SECTION 23 09 00 – BUILDING AUTOMATION SYSTEMS DESIGN CRITERIA

PART 1 - GENERAL

1.1. SUMMARY:

A. Building Automation Systems (BAS) engineering design criteria are determined by the specific application requirements, by related requirements of the Brown University Design and Construction Guidelines, by this document, and in meetings with the Brown Project Manager and FM Operations & Engineering staff.

B. Utility metering (electrical and thermal) is part of the Campus Central Metering System, which is not a part of the BAS.

C. Related Sections:
1. Section 01 13 01 – Design Guidelines for Energy and Environment
2. Section 01 17 01 – Building Systems Identification and Labeling
3. Section 23 00 00 – HVAC Design Criteria
4. Section 23 05 23 – HVAC&R Valves
5. Section 23 09 01 – BAS Naming Conventions and Alarms
6. Section 26 09 01 - Campus Central Metering System Design Criteria
7. Section 26 29 10 – Variable Speed Drives

1.2. CONTROL SYSTEM TYPES:

A. All new construction and renovated buildings shall have a minimum of one supervisory web-interfaced BAS controller, reporting to the respective BAS supervisory server. Smaller renovations may utilize existing BAS capacity to within 75% of any manufacturer specified limit.

B. All supervisory controllers shall utilize Bacnet IP over Ethernet communications.

C. All controls shall be networked Direct Digital Controls (DDC).

1.3. CONTRACTOR QUALIFICATION REQUIREMENTS

A. The BAS contractor shall be authorized by the respective manufacturer to install and sell the specified products.

B. The BAS contractor’s primary business shall be the engineering, programming and installation of HVAC control systems.

C. The BAS contractor shall have been in business for a period of at least five (5) years.

D. The BAS contractor shall have an office within a (75) mile radius of the job site.

E. The BAS contractor shall have a service department on call 24 hours a day and 7 days a week.

F. The BAS contractor team members shall be factory trained on the specified product, and they shall furnish curriculum vitae for each member upon request.

1.4. PROJECT DESIGN AND SUBMITTAL REQUIREMENTS:

A. DESIGN PHASE: The project design professional shall provide an Operational Narrative on the proposed Sequences of Operation for the new BAS system by the 60% or Design development submittal, and detailed, written sequences of operation for the new BAS system, based on the Design Development Operational Narratives, for the final Design Documents. These detailed sequences shall provide at a minimum:

1. Sequences in all modes of normal operation: on, off, occupied, unoccupied, warm-up, cool-down, summer, winter, economizer, etc.
2. Organization into logical groupings including: run/stop, pressure, economizer, coils, discharge air, humidification, dehumidification, hydronic temperature, etc.
3. Fire/smoke control system interfaces and sequences.
4. Schedule of operation.
5. Details of system operation for abnormal conditions, such as during and after a power outage. Include details such that a loss of status associated with power outages are not indicated as failures with a subsequent alarm.
6. Specific direction on failure scenarios for loss of signal and all safety device trips.
7. Setpoints, trip points, and ranges. Initially these shall be the designer's intent, and eventually be the actual settings at the time of as-built submittal.
8. Communications protocol and available points list for BAS interface for large unitary equipment such as chiller control panels.

B. CONSTRUCTION PHASE: The controls contractor shall provide fully developed Control Drawings based upon the operational sequences of the Engineer of Record. Drawings shall be developed in Microsoft Visio. These control drawings shall furnish at a minimum:

1. A network riser diagram indicating supervisory controllers and relative addressing as well as field controllers, interconnections to packaged equipment control systems and respective network wiring.
2. Schematic diagrams of all systems controlled or connected to the automation system in the format of the final graphical interface.
3. Schematic diagrams of all electrical interface connections indicating device, voltage, and any relevant terminal numbers.
4. A bill of material indicating for each component part furnished by contract or interfaced to and furnished by others:
5. A narrative Sequence of Operation indicating: the operational timeline of the respective system, including all initial set points and the adjustability of same, as well as details of system operation for abnormal conditions, such as during and after a power outage.

6. Detailed equipment and software data sheets.
7. Valve and damper schedules with all control parameters listed.
8. As applicable for the project, a schedule of rooms served by VAV boxes including:
    a. Room name relative to thermostat location.
    b. The air handler that the box is served from.
    c. Supervisory controller and field bus ID.
    d. Relative mechanical drawing number.
    e. Address.
    f. Associated equipment including sensors, reheat coils and radiation.
    g. Box size, inlet area, K factor, and all relative flow set points.

C. TURNOVER PHASE:

1. Provide all software and hardware required to operationally program, control, maintain, balance, diagnose and replace any and all components installed. Include licensing information and serial numbers as well as installation compact disks.
2. Furnish final control programs and algorithms for all primary systems and representative samples of terminal equipment. All applications are to be written as self-documenting and shall include at a minimum or as comments in the code:
    a. The originating author and the author of each revision.
    b. The originating date and the date of each revision.
    c. The building name.
    d. The system name.
    e. A description of the process.
    f. Any calls to other processes in the same controller and or applications running at the supervisory level or in another controller.
    g. All hardware inputs in list form.
    h. All hardware outputs in list form.
    i. All network inputs in list form.
    j. All network outputs in list form.
3. For projects that are renovations of existing systems and affect a portion of the building controls, the controls contractor shall furnish submittal shop drawings of project work that are consistent with existing drawings including compatible page numbers, a revised table of contents and revised schedules.
4. Operations and Maintenance (O&M) Manuals shall include a CD-ROM with complete Controls Drawings in editable Adobe PDF and Microsoft Visio format.
5. All software and hardware required to install, operate and maintain all components of the installed system shall be turned over to the Owner including, but not limited to, all operating discs, recovery discs, system backup discs and field controller programs on compact disk.

6. As-built control drawings shall include a Master Alarm List and updated control setpoints.
7. As-Built control drawings shall include a list of Bacnet device identifiers for all supervisory and field devices installed as part of the project.
8. The Engineer of Record shall review these submittals.
9. The final as-built control drawings and operational sequences shall be submitted prior to training.

1.5. BAS SYSTEM GENERAL DESIGN REQUIREMENTS:

A. GRAPHICS:

1. System graphics shall be provided.

B. ENERGY CONSERVATION:

1. Refer to section 01 13 01 Design Guidelines for Energy & Environment, for related design requirements.

C. SOFTWARE REVISIONS:

1. For new buildings and renovation projects, include in the project all upgrades and associated costs to bring the respective server application interface software components to the most recent release.

D. TRENDING AND TOTALIZATION:

1. All system data shall have the capability of being trended cyclically or historically.
2. Provide cyclical trending on terminal equipment for all analog input, analog output and calculated analog value data points initially set for 144 entries logged every 10 minutes.
3. Provide cyclical trending on terminal equipment for all binary input and binary output data points set for 144 entries logged on change of state.
4. Provide historical trending on central air side or water side equipment for all analog input, analog output and calculated analog value data points initially set for entries logged every 10 minutes.
5. Provide cyclical trending on central air side or water side equipment for all binary input and binary output data points set for entries logged on change of state.
6. Provide runtime totalization for all equipment binary status points.
7. Trend setpoints on Change of State (COS).

E. SHARED DATA POINTS:

1. BAS system design for individual buildings shall be as a true standalone facility.
2. Critical systems shall be configured to default to a sensor in the same Ethernet subnet on loss of reliability. Default to a failsafe value for shared data points upon loss of communication or lack of an appropriate substitute sensor.

F. SYSTEM SETPOINTS:

1. Record all of the as-built system setpoints in the default value field of the supervisory software.

G. STANDBY POWER:

1. In all buildings where standby generator power is available, all BAS controllers and devices shall be connected to the standby power system.
2. Uninterruptible Power Supply (UPS) is not required for BAS control panels except in specific cases as directed by Operations staff.

H. FIELD PANELS:

1. Field panels shall be fabricated and built in accordance with requirements of applicable UL Standards and comply with NEC section 408.18 "Switchboards and Panelboard Clearances".
2. Furnish and install as built copies of the control drawings in a pocket on the interior door representing all systems served by the respective field panel.
3. Furnish field panels with lockable doors. Provide 2 keys per panel to operations as part of the project turnover.
3. Field panels shall contain a duplex receptacle and a primary power disconnect.
4. Provide all BAS controllers and control panels with integral surge protection.
5. Each field panel transformer shall be included with circuit breaker overcurrent protection.
6. Field panel power source shall be machine labeled on the interior door indicating distribution panel name, distribution panel room number and distribution panel circuit number.
7. All field panel devices (controllers, relays, terminal blocks, ect.) shall be machine labeled referencing wiring diagram device names.
8. Field panels shall have all wiring concealed in wiring duct. Wiring duct fill shall not exceed 40% capacity.
9. Terminations in control panels shall be made with factory controller screw terminals. Auxiliary connections such as 24VAC power distribution shall be made on DIN rail mounted terminal strips. Wirenut connections are not allowed in control panels.
10. Field panel interconnection and remote device wiring shall be identified with machine printed labels referencing wiring diagram nomenclature.
11. Design field panel locations to include:
    a. One duplex receptacle within 10 feet
    b. 10 foot candles of lighting for all areas within the panel minimum working clearance.

I. CONTROL VALVES:

1. Control valves shall have design pressure and close-off ratings exceeding maximum operating conditions.

2. Control valves shall be mechanically fit with an isolation valve and union or flange on each connection.
3. Steam and HTHW valves shall be Normally-Closed.

J. VALVE AND DAMPER ACTUATORS:

1. Actuators on all steam and High Temperature Hot Water (HTHW) control valves shall be electric with a manual-override feature.
2. Actuators shall have a mechanical spring return mechanism. The failsafe position shall be based upon system design requirements.
3. Actuators for reheat valves and fan-coil units in non-critical applications may fail in place.
4. Actuators for reheat valves and fan-coil units in Critical applications (ie: Animal Care, Data, Archival Storage, Research labs and MRI facilities) shall be spring-closed.
5. All control valves 2-1/2 inch and larger shall be furnished with manual override features on their actuators.
6. Actuators shall be rated for a minimum of 60,000 full cycles and 500,000 partial cycles at the rated torque.
7. Actuators shall be sized for torque requirements to provide 100% damper seal at load conditions.
8. Provide actuators with a five year warranty.

K. AIR HANDLING UNIT AIR FILTERS:

1. Each air filter bank of 4,000 cubic feet per minute (cfm) and over in buildings with BAS requires an analog pressure transducer.
2. Air-to-air heat exchangers or energy recovery ventilators of 4,000 cfm and over require four temperature sensors for BAS temperature monitoring (inlet and outlet of both process and regeneration air), and an analog pressure transducer on each air pathway (one required for each rotary heat exchanger; two required for each flat plate or heat pipe.

L. CONTROL DAMPERS:

1. All dampers shall include seals.
2. Leakage for outdoor, isolation and exhaust shall not exceed 4 cfm per square foot of damper area when closed against 1.0 in. wc. pressure, as tested in accordance with AMCA Standard 500-D.
3. Installed linkages shall be non-binding and non-interfering across the full travel.
4. Linkage shall not be attached to damper blades.
5. Provide parallel blade dampers for 2 position applications.
6. Provide opposed blade dampers for modulating application.

M. HIGH TEMPERATURE HOT WATER HEAT EXCHANGERS:

1. Furnish each high temperature hot water heat exchanger with a manual reset high limit immersion sensor installed in the shell. High limit shall have dual contacts.
   a. Contact A shall be a digital input alarm for the BAS system.

b. Contact B shall disconnect the isolation / control valves(s) power supply.

2. Auxiliary contacts on the associated pump output contactor(s) shall disconnect the isolation / control valve(s) power supply.
3. The valve control algorithm shall be interlocked with the pump current transformer status point(s) in programming such that valve will be closed on a loss of pump status.
4. Furnish a paddle type flow switch on each medium temperature outlet to disable the high temperature control valve on loss of flow. The flow switches shall be installed in a serviceable location that does not require draining the entire building for service.

N. REQUIRED MEP SYSTEM BUILDING DATA POINTS (WHERE APPLICABLE):

1. Generator "Run" status
2. Automatic Transfer Switch "Connected to Emergency" status
3. Sewage ejector sump "High Level" and "Failure" alarms
4. Dewatering sump "High Level" and "Failure" alarms
5. Fire Pump "Run", "Not in Auto", "Power/Phase Loss" and "Phase Reversal" status
6. Fire alarm system "Alarm" and "Trouble" status
7. For boilers rated over 1MMBH:
   a. Steam:
      i. On/Off Status
      ii. Low Water Level Alarm (Low Water cut-off switch)
      iii. High Water Level Alarm (High Water cut-off switch)
      iv. High Steam Pressure Alarm
      v. Common Boiler Alarm (if provided)
      vi. Steam Pressure (analog input - may be common for multiple-boiler installations).
   b. Hot Water:
      i. On/Off Status
      ii. Low Water Level Alarm (Low Water cut-off switch)
      iii. Common Boiler Alarm (if provided)
      iv. Hot Water Temperature (analog input - may be common for multiple-boiler installations).

1.6. BAS DETAILED DESIGN REQUIREMENTS:

A. Equipment Controls:
1. Equipment shall not be supplied with manufacturer-furnished controls, with the exception of chillers and boilers. All controls shall be by the approved Brown University BAS vendor.
2. BAS controllers provided for air handlers and heating/cooling systems shall have an integral display with all relative points listed as read only.
3. The BAS controllers shall be native Bacnet.

4. Life Safety Systems including smoke control shall be hard-wired directly to the equipment controllers of the building fire alarm system only, and shall operate independently of the BAS.
5. Control components for Animal Care areas and limited access Research facilities shall be located outside of the area served (utility corridor) so that they can be serviced without entering the research space.
6. Unit heaters and other equipment not on the BAS shall have locked or concealed adjustment controls.
7. BAS control of small (1/3 HP or less) exhaust fan motors is not required.
8. Fan Coil units shall utilize the BAS vendor, not manufacturer, furnished control and valve systems.
9. Chillers shall be installed with manufacturer-supplied proof of flow switches on both the chilled water and condenser water inlet piping.
10. Boilers shall receive remote setpoint adjustments from the BAS.

B. Miscellaneous:

1. Wireless field bus controllers are prohibited.
2. Do not exceed 80% of any listed manufacturer specification (object count, device count, memory, etc.).
3. Provide a minimum of 20% spare capacity of each hardware point type on each controller.
4. Public space temperature sensors shall be non-adjustable.
5. Provide discharge air temperature sensors for all VAV boxes with reheat coils.
6. The occupant thermostat set point adjustment shall be +-2.0 deg F for private offices, conference rooms and classrooms. Public thermostats and thermostats for shared and large offices shall be non-adjustable.
7. All input and output signals shall utilize discrete wiring. A single drop networked sensor will be allowed for temperature only.
8. Specialty sensors (CO, CO2, O2, refrigerant, etc.) shall be a 0-10VDC or 4-20mA signal input to the BAS indicating the measured value.
9. Furnish a discharge temperature sensor downstream from each terminal box with reheat capability and for all research / animal care rooms.

C. Sequence Of Operation:

1. All HVAC controllers shall utilized fixed PI control algorithms only. Self-tuning algorithms are not allowed.
2. All systems shall restart automatically when personnel and equipment safety devices are reset to the safe state.
3. Equipment shall rotate on a regularly scheduled day (Tuesday-Thursday) between 10AM and 2PM
4. Brown prefers that chilled water systems stage based upon chiller load (%FLA). Chilled water temperature deviation should only be utilized as the secondary method for staging.

D. Control Interlocks:

1. All equipment with Hand- Off- Automatic switches shall operate in the Hand state regardless of the state of the BAS system.
2. All interlocks intended to: prevent injury, avoid damage to equipment, or required for Life safety (ie. Fire alarm shutdown) shall be hardwired and shall operate in both Hand and Automatic positions.
3. For air handling equipment, if sudden closure of dampers could cause pressure to develop in excess of ductwork system design pressure, provide low and high static switches where appropriate.

E. BAS Field Devices and Sensors:

1. All BAS controllers shall be installed in enclosures.
2. All control devices shall be configured and installed to permit ready access for inspection and servicing. Furnish and install rated duct access panels where required a minimum dimension of 18 inches by 18 inches square.
3. Outdoor air sensors shall be installed on the exterior of the building in the shade of the North face.
4. Do not locate room thermostats on exterior walls or in a direct sightline of sunlight.
5. BAS sensors for HTHW (350 deg F) applications shall be of extended range and suitable for the application.
6. Do not utilize outdoor CO2 (carbon dioxide) sensors; utilize a fixed reference value of 400PPM.

F. AIR-SIDE ECONOMIZER CONTROL:

1. Enable the economizer function when the outdoor air enthalpy is below 25 Btu/lb and disable it when above 26 Btu/lb, or when outdoor air temperature exceeds 70F dry bulb.

G. OCCUPANCY SENSORS:

1. If overall occupied/unoccupied control is not appropriate for the project, provide setback of temperature and ventilation through space occupancy sensors. Coordinate with lighting occupancy sensors for respective areas.

H. HUMIDIFICATION:

1. Furnish a discharge humidity sensor which will function as the high limit alarm and for reset of discharge air humidity control.
2. Humidification control sequencing shall utilize a space, exhaust or return-air humidity sensor to reset the discharge humidity set point. The humidification valve shall modulate to maintain this set point.
3. Do not utilize standalone devices to regulate BAS humidification signals.
4. The humidification system shall include an associated fan software status interlock and a hard wired sail type air flow switch or air flow proving switch.

I. CHILLED BEAMS CONTROL:

1. Provide a condensation sensor on each zone with operable windows to disable the chilled beam CHW control valve.

1.6. BACNET SYSTEM DESIGN REQUIREMENTS:

A. Change of value increments shall be equal to field point decimal precision.

B. Peer to peer communication between field controllers is not allowed.

C. The Bacnet device name shall match the equipment name as reflected on the contract drawings.

D. The BAS contractor is responsible for third party integration compliance with University standards. Only site applicable data shall be mapped and displayed.

E. Bacnet Device Instance Numbers shall utilize the following format:

Bacnet Supervisory and Field controller Instance ID numbering

MSTP Field Controllers

MAC Address	Brown Assigned Supervisory #	Brown Assigned Manufacturer #
XXX	XXX	X
For supervisory devices with multiple field busses, utilize 201-327 for address 001-127 on Field Bus #2	Contact Brown Application Engineer for assigned number	Andover = 1 JCI = 5 Other = 3
IE: MAC address 24 on field bus one of supervisory controller JCI NAE-37 will produce Instance # 0240375		
MAC address 3 on field bus one of supervisory controller Andover BCX-22 will produce Instance # 0030221		

Bacnet IP Controllers (Ethernet)

BACnet Vendor ID#	Brown Assigned Supervisory #
XXX	XXX
http://www.bacnet.org/VendorID/BACnet Vendor IDs.htm	Contact Brown Application Engineer for assigned number
IE: Supervisory controller JCI NAE-37 will produce Instance # 005037	
Supervisory controller Andover BCX-22 will produce Instance # 010022	

PART 2 – PRODUCTS:

2.1 BAS MANUFACTURERS:

A. Schneider Electric Andover - Bacnet

B. Johnson Controls – MESA Bacnet

C. Obtain approval in advance as to whether one, or both, vendors shall be considered acceptable for the project.

2.2 CONTROL VALVES:

A. Self-contained (thermostatically-controlled) valves for hot water radiators shall be Macon, fail-closed/minimum flow. Equivalent valves by Danfoss will be considered.

B. Terminal equipment valves up to 2 inches:
   1. Characterized ball type with stainless ball, stem, and trim.
   2. Globe valves with bronze body, stainless stem, and stainless plug.

C. HTHW valves shall be by Schubert and Salzer, ANSI flange, wafer design.

2.3 ACTUATORS FOR VALVES AND DAMPERS:

A. The preferred vendor for small electric actuators is Belimo. Belimo actuators are required for all critical applications, such as Animal Care, Data, and MRI facilities.

B. The preferred vendor for larger electric actuators is Bray. Bray valves shall be classified as high performance type.

C. Actuators shall include a hand wheel override feature.

2.4 TEMPERATURE SENSORS:

A. Johnson Controls temperature sensors shall be 1000 Ohm PLATINUM.

B. Andover temperature sensors shall be 10K Ohm THERMISTOR.

2.5 HUMIDITY SENSORS:

A. Acceptable manufacturers:
   1. Veris Industries
   2. Vaisala

B. Humidity sensors (wall and duct mounted) shall be capacitive type, with field - replaceable detection elements.

C. For normal use, provide sensors with +/- 3% accuracy. For lab locations, provide +/- 2% accuracy. Furnish NIST certified +/- 1% sensors for outdoor humidity sensors utilized for enthalpy free cooling calculations or control.

2.6 CO2 SENSORS:

A. Acceptable manufacturers:
   3. Veris Industries
   4. Vaisala

2.7 RELAYS:

A. Relays that are manufactured as self-contained assemblies with electrical nipple connections and factory supplied leads shall be manufactured by Functional Devices, model RIB (Relay in a Box).

B. General purpose panel-mounted relays and bases shall be manufactured by IDEC Corporation. Panel relays shall be mounted on suitable DIN rail.

2.8 DRY PRESSURE TRANSDUCERS:

A. Acceptable manufacturers:
1. Veris Industries
2. Setra Sensing Solutions

2.9 WET PRESSURE TRANSDUCERS:

A. Provide wet pressure transducers appropriate for the system served manufactured by Setra Sensing Solutions

2.10 DAMPERS

A. Acceptable manufacturers:
1. Ruskin
2. Greenheck
3. TAMCO

2.11 CURRENT SENSORS:

A. The acceptable manufacturer is Veris Industries.

B. Provide adjustable set point split-core sensors with a status indication light.

C. Current sensors installed on variable speed drives shall be rated for inverter duty.

PART 3 – EXECUTION

3.1 WIRING AND IDENTIFICATION:

1. BAS labeling and component designations shall match Brown labeling requirements; See Section 01701CPPR – Building Systems Identification & Labeling.

2. BAS junction boxes shall be marked with machine printed labels “BAS”.

3. All BAS wiring shall comply with the National Electrical Code and applicable Brown Division 26 Standards.

4. All BAS wire shall be stranded unless otherwise required by manufacturer.

5. All exposed wiring in utility rooms and mechanical rooms shall be run in electrical metallic tubing utilizing steel fittings (die-cast fittings are not acceptable).

6. Exterior conduit shall be rigid steel.

7. Conduits subject to weather, consistent moisture or exposed to physical damage as determined by the Operations staff shall be rigid steel.
8. All conduit entries to field panels shall be through the bottom of the field panel enclosure.
9. Field panels shall not be installed in hostile environments or where space temperatures exceed 100 degrees F.
10. Field panels shall be mounted 6’ 0” AFF to the top of the cabinet.
11. Low voltage class two and class three circuits as defined in article 725 of the National Electrical Code may be run exposed on cable tray, “j” hooks or other approved cabling support methods when installed concealed above readily accessible acoustic tile ceilings. All class two and class three cabling shall be plenum rated.
12. BAS field panels shall have power source panel name, room number and circuit breaker number posted on the inside door. Update the electrical as-built drawings to reflect this information.
13. All interconnection and field wiring shall be machine labeled referencing wiring diagram device names. All wiring shall be machine-labeled at each end with the device name.
14. Apply labels to all field devices indicating the field device name.
15. Field panels shall be marked on the exterior panel face with machine printed labels indicating the primary controlled system.
16. Field panels with Ethernet devices shall have the respective Ethernet address machine labeled on the interior door.

3.2 COMMISSIONING:

A. New BAS system installations and expansions of existing systems shall be fully commissioned. Furnish check out sheets indicating test, test date, technician, result and corrective action.

B. The BAS Contractor shall calibrate all field devices prior to commissioning.

C. The BAS contractor’s responsibilities for commissioning and check-out include:
   1. Work with the selected commissioning agent to review the intended system operation, activate all control, alarm and monitoring points to verify intended system operation, and run trends for selected data points to verify intended system operation and functionality.
   2. Provide all controls logic, graphics, and trends for review prior to the start of field commissioning activities.
   3. Provide completed calibration and operational checks for each individual point and function contained within the BAS.

4. Conduct the commissioning checkout with the use of point/function log sheets prepared by the commissioning agent. The Owner shall approve the log sheet format.
5. Submit completed commissioning log sheets to the Owner prior to the commencement of any final acceptance testing.

3.3 DEMOLITION

A. Delete all demolished systems and respective data points from BAS application software.

B. Pneumatic demolition shall be executed by licensed pipefitters utilizing listed pneumatic plugs and caps.

C. Remove from the building and dispose of all equipment that has been removed from service or demolished.

D. Turn over equipment requested by the Owner to the Owner's representative.

3.4 TRAINING:

A. Provide to the Owner completed as-built drawings and system documentation at least four (4) weeks prior to training. Training will not be accepted without 100% as built documents.

B. Upon completion of the work and prior to system acceptance by the Owner, a factory authorized representative of the control manufacturer shall provide instruction to the Owner's operating personnel who have responsibility for the mechanical and controls systems. The amount of training shall be no less than eight hours. Hours will be defined during the project design phase.

C. Provide two sessions per training session; one session shall be provided for each shift.

END OF SECTION