for each test instrument.
j. Identify which tests and systems should be completed prior to using the control system for test, adjustment, and balance work.
k. The Commissioning Agent may request further documentation necessary for the commissioning process.

2. Provide the Commissioning Authority and mechanical Commissioning Supervisor complete system logic diagrams, describing the proposed system programming, with programmed attributes shown. These diagrams shall be updated with field modifications from the start-up, check-out, and pre-functional testing prior to the beginning of the functional testing of the DDC system. Provide a copy of each proposed graphical interface screen with interface points shown for the entire system. Provide assistance to the Commissioning Authority in preparing the specific functional performance test procedures required, to include normal cut sheets and shop drawing submittals of commissioned equipment and any additional requested documentation, prior to normal O&M manual submittals. Review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
3. Pre-functional tests: Provide skilled technicians to execute startup of equipment and to execute the pre-initial checkout as described by the approved plan. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving. Verify and document the proper installation, addressing, calibration, programming, operation, and failure mode of DDC control points, sequences, and equipment and provide a copy to the commissioning authority. Provide a signed and dated certification to the Commissioning Authority and Commissioning Supervisor upon completion of the check-out of each controlled device, equipment, and system that installation, set-up, adjustment, calibration, and system programming is complete and as indicated on the Drawings, except functional testing. Completed pre-functional documentation of the system verification shall be submitted to the Commissioning Authority and Commissioning Supervisor for review and approval prior to the functional testing of the DDC control system or its being used in the testing of other equipment or systems, or other purposes. Copies of final field check-out sheets and trend logs shall be provided to the Commissioning Authority and Commissioning Supervisor for inclusion in the Commissioning Report.
4. Meet with the testing, adjusting, and balancing contractor prior to beginning the test, adjustment, and balance process and review the test, adjusting, and balancing plan to determine the capabilities and requirements of the control system in completing the testing, adjusting, and balancing process. For a given area, have all required pre-functional checklists, calibrations, startup and selected functional tests of the system completed and approved by the Commissioning Authority prior to beginning the testing, adjusting, and balancing effort. Provide the testing, adjusting, and balancing contractor with the appropriate software and any needed unique instruments for setting terminal units and instruct the testing, adjusting, and balancing contractor personnel in their use. Assist and cooperate with the testing, adjusting, and balancing contractor by providing a qualified technician to operate the controls as required to assist the testing, adjusting, and balancing contractor in performing his work, or alternatively, provide sufficient training for the testing, adjusting, and balancing contractor to operate the system without assistance. Verify the proper operation of affected controls at the completion of the test, adjustment, and balance procedure.

5. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the control systems for the respective air- or water-related systems.
6. Functional tests: Conduct and document a functional test under the direction of the Commissioning Authority of the complete installed DDC control system. Functional testing is intended to begin upon completion of a system but may be conducted in phases or sections, as defined by the requirements of the Functional Test, or as approved by the Commissioning Authority. The DDC system, or applicable portions of the system, shall have completed pre-functional testing and be approved by the Commissioning Authority and Commissioning Supervisor before being used for other purposes, such as test and balance measurements, or in support of the functional testing of other systems.
    a. Provide technicians and or knowledgeable programming personnel as required to conduct the required functional testing. Assist the Commissioning Authority in resolving issues found during the functional testing process.
    b. Assist in the functional testing of equipment and systems by implementing trend logs and equipment monitoring as specified in the contract documents. The monitoring and data logging capabilities of the DDC system shall be available for use in the commissioning process. Assist the Commissioning Authority in the testing and documentation process by using the data logging and trending capability of the DDC system in monitoring the testing effort and recording the performance of systems and interpreting the monitoring data, as necessary.
    c. The controls contractor shall coordinate with the University Facilities personnel and provide and set up a temporary testing operator station to allow full operator station interface with the system during the entire functional testing process. This temporary operator station shall provide all functions required of the system at the operator station, including real time graphic displays and report generation.
7. Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Authority and Design Professional and retest the equipment.

D. Seasonal Adjustment:
1. Assist the Commissioning Authority and Commissioning Supervisor with the seasonal adjustment process. During this effort the Commissioning Authority and Commissioning Supervisor will:
    a. Check and verify the calibration of temperature control devices and thermostats.
    b. Test and verify control sequences for proper operation for the season.
    c. Where deficient operation or defective equipment is discovered, provide corrective measures as required by the warranty provisions specified herein.

E. Refer to 23 09 00 for additional commissioning requirements.

END OF SECTION