

SECTION 25 10 00  
BUILDING AUTOMATION SYSTEM

**PART 1 – GENERAL**

1.01 SUMMARY

- A. Work hereunder includes a complete and operational, fully-tested, distributed logic, direct digital control system for control of HVAC systems and equipment. Associated work includes but is not limited to:
1. A network of stand-alone, microprocessor-based building controllers, custom application controllers, and application specific controllers. Work will include installation of new controllers and replacement of existing controllers located in the work area with new controllers that are web based and the most recent manufactured for the existing Trane Tracer Summit control system.
  2. Upgrades to the existing local workstation and communications network to allow web based operation of new controllers while maintaining existing controllers operational in other buildings on campus. At Owner's option, workstation may be replaced by Owner.
  3. Communication, control wiring, and power wiring as required.
  4. Addition of building operation and energy management software and related programming required to provide the control and monitoring sequences specified.
  5. Field Mounted Devices as specified and require for proper system operation.
  6. Control sequences as specified and required for proper system operation.
  7. Other materials and devices not shown as part of other work but necessary to provide mechanical and electrical system control and monitoring sequences specified.
  8. Complete as-built, site-verified control system drawings for all new and existing control equipment.

1.02 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

- A. Control Contractor to coordinate with other trades to ensure delivery and correct installation of products furnished but not installed under this section. Coordination to include a review of schedule, manufacturer's installation requirements, and equipment locations. Such products include but are not limited to the following.
1. Control Valves.
  2. Variable Frequency Drives.

1.03 PERFORMANCE REQUIREMENTS

- A. BACnet Compliance
1. The BAS shall exchange data between workstations or workstations and building level controllers over the Management Level Network and First-tier BAS Controller Level Network using BACnet Protocol in the form of BACnet objects.
  2. The BAS shall perform network functions using the following BACnet services:
    - a. Alarm and Event
    - b. Scheduling
    - c. Trending
    - d. Network Management
- B. Performance Standards:
1. Object Command. The maximum time between an operator command of a binary object and the reaction of the commanded device shall be 2 seconds. The maximum time between an operator command of an analog object and the start of object adjustment shall be 2 seconds.

2. Object Scan. All changes of state and change of analog values will be transmitted on system communications networks such that any data used or displayed at a controller will have been current within the previous 6 seconds.
3. Alarm Response Time. The maximum time from an object going into alarm to alarm annunciation at the workstation shall not exceed 45 seconds.
4. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 seconds. Contractor shall select execution times consistent with the process under control.
5. Performance. Programmable controllers shall be able to execute BAS PID control loops at a selectable frequency of a least once per second. The controller shall scan and update the process value and output generated at the same frequency.
6. Reporting Accuracy. The system shall report all values with an end-to-end accuracy no less than listed in Table 1.

<b>TABLE 1</b>	
<b>REPORTING ACCURACY</b>	
<i>Measured Variable</i>	<i>Reported Accuracy</i>
Water Temperature	+1°F
Delta-T	+0.25°F
Water Flow	+5% of full scale

#### 1.04 SUBMITTALS PRIOR TO STARTING WORK

- A. All required schematics and plans shall be submitted within 6 weeks of project award.
- B. All required schematics and plans shall be prepared on AutoCAD release 12 or higher.
- C. When manufacturers' product information applies to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawings shall clearly reference the pertinent specification or drawing.
- D. Building Automation System Hardware:
  - 1. Provide a complete bill of materials of new building automation control system hardware indicating quantity, manufacturer, model number, and technical data. Technical data shall include performance curves, product specification sheets, and installation/maintenance instructions.
  - 2. Network Communication Diagrams: Provide schematic diagram showing all new and existing BAS panels, communications cabling, and termination points for the entire facility. Diagrams for all existing equipment must be site verified. Identify power requirements and power source for each BAS panel. Identify equipment each BAS panel is controlling. Show termination numbers. The intention is to provide a complete and current set of control as-built drawings for all equipment in the work area as it is completed.
  - 3. Provide plans indicating locations of all BAS hardware both new and existing.
  - 4. Provide panel interior and exterior layout details for prefabricated control panels. Details shall include equipment layout and routing of wiring.
- E. Central System Hardware and Software:
  - 1. Provide schematic diagram of the central system including all control, communication, and power wiring. Label all cables and ports with computer manufacturers' model numbers and functions.
  - 2. Provide a list of color graphics screens to be provided. Indicate each screen content and relation to other screens.
- F. Controlled Systems:
  - 1. Provide an instrumentation list for each new controlled system including all controlled system elements in table format. Tables to show element name, type of device, manufacturer, model number, and product data sheet number.
  - 2. Provide a schematic diagram of each controlled system both new and existing. Include control points labeled with appropriate point names. Graphically show the location of all control elements.
  - 3. Provide a schematic wiring diagram for each controlled system both new and existing. Label all elements. Label all terminals.
  - 4. Provide a mounting, wiring, and routing plan-view drawing of new control systems. Layout to account for HVAC, electrical, and other system design and layout requirements.
  - 5. Provide a complete description of the function of each controlled system including sequence of operation.
  - 6. Provide a points list for all system controllers both new and existing including both input and output (I/O) points serving the entire facility. Note point designations, point function, controlled device associated with the I/O point, location of the I/O device, and point alarm requirements. Point data for controllers outside of the work area may be taken from as-built control drawings or the workstation database.

#### 1.05 SUBMITTALS DURING CONSTRUCTION

- A. Database Information: Four weeks prior to system start-up, provide two copies of complete database information for Engineers record. Database information will not be reviewed for conformance with Contract Documents. Database information shall include system configuration parameters, point

definitions, alarm and trending parameters, control parameters, and control software programs. Specifically document all control functions that cannot be performed by applications specific controllers using pre-programmed control routines or which must be performed by supervisory control from a general-purpose controller.

- B. Graphics: Provide three copies of all proposed graphics screens for review prior to installation. Allow 2 weeks for review.
- C. Contractor Verification: Provide Contractor checkout and testing documentation.

#### 1.06 CLOSEOUT SUBMITTALS

- A. Closeout submittals must be submitted 15 days prior to final completion for approval.
- B. Record documents shall include the following.
  - 1. Project record drawings. Project record drawings will be as-built versions of the Shop Drawings. Include one set of magnetic media including CAD drawings in .DWG format.
  - 2. Provide copy of testing and commissioning reports. Include trend logs used for verification.
  - 3. Update existing Project Operation and Maintenance Manuals. Remove information no longer appropriate and verify that the following information is current and complete.
    - a. Names, addresses and 24-hour telephone numbers of installing Contractors and the service representatives for each.
    - b. Operators manual with procedures for operating the control systems including logging on/off, alarm handling, producing point reports, trending data, overriding computer control, and changing set points and other variables.
    - c. A listing and documentation of all custom software created using the programming language including set points, tuning parameters, and object database.
    - d. A list of recommended spare parts with part numbers and suppliers.
    - e. Recommended preventive maintenance procedures for all system components including a schedule of tasks, time between tasks, and task descriptions.
  - 4. Supplemental Record Information
    - a. Provide two sets of programming manuals for any controller installed in the work area where the Owner does not have a current manual The manual shall include a description of the programming language (including syntax), statement descriptions (including algorithms and calculations used), point database creation and modification, and use of the program editor.
    - b. Update existing engineering, installation, and maintenance manuals explaining how to design and install new points, panels, and other hardware; preventive maintenance procedures; how to debug hardware problems; and how to replace or repair hardware.
    - c. Provide one set of magnetic/optical media containing backup files of the software and database.
    - d. Provide one set of magnetic/optical media containing files of all color graphic screens created for the project.
    - e. Provide one set of complete original issue documentation for any new third-party software including installation and maintenance instructions.
    - f. One set of new licenses, guarantees, and warranty documents for all new system equipment.

#### 1.07 QUALITY ASSURANCE

- A. Control Contractor shall have a local office within 120 miles of job site capable of providing routine and emergency maintenance services on all system components. Five year successful history in the design and installation of equipment and systems of same manufacturer and similar configuration to that proposed.
- B. Control Contractor to have in-house, factory-trained and factory-authorized installers and programmers.

- C. All products required to conform to BACnet Standards must be BACnet Testing Laboratory (BTL) listed.
- D. All products used in this application, except for those specifically indicated for reuse, shall be new and under current manufacture and shall be the most recent version offered by the manufacturer for the application. Spare parts shall be available from the manufacturer for at least five years after final completion.
- E. Control Contractor to have in-house, factory-trained and factory-authorized installers and programmers.

## 1.08 CODES AND STANDARDS

- A. Work, materials, and equipment shall comply with all local, state, and federal codes and ordinances including but not limited to the following.
  - 1. Each BASP shall be listed under UL916 (Energy Management Systems), UL864- UDTZ (Signal Systems Unit) and shall be tested to comply with sub-part J of Part 15 FCC rules for Class A computing equipment.

## **PART 2 – PRODUCTS**

### 2.01 ACCEPTABLE MANUFACTURERS

- A. Trane Summit to match existing

### 2.02 COMMUNICATIONS

- A. Architecture: Network architecture shall consist of three levels: a management level network, a first-tier controller level, and a second-tier controller level. As an alternative, the management level and first-tier controller levels may be combined into a single level.
  - 1. Management Level Network:
    - a. The Management Level Network will be used for communications between workstations or workstations and building level controllers.
    - b. The Management Level Network shall reside on industry standard Ethernet physical link using BACnet communications protocol.
    - c. The Management Level Network shall operate at a minimum of 2.5 M baud with full peer-to-peer network communication.
  - 2. First-tier BAS Controller Level Network:
    - a. The first-tier controller level will be used for communications between Building Controllers or Building Controllers and Advanced Application Controllers.
    - b. The first-tier BAS controller level shall reside on industry standard Ethernet physical link using BACnet communications protocol.
    - c. The first-tier BAS controller level shall operate at a minimum of 2.5 M baud with full peer-to-peer network communication.
    - d. The Second-tier BAS controller level will be used for communications between first-tier BAS controllers and custom programmable or application specific controllers.
    - e. The Second-tier BAS controller level shall be performed using peer-to-peer or MS/TP communications protocols.
- B. Contractor shall provide all communication media, connectors, repeaters, hubs, and routers necessary for network communications.

- C. Communications shall provide operator interface and value passing that is transparent to the system architecture as follows.
  - 1. Connection of an operator interface to any controller on the system will allow the operator to interface with all other controllers as if that controller were directly connected. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any controller on the system.
- D. All database values (e.g., objects, software variables, custom programming variables) of any controller shall be readable by any other controller on the system. Value passing shall be automatically performed by a controller when a reference to an object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform system value passing.

### 2.03 OPERATOR INTERFACE HARDWARE

- A. Provide all new software at existing facility workstation to provide web based connection to new controllers and to maintain connection to existing controllers not replaced under this Contract. Owner may choose to replace the workstation at their cost.

### 2.04 WORKSTATION GRAPHICS

- A. System Graphics: Update the graphic oriented operator workstation software to the latest offered by the manufacturer. Revise the existing system graphics to match the current system configuration and monitoring points.

### 2.05 SYSTEM APPLICATIONS SOFTWARE

- A. General: Provide any new system application software required to implement the Sequence of Operation. System applications are edited and archived on the PC workstation but executed on the appropriate building controller.

### 2.06 WORKSTATION APPLICATION EDITORS

- A. General: Provide Workstation Application Editors to edit any new applications that reside at system controllers. Applications shall be downloaded and executed at one or more of the controller panels.

### 2.07 SYSTEM CONTROLLERS

- A. First-tier Controllers (Building Controllers): Independent, stand-alone, microprocessor based controller to manage global control and communication. Provide the number of first tier controllers needed to meet specified performance requirements. As a minimum, provide one first-tier controller per building. BTL Listed. Controllers shall have the following general characteristics.
  - 1. Sufficient memory in each controller to support its operating system, database, and programming requirements including specified spare capacity.
  - 2. Controller operating system to manage input and output communications allowing distributed controllers to share real and virtual object information and allow central monitoring and alarms.
  - 3. Controller shall continually check the status of its processor and memory circuits. If an abnormal condition is detected, the controller shall assume a pre-determined failure mode, and generate an alarm notification.
  - 4. Controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
  - 5. Controller shall include a service communication port allowing connection to a portable operator's terminal.

- B. Advanced Application Controllers: Independent, stand-alone, microprocessor-based controller to provide local control of systems and equipment requiring advanced program sequences. Provide the number of advanced application controllers needed to meet specified performance requirements. BTL Listed. Controllers shall have the following general characteristics.
  - 1. Sufficient memory in each controller to support its operating system, database, and programming requirements including specified spare capacity.
  - 2. Controller operating system to manage input and output communications allowing distributed controllers to share real and virtual object information and allow central monitoring and alarms.
  - 3. Controller shall continually check the status of its processor and memory circuits. If an abnormal condition is detected, the controller shall assume a pre-determined failure mode, and generate an alarm notification.
  - 4. Controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
  - 5. Controller shall include a service communication port allowing connection to a portable operator's terminal.
  
- C. Application Specific Controllers: Independent, stand-alone microprocessor-based controller to control local equipment or systems where the associated sequence of operation can be met using pre-programmed control routines. Controllers should have the following general characteristics.
  - 1. Sufficient memory in each controller to control the target system.
  - 2. Non-volatile memory to maintain the BIOS and programming information in the event of a power failure.
  
- D. Controller hardware shall be suitable for the anticipated ambient conditions.
  - 1. Controllers used outdoors or in wet conditions mounted in NEMA 4x waterproof enclosure rated for operation at -40 degrees F to 150 degrees F.
  - 2. Controllers used in conditioned space mounted in dust-proof enclosures and rated for operation at 32 degrees F to 120 degrees F.
  
- E. Provide diagnostic LEDs for power, communication, and processor. All wiring connections made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
  
- F. All controllers shall operate at 90% to 110% of nominal voltage and perform an orderly shutdown below 80% nominal voltage. Operation protected against electrical noise at 5 to 120 Hz and from keyed radios up to 5 W at 3 feet.

## 2.08 INPUT/OUTPUT INTERFACE

- A. Hardwired inputs and outputs may connect to the system through a first-tier, custom application, or application specific controller.
  
- B. All input and output points protected so that shorting of the point to itself, to another point, or to ground will cause no damage to the controller. All input and output points protected from connected voltage up to 24V of any duration.
  
- C. Binary Inputs: Binary controller inputs shall provide a wetting current of at least 12 mA and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense "dry contact" closure without external power application required.
  
- D. Pulse Accumulation Inputs: In addition to standard binary input characteristics, pulse accumulation inputs shall accept up to 10 pulses per second.

- E. Analog Inputs: Analog inputs shall allow the monitoring of low-voltage (0 to 10VDC), current (4 to 20 mA), or resistance signals (thermistor or RTD). Analog inputs compatible with commonly available sensing devices.
- F. Binary Outputs: Binary outputs to provide on/off control or a pulsed low-voltage signal for pulse-width modulation. Provide three-position (on/off/auto) switch for each output along with indicator light. Output selectable for normally open or normally closed operation.
- G. Analog Outputs: Analog outputs to provide a modulating 0 to 10V or 4 to 20 mA signal for control of an end device. Provide two-position (auto/manual) switch, status lights, and manually adjustable potentiometer for each output. Analog output drift less than 0.4% of range per year.

## 2.09 WEB INTERFACE

- A. General:
  - 1. BAS supplier shall provide web-based access to the system via connection to Owner's Ethernet network connection in the adjacent telecom room.
  - 2. Contractor shall provide all communication media, connectors, repeaters, servers, hubs, and routers necessary for network connection.

## 2.10 POWER SUPPLIES AND LINE FILTERING

- A. Provide UL listed control transformers. Provide class 2 current-limiting type or furnish over-current protection in both primary and secondary circuits in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
- B. Provide transient voltage and surge suppression for all controllers either internally or as an external component. Surge suppression shall have the following minimum performance criteria.
  - 1. Dielectric strength of 1000 volts minimum.
  - 2. Response time of 10 nanoseconds.
  - 3. Transverse mode noise attenuation of 65 dB or greater.
  - 4. Common mode noise attenuation of 150 dB or better at 40 Hz to 100 Hz.

## 2.11 WIRING AND RACEWAYS

- A. Provide wiring, plenum cable, and raceways in accordance with Division 26.
- B. All insulated wire to have copper conductor. UL labeled for 90 degree C service

## **PART 3 – EXECUTION**

### 3.01 COORDINATION

- A. Testing and Balancing
  - 1. Provide to the Test and Balancing Contractor a set of all tools necessary to interface to the control system for testing and balancing purposes. Tools to be returned at the completion of test and balancing work.
  - 2. Provide training in the use of the tools.
  - 3. Provide a qualified technician to assist in the test and balancing process where required.
- B. Coordinate with controls specified in other sections or divisions. Other sections or divisions include controls and control devices to be part of or interfaced with the control system specified in this section. Integration and coordination with these controls shall be as follows.

1. All communications media and equipment required to interface with equipment specified in other sections provided hereunder unless specifically stated otherwise.
2. Each supplier of a control product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequence of operation.
3. Coordinate and resolve any compatibility issues arising between control products provided hereunder and those provided under other sections or divisions.
4. The Controls Contractor is responsible for providing all controls required to control all products specified under Division 23 unless specifically stated elsewhere.
5. The Controls Contractor is responsible for the interface of all controls products included in Division 23 unless specifically stated elsewhere.

### 3.02 WORKMANSHIP

- A. Install all equipment in accordance with manufacturers' recommendations.
- B. Install equipment, piping, and wiring/raceway parallel to building lines wherever possible.
- C. Provide sufficient slack and flexible connections in wiring to allow for vibration of piping and equipment.
- D. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100, Part A of the National Electric Code.

### 3.03 EXISTING EQUIPMENT

- A. In general, the Contractor may reuse any components needed to provide the specified sequence of operations except as specifically described below. Any existing control wiring, tubing, or devices that have been previously abandoned or that will be abandoned as the result of work under this Contract shall be removed.
- B. Existing Wiring: Contractor may reuse existing wiring provided the quality of the existing installation meets this specification. Verify the integrity of existing wiring and re-label in accordance with this specification. Remove wiring and/or tubing abandoned as the result of this work. Remove any wiring or tubing abandoned as part of previous work.
- C. Local Control Panels: Contractor may reuse existing control cabinets to locate new equipment where existing cabinets are in good condition. Remove all redundant or abandoned equipment within these cabinets. Patch face cover to fill all holes caused by removal of unused equipment.
- D. Unless specifically stated elsewhere, Contractor is not responsible for the repair or replacement of existing control system equipment that is not shown to be replaced but will be reused to meet the Sequence of Operation. Should the Contractor find existing equipment requiring maintenance, Contractor shall notify the Owner immediately. Repair will be performed under separate Contract.
- E. Temperature Sensor Wells: Contractor may reuse existing sensor wells in piping. Modify wells as required to provide proper fit of sensors.
- F. Control Valves and Actuators: Replace all existing control valves and actuators.
- G. Starters: Modify existing starter control circuits, if necessary, to provide hand/off/auto control of each starter controlled. Provide new starters or starter control package if required.

### 3.04 GENERAL WIRING

- A. All control and interlock wiring shall comply with national and electrical codes and Division 26. Where requirements of this section differ from 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 according to 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 Class 2 limits.
- D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling plenum return air plenums, approved cable not in raceway may be used provided cables are UL listed for the intended application.
- E. All wiring in mechanical, electrical, or service rooms and wiring located where it may be subject to damage shall be installed in raceway.
- F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring may not be used for low-voltage wiring except for the purpose of interfacing the two.
- G. Where Class 2 wiring is installed exposed, wiring is to be routed parallel or perpendicular to building lines and neatly tied at a maximum of 10-foot intervals.
- H. Where plenum cables are used without raceway, support or anchor cable from building structure. Do not anchor or support cable from ductwork, electrical raceways, piping, or suspended ceiling systems.
- I. Provide all wire-to-device connections at terminal block or terminal strip. Provide all wire-to-wire connections at terminal block.
- J. Neatly bundle wiring located within enclosures to permit access to devices and terminals.
- K. Maximum allowable voltage for control wiring shall be 120V. If only higher voltages are available, Contractor shall provide a step-down transformer.
- L. All wiring shall be installed as continuous lengths with no splices permitted between termination points.
- M. Install plenum wiring in sleeves where it passes through walls and floors. Provide fire-stop foam where necessary to maintain fire rating.
- N. Provide size of raceway and size and type of wire as required by NEC and as required to meet manufacturers' recommendations for connected equipment.
- O. Include one pull string in each raceway 1-inch or larger.
- P. Use color coded conductors throughout.
- Q. Locate control and status relays in designated enclosures only. Such enclosures include packaged equipment control cabinets unless such cabinets also contain Class 1 starters.
- R. Conceal all raceways except within mechanical, electrical, or service rooms. Maintain minimum raceway clearance of 6-inches from high temperature equipment such as steam piping or boiler flues.

- S. Secure raceways with raceway clamps fastened to the structure and spaced in accordance with code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be supported from ductwork, electrical raceways, piping, or suspended ceiling systems.
- T. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all raceways.
- U. Maintain updated wiring diagrams (as-built) at site with terminations identified.
- V. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3-feet in length and shall be supported at both ends. Flexible metal raceway less than 1/2-inch electrical trade size shall not be used. In areas exposed to moisture, including but not limited to chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

### 3.05 COMMUNICATION WIRING

- A. Install in accordance with 3.04 above.
- B. Follow manufacturers' recommendations for all communications cabling including but not limited to maximum pulling, tension, and bend radius.
- C. Do not install communications cabling in a raceway or enclosure containing Class 1 or other Class 2 wiring.
- D. Verify the integrity of the entire network immediately following cable installation using test measures appropriate for each cable.
- E. Provide a lightning arrestor between cables and grounds where cable enters or exits a building. Install arrestor in accordance with manufacturers' recommendations.
- F. All communications wiring shall be un-spliced length when that length is commercially available.
- G. All communications wiring shall be labeled to indicate origination and destination.
- H. Ground coaxial cable in accordance with NEC regulations article on "Communications Circuits, Cable and Protector Grounding."

### 3.06 IDENTIFICATION OF HARDWARE AND WIRING

- A. Label all wiring and cabling, including wiring and cabling terminating within factory fabricated panels, within 2 inches of termination with the BAS address or termination number.
- B. Label all pneumatic tubing at each end within 2 inches of termination with a descriptive identifier.
- C. Permanently label or code each point of field terminal strips to show the instrument or item served.
- D. Identify control panels with minimum 1/2-inch letters on laminated plastic nameplate.
- E. Identify all other control components with permanent labels. All plug-in components shall be labeled so that removal of component does not remove label.
- F. Arrange components so that UL or CSA labels are visible after equipment is installed.
- G. Identifiers shall match record documents.

- H. Provide laminated network communication diagrams, point-to-point wiring diagramming, and process control diagrams in each control panel for control components contained therein.

### 3.07 BAS CONTROLLER INSTALLATION

- A. Provide a separate BAS controller for each discrete system. A BAS controller may control more than one system provided that all points associated with the system are assigned to the same BAS controller. Points used for control loop reset, such as outside air temperature or space temperature, are exempt from this requirement.
- B. Building Controllers and Custom Application Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type. If input points are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used.
  - 1. Future use of spare capacity shall require providing the field device, field wiring, point database definition, and custom software. No additional controller boards or point modules shall be required to implement use of spare points.
- C. Provide sufficient internal memory for the specified sequences of operation and trend logging. Provide a minimum of 25% available memory free for future use.

### 3.08 PROGRAMMING

- A. Provide programming for the system as required to perform the sequence of operation. Provide all other programming necessary for proper operation of the system but not specified including but not limited to time delays, control deadbands, equipment interlocks, equipment sequencing, alarm notification, and control sequences recommended by equipment manufacturers.
- B. All control setpoints and loop tuning parameters accessible for review and adjustment at workstation graphics or through workstation menus without requiring modification of program code.
- C. For systems using text-based programming, embed comments in the programming code to clearly describe each section of the program.
- D. Contractor to provide time scheduling functions as specified in the Sequence of Operations. Independent schedules shall be provided for each system, unless otherwise specified.
- E. Contractor to provide alarming functions as specified in Sequence of Operations. Contractor shall also configure alarming functions as directed by Owner including setting alarm limits and differentials, states, type of notification, and alarm messages.
- F. Contractor shall configure trending and functions as directed by Owner including trend data collection and report format.
- G. Point Naming: Match existing Owner point naming convention.

### 3.09 GRAPHICS

- A. Add new or update existing graphics for all controlled systems and floor plans of the building to include new equipment. As a minimum, systems requiring graphics to include each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. On each graphic, show input and output points for the system. Also,

show relevant calculated points such as setpoints. Input, output, and software point values shall be changeable from graphic screen.

- B. Show terminal unit information on a “graphic” summary table. Provide dynamic information on each point shown.

### 3.10 CONTROL SYSTEM CHECKOUT AND TESTING

- A. Contractor shall completely test and verify specified control system performance associated with the control and monitoring of central plant equipment. Compile test results and include with written certification.
- B. Contractor shall furnish all labor and test apparatus required to calibrate and prepare for service all instruments, controls, and accessory equipment furnished hereunder.
- C. Contractor shall perform the following testing and verification.
- D. Verify that all control and communications wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
  - 1. Enable control systems and verify instrument calibration and end-to-end reporting accuracy of all input devices individually. Perform calibration in accordance with manufacturers’ recommendations. Repair or replace all temperature sensors requiring a calibration offset greater than +/- 1°F.
  - 2. Verify control stability and end-to-end reporting requirements are met.
  - 3. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that normal positions are correct.
  - 4. Verify that all analog output devices (IPs, actuators, etc.) are functional, start/stop and span are correct, and direction and normal position are correct.
  - 5. Verify that system operation complies with the sequence of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules.
  - 6. Tune all new BAS control loops and optimum start/stop routines. Control loops shall have stable controlled variable equal to setpoint, and shall maintain stable output signal without cycling. Control loops shall be maintained within +/- 1°F of setpoint or 2% of input sensor range. Output signal fluctuations shall not exceed 5% during normal operation.
  - 7. Alarms and Interlocks:
    - a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    - b. Trip interlocks using field contacts to check the logic and ensure that the fail-safe condition for all actuators is in the proper direction.
    - c. Test interlock actions by simulating alarm conditions to check the initiating value of the variable and the interlock action.
- E. Contractor shall maintain the following documentation.
  - 1. Calibration log including date, time, control system readout, means of verification, verification measurement, and required calibration offset for each analog input.
  - 2. BAS Loop Response: Supply trend data output in graphical form showing the step response of each BAS loop. The test shall show the loop’s response to a change in setpoint requiring a change in actuator position of at least 25% of full range. Provide sampling rate from 10 seconds to 1 minute depending on loop speed. Trend data shall show for each sample the set point, actuator position, and controlled variable values. Contractor shall retune any loop that indicates unreasonably under-damped or over-damped control.
  - 3. Demand Limiting: Supply trend data showing the action of any demand limiting functions. Document operation at maximum one-minute intervals for at least 30 minutes.

4. Operational Logs: Provide operational trend logs for each system indicating set points, operating points, valve positions, mode, and equipment status. Logs shall cover three 48-hour periods and have a sample frequency of not more than 5 minutes. Logs provided in both printed and disk formats.
- F. After system operation is completely verified, provide written certification to Owner that systems have been fully tested and are operating according to specifications and ready for functional testing. Provide copies of documentation signed by person performing tests. Documentation to include:
1. Calibration log
  2. BAS Loop Response Trends
  3. Demand Limiting Trends
  4. Operational Logs

### 3.11 DEMONSTRATION AND ACCEPTANCE

- A. Demonstration: Demonstrate operation of control system to Engineer and Owner including:
1. Menu functions.
  2. Point overrides.
  3. Control loop response after point modification.
  4. Alarm response time.

### 3.12 TRAINING

- A. Provide a minimum of eight (8) hours training to Owner's personnel in use and maintenance of BAS building management and control hardware and software. Training shall be provided in two (2) sessions of 4 hours each as follows:
1. The first session shall a brief system overview and training on log on procedures, data access and display, alarm and status descriptions, log requests, execution of commands, and other general system operation procedures including a specific review of new workstation features available using the new system.
  2. The second session shall include instruction on site-specific programs, graphics, and user interfaces.
- B. Manufacturers Training: Provide 24 hours of manufacturer training for at least 4 Owner's Representatives. Training shall be provided on a variety of topics as selected by the Owner. Training shall be performed at manufacturer's designated locations.

END OF SECTION