

## SECTION 230900 - INSTRUMENTATION AND CONTROL FOR HVAC

### PART 1 - GENERAL

#### 1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

#### 1.2 SYSTEM FEATURES AND ARCHITECTURE

- A. The controls system shall be web based and be capable of integrating multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection.

#### 1.3 SUBMITTALS

- A. Product Data: 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.
  - 1. Each control device labeled with setting or adjustable range of control.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
  - 1. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
  - 2. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.
  - 3. Details of control panel faces, including controls, instruments, and labeling.
  - 4. Written description of sequence of operation.
  - 5. Schedule of dampers including size, leakage, and flow characteristics.
  - 6. Schedule of valves including leakage and flow characteristics.
  - 7. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
  - 8. Listing of connected data points, including connected control unit and input device.
  - 9. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations.
  - 10. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
- C. Software and Firmware Operational Documentation: Include the following:
  - 1. Software operating and upgrade manuals.

2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
  3. Device address list.
  4. Printout of software application and graphic screens.
  5. Software licenses required by and installed for DDC workstations, laptops, engineering tools and control systems.
- D. Software Upgrade Kit: For Owner to use in modifying control software or web pages to suit future power system revisions or monitoring and control revisions.
- E. Maintenance Data: For systems to include in maintenance manuals. 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. Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

#### 1.4 QUALITY ASSURANCE

- A. Installer Qualifications: An experienced installer with at least 10 years of experience who is an approved installer of the automatic control system manufacturer for both installation and maintenance of units required for this Project.

#### 1.5 WARRANTY and SERVICE

- A. The Contractor shall warrant the system to be free from defects in material and workmanship for a period of two (2) years from the date of final acceptance of the work by the owner. Any defects shall be repaired or replaced, including materials and labor at no cost to the owner.
- B. The Contractor shall provide one (1) year of maintenance service for the HVAC controls system to begin concurrently with the 1<sup>st</sup> year of warranty. Service shall include inspection and adjustment of all operating controls and components. The service shall be performed every 3 months and documentation of service shall be provided to Facilities Operations.

#### 1.6 EXTRA MATERIALS

- A. Furnish the following extra materials to Facilities Operations at completion
1. 1 sensor of each type (Hydronic, air supply, humidity)
  2. 2 zone thermostats

## PART 2 - PRODUCTS

### 2.1 MANUFACTURERS

- A. HVAC controls system contractor shall provide a fully integrated system, UL listed, incorporating direct digital control for energy management, equipment monitoring and control as manufactured by: (Bid alternate M-1 and M-2 – Preferred Manufacturer Alternate)

1. Schneider Electric Buildings Americas ,Invensys IA series controls
2. Johnson Controls, Metasys Extended Architecture Controls

### 2.2 DDC EQUIPMENT (Workstations, laptops, printers, software, DDC control units)

#### A. Building Control Unit

1. The Building Control Unit (BCU) is the electronic link between the respective building and the campus network and shares information among all the DDC stand-alone panels within the respective building.
2. The building BCU shall be a networking stand-alone energy management panel enclosed in a sturdy metal enclosure. The microcomputer shall be at the least 16 bits. The microcomputer shall utilize a multi - tasking, multi - user operating system. The BCU shall have peripheral ports for a CRT, a printer, and an auto answer / auto dial modem, and network communications. The BCU shall have a battery back - up for the clock.
3. The building BCU shall be placed on the control vendor's Local Area Network (LAN) configuration within the respective building via its BUS ports. Fault tolerant operation of the Local Area Network shall guarantee that failure in communication or operation of any DDC controllers on the LAN shall not interrupt the communication between remaining units. The BCU shall also be connected to the Campus Wide Area Network via Ethernet connection with communications based on TCP/IP protocol. This connection is via the communication port. The BCU shall be furnished with a built-in software library.
4. The Ethernet card shall reside in the BCU. It shall communicate with the network via a 100 Mbps network adapter
5. The BCU shall have an operator interface port that allows a laptop to direct connect to the BCU and the individual local controllers. The interface connection shall provide all necessary communication so that the laptop can display visual indication of analog variables, binary (status) condition, and adjustment values, automatic operation, trouble, alarm condition and value, manual or override condition.
6. There shall be only one Ethernet connection per building to the University wide area network. The Ethernet connection may not be located in University telecommunication rooms. A standard University voice/data outlet should be installed adjacent to the BCU. The building control contractor shall be responsible for all Ethernet wiring, routers, or other hardware associated with Ethernet communication within the control system local area network. Control system Ethernet wiring shall not reside in the University telecom raceways.
7. A Laptop computer shall be provided that is capable of communication with the controls network through the BCU connection.
8. The laptop shall be capable of direct connecting with any controller in the system as well as the BCU. The laptop shall have all engineering software loaded and operational so that local control sequences can be modified as well as global control and point mapping in the

BCU. The laptop shall be provided with all necessary communication cables and communication adapters to direct connect to local controllers as well as the BCU.

B. DDC Controllers

1. DDC Controllers (stand-alone) shall be microprocessor-based with a minimum word size of 16 bits. They shall also be multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification.
2. Control of the mechanical systems shall be performed by a field programmable microprocessor-based direct digital controller (DDC), which incorporates closed loop control algorithms, all necessary energy management functions, and provides for digital display and convenient local adjustments of desired variables at the controller cabinet. Systems, which require the existing user-defined database to be reentered through the operator's terminal after a failure or power interruption, shall not be acceptable.
3. Each unit shall be capable of performing the following energy management functions:
  - a. Start/stop optimization
  - b. Time of day scheduling
  - c. Enthalpy economizer control
  - d. Supply air reset
  - e. Chilled water reset
  - f. Hot water reset
  - g. Event initiated programs
  - h. Night setback
  - i. Chiller sequencing
  - j. Chiller load monitoring
4. Each DDC shall be capable of performing all specified control functions in a completely independent manner. Additionally, DDCs shall be capable of being networked for single point programming and for the sharing of information between panels, including, but not limited to, sensor values, calculated point values, control set-points, tuning parameters, and control instructions.
5. Each DDC controller shall include its own microcomputer controller, power supply, input/output modules, termination modules, battery, and spare AC outlet. The battery shall be continuously charged and be capable of supporting all memory for a minimum of 72 hours. Upon restoration of system power, the control unit shall resume full operation without operator intervention.
6. Each DDC controller shall have at least one RS-232 communication port.

C. Building Operator Laptop computer: Provide as a minimum an IBM-compatible microcomputer with minimum configuration as follows:

1. Processor: Intel .2.5 GHz or better multi core processor, 8GB RAM, 1 GB Cache
2. Graphics: SVGA, minimum 1280 x 1024 pixels, 1 GB EDO video memory.
3. Screen: Minimum 17 inches
4. Standard keyboard, mouse and 1 GB flash drive.
5. Hard-Disk Drive: 500 GB or larger.
6. CD/DVDR-RW Drive: 48x.

7. Easily accessible USB ports on the laptop.
8. Gigabit Ethernet card
9. Operating System: Microsoft Windows Seven loaded and operational.
10. Prefer IBM, Dell or Compaq/HP

D. Graphic Display Requirements

1. Provide a windows based software package for the preparation of system graphics. The package shall be designed to work on the University's server infrastructure.
2. Include with this software a library of HVAC symbols such as fans, pumps, chillers, etc.
3. This section establishes standards for graphic displays as follows.
  - a. All operator workstations including the Laptop shall be programmed to display graphical representations of the mechanical systems and floor areas for which this system has control. Systems to be displayed include the air handlers, air terminal units, chillers, heat converters, pumping systems and similar mechanical devices.
  - b. Floor plans displays are required and shall indicate the approximate positions of controlled mechanical system elements, to include space temperature, within the floor layout.
  - c. All displays shall show real time data to include temperatures and run status.
  - d. The owner prior to installation on the web servers shall approve all graphic pages.
  - e. Summary pages to tabulate VAV box data including space temp, setpoint, box airflow, and DA temp, airflow setpoint, requested damper position, and HW valve position.

E. Application Software: Include the following:

1. Input/output capability from operator station.
2. Operator system access levels via software password.
3. Database creation and support.
4. Dynamic color graphic displays.
5. Alarm processing.
6. Event processing.
7. Automatic restart of field equipment on restoration of power.
8. Data collection.
9. Graphic development on workstation.
10. Maintenance management.

2.3 CONTROL PANELS

- A. Panels shall have hinged doors and be marked with engraved labels. Panels used as a location for mounting control devices shall have a document holder located on the inside of the door.
- B. Provide common keying for all panels
- C. Entrance and exit wiring should be on the panel sides.
- D. All heat generating devices shall be located at the top of the panel.

## 2.4 SENSORS and TRANSMITTERS

### A. Humidity Sensors

1. Accurate to +/- 3%
2. Room sensors; 20 – 90 % RH. Cover to match room thermostat.
3. Duct and outside air sensor; 0 – 100% RH
4. Duct and O.A. sensors that are used in an O.A. enthalpy calculation should be +/- 2%

### B. Pressure Sensors

1. Duct static pressure sensors shall have an accuracy of +/-1% of range
2. Low-range Space differential pressure sensors: with range of +/- 0.1” W.C. and accuracy of +/-1% of range

### C. Temperature Sensors

1. Platinum or nickel RTD, 100 or 1000 ohm, accurate to +/-0.5% or 10,000 ohm thermistors accurate to +/-0.5% across entire operating range of sensor.
2. Outside air sensors shall be shielded from solar radiation by both installation location and finned radiant energy rejection container.
3. Temperature sensors used in BTU calculations shall be a matched pair with a differential accuracy of +/-0.15F over entire range and supplied by the BTU system manufacturer.
4. Room space sensors may be thermistor type.

### D. Transducers

1. Provide a minimum 1¼” pressure gauge or LCD pressure display at the output of each I/P and E/P transducer

### E. Current Sensors

1. Proof of run for pumps and fans shall be by current sensed devices. If the proof of run cannot be adjusted to take into account variable speed operation and loss of load then an alternative device must be provided to confirm loss of load. As well as proof of motor operation.

## 2.5 METERS

- See specification 230519 for meter specifications, also reference the latest spec from NCSU Utilities Services Dept; July 2018 edition.

## 2.6 SENSORS

### A. Space Thermostats

1. All room thermostats in labs, classrooms and offices shall have exposed setpoint adjustment with internal stops or software stops for minimum and maximum setting initially set between 68 degrees and 76 degrees

2. All room thermostats in public areas will have concealed setpoint adjustments with blank cover.
3. Insulated mounting bases on exterior walls
4. Accuracy to +/-0.5%
5. Each thermostat shall be capable of reporting the space temperature and setpoint. In addition, each shall be capable of remote reset by the DDC system
6. Provide with override request and local setpoint adjust except where indicated (vestibules, elevator lobbies and corridors)
7. Label thermostats for VAV boxes with the VAV box that it controls.

## 2.7 CONTROL VALVES and ACTUATORS

### A. General

1. All control valves for HVAC equipment within mechanical equipment rooms and central station units shall utilize electronic actuation. Butterfly valves for air handling unit coil control are unacceptable unless they are high performance type and only with approval from the owner.
2. Preheating and cooling valves shall not be software interlocked so that both valves cannot be opened simultaneously except for override
3. Operator bodies shall be metal

### B. Hydronic Valves

1. Valves shall be sized so that pressure drop across valve is at least 25% of the coil pressure drop at full design flow.
2. For systems attached to the campus chilled water loops, pressure independent control valves shall be used at all cooling coils including small fan-coil units. Globe, butterfly or ball valves with automatic flow limiting devices attached are not an appropriate substitute for pressure independent control valves.
3. Valves shall remain closed (zero leakage) against 100% of the full shutoff head of the pump.
4. High performance butterfly valves shall have adjustable packing, EPDM seat with suitable metal back-up ring, upper and lower shaft thrust bearings, 316 SS one piece shaft and 316 SS disc with offset shaft/disc design. Valves shall be provided with electric proportional, 4-20 ma or 0–10 VDC signal with positive positioning mechanism.. Valves and actuators shall be manufactured by the valve manufacturer.
5. Valves shall be equal percentage. Install three-way valves were indicated on plans.
6. Two-position valves shall be line size.
7. Valve service rating shall be 125 psig. or greater except that valves in the campus chilled water piping shall be rated at 250 psig. or greater. The shaft to which the actuator(s) is coupled shall be square or hexagonal or round with one side flattened, to achieve secure coupling.
8. Terminal reheat valves shall be electric proportional, 4-20 ma or 0–10 VDC signal with positive positioning mechanism. Floating point or step control is not allowed. Prefer to use characterized flow ball valves.
9. Valves shall have stainless steel trim and seat.

### C. Steam system characterized control valves shall have the following characteristics:

1. Manufacturers (Acceptable)

- a. Belimo
  - b. Spence
  - c. Seimens
2. Class 125 brass(DZR)
  3. Internal Construction:
    - a. Stainless Steel Ball
    - b. ETFE Seat
    - c. Stainless Steel Seat
    - d. Characterizing Plate: Stainless Steel
    - e. Viton Packing
  4. Sizing: For pressure drop based on the following services:
    - a. Two Position: 20 percent of inlet pressure.
    - b. Modulating [15-psig (103-kPa) Steam]: 80 percent of inlet steam pressure.
    - c. Modulating [16- to 50-psig (110- to 350-kPa) Steam]: 50 percent of inlet steam pressure.
    - d. Modulating [More Than 50-psig (350-kPa) Steam]: 20 percent of inlet steam pressure.
  5. Flow Characteristics: Modified linear characteristics.
  6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of operating (inlet) pressure.

## 2.8 PRESSURE INDEPENDENT CONTROL VALVES

### A. Manufacturers

1. Griswold Controls
2. Delta P
3. Belimo

### B. Pressure Independent Actuated Ball Valves

1. Description: The pressure independent modulating control valve shall include a Pressure Compensating Cartridge, Actuated Ball Valve, and Manual Isolation Ball in a single valve housing.
  - a. Valve housing shall consist of forged brass, rated at no less than 360 psi at 250°F.
  - b. The control valve shall accurately control the flow from 0 to 100% full rated flow.
  - c. A universal mounting plate shall allow installation of actuators meeting the system electrical requirements and valve torque requirements as provided by Belimo, Honeywell, Johnson Controls, KMC, Neptronics, Siemens, or Schneider Electric.
  - d. The actuator and plate can be rotated after mounting.
  - e. Pressure Compensating Cartridge (PCC)
    - 1) PCC shall automatically compensate for pressure changes in valve and shall maintain a constant pressure drop across the flow limiting actuated ball.

- 2) The operating pressure range shall be available with the minimum range requiring 7 PSID to actuate the mechanism, or the minimum as scheduled.
- 3) Valve internal control mechanism includes a diaphragm and full travel linear coil spring.
- 4) Valves shall include an accessible/ replaceable cartridge.
- 5) Dual pressure/temperature test valves for verifying the pressure differential across the cartridge and flow limiting ball shall be standard.

f. Actuated Ball Valve

- 1) Valve ball shall consist of chemically plated nickel brass or stainless steel.
- 2) Actuator stem shall be removable/replaceable without removing valve from line.
- 3) Manufacturer shall be able to provide ball insert to limit flow to maximum flow rate with  $\pm 5\%$  accuracy.
- 4) Valve shall have EPDM O-rings behind the seals to allow for a minimum close-off pressure of 100 psi with 35 in-lbs of torque for 1/2" – 2" sizes.
- 5) Actuator shall provide minimum torque required for full valve shutoff position.

2. Warranty

All components shall be warranted by manufacturer for no less than one year from date of purchase.

2.9 DAMPERS and ACTUATORS

A. Dampers:

1. Maximum blade width of 8" with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Provide low leakage control dampers where not furnished with packaged units. Damper leakage rate shall not exceed 10 CFM/sq. ft. at 4" wg. Dampers shall have blade seals and stops. The shaft to which the actuator(s) is coupled shall be square or hexagonal or round with one side flattened, to achieve secure coupling.
3. Provide electric proportional, 4-20 ma or 0–10 VDC signal with positive positioning mechanism actuators for all automatic control dampers except dampers in VAV terminal units. Locate damper actuators outside of the air stream. Positioning relays will be provided for each damper section: one each for outside air, return air and relief air.
4. Control dampers used for outside air or exhaust shall be installed a minimum of 6" away from wall penetrations to allow for external mounting of actuators.
5. Throttling operation shall be opposed blade type.
6. Floating point or step control not allowed.

B. Actuators

1. Operator bodies shall be metal except for VAV box actuators
2. Damper and VAV box actuators shall directly couple around damper shaft

## 2.10 THERMAL AIRFLOW STATIONS

- A. Source Limitations: Obtain airflow and temperature measuring sensors and transmitters from single manufacturer.
- B. Description: Airflow station shall consist of one or more sensor probes and a remotely mounted microprocessor-based transmitter.
- C. Performance:
  - 1. Capable of independently processing up to 16 independently wired sensor assemblies.
  - 2. Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
  - 3. Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output.
  - 4. Listed and labeled by an NRTL as successfully tested as an assembly according to UL 873, “Temperature-Indicating and Regulating Equipment.”
  - 5. Components shall be interconnected by exposed NRTL- listed plenum-rated cable or non-listed cable placed in conduit.
  - 6. Each flow station shall be factory calibrated at a minimum of 16 airflow rates and three temperatures to standards that are traceable to NIST.
  - 7. Airflow Accuracy: Within 3 percent of reading over the entire operating airflow range.
    - a. Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets the performance requirements throughout the measurement range.
    - b. Temperature Accuracy: Within 0.2 deg F over entire operating range minus 20 to plus 140 deg F.
    - c. Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, non-condensing.
    - d. Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.
    - e. Pressure Drop: 0.05-inch wg at 2000 fpm across a 24-by24-inch area.
    - f. Instruments mounted in throat or face of fan inlet cone shall not negatively influence the fan performance by reducing flow more than 2 percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan in order to deliver Project design airflow indicated.
- D. Sensor Assemblies:
  - 1. Each sensor probe shall contain two individual wired, hermetically sealed bead-in-glass thermistors.
  - 2. Mount thermistors in sensor using a marine-grade, waterproof epoxy.
  - 3. Thermistor leads shall be protected and not exposed to the environment.
  - 4. Each Sensor assembly shall independently determine airflow rate and temperature at each measurement point.
  - 5. Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
  - 6. Sensor Probe Material: Gold anodized, extruded 6063 aluminum tube or Type 304 stainless steel.

7. Probe Assembly Mounting Brackets Material: Type 304 stainless steel.

E. Casing:

1. Factory mount sensor probes in an airflow station casing to create a single assembly for field mounting.
2. Material: Galvanized sheet steel at least 0.079 thick with coating complying with ASTM A 653/A 653 M, G90. Casings shall be stainless steel, 0.0781 inch thick, when connected to stainless duct and aluminum, 0.063 inch thick, when connected to aluminum duct.
3. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with zinc-rich paint.
4. Casing Depth: At least 8 inches.
5. Include casing inlet and discharge connections with a minimum 1.5-inch face flange.

F. Transmitter:

1. Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow and temperature readings of each independent sensor assembly.
2. Capable of field configuration and diagnostics using an onboard push-button. Interface and digital display.
3. Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:
4. Integral protection from transients and power surges.
5. Circuitry to ensure reset after power disruption, transients, and brownouts.

2.11 LABELS AND TAGS

1. Provide labels for all field devices including sensors, meters, transmitters and relays. Labels shall be plastic laminate and located adjacent to the device.
2. Labels of field devices (both locally and software ID's) shall be associated with their respective air handler, boiler, chiller, etc.
3. Junction box covers shall be painted yellow and labeled "DDC"

2.12 CONTROL WIRING

1. All control wiring shall be a minimum of No. 18 gauge.
2. All Control Wiring shall be in conduit see 260519.

PART 3 - EXECUTION

3.1 INSTALLATION

1. All wiring shall be in conduit. Conduit shall be run parallel or perpendicular to walls and building lines. Junction box covers shall be painted yellow and labeled "DDC"
2. Wires shall be labeled with mechanically prepared labels at their connection point to each apparatus point of connection.
3. Wiring shall not use the voice/data wire way/conduit systems as pathways.

3.2 ON-SITE TESTING

- A. When installation is complete, the controls contractor shall perform the following:
1. A 100% field calibration of all sensors and equipment.
  2. Verification of each control point by comparing the control command and the field device from the end device through the associated graphic point.
  3. Documentation of results shall be provided to the University prior to final acceptance.
  4. Sequence of operation testing of all programmed sequences.
  5. Contractor shall perform an on-site test simulating an Ethernet failure and verify that all sequences continue to perform as designed without external communications.

3.3 DEMONSTRATION

- A. The controls contractor shall demonstrate that controls are installed, adjusted and operate as required by the drawings and specifications. This demonstration shall be documented and may be conducted in conjunction with the training of University personnel. The documentation shall identify the item, the person performing the demonstration, date, and the signature of the University’s representative. The University’s Representative will select the items to be demonstrated. Items shall be demonstrated as follows:

| Item Demonstrated   | Controls Contractor (Name) | University’s Representative (Signature) | Date |
|---|----------------------------|---|------|
| 1. Disconnect one DDC from the building network to demonstrate that a single device failure will not disrupt peer-to-peer communication |                            |   |      |
| 2. Manually generate alarms at ___ points and demonstrate that the workstation(s) receive the alarms                                    |                            |   |      |
| 3. Calibration has been performed on at least sensors   |                            |   |      |
| 4. Point-to-point verification of the greater of points or ( ___ ) % of all points. Include labeling of points.                         |                            |   |      |
| 5. Sequence of operation for the air handling units including economizer cycle, reset , start/stop,                                     |                            |   |      |
| 6. Sequence of operation for the chilled water system including chiller(s)  |                            |   |      |
| 7. Sequence of operation for the hot water system   |                            |   |      |
| 8. Sequence of operation for ___ VAV terminal units including min/max air, reset,   |                            |   |      |
| 9. Sequence of operation for the boiler and steam system  |                            |   |      |
| 10. Sequence of operation of the HVAC controls system during a fire alarm   |                            |   |      |

|   |  |  |  |
|---|--|--|--|
| 11. Fail safe operation of AHU, chilled water system, steam and boiler system, hot water system , and terminal units. |  |  |  |
| 12. Graphics system is functional and that the layout is consistent with field conditions.                            |  |  |  |
| 13. Response to upset conditions and change of setpoint for selected systems  |  |  |  |

- B. Contractor shall support 3rd party commissioning. Prior to commencing Commissioning all items in sections 230900 3.2 and 3.3.A shall be completed and the results provided to the Owners Commissioning Authority. See spec section 230800 for all Commissioning requirements:

3.4 TRAINING

- A. The manufacturer and the controls contractor shall provide on-site training in the maintenance and operation of the installed system for up to six (6) personnel. The training shall be documented and a syllabus and O&M manuals shall be submitted and approved by Facilities Operations 2 weeks prior to the training. The training should include the following:

1. HVAC systems layout including the locations of air handlers, DDC controllers, VAV boxes, pumps, chillers. This will include a walk-thru at the building.
2. Sequence of operations for each control loop.
3. Accessing the control system including:
  - a. Logon procedure
  - b. Use of graphic and DDC pages
  - c. Password requirements
4. Operation and troubleshooting including:
  - a. Modification of setpoints, schedules
  - b. Overview of graphics and text pages
  - c. Trending of points
  - d. Calibration and adjustment
  - e. Hands on training in the troubleshooting and replacement of components including sensors, transmitters, control valves and actuators. Contractor shall have examples of each component and demonstrate measurement of input and output signals, and any operator adjustments available.
  - f. DDC controller functions and operation
5. Review of O&M manual and control system as-builts.

- B. The controls contractor shall provide an additional on-site training session nine (9) months after project completion. The purpose of the session will be to review any operational problems that have developed. In addition, the contractor will lead Facilities Operations personnel through a comprehensive annual preventative maintenance of the controls system. This shall be scheduled at least one (1) month in advance.

- C. The manufacturer and the controls contractor shall provide training for two (2) university employees at the manufacturer's training facility. Include all travel, lodging and expenses for the trainer or the university personnel. The training shall be documented and a syllabus must be submitted and approved by Facilities Operations prior to the training. The training should include the following:
1. Programming logic changes both local control and system (BCU)
  2. Expansion of the control system including hardware and software additions
  3. Graphics generation
  4. HVAC control systems

END OF SECTION 230900