County of El Paso Purchasing Department
500 East San Antonio, Room 500
El Paso, Texas 79901
(915) 546-2048 / Fax: (915) 546-8180

ADDENDUM 3

To: All Interested Proposers

From: Claudia Sepulveda, Bid Clerk/Buyer

Date: December 11, 2006

Subject: Bid# 06-106, Sheriff's Headquarters Remodeling Project

NOTICE TO BIDDERS:

This addendum shall be considered part of the Contract Documents for the above-mentioned project as though it had been issued at the same time and incorporated integrally therewith. Where provisions of the time and supplementary data differ from those of the original Contract Documents, this addendum shall govern and take precedence.

Bidders are hereby notified to make any necessary adjustments in their estimates on account of this addendum. It will be construed that each Bidder's Proposal is submitted with full knowledge and understanding of all modifications and supplemental data specified herein.

Acknowledge receipt of this addendum by inserting the number in the space provided on the bid form.

REVISE THE CONSTRUCTION DOCUMENTS AS FOLLOWS:

SPECIFICATIONS
Section 15952: Replace with attached section.

DRAWINGS
SHEET P 1.5: Modify gas line sizes as shown on attached drawing PA- 1.

The Purchasing Department received questions relating to the above referenced proposal. The Facilities Management Department has responded to the following questions:

1. The specifications state that a contractor has to have at least 5 years experience as a company. If we send you our qualifications as a company will we still be able to bid this project?

   The company can submit the bid, but if they don't meet the minimum experience they will not meet specifications.

2. There is no specific detail or information regarding countertop relocation or replacement. Are all countertops going to be replaced or, remove modify and relocate existing?

   Some countertops will be relocated and some will be new (i.e. 9/A-8.0 & 11/A-8.0). All relocated countertops are clearly labeled in the Existing Furniture Schedules as well as the Millwork Elevations. Furthermore, the existing countertops (including shapes & sizes) are clearly indicated in sheet A-8.1 for the bidder's reference.

3. There is no information about casework refinish or replacement. Which location will take new millwork? In which location millwork will be refinishing?

   All new millwork is clearly marked in sheet A-8.0. All existing millwork is clearly referenced to the existing furniture schedule.

4. Can we bid section 33000 (Cat. 6 Structured Cabling System) only?

   Yes, but the company needs to contact the General Contractors. If they are cabling system suppliers, manufacturers or installers, they need to be selected by the General Contractors.

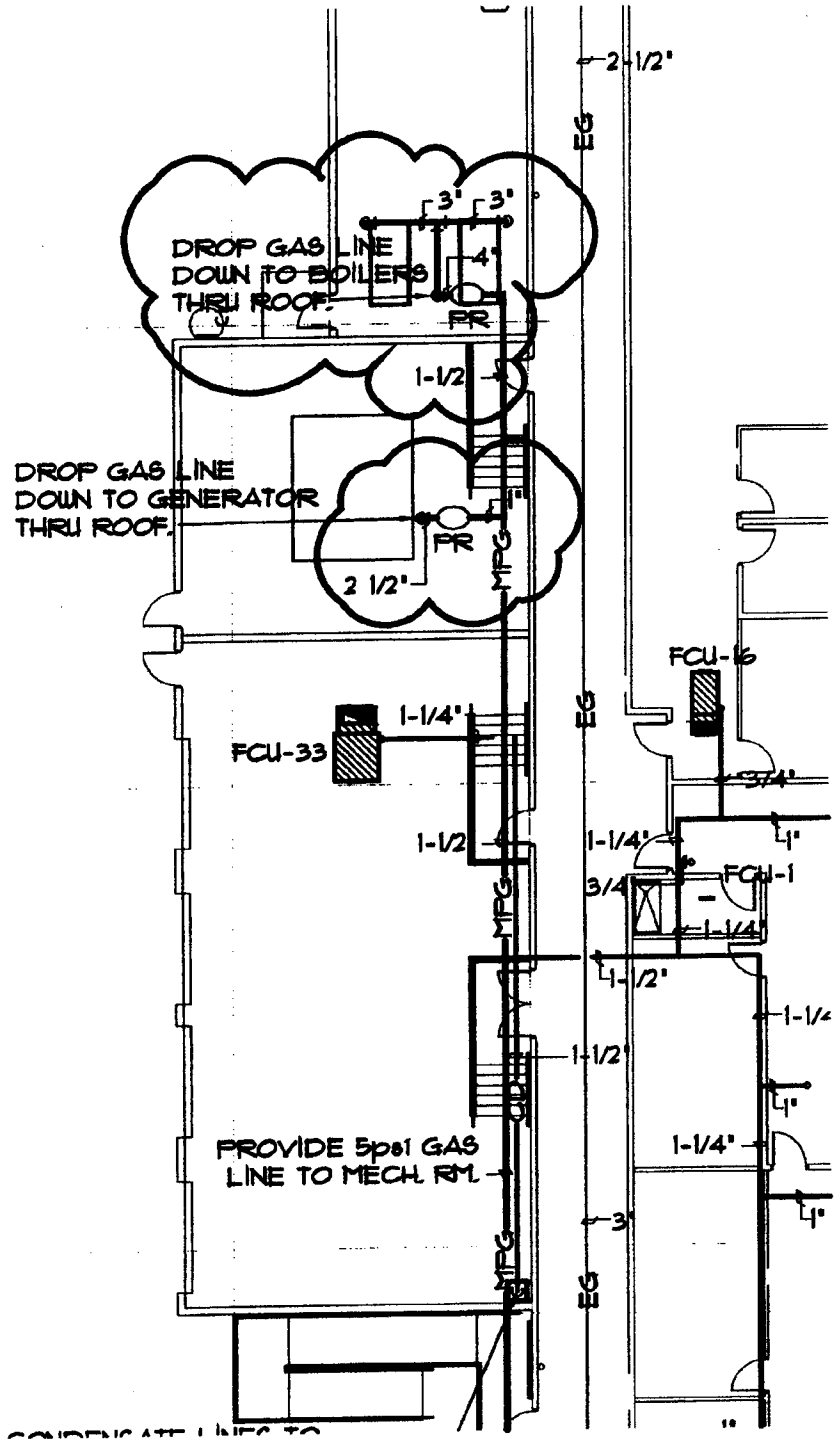
FLUID SYSTEMS, INC.
CONSULTING MECHANICAL ENGINEERS
POST OFFICE BOX 1809 • CANUTILLO, TEXAS 79835 • (915) 877-2148

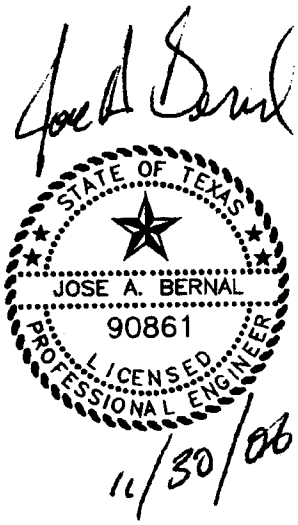
DATE: NOVEMBER 29, 2006 DRAWN BY: FLUID SYSTEMS INC.

JOB NUMBER: 2522 JOB DESCRIPTION: SHERIFF'S HEADQUARTERS

☒ SUPPLEMENTARY SHEET: PA-1 REFERENCE SHEET: P1.5
☐ ADDENDUM SHEET: _____

DESCRIPTION: ADD GAS LINES SIZES AS SHOWN.





11/30/06

SECTION 15952 – CONTROL, INSTRUMENTATION, AND VARIABLE FREQUENCY DRIVES

PART 1: GENERAL

1.1 Products Furnished But Not Installed Under This Section

A. Section 15180 - Heating and cooling piping:
   1. Control valves
   2. Press and temp sensor wells & sockets

1.2 Products Installed But Not Furnished Under This Section

- None

1.3 Products Not Furnished or Installed but integrated with the Work of this Section

- None

1.4 Related Sections

A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.
B. The following sections constitute related work:
   1. Section 15800 - Air Distribution
   2. Section 15950 - Testing, Adjusting, and Balancing

1.5 Description

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphic. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface.
B. The system shall directly control HVAC equipment as specified in Section 15900 Appendix A (Sequences of Operation). Each zone controller shall provide occupied and unoccupied modes of operation by individual zone. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified in Appendix A.
C. Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

1.6 Approved Control Systems

A. The following are approved control system suppliers, manufacturers, and product lines:

	Manufacturer	Product Line
	Automated Logic Corporation	
	Invensys	

B. The above list is alphabetical and does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.

1. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
2. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.7 Quality Assurance

A. Installer and Manufacturer Qualifications
   1. Installer shall have an established working relationship with Control System Manufacturer.
   2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.

1.8 Codes And Standards

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:
   1. National Electric Code (NEC)
   2. International Mechanical Code (IMC)
   3. ANSI/ASHRAE 135-2004: Data Communication Protocol for Building Automation and Control Systems (BACNET)

1.9 System Performance

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).
   1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
   2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
   3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
   4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
   5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
   6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
   7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
   8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 sec of other workstations.
   9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
   10. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table 1
Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5°C (±1°F)
Ducted Air	±0.5°C (±1°F)
Outside Air	±1.0°C (±2°F)
Dew Point	±1.5°C (±3°F)
Water Temperature	±0.5°C (±1°F)
Delta-T	±0.15°C (±0.25°F)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale

Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 ppm

Note 1: Accuracy applies to 10% - 100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

Table 2
Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0°C (±2.0°F)	
Duct Temperature	±1.5°C (±3°F)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.10 Submittals

A. Product Submittal Requirements: Provide submittals within 12 weeks of contract award on the following:
    1. Direct Digital Control System Hardware
        a. Complete bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
        b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
            i. Direct digital controllers (controller panels)
            ii. Transducers and transmitters
            iii. Sensors (include accuracy data)
            iv. Actuators
            v. Valves
            vi. Relays and switches
            vii. Control panels
            viii. Power supplies
            ix. Batteries
            x. Operator interface equipment
            xi. Wiring
        c. Wiring diagrams and layouts for each control panel. Show termination numbers.
        d. Floor plan schematic diagrams indicating field sensor and controller locations.
        e. Riser diagrams showing control network layout, communication protocol, and wire types.
    2. Central System Hardware and Software
        a. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
        b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
            i. Central Processing Unit (CPU) or web server
            ii. Monitors
            iii. Keyboards
            iv. Power supplies
            v. Battery backups
            vi. Interface equipment between CPU or server and control panels
            vii. Operating System software
            viii. Operator interface software
            ix. Color graphic software
            x. Third-party software

c. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems
   a. Riser diagrams showing control network layout, communication protocol, and wire types.
   b. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
   c. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
   d. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
   e. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified in Section 15900 Appendix A. Indicate alarmed and trended points.
4. Description of process, report formats, and checklists to be used in Section 15900 Article 3.16 (Control System Demonstration and Acceptance).

B. Project Record Documents. Submit four copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:
   1. Project Record Drawings.
   2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 15900 Article 3.16 (Control System Demonstration and Acceptance).
   3. Operation and Maintenance (O&M) Manual. Printed, electronic, or online help documentation of the following:
      a. As-built versions of submittal product data.
      b. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
      c. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
      d. Licenses, guarantees, and warranty documents for equipment and systems.
      e. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

1.11 Warranty

A. Warrant work as follows:

1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
3. If Engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.12 Ownership Of Proprietary Material

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:
    1. Graphics
    2. Record drawings
    3. Database
    4. Application programming code
    5. Documentation

PART 2: PRODUCTS

2.1 Materials

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2 Communication

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a unified control network. A gateway (translator) shall communicate with third-party equipment furnished or installed by others.
B. Install new wiring and network devices as required to provide a complete and workable control network. Use existing Ethernet backbone for network segments marked "existing" on project drawings.
C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
    1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
    2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 15900 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.
E. System shall automatically synchronize controller time clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.
F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.3 Operator Interface

A. Operator Interface. Web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.
B. Communication. Workstation or web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol.
C. Hardware. Each workstation or web server shall consist of the following:

1. Hardware Base. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified in Section 15900 Paragraph 1.9. Hard disk shall have sufficient memory to store system software, one year of data for trended points specified in Appendix A, and a system database at least twice the size of the existing database at system acceptance. Configure computers and network connections if multiple computers are required to meet specified memory and performance. Web server or workstations shall be IBM-compatible PCs with a minimum of:
    a. Intel Pentium 2.66 GHz processor
    b. 1 GB RAM
    c. 40 GB hard disk providing data at 100 MB/sec
    d. 48x CD-ROM drive
    e. Serial, parallel, and network communication ports and cables required for proper system operation

D. Operator Functions. Operator interface shall allow each authorized operator to execute the following functions as a minimum:
    1. Log In and Log Out. System shall require user name and password to log in to operator interface.
    2. Point-and-click Navigation. Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
    3. View and Adjust Equipment Properties. Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.
    4. View and Adjust Operating Schedules. Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.
    5. View and Respond to Alarms. Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.
    6. View and Configure Trends. Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.
    7. View and Configure Reports. Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.
    8. Manage Control System Hardware. Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.
    9. Manage Operator Access. Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of

operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

E. System Software.
   1. Operating System. Web server shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows XP Pro, Red Hat Linux, or Sun Solaris.
   2. System Graphics. Operator interface 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. 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.
      b. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
      c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
      d. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. 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 (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

F. System Tools. 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 standard IBM-compatible PCs 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. Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
   3. System Configuration. Operators shall be able to configure the system.
   4. Online Help. Context-sensitive online help for each tool shall assist operators in operating and editing the system.

5. Security. System shall require a user name and password to view, edit, add, or delete data.
    a. Operator Access. Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object.
    b. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
    c. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.
6. System Diagnostics. System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).
7. 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 specified in Section 15900 Appendix A (Sequences of Operation).
8. Alarm Messages. Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.
9. Alarm Reactions. Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
10. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.
11. Trend Configuration. 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 in Section 15900 Appendix A (Sequences of Operation).
12. Object and Property Status and Control. Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.
13. 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.
14. 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:
    i. Alarm History.
    ii. Trend Data. Operator shall be able to select trends to be logged.
    iii. Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

15. Graphics Generation. Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.
16. Graphics Library. Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.
17. Custom Application Programming. Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:
    a. Language. Language shall be graphically based or English language oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall allow for free-form programming that is not column-oriented or "fill-in-the-blanks."
    b. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
    c. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.

d. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
e. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
f. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.
g. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.
    i. Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.
    ii. System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

2.4 Controller Software

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.
B. System Security. See Paragraph 2.3.F.5 (Security) and Paragraph 2.3.F.15.c (Operator Activity).
C. Scheduling. See Paragraph 2.3.D.4 (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:
    1. Weekly. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
    2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
    3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.
E. Binary and Analog Alarms. See Paragraph 2.3.F.7 (Alarm Processing).
F. Alarm Reporting. See Paragraph 2.3.F.9 (Alarm Reactions).
G. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.
H. Demand Limiting.
    1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.
    2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified in Section 15900 Appendix A (Sequences of Operation). When demand drops below adjustable levels, system shall restore loads as specified.
I. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Section 15900 Appendix A (Sequences of Operation).
J. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Section 15900 Appendix A (Sequences of Operation).
K. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.
L. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.
M. Energy Calculations.
    1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
    2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.
N. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.
O. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.
P. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Section 15900 Appendix A (Sequence of Operations).

2.5 Controllers

A. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 15900 Article 1.9 (System Performance).
B. Communication.
    1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
    2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
    3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
    4. Stand-Alone Operation. Each piece of equipment specified in Section 15900 Appendix A shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.
C. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
    1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
    2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
D. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.
E. Serviceability.
    1. Controllers shall have diagnostic LEDs for power, communication, and processor.
    2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
    3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
F. Memory.
    1. Controller memory shall support operating system, database, and programming requirements.
    2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
    3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

G. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
H. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.6 Input and Output Interface

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.
B. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.
C. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.
D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.
E. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.
F. Binary Outputs. Binary outputs shall send an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.
G. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.
H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.
I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.7 Power Supplies And Line Filtering

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
    a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
    b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.
1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
b. Dielectric strength of 1000 V minimum
c. Response time of 10 nanoseconds or less
d. Transverse mode noise attenuation of 65 dB or greater
e. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.8 Auxiliary Control Devices

A. Electric Damper and Valve Actuators.
1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range. Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)
4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.

B. Control Valves.
1. General. Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.
2. Type. Provide two- or three-way control valves for two-position or modulating service as shown.
3. Water Valves.
    a. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball.
    b. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.

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

c. Ports. Valves providing modulating service shall have equal percentage ports.

d. Sizing.
i. Two-position service: line size.
ii. Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 35 kPa (5 psi).
iii. Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi).

e. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.
i. Water zone valves: normally open.
ii. Heating coils in air handlers: normally open.
iii. Chilled water control valves: normally closed.
iv. Other applications: as scheduled or as required by sequences of operation.

4. Steam Valves.
a. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide minimum close-off pressure rating equal to 150% of operating (inlet) pressure.
b. Ports. Valves providing modulating service shall have linear ports.
c. Sizing.
i. Two-position service: select pressure drop equal to 10%-20% of inlet psig.
ii. Modulating service at 100 kPa (15 psig) or less: select pressure drop equal to 80% of inlet psig.
iii. Modulating service at 101-350 kPa (16-50 psig): select pressure drop equal to 50% of inlet psig.
iv. Modulating service at over 350 kPa (50 psig): select pressure drop as scheduled on drawings.

C. Binary Temperature Devices.
1. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

D. Temperature Sensors.
1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2(10 ft^2) of duct cross-section.

3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.

E. Relays.
1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

F. Current Switches.
1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

G. Pressure Transducers.
1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

H. Local Control Panels.
1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

2.9 Wiring And Raceways

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 16.
B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

2.10 Fiber Optic Cable System

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.
B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

PART 3: EXECUTION

3.1 Examination

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.
B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.
C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 15900 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 Protection

A. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.
B. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 Coordination

A. Site.
    1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other

trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Submittals. See Section 15900 Article 1.10 (Submittals).
C. Test and Balance.
1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
2. Train Test and Balance Contractor to use control system interface tools.
3. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

D. Life Safety.
1. Duct smoke detectors required for air handler shutdown are provided under Division 16. Interlock smoke detectors to air handlers for shutdown as specified in Section 15900 Appendix A (Sequences of Operation).
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 15. Interlock smoke dampers to air handlers as specified in Section 15900 Appendix A (Sequences of Operation).
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 15. Fire and smoke damper control is provided under Division 16.

E. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows.
1. Communication media and equipment shall be provided as specified in Section 15900 Article 2.2 (Communication).
2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described in Section 15900 Appendix A regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 General Workmanship

A. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.
B. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.
C. Install equipment in readily accessible locations as defined by National Electrical Code (NEC) Chapter 1 Article 100 Part A.

D. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.
E. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

3.5 Field Quality Control

A. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 15900 Article 1.8 (Codes and Standards).
B. Continually monitor field installation for code compliance and workmanship quality.
C. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.6 Wiring

A. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 16, and manufacturer's recommendations. Where the requirements of Section 15900 differ from Division 16, Section 15900 shall take precedence.
B. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC and Division 16.
C. Low-voltage wiring shall meet NEC Class 2 requirements. Subfuse low-voltage power circuits as required to meet Class 2 current limit.
D. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed for the intended application.
E. Install wiring in raceway where subject to mechanical damage and at levels below 3 m (10ft) in mechanical, electrical, or service rooms.
F. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.
G. Do not install wiring in raceway containing tubing.
H. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 3 m (10 ft) intervals.
I. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.
J. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.
K. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.
L. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
M. Use color-coded conductors throughout.

N. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.
O. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment such as steam pipes or flues.
P. Adhere to requirements in Division 16 where raceway crosses building expansion joints.
Q. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.
R. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.
S. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.
T. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.7 Communication Wiring

A. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).
B. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.
C. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.
D. Verify entire network's integrity following cable installation using appropriate tests for each cable.
E. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.
F. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
G. Label communication wiring to indicate origination and destination.
H. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.8 Fiber Optic Cable

A. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.9 Installation of Sensors

A. Install sensors according to manufacturer's recommendations.
B. Mount sensors rigidly and adequately for operating environment.
C. Install room temperature sensors on concealed junction boxes properly supported by wall framing.
D. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.
E. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.
F. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2 (1 ft^2) of coil area.
G. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
H. Install outdoor air temperature sensors on north wall at designated location with sun shield.
I. Differential Air Static Pressure.
    1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
    4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
    5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
    6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.
J. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

3.10 Flow Switch Installation

A. Use correct paddle for pipe diameter.
B. Adjust flow switch according to manufacturer's instructions.

3.11 Actuators

A. General. Mount actuators and adapters according to manufacturer's recommendations.
B. Electric and Electronic Damper Actuators. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.
    1. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
    2. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, then tighten linkage.
    3. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
    4. Provide necessary mounting hardware and linkages for actuator installation.
C. Valve Actuators. Connect actuators to valves with adapters approved by actuator manufacturer.

3.12 Warning Labels

A. Affix permanent warning labels to equipment that can be automatically started by the control system.
    1. Labels shall use white lettering (12-point type or larger) on a red background.
    2. Warning labels shall read as follows.

CAUTION
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.

B. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
    1. Labels shall use white lettering (12-point type or larger) on a red background.
    2. Warning labels shall read as follows.

CAUTION
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.13 Identification of Hardware and Wiring

A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.
B. Label pneumatic tubing at each end within 5 cm (2 in.) of termination with a descriptive identifier.
C. Permanently label or code each point of field terminal strips to show instrument or item served.
D. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.
E. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.
F. Label room sensors related to terminal boxes or valves with nameplates.
G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.
H. Label identifiers shall match record documents.

3.14 Programming

A. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 15900 Appendix A (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix C may be used.
B. Software Programming. Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.
    1. Application Programming. Provide application programming that adheres to sequences of operation specified in Section 15900 Appendix A. Program documentation or comment statements shall reflect language used in sequences of operation.
    2. System Programming. Provide system programming necessary for system operation.
C. Operator Interface.
    1. Standard Graphics. Provide graphics as specified in Section 15900 Article 2.3 Paragraph E.2 (System Graphics). Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List in Section 15900 Appendix A. Point information on graphics shall dynamically update.
    2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation) as described in Section 15900.

3.15 Control System Checkout and Testing

A. Startup Testing. Complete startup testing to verify operational control system before notifying Owner of system demonstration. Provide Owner with schedule for startup testing. Owner may have representative present during any or all startup testing.
    1. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 15900.
    2. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
    3. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
    4. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
    5. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
    6. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
    7. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
    8. Alarms and Interlocks.
        a. Check each alarm with an appropriate signal at a value that will trip the alarm.
        b. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
        c. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.16 Control System Demonstration and Acceptance

A. Demonstration. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified in Article 3.17 (Control System Checkout and Testing). Provide Engineer with log documenting completion of startup tests.
B. Acceptance.
    1. After tests described in this specification are performed to the satisfaction of both Engineer and Owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.

2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 15900 Article 1.10 (Submittals).

3.17 Cleaning

A. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.
B. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.
C. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.18 Training

A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.
B. Training shall enable students to accomplish the following objectives.
    1. Proficiently operate system
    2. Understand control system architecture and configuration
    3. Understand DDC system components
    4. Understand system operation, including DDC system control and optimizing routines (algorithms)
    5. Operate workstation and peripherals
    6. Log on and off system
    7. Access graphics, point reports, and logs
    8. Adjust and change system setpoints, time schedules, and holiday schedules
    9. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
    10. Understand system drawings and Operation and Maintenance manual
    11. Understand job layout and location of control components
    12. Create, delete, and modify alarms, including configuring alarm reactions
    13. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs
    14. Configure and run reports
    15. Configure and calibrate I/O points
    16. Maintain software and prepare backups
    17. Add new users and understand password security procedures
C. Instructors shall be factory-trained and experienced in presenting this material.

3.19 Sequence of Operation

See Section 15900 Appendix A (Sequences of Operation).

3.20 Points List

Points lists are integrated into Section 15900 Appendix A (Sequences of Operation).

APPENDIX A: Sequences of Operation

1. Fan Coil Unit (FCU) (typical of 33)

   Run Conditions - Scheduled:
   The unit shall run according to a user definable time schedule in the following modes:

   - Occupied Mode: The unit shall maintain
     - A 74°F (adj.) cooling setpoint
     - A 70°F (adj.) heating setpoint.
   - Unoccupied Mode (night setback): The unit shall maintain
     - A 85°F (adj.) cooling setpoint.
     - A 55°F (adj.) heating setpoint.

   Zone Setpoint Adjust:
   The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

   Zone Optimal Start:
   The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

   Zone Unoccupied Override:
   A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

   Freeze Protection:
   The unit shall shut down and generate an alarm upon receiving a freezestat status.

   Smoke Detection:
   The unit shall shut down and generate an alarm upon receiving a smoke detector status.

   Fan:
   The fan shall run anytime the unit is commanded to run, unless shutdown on safeties.

   Cooling Coil Valve:
   The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

   The cooling shall be enabled whenever:

- Outside air temperature is greater than 60°F (adj.).
- AND the zone temperature is above cooling setpoint.
- AND the fan is on.

Heating Coil Valve:
The controller shall measure the zone temperature and modulate the heating coil valve to maintain its heating setpoint.

The heating shall be enabled whenever:

- Outside air temperature is less than 65°F (adj.).
- AND the zone temperature is below heating setpoint.
- AND the fan is on.

Mixed Air Dampers:
The outside air damper shall open to provide a fixed percentage outside air ventilation anytime the unit is occupied and shall close anytime the unit stops. The damper open position shall be set during testing and balancing. The mixed air dampers shall close 1sec (adj.) after the fan stops.

If Optimal Start Up is available the outside air damper shall close and the return air damper shall open.

Discharge Air Temperature:
The controller shall monitor the discharge air temperature.

Alarms shall be provided as follows:

- High Discharge Air Temp: If the discharge air temperature is greater than 120°F (adj.).
- Low Discharge Air Temp: If the discharge air temperature is less than 40°F (adj.).

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points					
Point Name	AI	AO	BI	BO	AV	BV	Sched	Trend	Alarm	Show On Graphic
Zone Temp	×							×		×
Zone Setpoint Adjust	×									×
Discharge Air Temp	×							×		×
Cooling Valve		×						×		×
Heating Valve		×						×		×
Zone Override			×					×		×
Freezestat			×					×	×	×
Smoke Detector			×					×	×	×
Fan Status			×							×
Fan Start/Stop				×				×		×
Mixed Air Dampers				×				×		×
Schedule							×			
Heating Setpoint								×		×
Cooling Setpoint								×		×

2. Air Cooled Chiller System

Chiller - Run Conditions:
The chiller shall be enabled to run whenever:

- A definable number of chilled water coils need cooling
- AND the outside air temperature is greater than 54°F (adj.).

To prevent short cycling, the chiller shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The chiller shall run subject to its own internal safeties and controls.

Chiller:
The chiller shall be enabled a user adjustable time after pump statuses are proven on. The chiller shall therefore have a user adjustable delay on start.

The delay time shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The chiller shall run subject to its own internal safeties and controls.

Alarms shall be provided as follows:

- Chiller Failure: Commanded on, but the status is off.
- Chiller Running in Hand: Commanded off, but the status is on.

- Chiller Runtime Exceeded: Status runtime exceeds a user definable limit.

Chilled Water Supply Temperature - Setpoint Reset:
The chilled water supply temperature setpoint shall reset using a trim and respond algorithm based on cooling requirements.

The chilled water supply temperature setpoint shall reset to a lower value as the facility's chilled water valves open beyond a user definable threshold (90% open, typ.). Once the chilled water coils are satisfied (valves closing) then the chilled water supply temperature setpoint shall gradually rise over time to reduce cooling energy use.

Chilled Water Temperature Monitoring:
The following temperatures shall be monitored:

- Chilled water supply.
- Chilled water return.

Alarms shall be provided as follows:

- High Chilled Water Supply Temp: If the chilled water supply temperature is greater than 55°F (adj.).
- Low Chilled Water Supply Temp: If the chilled water supply temperature is less than 38°F (adj.).

	Hardware Points				Software Points					
Point Name	AI	AO	BI	BO	AV	BV	Sched	Trend	Alarm	Show On Graphic
Chilled Water Return Temp	×							×		×
Chilled Water Supply Temp	×							×		×
Chilled Water Supply Temp Setpoint Reset		×						×		×
Chiller Status			×					×		×
Chiller Enable				×						×
Chiller Failure									×	

Chilled Water Pumps

Chilled Water Pump System - Run Conditions:
The chilled water pumps shall be enabled whenever:

- A definable number of chilled water coils need cooling.
- AND the outside air temperature is greater than 54°F (adj.).

3. Hot Water Boilers

Boiler System Run Conditions:
The boiler system shall be enabled to run whenever:

- A definable number of hot water coils need heating.
- AND outside air temperature is less than 65°F (adj.).

To prevent short cycling, the boiler system shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The boiler shall run subject to its own internal safeties and controls.

The boiler system shall also run for freeze protection whenever the outside air temperature is less than 38°F (adj.).

Hot Water Pump Lead/Lag Operation:
The two hot water pumps shall operate in a lead/lag fashion.

- The lead pump shall run first.
- On failure of the lead pump, the lag pump shall run and the lead pump shall turn off.
- On decreasing hot water differential pressure, the lag pump shall stage on and run in unison with the lead pump to maintain hot water differential pressure setpoint.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Hot Water Differential Pressure Control:
The controller shall measure hot water differential pressure and modulate the hot water pump VFDs in sequence to maintain its hot water differential pressure setpoint.

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate hot water pump speeds to maintain a hot water differential pressure of 12lb_f/in^2 (adj.). The VFDs minimum speed shall not drop below 20% (adj.).

On dropping hot water differential pressure, the VFDs shall stage on and run to maintain setpoint as follows:

- The controller shall modulate the lead VFD to maintain setpoint.
- If the lead VFD speed is greater than a setpoint of 90% (adj.), the lag VFD shall stage on.
- The lag VFD shall ramp up to match the lead VFD speed and then run in unison with the lead VFD to maintain setpoint.

On rising hot water differential pressure, the VFDs shall stage off as follows:

- If the VFDs speeds drops back to 60% (adj.) below setpoint, the lag VFD shall stage off.
- The lead VFD shall continue to run to maintain setpoint.

Boiler Lead/Standby Operation:
The two boilers shall operate in a lead/standby fashion when called to run and flow is proven.

- The lead boiler shall run first.
- On failure of the lead boiler, the standby boiler shall run and the lead boiler shall turn off.

The designated lead boiler shall rotate upon one of the following conditions: (user selectable):

- manually through a software switch
- if boiler runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Boiler 1
  - Failure: Commanded on but the status is off.
- Boiler 2
  - Failure: Commanded on but the status is off.
- Lead Boiler Failure: The lead boiler is in failure and the standby boiler is on.

Hot Water Supply Temperature Setpoint:
The boiler shall maintain a hot water supply temperature setpoint as determined by its own internal controls (provided by others).

Primary Hot Water Temperature Monitoring:
The following temperatures shall be monitored:

- Primary hot water supply.
- Primary hot water return

	Hardware Points				Software Points					
Point Name	AI	AO	BI	BO	AV	BV	Sched	Trend	Alarm	Show On Graphic
Hot Water Differential Pressure	×							×		×
Primary Hot Water Return Temp	×							×		×
Primary Hot Water Supply Temp	×							×		×
Hot Water Pump 1 VFD Speed		×						×		×
Hot Water Pump 2 VFD Speed		×						×		×
Hot Water Pump 1 VFD Fault			×						×	×
Hot Water Pump 2 VFD Fault			×						×	×
Hot Water Pump 1 Status			×					×		×
Hot Water Pump 2 Status			×					×		×
Boiler 1 Status			×					×		×
Boiler 2 Status			×					×		×
Hot Water Pump 1 Start/Stop				×						×
Hot Water Pump 2 Start/Stop				×						×
Boiler 1 Enable				×						×
Boiler 2 Enable				×						×
Hot Water Differential Pressure Setpoint					×					×
Boiler 2 Failure									×	
Boiler 1 Failure									×	