

## SECTION 15900 - HVAC INSTRUMENTATION AND CONTROLS

## PART 1 - GENERAL

## 1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

## 1.2 SUMMARY

- A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls.
- B. Related Sections include the following:
  - 1. Division 15 Section "Basic Mechanical".
  - 2. Division 15 Section "Sequence of Operation" for requirements that relate to this Section.
  - 3. Division 15 Section "Testing, Adjusting, and Balancing"
  - 4. Division 16

## 1.3 SYSTEM DESCRIPTION

- A. Furnish all labor, materials, equipment, and service necessary for a complete and operating control system.
- B. The system shall be complete in all respects including labor, materials, equipment, and services necessary, and shall be installed by personnel regularly employed by the manufacturer. Documents are diagrammatic only. Equipment and labor not specifically referred to herein or on the plans, which are required to meet the functional intent, shall be provided without additional cost to the Owner.
- C. Control system consists of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories to control mechanical systems.

## 1.4 SUBMITTALS

- A. Product Data: Furnish in accordance with Division 1 requirements.
- B. Contractor shall provide shop drawings or other submittals on all hardware, software, and installation to be provided. No work may begin on any segment of this project until the Engineer and Owner have reviewed submittals for conformity with the design intent. All drawings shall be done on AutoCAD or VISIO, and provided to the Owner on floppy disk. When manufacturer's cut-sheets apply 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 specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements.
- C. Include a complete bill of materials of equipment to be used indicating quantity, manufacturer, model number, and other relevant technical data.

- D. Controlled Systems:
1. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
  2. A schematic wiring diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, it shall be labeled with the same name. All terminals shall be labeled.
  3. An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number. Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated. Each control device shall be labeled with setting or adjustable range of control.
  4. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
  5. A point list for each system controller including both inputs and outputs (I/O), point number, the controlled device associated with the I/O point, and the location of the I/O device. Software flag points, alarm points, etc.
- E. Maintenance Data: For systems to include in maintenance manuals specified in Division 1. Include the following:
1. Maintenance instructions and lists of spare parts for each type of control device and compressed-air station.
  2. Interconnection wiring diagrams with identified and numbered system components and devices.
  3. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
  4. Calibration records and list of set points.
- F. Qualification Data: For firms and persons specified in "Quality Assurance" Article.

## 1.5 QUALITY ASSURANCE

- A. All products used in this project installation shall be new and currently under manufacture and shall have been applied in similar installations for a minimum of two years. This installation shall not be used as a test site for any new products unless explicitly approved by the owner's representative in writing. Spare parts shall be available for at least five years after completion of this contract.
- B. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the temperature control system manufacturer.
- C. All work, materials, and equipment shall comply with the rules and regulations of all codes and ordinances of the local, state, and federal authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

- E. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilation Systems."
- F. Year-2000 Compliant: Computer hardware and software shall be capable of accurately processing, providing, and receiving date data from, into, and between the twentieth and twenty-first centuries, including leap-year calculations.

#### 1.6 CONTRACTOR QUALIFICATIONS

- A. Qualified Bidders: System shall be as manufactured, installed and serviced by:
  - 1. Invensys (Maine Controls)
  - 2. Johnson Controls, Inc.
  - 3. IB Controls
  - 4. Trident Controls
  - 5. Honeywell
  - 6. Siemens
  - 7. Northeast Controls-CIRCON

#### 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to unit manufacturer.
- B. The contractor shall protect all work and material from damage by his/her work or employees.
- C. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

#### 1.8 COORDINATION

- A. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition.
- B. Coordinate and schedule work with all other work in the same area, or with work that is dependent upon other work, to facilitate mutual progress.
- C. Coordinate location of thermostats and other exposed control sensors with plans and room details before installation.
- D. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the controls system specified in this section. These controls shall be integrated into the system and coordinated by the contractor.
- E. Sheet Metal Subcontractor:
  - 1. Installation of automatic control dampers.
  - 2. Access doors where and as required.

- F. HVAC Contractor:
1. Installation of immersion wells and pressure tappings, along with associated shut-off cocks.
  2. Installation of flow switches.
- G. Testing and Balancing Contractor:
1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
- H. Electrical Subcontractor:
1. All power wiring and line voltage interlock wiring such as exhaust fan interlocked to supply fan.
  2. All control wiring shown on electric plans such as unit heater line-voltage room thermostats.
- I. Complying with the principle of "unit responsibility" all electrical work for automatic controls, except as otherwise specified, or shown on the electrical drawings shall be included in Division 15. Electrical work shall, in general, comply with the following, unless otherwise directed by Division 16:
1. All electrical work shall comply with the N.E.C. and local electrical codes.
  2. All low voltage wiring in finished rooms shall be concealed below working heights and exposed above.
  3. Electrical work may include both line voltage and low voltage wiring, as required.
  4. Conduit network for power systems may be used for running control high voltage wiring.
  5. All safety devices shall be wired through both hand and auto positions of motor starting device to insure 100% safety shut-off.
  6. All magnetic starters furnished by Electrical Contractor for mechanical equipment shall be furnished with integral 120 volt control transformers, sized to handle the additional VA needed for the controls - pilots, EP valves, etc.
  7. The motor starter supplier shall provide auxiliary contacts as required for interlock by BAS Contractor; the supplier shall estimate an allowance of at least one auxiliary contact per starter. All interlock and control wiring shown on the electrical plans is by the electrical subcontractor.
- J. Coordinate with controls specified in other sections of divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
1. All communication media and equipment shall be provided as specified in Part 2, "Communication" of this specification.
  2. Each supplier of a controls product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequences of operation described in this section.
  3. The contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this section and those provided under other sections or divisions of this specification.
  4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
  5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

## 1.9 WARRANTY

- A. Refer to Division 1 Requirements.
- B. At the end of the final start-up, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the engineer, the engineer shall sign certificates certifying that the control system's operation has been tested and accepted in accordance with the terms of this specification. The date of acceptance shall be the start of warranty. All work shall have a single warranty date, even when the owner has received beneficial use due to an early system start-up.
- C. All components, system software, and parts supplied by the BAS contractor shall be guaranteed against defects in materials and workmanship for one year from acceptance date. The BAS contractor at no charge shall furnish Labor to repair, reprogram, or replace components during the warranty period. All corrective software modifications made during warranty periods shall be updated on all user documentation and on user and manufacturer archived software disks. The Contractor shall respond to the owner's request for warranty service within 24 hours during normal business hours.
- D. Provide remote service diagnostic monitoring from the nearest service location. At the request of the owner, a service diagnostic call will be made to troubleshoot and resolve (if possible) any reported system complaints. The owner will provide a dedicated telephone line for connection to the system.

## PART 2 - PRODUCTS

### 2.1 BOILER CONTROLLER

- A. Manufacturer:
  - 1. Tekmar Boiler Control #264 (Basis of Design)
  - 2. Caleffi BLR Series
- B. Microprocessor based control designed to maximize the comfort and efficiency of a hydronic heating system.
- C. Four Stage Boiler & DHW control shall allow for the control of four separate on /off boiler stages based on outdoor; air temperature, control for indirect Domestic Hot Water (DHW) generation and a Setpoint load.
- D. The controller shall include a large Liquid Crystal Display (LCD) in order to view system status and operating information. The same LCD is used when setting up and installing the control. Features shall include
  - 1. Equal Run Time Rotation
  - 2. Intelligent boiler operation
  - 3. Digital temperature readouts
  - 4. Pump exercising.
  - 5. Pump start-stop.
  - 6. Warm Weather Shut Down
  - 7. DHW post purge
  - 8. Outside air reset based on outside air temperature.
  - 9. DHW priority
  - 10. Automatic differential for boiler operation, to prevent short cycling.

- E. The 264 controls up to four stages in order to supply the required target temperature. After each stage is turned on in the firing sequence, the control waits a minimum amount of time before turning on the next stage. The minimum time between stages is the total of the fire delay setting plus the minimum inter-stage delay selected by the boiler mass setting. After the minimum time delay between stages has expired, the 264 examines the control error to determine when the next stage is to fire. The control error is determined using Proportional, Integral, and Derivative (PID) logic.
- F. Furnish and install a Tekmar 070 outside air sensor.

## 2.2 AUXILIARY CONTROL DEVICES

- A. Motorized control dampers, unless otherwise specified elsewhere, shall be as follows:
  - 1. Control dampers shall be the parallel or opposed blade type as follows:
    - a. Two-position shutoff dampers may be parallel or opposed blade type with blade and side seals.
  - 2. Damper frames shall be 13 gauge galvanized steel channel or 1/8 in. extruded aluminum with reinforced corner bracing.
  - 3. Damper blades shall not exceed 8 inches in width or 48 inches in length. Blades are to be suitable for medium velocity performance 2000 fpm. Blades shall be not less than 16-gauge.
  - 4. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze or better.
  - 5. All blade edges, top, and bottom of the frame shall be provided with replaceable butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel. The blade seals shall provide for a maximum leakage rate of 10 cfm per ft<sup>2</sup> 4 in. w.g. differential pressure. Provide airfoil blades suitable for a wide-open face velocity of 1500 fpm.
  - 6. Individual damper sections shall not be larger than 48 in. x 60 in. Provide a minimum of one damper actuator per section.
  - 7. Modulating dampers shall provide a linear flow characteristic where possible.
  - 8. Dampers shall have exposed linkages. Dampers over 48" in applications where sectioning is not applicable shall be supplied with a jackshaft to provide sufficient force throughout the intended operating range.
- B. Electronic damper/valve actuation shall be provided.
  - 1. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque and shall have a 2-year manufacturer's warranty, starting from the date of installation. Manufacturer shall be ISO9001 certified. Actuators shall be as manufactured by BELIMO.
  - 2. The actuator shall be direct coupled over the shaft, enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The fastening clamp assembly shall be of a "V" bolt design with associated "V" shaped toothed cradle attaching to the shaft for maximum strength and eliminating slippage. Spring return actuators shall have a "V" clamp assembly of sufficient size to be directly mounted to an integral jackshaft of up to 1.05 inches when the damper is constructed in this manner. Single bolt or setscrew type fasteners are not acceptable.
  - 3. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.
  - 4. For power-failure/safety applications, an internal mechanical, spring return mechanism shall be built into the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable.

5. All spring return actuators shall be capable of both clockwise or counterclockwise spring return operation by simply changing the mounting orientation.
  6. Proportional actuators shall accept a 0 to 10 VDC or 0 to 20 mA control signal and provide a 2 to 10 VDC or 4 to 20 mA operating range. An actuator capable of accepting a pulse width modulating control signal and providing full proportional operation of the damper is acceptable. All actuators shall provide a 2 to 10 VDC position feedback signal.
  7. All 24 VAC/VDC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 watts for DC applications. Actuators operating on 120 VAC power shall not require more than 10 VA. Actuators operating on 230 VAC power shall not require more than 11 VA.
  8. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-lb torque capacity shall have a manual crank for this purpose.
  9. All proportional actuators shall have an external, built-in switch to allow the reversing of direction of rotation.
  10. Actuators shall be provided with a conduit fitting and a minimum three-foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
  11. Actuators shall be Underwriters Laboratories Standard 873 listed and Canadian Standards Association Class 4813 02 certified as meeting correct safety requirements and recognized industry standards.
- C. Control Valves:
1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.
  2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
    - a. Two-way: 150% of total system (pump) head.
    - b. Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
  3. Water Valves:
    - a. Body and trim style and materials shall be in accordance with manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.
    - b. Sizing Criteria:
      - 1) Two-position service: Line size.
      - 2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
    - c. Valves ½ in. through 2 in. shall be bronze body or cast brass ANSI Class 250, spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or stainless steel ball.
    - d. Water valves shall fail normally open or closed, as described in sequences.
- D. Room thermostats: Honeywell T87F3467 "Easy to See with large raised markings and a click at each 2 degree set point change" Round Model; with "Easy to Use" accessory.
- E. Binary Temperature Devices
1. Low-voltage space thermostat shall be 24 V, mercury-switch type, with adjustable anticipation heater, 55°F to 85°F set point range, 2°F maximum differential, and vented ABS plastic cover equal to Honeywell T87F Easy-To-See Model.

2. Low-limit thermostats. Low-limit air-stream thermostats shall be UL listed, vapor pressure type, with an element of 20-foot minimum length. Element shall respond to the lowest temperature sensed by any 1-foot section. Low-limit thermostats shall be manual reset.
- F. Flow-proving switches shall be differential pressure type. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 enclosure, with scale range and differential suitable for intended application or as specified.
- G. Relays
1. Control relays shall be UL listed plug-in type. Contact rating, configuration, and coil voltage shall be suitable for application.
  2. Time delay relays shall be UL listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable  $\pm 200\%$  (minimum) from set point shown on plans. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.
- H. Override timers shall be spring-wound line voltage, UL listed, with contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless otherwise specified. Timer shall be suitable for flush mounting on control panel face and located on local control panels or where shown.
- I. CARBON MONOXIDE (CO) MONITOR / TRANSMITTER:
1. Basis of Design: Kele model GMT gas monitor/transmitter; or approved equal.
  2. Microprocessor-based system for continuous effective monitoring of *toxic* gases.
    - a. Detection range: 0-500 ppm
    - b. Accuracy 3%
    - c. Alarm set point 35 ppm
  3. Features:
    - a. Provide 4-20 mA output in proportion with DPDT alarm contacts.
    - b. Gas concentration display: 10-step progressive LED.
    - c. Visual Indicators shall be Green light "normal operation".
    - d. Provide audible alarm: 65 dBA at 3 ft.
    - e. Electromechanical S1-type sensor.
    - f. UL listed.
    - g. 2 year warranty

## 2.3 WIRING AND RACEWAYS

- A. Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 16.
- B. All insulated wire to be copper conductors, UL labeled for 90°C minimum service.
- C. Connectors: all optical fibers shall be field-terminated with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

## PART 3 - EXECUTION

### 3.1 EXAMINATION



- A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.
- B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started. Verify that duct-, pipe-, and equipment-mounted devices and wiring are installed before proceeding with installation.
- C. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and the expense of—this contractor.

### 3.2 GENERAL WORKMANSHIP AND FIELD QUALITY CONTROL

- A. Install all components in accordance with the manufacturer's recommendations.
- B. Install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.
- C. Provide sufficient slack and flexible connections 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 Electrical Code (NEC).
- E. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
- F. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.
- G. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances.
- H. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
- I. Contractor shall have work inspected by local and/or state authorities having jurisdiction over the work.

### 3.3 WALL MOUNTED SENSOR/THERMOSTAT INSTALLATION

- A. Verify location of thermostats and other exposed control sensors with plans and room details before installation. Locate at 48 inches above the finished floor.
- B. Install guards on thermostats in the following locations:
  - 1. Entrances.
  - 2. Public areas.

## 3. All Corridors

## C. CARBON MONOXIDE MONITOR/TRANSMITTER

1. Verify location of carbon monoxide transmitter with room layout and details before installation.
2. Install transmitter in strict accordance with manufacturer's installation instructions.
  - a. Maximum surveillance radius: 50 ft.
  - b. Mounting height: 3 to 5 ft. above floor.

## 3.4 WIRING

- A. All control and interlock wiring shall comply with national and local electrical codes and Division 16 of this specification. Where the requirements of this section differ from those in Division 16, the requirements of Division 16 shall take precedence.
- B. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Division 16 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 current limit).
- D. All wiring in mechanical, electrical, or service rooms—or where subject to mechanical damage—shall be installed in raceway at levels below 10ft.
- E. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
- F. Do not install wiring in raceway containing tubing.
- G. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and *neatly* tied at 10 ft intervals.
- H. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.
- I. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
- J. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
- K. Size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
- L. Include one pull string in each raceway 1 in. or larger.
- M. Use coded conductors throughout with conductors of different colors.
- N. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

- O. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 in. from high-temperature equipment (e.g., steam pipes or flues).
- P. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
- Q. Install insulated bushings on all raceway ends and openings to enclosure.
- R. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
- S. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 ft in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, for example chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
- T. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

### 3.5 INSTALLATION OF ACTUATORS

- A. Electric/Electronic
  - 1. Dampers: Actuators shall be direct-mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° available for tightening the damper seals. Actuators shall be mounted following manufacturer's recommendations.
  - 2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

### 3.6 PROGRAMMING

- A. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor.

### 3.7 CONTROL SYSTEM CHECKOUT AND TESTING

- A. Start-up Testing: All testing listed in this article shall be performed by the contract and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the Owner's representative is notified of the system demonstration.
- B. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
- C. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.

- D. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturer's recommendations.
- E. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
- F. Verify that all analog output devices are functional, that start and span are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
- G. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules.

### 3.8 CONTROL SYSTEM DEMONSTRATION

- A. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
- B. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer may be present to observe and review these tests. Provide at least 10 days notification in advance of the start of the testing procedures.
- C. Checklists and forms shall be completed for all systems as part of the demonstration.
- D. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and testing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
- E. As each control input and output is checked, a log shall be completed showing the day, technician's initials, and any corrective action taken or needed.
- F. Demonstrate compliance with sequences of operation through all modes of operation.
- G. Demonstrate complete operation of operator interface.
- H. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

### 3.9 CONTROL SYSTEM ACCEPTANCE

- A. All tests described in this specification shall have been performed to the satisfaction of both the Engineer and Owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of

the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.

- B. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

### 3.10 CLEANING

- A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.
- B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.
- C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be required to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

### 3.11 TRAINING

- A. Provide a minimum of 4 hours of training.
- B. Train the designated staff of owner's representative and owner to enable them to do the following:
  - 1. Proficiently operate the system
  - 2. Understand system components
  - 3. Adjust and change system set points, time schedules, and holiday schedules
  - 4. Recognize malfunctions of the system.
  - 5. Understand system drawings and Operation and Maintenance manual
  - 6. Understand the job layout and location of control components
- C. The instructor(s) shall be factory-trained instructors experienced in presenting this material.

END OF SECTION 15900