SECTION 230923

INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 CONDITIONS & REQUIREMENTS

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

B. All work shall comply with the requirements of the Conditions of the Contract (General and Special), with the Contract Drawings, and with all other contract documents.

C. Any deviations from the requirements of the Contract Documents must be submitted in writing along with bid documents.

1.2 RELATED DOCUMENTS

A. In case there is a discrepancy between this specification and Division 21, Division 22, Division 23, Division 26 and Division 28 specifications and their associated drawings, then the Bidder shall assume the more stringent requirement for his bid.

B. Commissioning of a system or systems specified in section 019113 is part of the construction process. Documentation and testing of these systems, as well as training of the FRA's operation and maintenance personnel, is required in cooperation with the FRA's representative and the commissioning agent. Project closeout is dependent on successful completion of all commissioning procedures, documentation, and issue closure. Refer to section 019113, commissioning, for detailed commissioning requirements.

1.3 SUMMARY

A. Section Includes:

1. DDC system for monitoring and controlling of HVAC systems.
2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

1.4 SCOPE OF WORK

A. Control Contractor shall:

1. Provide installations of controllers and instruments provided by system and device manufacturers for equipment monitoring and control as herein specified. The scope shall include controllers, microprocessor-based controller unit panels, instrumentation, end control devices, wiring, conduit, and related systems integration as follows:

a. Air Handling Units (AHU)
b. Supply Fans

~~b.~~**c.** Exhaust Fans
~~c.~~**d.** Chilled / Condenser Water Systems
~~d. DX - Split VRF Systems~~
~~e. Heat Exchangers~~
~~f.~~**e.** Electrical Metering
~~g.~~**f.** Fuel Oil System / Generator
~~h.~~**g.** Energy Meters
~~i.~~**h.** Programmed Start-Stop of Systems
~~j.~~**i.** Monitoring and controlling of Space Conditions
~~k.~~**j.** Alarm Annunciation.

2. The scope of the contractor shall include the integration of the BMS (underground) with the existing central BMS system which is dedicated to the monitoring of the facility buildings (topside). The existing system shall be modified and/or expanded to support the modification, demolishing and installation of equipment as part of this project.
3. Provide required DDC control system hardware along with sensing devices, control valves, dampers and actuators as specified herein.
4. Provide a complete operational system including all work specified herein, specified in associated specifications for mechanical and electrical work and shown on all contract drawings.
5. The Contractor shall assume all control points referred to in this specification as well as the specifications in Division 23 and Division 26. The contractor is also responsible for all instrumentation and controls shown on the controls drawings, Division 23 and Division 26 drawings.
6. The BMS system shall provide equipment supervision and control, alarm management, energy management, information management, historical data collection and archiving and be capable of integrating multiple building functions.
7. The system shall employ standard networking practices and conventions, co-exist with existing Ethernet networks, and manage system data using generally accepted database storage and retrieval methods and standards.
8. Provide all wiring, raceways and electrical work associated with the BMS. This shall include and to be limited to the following:

    a. Controls wiring and conduit between control panels.
    b. Controls wiring and conduit between control panels and field instrumentation, external equipment control systems
    c. Wiring and conduit for the BMS communication networks.
    d. Contractor shall make use of raceways provided by others if possible as shown on system architecture drawings.

9. Provide all electrical work associated with the BMS.
10. Provide all wiring in accordance with the latest editions of the local electrical code and the NEC.
11. Divisions 26 to provide dedicated circuits as required, refer to Division 26 drawings for junction box locations. Controls contractor to provide transformers and field terminations.
12. Incorporate surge transient protection into the design of the system to protect the electrical components in all DDC controllers, TECs, panels, servers and workstations.
13. Install all DDC controllers with spare hardware capacity for future additions of at least 15% of each type of point and 25% spare memory capacity for future connection.
14. Provide control power transformers for valve actuators, damper actuators and all instruments and devices provided under this contract for low voltage operation.
15. Provide all wells for water monitoring devices, temperature sensors, flow switches and alarms, as required.
16. Furnish control dampers and actuators not integral to the factory assembled air handling units. Furnish dampers, meeting or exceeding the specifications, listed in the associated

sections and located as shown on all drawings. Coordination is required with Division 23, regarding the installation, final sizing and method of fixing and delivery of the dampers.

17. Provide system graphics for each system as specified herein.
18. Provide engineering and shop drawings as specified herein.
19. Provide field supervision of the associated elements of work as specified herein.
20. Provide mechanical installation of all control instrumentation etc. as specified herein.
21. Provide testing, calibration and commissioning as specified herein.
22. Provide demonstration of operation and system performance testing as specified herein.
23. Provide as-built drawings as specified herein.
24. Provide Operation and Maintenance manuals as specified herein.
25. Provide Personnel Training as specified herein.
26. Provide attendance and support during the commissioning of the project to Divisions 23 and 26, as required by the coordinated commissioning program.
27. With commencement of the project provide test procedure documents (TPD) describing the testing of all interfaces between the BMS and other systems for approval by the FRA, the Engineer and the Management Contractor.
28. Installation of access doors is not provided by this section, however, the controls manufacturer shall furnish access doors as required, for equipment provided and installed by this section.

1.5 DEFINITIONS

A. Explanations of terms utilized in this Specification:

1. Provide: Furnish and install, complete, the specified material, equipment or other item and perform all required labor to make a finished and acceptable installation.
2. Furnish: Purchase, store and deliver the specified material, equipment or other item to the project site complete with all necessary appurtenances, supports, etc.
3. Install: Unload at the delivery point at the site and perform every operation necessary to establish secure mounting and correct operation at the proper location in the project.
4. By others: By persons or parties responsible for work at the project other than the party or parties who have been awarded the contract for the work of this trade. In the event that this document is used to acquire work as part of a general construction contract, the words "by others" or "by other trades" shall mean by persons or parties who are not anticipated to be the Contractor for this trade working together with the Construction Manager (CM). In this context, the words "by others" or "by other trades" shall not be interpreted to mean not included in the overall contract.
5. Ductwork: Ductwork, volume dampers, motorized dampers, fire and smoke dampers, diffusers, registers, supports and all other items required for a complete functional system.
6. Piping: Piping, valves, strainers, supports and all other items required for the circulation of water to and from HVAC equipment.
7. Concealed: Embedded in masonry or other construction, installed behind wall furring, within double partitions, above inaccessible ceilings, in crawl spaces, in shafts, etc.
8. Exposed: Not concealed.

1.6 RELATED WORK

A. Related Documents and Sections: Examine Contract Documents for requirements that directly affect or are affected by Work of this Section. A list of those Documents and Sections include, but is not limited to the following:

1. Drawings and general provisions of the Contract, including General and Supplementary Conditions, and Division 01 General Requirements Specification Sections, apply to this Section.
2. Other Related Sections:

    a. All Division 21 Equipment Sections
    b. All Division 22 Equipment Sections
    c. All Division 23 Equipment Sections
    d. All Division 26 Equipment Sections
    e. All Division 28 Equipment Sections

1.7 COORDINATION

A. Coordinate work under provisions of Division 1 as applicable.

B. Ensure installation of components is complementary to installation of similar components in other systems.

C. Coordinate installation of system components with installation of mechanical systems equipment such as air handling units and air terminal units.

D. Contractor to coordinate all BMS integrations, inputs and outputs to systems and equipment with final approved submittals.

E. Ensure system is completed and commissioned.

F. Division 23 - BMS Contractor shall be responsible for all electrical work associated with the BMS control system as detailed below.

1. Perform all wiring in accordance with all local and national codes. Refer to Division 26, Electrical Specifications for areas requiring more stringent installation procedures.
2. Provide 120-volt branch circuits from junction boxes to DDC panels.
3. Provide 120VAC for all instruments, valves, dampers, and control devices requiring 120VAC supply. All work shall be installed in accordance with Division 26.
4. Provide 24-volt power, control and network interface wiring from network DDC controllers and panels to all application specific controllers (VAVs, TECs etc.), local display devices through end control devices, complying with requirements of Division 26.
5. Provide BMS internal logic to coordinate all necessary fire alarm system smoke shutdown for variable frequency drive and motor starters related to emergencies as well as fire alarm system duct mounted smoke detectors according to local code requirements.
6. Provide transformers, where required, to match control voltage with actuator or sensor voltage.

G. The Division 23, Mechanical Contractor shall provide the following:

1. All openings and pressure taps for water monitoring devices, flow switches, control valves and wells furnished by the BMS Contractor.
2. Installation of all dampers and measuring devices. All control dampers shall be furnished by BMS Contractor where not specified as an integral component of a packaged unit.
3. Furnish and install all access doors.
4. Items furnished by BMS Contractor but installed by Sections of Division 23, Mechanical Contractor:

a. Flow elements directly installed in the piping or ductwork, such as airflow measuring inlet probes, magmeters, pressure switches and thermowells.
b. Automatic control valves.
c. Control dampers.

H. The Division 26, Electrical Contractor shall provide the following.

1. Wiring of power feeds through all disconnects, starters, and to electric motors.
2. Division 26 contractor to provide all line voltage 120 VAC power wiring from electrical panels to junction boxes for the purpose of powering control panels. Junction boxes to be provided by Division 26 and shall be wired in conduit from dedicated circuits. Division 26 shall provide circuit breakers at all electrical panels for use by the BMS contractor.
3. Motor starters and motor feeder
4. If upon Div. 23 contractor's final sizing of control devices it has been determined that the power required for the assembly exceeds the power available from the BMS control panel, the Div.23 contractor shall coordinate with the Div. 26 contractor for additional power.

I. The Division 28, Fire Alarm System Contractor shall provide the following.

1. Wiring of power feeds through all smoke detectors.
2. Smoke detectors shall be furnished by Division 28 and installed by Division 23.
3. All necessary monitored relays and outputs to BMS for the purposes of alarming and smoke control functions and pressurization as required by BMS and described herein and on contract drawings.

1.8 REFERENCE STANDARDS

A. All work shall conform to the following Codes and Standards, where applicable:

1. National Fire Protection Association (NFPA) Standards, as specified.
2. National Electrical Code (NEC) and applicable local Electrical Code.
3. Underwriters' Laboratories (UL) listing and labels, as specified.
4. Factory Mutual (FM).
5. American National Standards Institute (ANSI).
6. National Electric Manufacturers' Association (NEMA).
7. American Society of Mechanical Engineers (ASME).
8. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
9. Air Movement and Control Association (AMCA).
10. Institute of Electrical and Electronic Engineers (IEEE).
11. American Standard Code for Information Interchange (ASCII).
12. Manufacturer's Standardization Society of the Valve and Fitting Industry (MSS).
13. Electronics Industries Association (EIA).
14. Occupational Safety and Health Administration (OSHA).
15. American Society for Testing and Materials (ASTM).
16. NFPA 92A and 92B
17. NFPA 101, 2002

1.9 GENERAL PRODUCT DESCRIPTION:

A. The building management system provided and installed shall be a distributed logic control system complete with all software and hardware functions. The system shall be based on

ANSI/ASHRAE Standard 135, BACnet controlling all mechanical equipment using BTL (BACNET Testing Labs) Certified native BACnet-compliant components.

B. The building management system shall consist of the following:

1. BMS Server
2. Stand-alone DDC Controllers (32 bit processors) for all main equipment. The intent of this specification is that the loss of any one DDC controller shall not affect the operation of other HVAC systems. It shall only affect the points connected to the failed DDC controller. It is not acceptable that any control loops are split across two or more DDC control panels.
3. Stand-alone Terminal Equipment Controllers (TECs) shall only be used for terminal equipment.
4. One (1) portable operator's terminal to be connected and communicating simultaneously with the entire BMS. The portable operator terminal shall be able to monitor, adjust, trend, edit, modify, add, delete, backup the entire BMS system (including Terminal Equipment Controllers, DDC controllers, etc.) point database and all programs, provided the operator has the appropriate password access.
5. Operator workstation and the associated peripherals.

C. The system shall be modular in nature and permit expansion of both capacity and functionality through the addition of sensors, actuators, DDC Controllers, and operator devices.

D. Controllers shall assign password access and control priorities to either fully assignable point groups or each point individually. The logon password (at PC workstation or portable operator terminal) shall enable the operator to monitor, adjust and/or control only the points that the operator is authorized for. All other points shall not be displayed at the PC workstation or portable terminal. (E.g. all base points shall be accessible to any base building operators, but only electrical points shall be accessible to house electricians). Passwords and priority levels for every point shall be fully programmable and adjustable.

E. The BMS system shall operate with an input voltage rated at 120 Volts, 1 phase, 60 Hertz. All units shall be grounded in accordance with the local Electrical Code and the NEC. All units shall be supplied with filtered power, if required, to preclude noise generation. Signal range shall be 4-20 mA or 0-10 VDC.

F. The BMS shall be programmed to automatically detect critical alarms that require notification, create an action statement for each alarm, and select the person to receive the notification via e-mail, pager, and cell phone. Software shall operate with any numeric or alphanumeric paging system. Paging database shall be password protected. When a critical alarm occurs, a paging box is automatically displayed indicating which report is being sent to which pager and the progress of the page. For alphanumeric systems, page shall indicate exactly where and what alarm has occurred so that an operator can go directly to the problem without need of an operator terminal to diagnose the problem.

G. The control system shall be a high speed, peer to peer BACnet network of DDC controllers and a web based operator interface. All schedules, setpoints, trends, and alarms shall be BACnet objects.

H. Workstation information access shall be BACnet protocol. Communications shall use ISO 8802-3 (Ethernet) Data Link/ Physical layer protocol.

1.10 SUBMITTALS

A. Multiple Submissions:

1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.

B. Submit under provisions of Section 01 3300 – SUBMITTAL PROCEDURES, Division 01 as applicable. Shop drawings to be provided in PDF Format.

C. Contractors will provide a Compliance Review of the Specifications, Drawings and Addenda (if any). The Compliance Review is a paragraph-by-paragraph (Drawing by Drawing) review of the Specifications and Drawings with the following information, “C”, “D” or “E” marked in the margin of the original Specifications and any subsequent Addenda. Narrative text shall accompany the Drawing Compliance Review.

1. “C”: Comply with no exceptions.
2. “D”: Comply with deviations. For each and every deviation, provide a numbered footnote with reasons for the proposed deviation and how the intent of the Specification can be satisfied.
3. “E”: Exception, do not comply. For each and every exception, provide a numbered footnote with reasons and possible alternatives.
4. Note: Unless a deviation or exception is specifically noted in the Compliance Review, it is assumed that the Bidder is in complete compliance with the plans and Specifications. Deviations or exceptions taken in cover letters, subsidiary documents, by omission or by contradiction do not release the contractor from being in complete compliance, unless the exception or deviation has been specifically noted in the Compliance Review. The Bidder may submit the latest state-of-the-art components in lieu of specified items. The engineer and FRA will review deviations from the Specifications.

D. Submit shop drawings for each system automatically controlled and integrated. The submittals shall be provided with a comprehensive index and each page of the submittal shall be provided with a page number, drawings shall have a drawing / sheet number, date and revision. Revisions of submittals if required shall provide necessary revision clouding of affected areas on all drawings resubmitted. Drawing submittals shall comprise, at a minimum the following information:

1. Trunk cable schematic showing programmable control unit locations, and trunk data conductors.
2. Process and instrumentation diagrams indicating monitored systems, including fans, pumps, coils, dampers, valves, control devices and control points as well as data (connected and calculated) point addresses, and operator notations.
3. Complete system architecture flow diagram with peripheral devices, power supplies, diagrams, modems, and interconnections including detailed designations of all system components and local area networks.
4. DDC system electrical power riser diagram indicating the following:

    a. Each point of connection to field power with requirements (volts/phase//hertz/amperes/connection type) listed for each.
    b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
    c. Each product requiring power with requirements (volts/phase/ hertz / amperes/ connection type) listed for each.

d. Power wiring type and size, race type, and size for each.

5. Descriptive data and sequence of operation of operating, user, and application software.
6. Valve and damper schedule coordinated with mechanical drawing and equipment cut-sheets. Valve schedules to include all engineering related information as a minimum, valve tag, service, flow, units, system pressure, coil pressure drop, line size, design pressure drop, valve pressure drop, Cv, valve size, valve type, rating, spring position, pipe connection style, manufacturer, model, control signal, feedback, operating speed, actuator manufacturer, actuator model, and operating voltage.
7. System graphics and inclusive of a master organizational plan.
8. Provide detailed points list, clearly differentiating between analog and digital, input and output points as well as all serial integration (soft points). An allowance for future point integration shall be made to ensure any points found to be necessary during commissioning and start-up can be added.
9. Indicate all required electrical wiring of connected data points, including connected control unit and input device, field control panel layout and locations, and parts list coordinated with power panel locations. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.
10. Provide details of faces of control panels, including controls, instruments, and labeling.
11. Indicate each control panel required, with internal and external wiring clearly indicated.
12. For all system elements, controllers, TECs, etc., provide BACnet Protocol Implementation Conformance Statements (PICS) as per ANSI/ASHRA Standard 135.
13. Provide a complete set of architectural backgrounds updated with all electrical and mechanical equipment controlled by the BMS including field control panel locations.

E. Product Data: Provide data for each system component and software module.

F. Provide sample(s) of all proposed space mounted sensors for review and written approval by FRA's Representatives.

G. Provide sample of label to be provided for each control device with setting or adjustable range of control for written approval by FRA's Representative.

H. Provide sample(s) of proposed graphic for review and written approval by FRA's Representatives.

I. Prior to installation submit reduced size shop drawings of piping and ductwork showing the proposed installation location of all field devices including sensors, switches, stats, etc.

J. Operating and Maintenance Data

K. Point by Point and functional testing Commissioning plan and reports.

1.11 PROJECT RECORD DOCUMENTS

A. Submit under provisions of Division 1 as applicable.

B. Accurately record actual location of control components, including panels, thermostats, and sensors

C. Revise shop drawings to reflect actual installation and operating sequences.

D. Include data specified in "Submittals" in final "Record Documents" form.

1.12 OPERATION AND MAINTENANCE DATA

A. Submit under provisions of General Conditions and Division 1 as applicable.

B. Provide operation and maintenance manuals to serve as training and reference material for all aspects of day to day operation of the system.

C. Operators Manual shall include

1. As built shop drawings
2. Color coded wiring diagrams.
3. Principle of operation and detailed narrative sequences.
4. Description of manual override of control points.
5. Step by step instructions for operating system in different control modes.

D. Maintenance Manual shall include

1. Table of multi-conductor DDC cable tag numbers, with corresponding panel, system, floor and area served.
2. Overall system shielding and grounding scheme.
3. Routine preventive maintenance procedures and corrective diagnostic trouble shooting procedures.
4. Parts lists and manufacturer's catalog numbers and ordering information.
5. List of ordinary and special tools, operating materials, supplies and test equipment.
6. Interlock ladder wiring diagrams for each system showing interfaces between panels mounted and field equipment.
7. Control panel arrangement drawing.
8. Equipment brochure and service manual

a. Equipment descriptive literature
b. Performance data, model number
c. Installation instructions
d. Recommended spare parts
e. Lubrication instructions

E. Programming manual

1. Complete programming manual including complete program listing and flowcharts for all sequence of operations
2. Documentation on application programs

F. Submit 2 hard copies and one CD ROM of operating, maintenance and programming manuals for review by FRA and engineer.

1.13 QUALIFICATIONS / QUALITY ASSURANCE

A. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the Specification requirements.

B. Manufacturer's Qualifications: Firms regularly engaged in manufacture of DDC control equipment, of types and sizes required, and whose products have been in satisfactory use in similar service for not less than 10 years. The manufacturer shall be ISO 9000 certified.

C. Installer's Qualifications: Company specializing in applying the work of this Section with minimum ten years documented experience and approved by manufacturer.

D. Install system using competent workmen who are fully trained in the installation of temperature control equipment and are direct employees of the controls installer. Installing wholesalers, franchisers, dealers, distributors are not acceptable. Electrical subcontractors for the installation of distribution wiring and power are acceptable.

E. Single source responsibility of BMS Contractor to include complete software, graphics installation and proper operation of the control system, debugging, and proper calibration of each component in the entire system. Third party software/programming and graphics package is not acceptable.

F. BMS Contractor shall have an in-place support facility within 100 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment for a period of not less than 10 years.

G. Manufacturers shall submit evidence of electric and DDC parts availability through authorized parts wholesaler at time of bid.

H. Commissioning of a system or systems specified in this section is part of the construction process which includes documentation and testing of these systems, as well as training of the FRA's operation and maintenance personnel.

I. Quality Assurance Program

1. The BMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements.

   a. The BMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is responsible for the management of the program.
   b. The Quality Assurance Manager shall provide or maintain

      1) Documentation of training for employees-including office, field, and subcontractors- on the Quality Assurance Program.
      2) Written verification that each worker on the project has read the Specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
      3) A detailed audit trail for all Quality Assurance issues, including: problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.

   c. Each individual team member shall be responsible for identifying and reporting Quality Assurance problems and for assisting, as requested by the Quality Assurance Manager, in the resolution thereof.

1.14 PRE-INSTALLATION CONFERENCE

A. Convene a conference one week prior to commencing work of this Section, under provisions of General Conditions and Division 1 as applicable.

B. Require attendance of parties directly affecting the work of this Section.

1.15 EXTRA MATERIALS

A. Submit maintenance materials under provisions of General Conditions and Division 1 as applicable.

B. Provide spare parts list.

1.16 PROTECTION OF SOFTWARE RIGHTS

A. Prior to delivery of software, the FRA and the party providing the software will enter into a software license agreement with provisions for the following:

1. Limiting use of software to equipment provided under these specifications.
2. Limiting copying.
3. Preserving confidentiality.
4. Prohibiting transfer to a third party.
5. Provided they are available at a cost satisfactory to the FRA warranties of unlimited duration.

1.17 CODES AND APPROVALS

A. All work, materials, and equipment shall comply with the rules and regulations of all codes and ordinances of the local and state, and federal authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications. As a minimum, the installation shall comply with current editions in effect 90 days prior to receipt of bids of the following codes. All products of the DDC system shall be provided with the following agency approvals. With the submittal documents, verification that the approvals exist for all submitted products shall be provided. Systems or products not currently offering the following approvals are not acceptable.

1. NEMA standards pertaining to components and devices for DDC control systems.
2. NEMA EMC1 - Energy Management Systems Definitions.
3. Requirements of NEC pertaining to installation of DDC control systems, including, but not limited to, remote-control, signaling and power-limited circuits.
4. Provide DDC control system components and ancillary equipment which are UL-listed and labeled.
5. The BMS system shall be UL916PAZX listed.
6. Federal Communications Commission (FCC) Rules, pertaining to components and devices for DDC control systems and Section 15 governing radio frequency electromagnetic interference and be so labeled
7. Electronic Industries Association (EIA) Std RS-232 pertaining to interfacing requirements for connecting data terminals and communication equipment.
8. IEEE Std 488, "Standard Digital Interface for Programmable Instrumentation", for interfacing instrumentation into system.
9. ANSI X3.4, "Code for Information Interchange", requirements for interfacing computer data processing with communication terminal equipment.
10. ASME MC85.1 - Terminology for Automatic Control

B. The following current NFPA and ASHRAE Standards and Guides are applicable.

1. NFPA 90A “Standard for the Installation of Air Conditioning and Ventilating Systems” where applicable to controls and control sequences
2. NFPA 90B Warm Air Heating, Air Conditioning
3. NFPA 92A, Recommended Practice for Smoke-Control Systems

4. NFPA 92B, Guide for Smoke Management Systems in Malls, Atria, and Large Areas
5. ASHRAE 85 - Automatic Control Terminology for Heating, Ventilating, Air Conditioning
6. ASHRAE 135 - Building Automation and Control Networks (BACnet)

C. All system components are to be designed and built to be fault tolerant.

1. Provide satisfactory operation without damage at 110% above and 85% below rated voltage and at +3 hertz variations in line frequency.
2. Provide static, transient, and short circuit protection on all inputs and outputs. Communication lines shall be protected against incorrect wiring, static transients and induced magnetic interference. Bus connected devices shall be AC. coupled, or equivalent so that any single failure will not disrupt or halt bus communication.

1.18 WARRANTY

A. The system, including all hardware, software and workmanship, shall be guaranteed for a period of one (1) year from the date of final acceptance. Any manufacturing defects arising during this warranty period shall be corrected at no cost to the FRA. Warranty shall include one complete heating and cooling season.

B. All applicable software, as detailed in this specification, shall be updated by the BMS contractor free of charge during the warranty period to ensure that the system software is the most up-to-date software available, for the system hardware installed, at the end of the warranty.

C. The system shall be free from defects in installation workmanship for a period of one year from acceptance. The BMS Contractor shall, free of charge, correct any defects in workmanship within one week of notification in writing by the FRA.

D. All corrective software modifications made during the warranty service period shall be updated on all user documentation and on user and manufacturer archived software disks.

1.19 TRAINING

A. Provide 10 days of training on site

B. The BMS Contractor shall provide instructors to give full instructions to designated personnel in the adjustment, operation and maintenance of the system installed. Instructors shall be thoroughly familiar with all the aspects of the subject matter they are to teach. All training shall be held during the normal work hours of 8:00am to 4:30pm weekdays.

C. Training shall include but not limited to:

1. Explanation of drawings and operations and maintenance manuals.
2. Walk thru of the job to locate control components.
3. DDC Controller and TEC operation.
4. Explanation of adjustment, calibration and replacement procedures.

D. Training of the FRA's operation and maintenance personnel is required in cooperation with the FRA's Representative. Provide competent, factory, authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the Construction Manager after submission and approval of formal training plans.

1.20 TECHNICAL PROPOSALS

A. Technical proposals shall be prepared in accordance with these specifications. Two (2) copies of the proposal shall be submitted to the consulting engineer at time of bid. Proposals that are unbound, loose, in a file folder, stapled, stapled in a manila file folder, etc., will not be acceptable. The technical proposal shall include the following data/information as a minimum. The order of listing here is not intended to indicate, nor should it be construed to indicate, the relative importance of the data/information:

1. Information on organizational capability to handle this (project management, personnel, manufacturing, single source responsibility, etc.). Including contact references.
2. Information on training program to demonstrate specification compliance.
3. System Configuration as Proposed including technical data to support the information below:

    a. Describe system architecture including a schematic layout with location and type (model number) of all DDC control panels.
    b. Describe system operation, functions and control techniques.
    c. Modularity.
    d. Provisions against obsolescence due to technological advancement.
    e. Provide hardware and software data sheets on system interfaces and integration requirements.

4. Detailed description of all operating, command, application, and energy management control software provided for this project.
5. A written guarantee of how long the system proposed will be a standard product and backed by ongoing parts availability and factory trained field support.
6. A signed certificate stating the Contractor has read the performance and functional requirements, understands them and his technical proposal shall comply (line by line conformance) with all parts of the specification. (Concordance Summary-).
7. Supply with the proposal a recommended spare parts listing, which the FRA should maintain at the site, with the associated costs of each part. Contractor shall provide lists for both warranty period spare parts requirements as well as spare parts needed beyond the warranty period. Spare parts shall be made available for 10 years beyond warranty period.
8. Line by line specification concordance statement.
9. Information on the maintenance during warranty period.
10. Information on service contract.

B. Submit technical proposals with pricing in accordance with the Instructions to Bidders.

PART 2 - PRODUCTS

2.1 ACCEPTABLE BMS MANUFACTURERS

A. Manufacturer: Company shall be one of the following manufacturers:

1. Johnson Controls - Metasys

B. Installers/Integrators: Company specializing in applying the work of this section with minimum 10 years documented experience approved by the manufacturer and determined acceptable following a review of pre bid qualification package.

2.2 ENVIRONMENT

A. All equipment detailed in this specification or other equipment associated with the BMS shall be capable of operation in the following conditions without detriment to the equipment.

1. 0-45°C (32°F – 113°F)
2. 0-95% RH

2.3 NETWORKING COMMUNICATIONS:

A. The design of the BMS shall network the servers, operator workstations, DDC and TEC Controllers all communicating via BACnet. The network architecture shall consist of two levels, a primary high performance Building Level Network (BLN) for all DDC controllers and operator workstations and a secondary, Floor Level Network (FLN) that connects TECs for terminal units.

B. Access to system data shall not be restricted by the hardware configuration of the building management system. The hardware configuration of the BMS network shall be totally transparent to the user when accessing data or developing control programs.

C. Building Level Network

1. The servers, operator workstation and DDC Controllers shall communicate on the BLN such that communications may be executed directly between DDC Controllers, directly between workstations and between DDC Controllers and workstations via a BACnet LAN.
2. All operator devices either network resident or connected via dial-up modems, shall have access to all point status and application report data or execute control functions for any and all other devices via the BLN or FLN. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the network data.
3. BLN shall provide the following minimum performance:

a. Provide high-speed data transfer rates for alarm reporting, report generation and upload/download network devices. System performance shall insure than an alarm occurring at any DDC Controller is displayed at the PC workstation or other DDC controllers or alarm printers within 5 seconds.
b. Support of any combination of DDC Controllers and operator workstations directly connected to the BLN. A minimum of 30 devices shall be supported on a single BLN.
c. Message and alarm buffering to prevent information from being lost.
d. Error detection, correction and re-transmission to guarantee data integrity.
e. Synchronization of real-time clocks between DDC Controllers, including automatic daylight savings time corrections.
f. All network wiring between DDC Controllers and DDC Controllers, servers and operator workstations shall be in conduit (as a minimum).
g. The BLN shall allow the DDC Controllers to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central or intermediate processing device. DDC Controllers shall send alarm reports to multiple operator workstations without dependence upon a control or intermediate processing device. The peer-to-peer network shall also allow any DDC controller to access, edit, modify, add, delete, back up, restore all system point database and all programs.
h. The BLN shall allow the operators to assign password access and control priorities to each point individually. The logon password (at any PC workstation or portable

operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. All other points shall not be displayed at the PC workstation or portable terminal. (e.g. all base building points shall be accessible to any base building operators, but only electrical points shall be accessible to house electricians). Passwords and priorities for every point shall be fully programmable and adjustable.

D. Floor Level Network

1. This level communication shall support a family of Terminal Equipment Controllers and shall communicate be-directionally with the BLN through DDC Controllers for transmission of global data via a BACnet LAN.
2. Terminal Equipment Controllers shall be arranged on the FLN in a functional relationship manner with DDC Controllers.

E. Web Browser Interface

1. The web browser shall provide a comprehensive user interface. Using a collection of web pages, it shall be constructed to “feel” like a single application and provide a complete and intuitive mouse/menu driven operator interface. It shall be possible to navigate through the system using a web browser. The web browser shall provide for Navigation and Action for display of animated colorgraphics, schedules, alarms/events, live graphic program, active graphic setpoint controls, configuration menus for operator access, reports, trends, reporting actions for events.
2. On launching the web browser and selection of appropriate domain name of IP address, the operator shall be presented with a login page that will require a login name and password. Navigation of the system shall dependent on the operator’s security access privileges.
3. Provide remote alarm notification utilizing standard beeper, cell phone, smart-phone or e-mail.

2.4 DDC CONTROLLER

A. Controllers shall be complete with uninterruptible power supplies (1/2 hour rated), a real time clock, input and output modules, memory, processors and all other items necessary for proper and correct interfacing and operation of the control functions described in this Specification.

B. All controllers shall have peer-to-peer communications. All controllers shall have a standalone capability such that a failure of the operator’s station shall still permit the plant and controls associated with the controllers, to continue to operate normally with the controllers continuing to communicate with one another.

C. In the event of transmission failure in the controller network the controllers shall continue to operate with all sequence interlocks and control strategies operating normally except those that require global information. Either user adjustable default values or the last sensed value (user selectable) shall then be assumed for these global parameters.

D. Controllers shall be able to provide the operator’s station with status information concerning their internal operations. This information shall include, but not be limited to:

1. Data transmission and verification.
2. Input/output point status (i.e. sensor fault, point forced, etc).
3. Program status (i.e. program error, program running, etc).
4. Internal battery condition.

E. All necessary interfacing equipment shall be provided so that the controllers are fully compatible with all items of plant and equipment.

F. The controller shall be capable of accepting binary, analog, pulsed inputs and providing binary and analog outputs.

1. Binary input - Shall monitor the change of state of a dry contact.
2. Pulsed input - Pulses (dry contact closures i.e. binary type input) originating typically from flow meters, electrical kWh or kVA meters, etc. and shall be accumulated into registers. A register shall be resettable to zero either by software or operator command. The input must be able to accept pulses up to a frequency of 10Hz with a minimum duration of 50ms. All counts must be stored in a non-volatile register so the count value is not affected by a power failure.
3. Binary output - A dry contact. Should binary outputs be used to drive modulating actuators, other than for terminal unit applications, a potentiometer shall be fitted to the actuator and connected to the BMS to provide actuator position feedback. The controller shall use this feedback to ensure the accuracy of positioning of the actuator.
4. Analog inputs - Analog to digital conversion (ADC) with a minimum resolution of 1024 counts (10 Bit) over the input range (i.e. 0-10V, 2-10V, 0-20mA, 4-20mA etc.) of the sensor. The sensor range shall match the process control range. Any equipment necessary for the conversion of an input signal to the required input level shall be provided.
5. Analog outputs - Digital to analog conversion (DAC) shall be performed by the controllers with a minimum resolution of 256 counts (8 Bit) over the output range which shall also match the control range of the device and/or system being controlled. Any equipment necessary for the conversion of the output signal to the required process level (i.e. 0-10V, 2-10V, 0-20mA, 4-20mA etc.) shall be provided.
6. Where analog outputs are specified driving damper and valve actuators, they shall not be used to drive raise/lower actuators through interface devices.
7. Universal inputs-Shall be configurable to either binary or analogue input and shall have the features defined above.

G. Hardware Override Switches: The operator shall have the ability to manually override automatic or centrally executed commands at the DDC panel via local, point discrete, on board hand/off/auto switches for binary control points and gradual switches for analog control type points. These override switches shall be operable whether the panel is powered or not. In lieu of onboard switches, switches may be flush mounted on a panel adjacent to the DDC panel.

H. Each controller or controller location shall be provided with spare hardware capacity for future additions of at least 15 percent of each type of point. Universal inputs may be counted as either a spare digital or analog point, but not both. Note that this spare capacity may be accomplished by the addition of input/output modules. Memory shall also be sufficient to allow all programs associated with these points to be run in the controller. The Contractor shall state in his offer how many spare points are actually available on each controller or at each controller location and the expansion capability.

I. The controllers shall be provided with their own internal battery backup power supply, capable of maintaining all memory including the real time clock for not less than 72 hours. The battery shall be easily replaceable i.e. not soldered to the PCB.

J. Each analog input shall be calibrated (to compensate for non-linear characteristics of input devices, line resistance and similar items) to achieve an accuracy, of the displayed value on the operator's station, as detailed in this specification for each sensing device. Calibration and scaling data shall be retained in the controller memory. Open or closed circuits on sensor inputs shall be recognized by the controller and annunciated as alarms on the system operator's station(s).

K. It shall be possible to characteristics each analog output to an actuator in order to obtain a near-linear response from the device the actuator is controlling. This may take the form of a look up table with a minimum of 6 coordinates, such that the linear output from a control loop is converted into a non-linear control signal to the actuator.

L. The controllers shall be mounted in control panels, which shall meet the following environmental requirements:

1. Control panels located in heated areas shall be NEMA Type 1.
2. Control panels located in unheated areas or in areas subject to dust or oil shall be NEMA Type 12.
3. Control panels located in exterior areas or in areas subject to rain, dripping liquid, or hosing, including kitchen areas shall be NEMA Type 4X, stainless steel.

M. The controllers shall be constructed so that the control panels and internal terminal strips can be mounted, and electrical terminations made, with all electronics being added at a later date during the testing and commissioning.

N. DDC controllers shall be used for main HVAC equipment controls.

O. Power fail restart: In the event of a loss of normal power there shall be an orderly shutdown of all standalone DDC panels to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for critical control configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours. Upon restoration of normal power, the DDC panel shall automatically resume full operation without manual operation. Should DDC panel memory be lost for any reason, the panel will automatically receive a download via the BMS network. In addition, the user shall have the capability of reloading the DDC panel via portable operator terminal or lap-top computer.

2.5 DDC CONTROLLER RESIDENT SOFTWARE FEATURES

A. All software relating to plant control and monitoring detailed in this Specification shall reside at controller or unitary controller level. Only management software shall reside at the operator station.

B. All programs shall be scanned every two seconds as a minimum.

C. Software shall include diagnostic routines that check hardware for correct operation. All hardware faults shall be annunciated on the operator's station(s).

D. For further details see Device Schedule in this Specification.

2.6 TERMINAL EQUIPMENT CONTROLLERS (TEC)

A. Where a controller is used to monitor and control exhaust fans, FCUs, etc, they shall be classed as terminal equipment controllers (TECs).

B. TECs shall be either small freely programmable controllers or firmware application specific controllers, which shall be selected to meet the performance requirements of the Specification.

C. Each TEC shall meet the specified requirements of a controller except where specified to the contrary.

D. Each TEC shall have its application program, setpoints, limits and schedules etc., battery backed for a minimum of 2 years.

E. Real time clock functions are not essential where these commands are generated by other controllers, which shall also control the transfer of information to, from and between TECs on the same communications network.

F. Each TEC shall be interrogated and adjusted by an operator's station or portable terminal that may plug into the network at any point.

G. Only input and output points necessary to meet the functional requirements of this specification are required to be supplied. The spare capacity requirement, as detailed in the section covering DDC Controllers, is not required.

H. BMS Contractor shall utilize DDC control panels for area terminal reheat and humidifier applications. TEC controllers for this application are not acceptable.

2.7 PORTABLE OPERATOR'S TERMINAL (POT)

A. Provide a laptop computer and a full featured keyboard.

B. The portable operator's terminal shall plug directly into individual DDC panels. Provide a user-friendly English language-prompted interface for quick access to system information.

1. The Contractor shall supply the Notebook type PC computers, indicated on the Contract Drawings and as specified herein, that shall be capable of accessing all system data.
2. Each notebook computer shall be Dell Precision M6800 or approved equal, with the following minimum requirements:

    a. IBM compatible, 64-bit Intel Core i7-620 Dual Core processor, 2.66GHz, 4MB L2 cache, 8GB DDR3-1066MHz SDRAM, 500GB (7200rpm) SATA hard drive.
    b. External optical mouse, 2GB graphics card, V.92/56k modem, wireless network card, 2 deep-socketed PCMCIA type-II slots, sound card and speakers.
    c. 17in FHD display, 1920x1080 resolution.
    d. Each notebook computer shall be supplied with a padded carrying case.

3. Each notebook computer shall be equipped with the most recent issue of the following software:

    a. Microsoft Windows operating system, latest version with latest service pack version.
    b. Microsoft Office, latest version.
    c. McAfee Antivirus, latest version
    d. DVD+RW and CD-RW "Roxio" editing software, latest version, and 10 blank DVD+RW DVDs.
    e. All software necessary for viewing CD-ROM O&M Manual.
    f. All utilities necessary for management of the network of controllers and devices.
    g. All BMS software and licenses necessary to perform all the all the monitoring, command and diagnostic functions required by a system operator or a service technician. Usage shall be controlled by License Keys installed on the notebook computer.

2.8 BUILDING MANAGEMENT SYSTEM SERVER - RACK MOUNTED:

A. BMS server shall be provided for information management, network alarm management and database management functions. All real time control functions shall be resident in the DDC Controllers to facilitate greater fault tolerance and reliability.

B. Contractor shall make all necessary mounting and installation within wall mounted enclosure provided by IT Contractor within the CDR according server manufacturer's recommendations. Contractor shall connect BMS Server to network switch provided by SDSTA. Contractor to provide all necessary hardware for connections, including Cat6/6A U/UTP RJ45 patch cable to the Ethernet switch. Contractor shall coordinate with networking contractor and provide all hardware and software to connect to networking equipment provided by others.

C. The Contractor shall supply the Server indicated on the Contract Drawings or specified herein. The Server shall be an IBM compatible, blade type computer no larger than 2U.

D. Each Server shall have Server a hard drive capacity sufficient to store all data collected by the system for one calendar year, and device for transferring data and programs onto an external hard drive or USB memory key.

E. Each Server shall be purchased within 6 months of substantial completion of the Contract. Each Server shall be Dell Precision Rack 7910 Workstation Series or approved equal, with the following minimum requirements (hardware shall be the latest version available at time of purchase):

1. Processor - Intel Xeon Processor E5-2600 v4 or later
2. Operating System-Windows 7 Professional, 64Bit, English
3. Memory 8GB Dual Channel DDR3 SDRAM at 1600MHz
4. Hard Drive 1TB 7200 RPM SATA Hard Drive 6.0 Gb/s
5. NVIDIA Tesla K20C Computing Processors (GPGPU)
6. Dell Wireless 1703 802.11b/g/n, Bluetooth v4.0+LE
7. Integrated 10/100/1000 Ethernet
8. All necessary serial, parallel, and network communication ports and all cables for proper system operation.
9. Contractor shall supply two (2) 64 GB (minimum) USB 2.0 Flash Drives.

F. Each Server is to be used for System Monitoring and System Maintenance shall be equipped with the latest version of the following software:

1. All BMS software necessary to perform all the monitoring functions specified herein.
2. All BMS software necessary to perform all the monitoring, command and data management functions required by the Server.
3. All utilities necessary for management of the network of controllers and devices.

2.9 BUILDING MANAGEMENT SYSTEM OPERATOR WORKSTATION HARDWARE (OWS) – DESKTOP TYPE

A. The Contractor shall supply the Operator Workstations (OWS) indicated on the Contract Drawings or specified herein, as a minimum one located underground within Control Room and a second topside, location to be determined.

B. Contractor shall connect BMS Topside workstation to network switch provided by SDSTA. Contractor to provide all necessary hardware for connections, including Cat6/6A U/UTP RJ45

patch cable to the Ethernet switch. Contractor shall coordinate with networking contractor and provide all hardware and software to connect to networking equipment provided by others.

C. Each OWS shall be an IBM compatible, desktop type personal computer in a vertical case. Each OWS shall have its own graphic display system (monitor) and printer, a hard drive capacity sufficient to store all data collected by the system for one calendar year, and device for transferring data and programs onto a portable electronic media such as a DVD, external hard drive or USB memory key.

D. Each OWS shall be purchased within 6 months of substantial completion of the Contract. Each OWS shall be Dell Precision Series or approved equal, with the following minimum requirements (hardware shall be the latest version available at time of purchase):

1. Processor -3rd Generation Intel Core i7-3770 processor (up to 3.90 GHz)
2. Operating System-Windows 7 Professional, 64Bit, English
3. Memory 8GB Dual Channel DDR3 SDRAM at 1600MHz
4. Hard Drive 1TB 7200 RPM SATA Hard Drive 6.0 Gb/s
5. Video Card AMD Radeon™ HD 7570 1GB GDDR5IBM compatible, Intel Dual Core, 3.2 GHz processor, 2 MB L2 Cache, 2 GB dual channel SDRAM, a 250GB SATA (10K RPM) hard drive.
6. Media Card Reader
7. Dell KB213 Wired Multimedia Keyboard, US-English
8. Dell Laser Mouse
9. 16X CD/DVD burner (DVD+/-RW), write to CD/DVD
10. Dell Wireless 1703 802.11b/g/n, Bluetooth v4.0+LE
11. Integrated 7.1 with WAVE MAXXAudio 4
12. Integrated 10/100/1000 Ethernet
13. US Power Cord
14. Dell Professional P2212H, Widescreen, 21.5" VIS, HAS, VGA,DVI with speakers and subwoofer.
15. All necessary serial, parallel, and network communication ports and all cables for proper system operation.
16. Contractor shall supply two (2) 64 GB (minimum) USB 2.0 Flash Drives.

E. Each OWS shall be equipped with the latest version of the following software:

1. Microsoft Windows operating system, latest version with latest service pack version.
2. Microsoft Office Software, latest version.
3. Microsoft Express or Outlook, latest version.
4. McAfee Antivirus, latest version.
5. DVD+RW and CD-RW "Roxio" editing software, latest version, and 10 blank DVD+RW DVDs.
6. All software necessary for viewing CD-ROM O&M Manual.

F. Each OWS is to be used for System Monitoring and System Maintenance shall be equipped with the latest version of the following software:

1. All BMS software necessary to perform all the monitoring functions specified herein.
2. All BMS software necessary to perform all the monitoring, command and data management functions required by the OWS.
3. All utilities necessary for management of the network of controllers and devices.

G. One laser type printer shall be provided for each OWS, capable of printing 30 pages per minute with a resolution of 1200 X 1200 D.P.I., and 64MB of memory. Printer shall be a Dell, Model 3300DN or approved equal, supplied with a 90 day supply of paper.

2.10 UNINTERRUPTABLE POWER SUPPLY

A. The following equipment shall be provided with uninterruptible power supplies:

1. BMS Workstation.
2. DDC Control Panels
3. Servers
4. Gateways/network equipment

B. Provide a UPS rated for ½ hour operation (minimum 1.5 KVA) of all loads normally fed from panel or workstation.

C. All equipment shall be provided with uninterruptible power supplies capable of running all hardware for a period of 1/2 hour, this shall include all controllers, servers, switches, monitors and printers.

D. UPS shall be provided with a dry contact for monitoring of general alarm including battery failure.

E. UPS for Server shall be rack mounted adjacent to server and shall be no larger than 2U, final coordination is required with ITC contractor and approved rack submittals.

F. Manufacturer/Model

1. American Power Conversion Back-Ups ES or equal.

2.11 WORKSTATION OPERATOR INTERFACE

A. Basic Interface Description

1. Provide scaled floor plans (Auto Cad or approved equivalent) indicating equipment location, service, and system data as required by the FRA. Graphics to incorporate integrated points communicated via BMS. Origin of information shall be transparent to the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BMS.
2. All graphics to include dynamic screen link points for the following as a minimum;

a. Manufacturer cut sheets files, either in PDF or other file format for instrumentation and control device represented. All cut sheets to be provided with selection of model provided clearly identified by markings.
b. Sequence of operations text file for the systems and devices represented.
c. Control system As-Builts

3. Operator workstation interface software shall minimize operator training through the use of English language prompting, 30 character English language point identification, on line help and industry standard PC application software. The software shall provide, as a minimum, graphical viewing and control of environment, scheduling and override of building operations, collection and analysis of historical data, definition and construction of dynamic color graphic displays, editing, programming, storage and downloading of controller databases, and the ability to export data with Microsoft Word for Windows and Excel for Windows.
4. Provide a graphical user interface which shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change

set points from graphical displays through the use of a mouse or similar pointing device. Provide functionality such that all operations can also be performed using the keyboard as a backup interface device. Provide additional capability that allows at least 10 special function keys to perform often-used operations

5. The software shall provide a multi-tasking Microsoft Windows environment that allows the user to run several applications simultaneously. Other Windows applications shall run simultaneously with the BMS software including Word, Excel, Access, etc. Provide functionality such that any of the following may be performed simultaneously, and in any combination, via user-sized windows. The operator shall be able to drag and drop information between applications (e.g. click on any point in the alarm screen and drag it into the dynamic trend graph screen to initiate a dynamic trend).

    a. Dynamic color graphics and graphic control
    b. Alarm management coordinated with other specification sections
    c. Week or Month at a Glance with 365 day time-of-day scheduling
    d. Trend data definition and presentation
    e. Graphic definition
    f. Graphic construction

6. Operator specific password access protection shall allow the user to limit workstation control, display and data base manipulation capabilities for each object in the system. An object shall be defined as any input or output point, set point, system program, etc. The operator privileges shall "follow" the operator to the portable operator terminal or DDC controller that the operator logs on to. Provide a minimum of 200 passwords.
7. Operators will be able to perform only those commands on the objects available based on their respective passwords. Menu selections displayed shall be limited to only those items defined for the access level of the password used to log-on.
8. An audit trail report to track system object changes, accounting for operator initiated actions, change made by a particular person or changes made to a specific piece of equipment, designated time frame shall be printed out on command or automatically and archived for future reference. The operator activity tracking data shall be stored in a tamper proof buffer.
9. Software shall allow the operator to perform commands including, but not limited to start up or shutdown of equipment, adjust set points (including multiple TEC subpoints to new settings with one command), add/modify/delete time programming, enable/disable process execution, lock/unlock alarm reporting, enable/disable totalization, enable/disable trending, override PID loop set points, enter temporary override schedules, define holiday schedules, change time/date, automatic daylight savings time adjustments, enter/modify analog warning and alarm limits, View limits, Enable/disable demand limiting for each meter, Enable/disable duty cycle for each load. All values (including setpoints) indicated within specification sequences, including those labelled as adjustable (adj.), shall be modifiable, with the proper password level, from the operator interface or via a function block menu. For these points, it is unacceptable to have to modify programming statements to change the setpoint.
10. Reports shall be generated and directed to either display or disk. As a minimum, the system shall allow the user to easily obtain the following types of reports:

    a. A general listing of all points in the network
    b. List of all points currently in alarm.
    c. List of all points currently in override status.
    d. List of all disabled points.
    e. List of all points currently locked out.
    f. DDC Controller trend overflow warning.
    g. List all weekly schedules.
    h. A DDC controller point module status report.
    i. A change of value cross reference report indicating user defined limit changes.

j. Summaries shall be provided for specific points, for a logical point group, for a user-selected group or groups or for the entire facility without restriction due to the hardware configuration of the building management system. Under no conditions shall the operator need to specify the address of the hardware controller to obtain system information.

k. Provide a custom reporting package that allows the operator to select, modify, or create custom reports. Each report shall be definable as to data content, format, interval and date. Report data shall be capable of being archived on hard disk for historical reporting. Each physical point or pseudo point shall be assigned an English descriptor for use in reports. The integrated Custom Report Writer capability shall allow the user to format reports of any mix of text, points with status, value and descriptors, and perform calculations, or add graphs. The user shall have the capability to modify the defined reports or design unique reports that collect and disperse different combinations of data from the system and to modify or add to the BMS Custom Report Writer macros which control the data collection process. A custom report drop down item under the report bar item displays a report dialog box that allows you to schedule, run and view these reports. Spreadsheet packages which require off-line execution or manual translation of date files from one program format to another are not acceptable.

11. User-definable, automatic log-off timers of from 5 to 60 minutes shall be provided to prevent operators from inadvertently leaving devices on-line.

B. Scheduling

1. Provide a graphical spreadsheet-type format for simplification of time-of-day scheduling and overrides of building operations. Provide the following spreadsheet types: weekly, monthly and yearly schedules for a minimum of 365 days in advance.
2. Weekly schedules shall be provided for each building zone or piece of equipment with a specific occupancy schedule. Each schedule shall include columns for each day of the week as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting occupancy and vacancy times into appropriate information blocks on the graphic. In addition, temporary overrides and associated times may be inserted into blocks for modified operating schedules. After overrides have been executed, the original schedule will automatically be restored.
3. Zone schedules shall be provided for each building zone as previously described. Each schedule shall include all controllable points residing within the zone. Each point may have a unique schedule of operation relative to the zone's occupancy schedule, allowing for sequential starting and control of equipment within the zone. Scheduling and rescheduling of points may be accomplished easily via the zone schedule graphic.
4. Monthly calendars for a 24-month period shall be provided which allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

C. Collection and Analysis of Historical Data

1. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals or changes of value, both of which shall be user-definable. Trend data may be stored on hard disk for future diagnostics and reporting.
2. Trend data report graphics shall be provided to allow the user to view all trended point data. Reports may be customized to include individual points or pre-defined groups of at least 10 points. Provide additional functionality to allow any trended data to be

transferred easily to an off-the-shelf spreadsheet package such as Microsoft Excel. This shall allow the user to perform custom calculations such as energy usage, equipment efficiency and energy costs and shall allow for generation of these reports on high-quality plots, graphs and charts.

3. Provide additional functionality that allows the user to view trended data on trend graph displays. Displays shall be actual plots of both static and/or real-time dynamic point data. A minimum of 6 points may be viewed simultaneously on a single graph, with color selection and line type for each point being user-definable. Displays shall include an 'X' axis indicating elapsed time and a 'Y' axis indicating a range scale in engineering units for each point. The 'Y' axis shall be manually or automatically scalable at the user's option. Different ranges for each point may be used with minimum and maximum values listed at the bottom and top of the 'Y' axis. All 'Y' axis data shall be color-coded to match the line color for the corresponding point.

    a. Static graphs shall represent actual point data that has been trended and stored on disk. Exact point values may be viewed on a data window by pointing or scrolling to the place of interest along the graph. Provide capability to print any graph on the system printer for use as a building management and diagnostics tool.
    b. Dynamic graphs shall represent real-time point data. Any point or group of points may be graphed, regardless of whether they have been predefined for trending. The graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of screens to be stored on the workstation disk for future recall and analysis. As with static graphs, exact point values may be viewed and the graphs may be printed.

D. Dynamic Color Graphic Displays:

1. Provide graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, supply and exhaust fans and condensate systems to optimize system performance analysis and speed alarm recognition.
2. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection or text-based commands.
3. Dynamic point values (e.g. temperature values, humidity values, flow values and status indication) shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.
4. The windowing environment of the PC operator workstation shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
5. Graphic generation software shall be provided to allow the user to add, modify or delete system graphic displays via an off the shelf graphics package.

    a. The BMS Contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems and electrical symbols.
    b. Graphical displays can be created to represent any logical grouping of system points or calculated data based upon building function, mechanical system, building layout or any other logical grouping of points which aids the operator in the analysis of the facility.
    c. To accomplish this, the user shall be able to build graphic displays that include point data from multiple DDC Controllers including Terminal Equipment Controllers or terminal units.

6. Provide an automatically updated, dynamic display of the site specific BMS architecture indicating the status of all controllers, PC workstations and networks.

7. The graphic development package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following:

   a. Define symbols.
   b. Position and size symbols.
   c. Define background screens.
   d. Define connecting lines and curves.
   e. Locate, orient and size descriptive text.
   f. Define and display colors for all elements.
   g. Establish correlation between symbols or text and associated system points or other displays.

8. For each air handling unit provide a tabular graphic summary of that unit and its associated air distribution system. Graphics shall contain, at a minimum, the following information:

   a. Supply fan's current operating speed and setpoint.
   b. Manual adjustment of supply fan speed.
   c. Supply air static pressure and temperature.
   d. Current damper position or command.
   e. Current associated space temperature.
   f. Current preheat, reheat, and cooling valve positions or commands.
   g. A commandable override point to place all associated terminal units at maximum airflow.
   h. A commandable override point to place all associated terminal units at minimum airflow.

E. System Configuration and Definition

1. All temperature and equipment control strategies and energy management routines shall be definable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.
2. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently add, delete or modify any system object including DDC controllers, operator workstations, equipment controllers, reporting definitions, control loops, energy management applications, time and calendar-based programming, totalization, historical data trending, custom control processes, graphic displays, operator passwords, alarm messages, dial up telecommunications definitions, points of any type, etc.
3. Definition of operator device characteristics for individual points, applications and control sequences shall be performed using instructive prompting software.

   a. Libraries of standard application modules such as temperature, humidity and static pressure control may be used as "building blocks" in defining or creating new control sequences. In addition, the user shall have the capability to easily create and archive new modules and control sequences as desired via a word processing type format. Provide a library of standard forms to facilitate definition of point characteristics. Forms shall be self-prompting and incorporate a fill-in-the-blank approach for definition of all parameters. The system shall immediately detect an improper entry and automatically display an error message explaining the nature of the mistake.
   b. Programming shall be performed with the BMS system online, and not interfere with BMS system operation.
   c. Inputs and outputs for any process shall not be restricted to a single DDC Controller, but shall be able to include data from any and all other network panels to allow the development of network-wide control strategies. Processes shall also

allow the operator to use the results of one process as the input to any number of other processes (cascading).

d. Provide the capability to backup and store all system databases on the server or workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate DDC Controller. Similarly, changes made at the DDC Controllers shall be automatically uploaded to the workstation, ensuring system continuity. The user shall also have the option to selectively download changes as desired.

e. Provide a program testing utility which allows visual dynamic simulation capability of the symbolically displayed control programs provided. User shall be able to select any portions of inputs, outputs and intermediate program points for visual dynamic display of intermediate values and or results. Provide ports for symbolic engineering tool at each DDC Controller, and (for TECs) at space temperature sensors noted on the plans or as described herein. The symbolic engineering utility shall be self-documenting and shall generate a complete controller program including I/O definition and engineering unit processing requirements, alarm limits, DDC operational program, and English text for all data points. Engineering program documentation shall include computer-driven output of all program data.

f. Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed.

2.12 ALARM PROCESSING

A. Alarms shall be classified by their alarm type. The means shall be provided for enabling and disabling each individual alarm on the system. The contractor is responsible for enabling and setting all alarms within the BMS.

B. Once generated, the alarm shall be processed by its associated alarm type as defined in the I/O Point Schedules. The alarm types shall be as follows:

1. General Mismatch - Mismatch: The alarm is associated with an output command point and an input giving status feedback of the output command. The alarm is generated when the status feedback does not correspond with the output command status for longer than a defined time delay period.
2. Critical Mismatch – See above.
3. General Binary - The alarm is associated directly with an external volt free contact (i.e. a digital input). The alarm may be generated by transitions from either open to closed status, closed to open status, or any change of state. A time delay shall be associated with the alarm such that the alarm does not occur until the required alarm state has existed for longer than the delay period.
4. Critical Binary – See above.
5. General Analog - The alarm is associated directly with an analog input. The alarm is generated by the BMS due to a measured variable exceeding specified limits. It shall be possible to define the limits in two ways:

   a. Fixed limits. The point has fixed upper and lower alarm limits. If the measured variable rises above the upper limit, or falls below the lower limit, then an alarm is generated. e.g. high alarm limit = 80°F, low alarm limit = 45°F.

   b. Floating limits. The point has an associated setpoint, and an alarm is generated when the measured variable deviates either above or below the setpoint by more than a given alarm limit value. If the setpoint is changed, the alarm limits are automatically moved to suit, e.g. setpoint = 66°F, alarm limits = Setpoint ± 2°F.

6. Critical Analog – See above.
7. Hand/Off/Auto (HOA) - The alarm is associated with the placement of the HOA switches in the Hand or Off position. HOA switches include but are not limited to controllers and variable frequency drives.

C. The above alarm limits shall have associated hysteresis bands to avoid nuisance alarming. A time delay shall be associated with the alarm such that the alarm does not occur until the required alarm state has existed for longer than the delay period.

D. The operator's station display shall have a dedicated area at the top or bottom of the screen for use as an alarm banner. The alarm banner shall display, as a minimum, the two latest unacknowledged alarms at the top of the current alarm list. Alarms shall be entered into the list according to their type and event order, with the most recent alarm being at the top of the list. As new alarm events occur, the list shall be sorted to keep the list in the desired order.

E. On occurrence, all alarms shall be put in the alarm list. In addition, the following actions shall be taken dependent upon the alarm type.

F. Critical Alarms

1. The alarm printout shall be in bold text to clearly differentiate it from general or maintenance alarms.
2. The banner alarm message display shall be differentiated by means of text size or color from general alarms.
3. Shall generate an audible alarm at the operator's station.
4. Shall have the ability to bring up an associated alarm graphic or text screen at the operator's station.

G. General Alarms

1. Shall generate a banner alarm message.
2. Shall generate an audible alarm at the operator's station.
3. Shall have the ability to bring up an associated alarm graphic or text screen at the operator's station.

H. It shall be possible, at the highest operator password level, to enable and disable the audible alarm feature of the operator's station. In addition the keyboard facility to mute the audible alarm shall be provided. Alarms that have been muted shall be re-annunciated if not acknowledged within a user specified time.

I. Alarms shall remain active until acknowledged by an operator logged on with the appropriate password level, even if the alarm has physically cleared. Upon acknowledgement, the alarm shall be moved to the appropriate place in the alarm list, the alarm banner shall be updated as necessary. When an alarm is acknowledged, the audible alarm, if enabled, shall be muted unless another unacknowledged critical or general alarm exists on the system.

J. The system shall be capable of alarm notification escalation during periods in which alarms go unacknowledged for a period of time. The escalation shall provide means to notify assigned individuals and/or groups via all means addressed within this specification. The escalation shall be tiered in a manner so that multiple stages of escalation are programmable.

K. It shall be possible to acknowledge alarms on both an individual and group basis.

L. Upon clearance of an alarm, it shall be removed from the alarm list.

M. All alarm events shall be included in the historical data program.

N. It shall be possible to view or print the contents of the alarm list in historical order, using the following selection criteria:

1. All alarms in the alarm list.
2. Critical alarms only.
3. General alarms only.
4. Hand/Off/Auto alarms only.
5. Acknowledged alarms only.
6. Selection of alarms associated with an individual drive or plant equipment only.

2.13 CONFIGURATION

A. Configuration data shall be stored in the DDC Controllers or the Terminal Equipment Controllers. Configuration data shall include but not be limited to the following:

1. The point identifier (minimum of 12 characters).
2. The point descriptor (minimum of 32 characters).
3. The engineering unit applicable (°F, psi, gpm etc).
4. The point alarm message if applicable (minimum of 80 characters).
5. Other miscellaneous information necessary for the correct operation of the entire BMS (e.g. trending run hours, accumulation, access levels etc).

2.1 BMS INTEGRATION WITH OTHER SYSTEMS AND DEVICES

A. VFD(s)

1. The BMS shall be able to start and stop and control the VFD speed via a hardwired point based on the sequence of operations program.
2. The communication interface shall allow the BMS read capabilities.
3. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the VFD manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.
4. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Start / Stop	DO	No	Yes	Yes	Yes
Speed Modulation	AO	No	Yes	Yes	Yes
Status (Current Sensor)	AI	Yes	Yes	Yes	Yes
VFD Fault	DI	Yes	Yes	Yes	Yes
HOA Not in Auto	DI	Yes	Yes	Yes	Yes
VFD in Bypass	DI	Yes	Yes	Yes	Yes
Forward / Reverse Status	SW	No	No	No	Yes
Drive Ready Status	SW	No	No	No	Yes
At Setpoint Status	SW	No	No	No	Yes
Resets Faults	SW	No	No	No	Yes
Output Speed min-1	SW	No	No	No	Yes
Output Frequency Hz	SW	No	No	No	Yes
DC Bus Voltage V	SW	No	No	No	Yes
Motor Voltage V	SW	No	No	No	Yes
Motor Current A	SW	No	No	No	Yes

Motor Torque %	SW	No	No	No	Yes
Motor Power %	SW	No	No	No	Yes
Drive Thermal State %	SW	No	No	No	Yes
Energy Counter kWh	SW	No	No	No	Yes
Run Time	SW	No	Yes	Yes	Yes
Last Error Code	SW	No	No	No	Yes

~~B. Split Air Conditioning Units~~

~~1. The communication interface shall allow the BMS read capabilities.~~
~~2. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the Split Air Conditioning Units manufacturer for this integration. This integration shall be done via BACnet IP or BACnet MSTP.~~
~~3. Typical Software Points shall be as follows:~~

~~Point~~	~~Type~~	~~Alarm~~	~~Short Term Trend~~	~~Long Term Trend~~	~~On BMS Graphic~~
~~Space Temperature~~	~~SW~~	~~Yes~~	~~Yes~~	~~Yes~~	~~Yes~~
~~Space Humidity~~	~~SW~~	~~Yes~~	~~Yes~~	~~Yes~~	~~Yes~~
~~Unit Status~~	~~SW~~	~~No~~	~~Yes~~	~~Yes~~	~~Yes~~
~~Unit Runtime~~	~~SW~~	~~No~~	~~Yes~~	~~Yes~~	~~Yes~~
~~General Alarm~~	~~SW~~	~~Yes~~	~~Yes~~	~~Yes~~	~~Yes~~

~~C.~~**B.** BTU Meters

1. The communication interface shall allow the BMS read capabilities.
2. It shall be the responsibility of the BMS contractor to review requirements and coordinate with the equipment manufacturer for this integration. This integration shall be done via BACnet MSTP.
3. Typical Software Points shall be as follows:

Point	Type	Alarm	Short Term Trend	Long Term Trend	On BMS Graphic
Water BTU	SW	Yes	Yes	Yes	Yes
Water Flow	SW	Yes	Yes	Yes	Yes
Water Temperature	SW	Yes	Yes	Yes	Yes

2.2 INFORMATION REDIRECTION

A. It shall be possible for the system to redirect information to other locations and/or printers on a time schedule basis (including holiday programming) or manual command basis.

2.3 RESPONSE TIMES

A. The response times detailed below are the maximum acceptable response times.

B. Alarms: The time from activation of an alarm (at the source) to annunciation on an operator's station, printer or to another DDC controller shall not exceed 10 seconds.

C. Graphic Displays: A graphic display shall be displayed complete with updated information from the field for all points, within 15 seconds of the operator request.

D. Once displayed all point information will be updated from the field and displayed at intervals not exceeding 30 seconds.

E. Logical Groups: A logical group shall be displayed complete with updated information from the field for all points within 15 seconds of the operator's request. Once displayed the value shall be refreshed every 10 seconds.

F. Selected Points: The field value of a single input, output or virtual point shall be displayed on the operator's station screen within 5 seconds of a request.

G. Global Program: the time from occurrence of an event tom one controller or unitary controller to the activation of the output of another controller or unitary controller shall not exceed 10 seconds.

2.4 TRANSIENT/SPIKE PROTECTION

A. Suppressors shall be fitted to all controller input points for protection against voltage transients, spikes etc.

B. The communication network(s), the BLN and the FLN, shall be isolated against transient disturbances via optical couplers or other approved means. Where running between buildings, lightning protection devices shall be installed on the communications network at the point of entry to each building.

2.5 ELECTROMAGNETIC PROTECTION

A. All components of BMS and the entire BMS system shall comply with the requirements of the relevant Emission and Immunity Standards.

B. In order to avoid corruption of the BMS equipment operation by electrical interference, all wiring shall be installed to minimize coupling of electromagnetic and electrostatic interference on low voltage signals and data wiring. Where mixed wiring is unavoidable braided screen mains cable, dressed close to metalwork, is preferred, but the Tendered shall clearly specify the methods by which he intends to eliminate any such interference with his signal and data transmission.

C. The BMS shall be protected from interference by the operation of hand held radio transmitters, radio pagers, etc. within 1 meter of the equipment.

2.6 BMS STANDARD PROGRAMS

A. The device schedules included in this Specification provide details of inputs monitored and outputs controlled by the BMS. All point types are described in the section covering DDC Controllers in this Specification. The BMS system shall allow for the following point functionality and standard programs to be available:

1. Point Override
2. Manual Start/Stop
3. Fixed Time Program
4. Optimum Start/Stop – program shall calculate the optimum start time for plant systems, e.g. the AHU, based on occupancy time and on internal space and outside conditions.
5. Control Loops

6. Rotational Point
7. Run Time Totalization
8. Anti-short Cycling
9. Staggered Start
10. User Definable Software
11. General Control Requirements

2.7 TEMPORARY ETHERNET SWITCHES

A. Controls contractor to provide temporary Ethernet switches to complete and or commission the system if the IT infrastructure is not ready. Final commissioning by contractor to be completed with the permanent IT infrastructure.

2.8 FIELD DEVICES

A. General
1. All control signals shall be via 4-20 mA or 0-10 VDC loops.
2. It is the contractor's responsibility to properly select all instruments for process and application suitability, inclusive of materials and operating ranges.
3. Input/Output sensors and devices shall be closely matched to the requirements of the BMS for accurate, responsive, noise-free signal input/output. Control input response shall be highly sensitivity and matched to the loop gain requirements for precise and responsive control. Provide the following instrumentation as required by the monitoring, control and optimization functions.

B. Temperature Sensors/Transmitters/Thermowells
1. Thermistors based temperature sensors shall be paired with a 4 wire 4-20 mA output transmitter. Transmitter shall have built-in circuit protection against reverse polarity and supply voltage transients.
2. RTD based temperature sensors shall use platinum elements only, nickel or silicon RTDs are not acceptable.
3. Air stream averaging type
   a. The assembly shall consist of a capillary type element, housed in a flexible sheath contained in housing suitable for duct mounting.
   b. Probe length: 1 ft./4 square ft. of duct area
   c. All duct cross sections greater than 10 square feet to have serpentine-averaging element to adequately average stratified air temperature.
   d. Temperature Monitoring Range: +20 to +120°F
   e. Factory calibration point: 70°F.
   f. Accuracy: ± 0.5 °F.
4. Air stream insertion / non-averaging type.
   a. The assembly shall consist of an insertion type element contained in a housing suitable for duct mounting and mounted on probe whose maximum length shall be 12 inches or ½ duct diameter, whichever is smaller.
   b. Temperature Monitoring Range: +20 to +120°F
   c. Factory calibration point: 70°F.
   d. Accuracy: ± 0.5 °F.
   e. For outside air applications, mount with weather protection and sun shield.
5. Space monitoring type - Traditional
   a. The assembly shall consist of an element contained in a ventilated enclosure.
   b. Temperature Monitoring Range: +20 to +120°F
   c. Factory calibration point: 70°F.
   d. Accuracy: ± 0.5 °F.
   e. Provide low profile combination temperature and humidity sensors for Gallery/Exhibit Areas as applicable

f. Coordinate Temperature Sensor faceplate requirements with FRA Construction Coordinator/ FRA and engineer. Faceplates options shall include color, blank faceplate option, display faceplate option, setpoint adjustment option and occupied/unoccupied override option) Submit for approval.

6. Space monitoring type – Electric /Line Voltage Thermostats
   a. Furnish and install all line voltage thermostats for unit heaters.
   b. Thermostats contacts shall be rated for maximum heater amperage and shall be snap acting, SPDT.
   c. Thermostat cover shall provide exposed set point and key adjust.
   d. When used for unit heaters - Furnish and install strap on aquastats to prevent unit heaters from operating without hot water or steam
7. Liquid insertion type
   a. The assembly shall be provided with a housing suitable for pipe mounting.
   b. The transmitter shall be compatible with the temperature element and the DDCP.
   c. Transmitter shall have built-in circuit protection against reverse polarity and supply voltage transients.
   d. Include a stainless steel thermowell, maximum length shall be 6 inches or 3/4 of pipe diameter, whichever is smaller.
   e. Temperature Monitoring Range: The sensor range shall be suitable to the process being monitored.
   f. Factory calibration point: Middle of process range.
   g. Accuracy: ± 0.5 °F.
8. Freezestats
   a. Furnish and install for each air handling unit with outdoor air connections, a low temperature safety thermostat (freezestat) with 20 ft sensing element installed in a serpentine fashion across the inlet of the cooling coil (one freezestat per coil section) in the air stream arranged to stop the unit supply fan and its associated return air fan should the temperature at any point along the sensing element fall below 39°F (adjustable) for an adjustable time period.
   b. Low temperature detector shall be automatic reset, DPDT type.
   c. Provide manufacturer specified / accept able clips for recommended support.
9. Thermowells
   a. Provide a Thermowell for every thermistor temperature sensing element installed in piping and equipment. Provide a separate calibration thermowell for every thermistor. Refer to installation detail shown on drawings.
   b. Thermowells shall be Type 304 stainless steel, or brass tapered pattern, 3/4 inch NPT external process connection, 1/2 inch NPT internal thread, with lagging extension, equal to insulation thickness, where installed in insulated piping. Thermowells shall have an insertion length of at least 1/3 of pipe diameter but in no case shall wells be less than 4-1/2 inch insertion length. Maximum immersion length shall be 6 inches or 3/4 of pipe diameter, whichever is smaller. Thermowells shall be rated for maximum system operating pressure, temperature and fluid velocity.
   c. Internal bore of Thermowells shall be sized to exactly fit the diameter of the sensing element to be installed.
   d. Provide necessary thermally conductive material for proper sensor to thermowell contact.

C. Pressure Sensors/Transmitters/Switches
1. Air Differential Pressure Switch
   a. Differential pressure switches shall be diaphragm type, with die-cast aluminum housing and an adjustable set point.
   b. Output: Switches contact shall be DPDT and rated a minimum of 5 amps at 120 VAC.
   c. Switch pressure range shall be suited for application (e.g. filter 0-2.0", fan status 0-5.0", etc.).

d. Sensor shall be adjustable for zero and span.
e. All exposed tubing shall be capped with static pressure tips.

2. Air Differential Pressure Transmitter
   a. Sensors shall be suitable for low pressures likely to be encountered and be selected for approximately 50% over range and have 4-20ma output.
   b. Connect to measuring points with valved lines for testing and calibration.
   c. Sensors shall be adjustable for zero and span.
   d. Sensors for VFD fan control shall be located 2/3rds downstream of fan.
   e. All exposed tubing shall be capped with static pressure tips.
3. Air Static Pressure Transmitter
   a. Sensors shall be suitable for low pressures likely to be encountered and be selected for approximately 50% over range and have
   b. Output: 4-20 mA
   c. Connect to measuring points with valved lines for testing and calibration.
   d. Sensors shall be adjustable for zero and span.
   e. Sensors shall be located 2/3rds downstream of index run.
   f. All exposed tubing shall be capped with static pressure tips.
4. Water Pressure / Differential Pressure Switch
   a. Switches shall be diaphragm actuator type, with epoxy coated aluminum housing and an adjustable set point.
   b. Output: Switch contact shall be SPDT, 15A 120VAC.
   c. Switch pressure range shall be suited for application
   d. Actuator seal to be compatible with process temperature limits
   e. Accuracy : 1% of nominal range
   f. Sensor shall be adjustable for zero and span.
   g. Manufacturer: Ashcroft
5. Water Pressure / Differential Pressure Transmitter
   a. Provide a variable capacitance 2-wire, 4-20 mA differential pressure transmitter assembly. Differential pressure transmitters shall be enclosed in a gasketed, dust and watertight housing. All body cavities open to the process fluid shall be provided with drain ports at the cavity bottom and vent ports at the top of the cavity. Both drain and vent ports shall be minimum ¼ inch – 18 NPT.
   b. The transmitter shall have continuously adjustable (externally) zero and span. These adjustments shall be made within the transmitter housing without a change of parts.
   c. The transmitter shall be capable of sustaining differential pressures in either direction, up to the body rating without damage to the instrument or a loss of accuracy or zero shift.
   d. The transmitter shall be fully compensated for both process and ambient temperature variations and a calibrated accuracy of ±0.25% of calibrated span.
   e. Provide local LCD display and wire-on-tag with instrument service information.
   f. Provide manufacturers standard 316 stainless steel, 5-valve manifold and pressure gauges for supply and return pressures.
   g. Manufacturer: Rosemount 3051S, 316 stainless steel or approved equal.

D. Level Transmitter
1. Level Transmitter ~~–~~ ~~Spray Chamber~~**Cooling Tower Collection** Basin**s**

   a. Electronic Water Level Package: Each cooling ~~spray chamber~~**tower collection** basin (~~Two~~ **four** in total) shall be provided with one analog level sensor capable of measuring the entire span of basin. Level sensors shall be connected to the BMS by the controls contractor. The analog sensor shall be used to monitor the entire range of the basin level as well as the levels whereby the BMS intiate HIGH HIGH and LOW LOW level alarms. The contractor shall be responsible for the full mechanical installation of all mounting hardware, stilling well and sensors and transmitters listed below.

b. Transmitter shall be capable of monitoring entire level of basin.
c. Provide Guided Wave Radar (GWR) loop-powered, 24 VDC level transmitter Coaxial guided wave radar probe and transmitter in stilling well. Coordinate instrument mounting and stilling well for proper measure.
d. Device shall be a 2-wire device with a 4-20 mA output signal
e. Remote mounted transmitter/indicator shall be angled, dual compartment enclosure with 4-button keypad and graphic LCD display
f. Provide all accessories, mounting brackets for probe mounting within basin and remote mounting of transmitter / indicator outside of basin including all extension cabling. Contractor to select specifics model probes and accessories to suit particulars of installation.
g. Analog Outputs for level monitoring
h. Sensor / transmitter shall be mounted in a NEMA 4X enclosure
i. Provide all accessories, mounting brackets for probe mounting within basin and remote mounting of transmitter / indicator outside of basin including all extension cabling.
j. The transmitter shall have continuously adjustable (externally) zero and span. These adjustments shall be made within the transmitter housing without a change of parts.
k. The transmitter shall be fully compensated for both process and ambient temperature variations and a calibrated accuracy of ±0.25% of calibrated span.
l. Sensor / transmitter shall be mounted in a NEMA 4X enclosure
m. Manufacturer – Rosemount 3300 Series or Magnetrol 706 Series

E. Flow Sensors/Transmitters/Switches
1. Air Flow Measurement Stations - Fan Inlet and Outside Air Intake / Exhaust Air Flow
a. General: The airflow measurement stations shall be capable of monitoring airflow and temperature rates at each measurement location. The system shall be factory tested prior to shipment and shall not require calibration or adjustment over the life of the equipment, when installed in accordance to manufacturer's guidelines.
b. Provide fan inlet and outdoor airflow measuring devices for air handling units as shown on drawings. Each airflow measuring device shall consist of multiple measuring probes.
c. Installed accuracy shall be percent of reading and demonstrated at both maximum and minimum airflow rates for each measurement location.
d. The operating airflow range shall be 0 fpm to 5,000 fpm.
e. A single manufacturer shall provide both the airflow measuring probe and transmitter.
f. Sensor assembly
1) Each sensing point shall independently measure airflow and temperature prior to averaging. Sensors shall be calibrated to NIST-traceable standards for both airflow and temperature. Heated element, bead in glass hermetically sealed thermistor probes.
2) Provide quantity of probes to meet manufacturer's minimum installation requirements. Provide quantity of airflow measuring probes to maintain specified accuracy and performances.
3) Each airflow measuring device shall consist of multiple measuring probes. Provide quantity of airflow measuring probes to maintain specified accuracy and performances.
4) The operating environmental range for the airflow probes shall be 20 deg f to 140 deg f, 99% R (non-condensing).
5) The sensor shall have an accuracy ± 2% of reading over the entire operating range and be fully temperature compensated.
g. Transmitter and Electronics Enclosure
1) The transmitter shall operate on 24 VAC. The transmitter shall have a minimum 16 character alphanumeric LCD display for airflow, temperature,

and system diagnostics. Analog output signals shall be user selectable (0-10 VDC or 4-20 mA). All inputs and outputs shall be fused, protected, and internally isolated from the 24 VAC power supply. The transmitter shall have a non-drifting adjustment for output signal offset/gain. The transmitter display shall be capable of being configured in either I.P. or S.I. units. The transmitter shall accept a user-defined area to display volumetric flow rates in CFM.

2) The enclosure shall be aluminum alloy for indoor use and capable of operating over a temperature range of +30° F to +120° F. The electronics shall be installed inside and protected from the weather. Exterior installation or areas acceptable to high levels of moisture use NEMA4 enclosure.

h. Temperature Output to BMS
   1) Provide temperature monitoring output to BMS in accordance with mechanical drawings.

i. Acceptable manufacturers:
   1) Ebtron, Inc (Gold Series)

j. BMS contractor shall employ factory trained Ebtron technician as part of this contract to assist in design and to inspect all outside air measurement installations and assist in calibrating and adjusting the Ebtron outside air sensors as required to meet final balancing setting to provide accurate BMS monitoring and control.

2. Liquid Flow - Magnetic Flow Meter
   a. The flow transmitter shall be a full sized magnetic flow meter.
   b. The flow meter shall be field-programmable with all site criteria being capable of input or change on-site by the use of plug-in hand-held terminal. All programming will be menu-driven and input in plain English.
   c. System Requirements
      1) Intrinsic Accuracy: Within 1 percent of actual flow above 1 fps.
      2) Calibrated Accuracy: 0.5 percent of actual flow above 1 fps.
      3) Flow Range Ability: Bidirectional including active zero sensitivity.
      4) Sensitivity: 0.001 ft./sec.
      5) Respectability: High precision: 0.15%.
   d. Flow Transmitter
      1) The flow transmitter shall be solid state design utilizing high reliability circuit elements and compound shall be micro-computer controller. The transmitter shall be housed in a NEMA 4X enclosure suitable for remote mounting. The transmitter shall be furnished with built-in fault alarm, and self diagnostic program to accurately track the metering systems performance. The programming shall be battery backed in RAM.
      2) The transmitter shall be equipped with an isolated 4-20 ma output signal, proportioned to flow, and be able to drive a restive load of up to 800ohms.
   e. The flow meter shall be provided will flow sizing calculation data.
   f. Manufacturer / Model
      1) Rosemount / Sensor Model 8705, Transmitter Model 8732C

F. Miscellaneous Sensors
   1. Humidity Sensors
      a. The assembly shall consist of a humidity sensor utilizing a resistance change bulk polymer sensing element mounted in a housing suitable for the following applications – Outdoor, Return, and Space.
      b. Sensor Humidity Operating Range: 0 to 100%.
      c. Accuracy: ±2.5% RH between 50 and 104 DegF.
      d. Repeatability: 0.5% RH/year
      e. Sensitivity: 0.4%RH
      f. Hysteresis: Less than 1%.
      g. Stability: Better than 1.0% RH over a year. (Long term stability)
      h. Temperature effect: Temperature compensated with less than 0.06% per °F.

i. Supply voltage: 18-38 VDC
j. Output: Two-wire loop-powered, 4-20 ma, %0 to 100% linear
k. Adjustments: One point with calibrator (duct mounted applications).
l. Operating temperature: -40°F to 130°F
m. Storage temperature: -85°F to 158°F
n. Max load: (Supply voltage 10VDC)/0.02, 700Ohms@ 24VDC
o. Connections screw terminals for loop terminations.
p. Provide 2 years warranty.
q. Sensor manufacturer shall send samples, mounting options and appearance to FRA Construction Coordinator for approval prior to shipment.
r. Manufacturer - Vaisala

2. Combination Temperature and Humidity Sensors
   a. The assembly shall consist of a temperature and humidity sensor mounted in a ventilated housing suitable for wall mounting.
   b. Coordinate Temperature Sensor faceplate requirements with FRA Construction Coordinator/ FRA and engineer.
   c. Faceplates options shall include color, blank faceplate option, display faceplate option, setpoint adjustment option and occupied/unoccupied override option) Submit for approval.
   d. Humidity Sensor
      1) Sensor Humidity Operating Range: 0 to 100%.
      2) Accuracy: ±2.5% RH between 50 and 104 DegF.
      3) Repeatability: 0.5% RH/year
      4) Sensitivity: 0.4%RH
      5) Hysteresis: Less than 1%.
      6) Stability: Better than 1.0% RH over a year. (Long term stability)
      7) Temperature effect: Temperature compensated with less than 0.06% per °F.
   e. Temperature Sensor
      1) Sensor Operating Range: 20 DegF to 120 DegF
      2) Accuracy: ±1 DegF.
      3) Repeatability: 0.5% RH/year
      4) Sensitivity: 0.4%RH
      5) Hysteresis: Less than 1%.
      6) Stability: Better then 1.0% RH over a year. (Long term stability)
   f. Output: Two - Two-wire loop-powered, 4-20 ma, %0 to 100% linear
   g. Adjustments: One point with calibrator (duct mounted applications).
   h. Operating temperature: -40°F to 130°F
   i. Storage temperature: -85°F to 158°F
   j. Max load: (Supply voltage 10VDC)/0.02, 700Ohms@ 24VDC
   k. Connections screw terminals for loop terminations.
   l. Provide 2 years warranty.
   m. Manufacturer - Vaisala
3. Carbon Dioxide Sensor – Duct Mounted
   a. Provide duct mounted carbon dioxide infrared microprocessor based sensor.
   b. Measurement range of 0 to 2000 PPM; accuracy +/-40 ppm (+/- 3% of reading)
   c. Analog Output: 4-20mA or 0-10VDC and Modbus proportional output signal, temperature compensated Maximum drift of ±100 PPM per year.
   d. Relay Output: 1 DPDT contact 5A, 30 VDC or 250VAC, Alarm contacts to close when user defined setpoint is reached. Adjustable alarm limit of 0 to 2000 PPM, factory set at 1000 PPM of carbon dioxide.
   e. Microprocessor based offset algorithm to automatically compensate for drift.
   f. Maximum response time: < 60 sec.
   g. Power requirements: 24VAC/VDC 200mA
   h. Manufacturer / Model
      1) Vulcain / 90DM3A
4. Carbon Dioxide Sensor– Wall / Surface Mounted

a. The carbon dioxide sensor shall provide an output signal correspondence linearly to 0-2000 ppm/0-5000 ppm (user adjustable) of CO2 using Non-dispersive Infrared (NDIR) technology.
b. The CO2 concentration shall be determined by measuring the attenuation of a specific wavelength of infrared light travels from its source to a detector along a defined optical path. The sensor shall detect the amount of attenuation and convert it into a 0 to 10 VDC analog output signal, which corresponds linearly to 0 to 2000 ppm sensed concentration of CO2.
c. The sensor features shall have a membrane filter to help prevent contaminants from entering the sensing chamber and yet remain permeable to CO2.
d. A microprocessor-based offset compensation algorithm shall automatically compensate for drift. The compensation algorithm shall include a self-test that can detect problems (such as excessive drift) and initiate an alarm signal.
e. In addition to compensating for drift, the microprocessor shall speed the full calibration process by automatically adjusting the span (of the 0 to 2000 ppm output range). One easy accessed button shall complete this process.
f. Provide a separate 24 VAC transformer and power and control wiring.
g. The sensor shall be suitable for duct and space mounting as shown on the drawings. Provide carbon dioxide sensors as quantified in device schedule and shown mechanical drawings.
h. Sensor minimum requirements:
    1) Accuracy ± ppm CO2, up to 1500 ppm ±5 percent of reading above (at room conditions).
    2) Repeatability ±10ppm CO2
    3) Maximum Drift ±50ppm CO2 per year
    4) Output Signal 0 to 10 VDC/4-20 mA proportional over the 0 to 2000 ppm/0-5000ppm CO2 range
i. Alarm Relay: SPST normally open dry rated for 10W maximum, 100 or 500 mA DC maximum with adjustable limit (0-2000 CO2 factory set at 1000ppm ±50ppm CO2)
j. Alarm Set Resolution ±20ppm CO2 minimum
k. Alarm Hysteresis 50ppm CO2
l. Calibration Adjustments Automatic zero compensation and span calibrations; uses calibrated span and zero.
m. Calibration interval – greater than two (2) years
n. Adjustment Resolution 20ppm CO2 minimum
o. Response Time: <30 seconds to 63 percent of step change, <60 seconds to 100 percent of step change
p. Warm up time: 5 minutes
q. Ambient Operating Conditions 32 to 122°F
r. 5 to 95 percent RH, non-condensing
s. Provide a calibration kit (flow system type) including zero gas and test carbon dioxide gas. Turn over complete kit to FRA at warranty start date
t. Provide weatherproof enclosure for outdoor air mounting
u. Manufacturer / Model
    1) Vaisala / GMW25.

5. Current Sensors - Analog Output
a. Provide and install split core current sensors to interface with the DDC system as described in Sequence of Operations and as shown on Control Drawings.
b. Units shall be UL listed.
c. Each sensor shall be two wire, loop powered and sized for expected amperage.
d. Analog Output Current Transducer
e. Typical installations used for the determination of current consumption of fan and pump motor in remote starter enclosures.
f. Power requirements: Self powered, 0-60 Amp rating
g. Output: 0-5 VDC

h. Accuracy +/-2.0% Full scale
i. Manufacturer: Veris - Hawkeye H922

6. Current Sensors - Analog Output - Variable Frequency Drive Applications
   a. Typical installations used for the determination of VFD driven fan and pump motor status points in remote starter enclosures.
   b. Self-adjusting setpoint, automatic compensation for effects of frequency and amperage changes related to VFD (insensitive to frequencies 10-80 hz)
   c. Current sensor shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   d. Power requirements: Self powered induced from line
   e. Accurate to 0.5% full scale
   f. Output: 4-20mA
   g. Manufacturer: Veris - Hawkeye H720
7. Digital Output Current Switch
   a. Typical installations used for the determination of fan and pump motor status points in remote starter enclosures.
   b. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   c. Power requirements: Self powered induced from line
   d. Adjustable setpoint 1-135A
   e. Output: One normally open contact; 1 A rating at 30VAC/VDC
   f. Manufacturer: Veris - Hawkeye H908
8. Digital Output Current Switch (-Variable Frequency Drive Applications)
   a. Typical installations used for the determination of VFD driven fan and pump motor status points in remote starter enclosures.
   b. Self-adjusting setpoint, automatic compensation for effects of frequency and amperage changes related to VFD
   c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   d. Power requirements: Self powered induced from line
   e. Output: One normally open contact; 0.1 A rating at 30VAC/VDC
   f. Manufacturer: Veris - Hawkeye H904
9. Occupancy Sensors
   a. Occupancy sensors shall be provided to interface with the DDC system as described in Sequence of Operations.
   b. Occupancy Switch can be combined with space temperature sensor. Sensor shall use either passive infrared or ultrasonic technology with sensitivity adjustment
   c. Power requirements: 24 VDC
   d. Output: 2 Form C contacts; 1 A rating at 24VDC
   e. Manufacturer:
10. Water Leak Detection Sensors
   a. Water leak detection sensors shall be provided to interface with the DDC system as shown on Control Drawings.
   b. Sensors: Shall be comprised of two gold-plated sensing probes for corrosion resistance and microchip technology for dependable and accurate detection of conductive liquids. Supervised operation—signals on leak detected, circuit failure or power loss
   c. Power requirements: 24 VAC/VDC, 100mA, 50/60Hz, 3 VA (max)
   d. NEMA 1 Enclosure
   e. Output: 2 Form C contacts; 3 A rating at 24VAC
   f. Manufacturer: Emerson, Liqui-tect

G. BTU Energy Metering System

1. Water Metering System
   a. Liquid Flow - Magnetic Flow Meter
      1) The flow transmitter shall be a full sized magnetic flow meter.
      2) System Requirements
         a) Intrinsic Accuracy: Within +/-0.25 percent of actual flow 0.04 to 6 fps
         b) Flow Range Ability: Bidirectional including active zero sensitivity.
         c) Sensitivity: 0.001 ft./sec.
         d) Repeatability: High precision: 0.15%.
      3) Flow Transmitter
         a) The flow transmitter shall be solid state design utilizing high reliability circuit elements and compound shall be micro-computer controller. The transmitter shall be housed in a NEMA 4X enclosure suitable for remote mounting. The transmitter shall be furnished with built-in fault alarm, and self-diagnostic program to accurately track the metering systems performance. The programming shall be battery backed in RAM.
         b) The transmitter shall be equipped with an isolated 4-20 ma output signal, proportioned to flow, and be able to drive a restive load of up to 800ohms.
      4) The flow meter shall be provided will flow sizing calculation data.
      5) The flow meter shall be field-programmable with all site criteria being capable of input or change on-site by the use of plug-in hand-held terminal. All programming will be menu-driven and input in plain English.
      6) Manufacturer / Model
         a) Rosemount / Sensor Model 8705, Transmitter Model 8732C
   b. Precision matched RTDs: 1,000 ohm platinum
      1) Differential Temperature Accuracy: 0.02 deg F (with ice both calibration).
      2) Transducers: (High Temperature)
   c. Installation, programming and Start-Up
      1) The manufacturer and/or factory representative of the energy meter shall provide field supervision at the project site for the installation of the metering equipment. The manufacturer and/or factory representative of the meter shall provide on-site programming of the meter, installation check and commissioning of the meter.
   d. Energy Meter
      1) Provide a Kessler Ellis Products Supertroll II energy flow meter (with matched supply and return temperature sensors) for hot and chilled water BTU measurement applications.
      2) Provide local LCD display and wire-on-tag with instrument service information.
      3) NEMA 4X front.
      4) The computer shall have on board self-diagnostics, and ROM based stored fluid properties for water.
      5) The computer shall be capable of a Modbus RTU output for all the device parameters monitored including, but not limited to instantaneous flow.
   e. Training

      1) The manufacturer and factory representative of the flow-meter shall provide a minimum of one half-day of operation orientation and instruction on the operation of the flow-meter consecutive with the installation of the flow meter.

H. Automatic Control Valves
   1. Control valves assemblies shall be provided and delivered from a single manufacturer as a complete assembly.

2. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.
3. Pressure- Independent Control Valves - Modulating
   a. Construction
      1) All control valves shall be of the pressure- independent design. All control valves shall have a constant control valve authority of 100% over the full allowable pressure and flow range. All control valves must offer a hand wheel.
      2) All control valves shall have documented measuring accuracy of +/- 10% within the normal setting range of the valve.
      3) All control valves shall have integral self-sealing ports for measuring differential pressure and fluid temperature using standard pressure and temperature test probes. Pressure ports for flow measurements shall not be required if valve assembly provides permanent means of flow measurement via electronic flowmeter.
      4) All control valves shall have maximum body ratings in accordance with system design pressure at rated system design temperature.
      5) All control valves must include a locking stop to ensure the balanced position while in operation and to prevent hand wheel repositioning after setting.
      6) All control valves shall have adjustment for precise readout. The hand wheel shall be adjustable while the valve is in operation with the actuator installed.
      7) All control valves shall be manufactured by the company complying with international quality standard ISO 9001.
      8) All actuators shall be capable of operating over the full flow and pressure range of the valve.
   b. Material Characteristics
      1) All control valves in shall have brass bodies and NPT threaded connections to match the piping system. All wetted brass parts shall be alloyed to resist dezincification (DZR). No dielectric fittings shall be required for installation. The flexible components shall be made of EPDM and PTFE.
   c. Valve Sizing
      1) All control valves shall be sized to perform in a normal operation range at a minimum differential pressure of 5-50 psi or less. All control valves shall have a maximum working differential pressure of no less than 50 psi. All control valves shall be selected based on their allowable flow range.
   d. Manufacturer
      1) Belimo or equal.
   e. Warranty
      1) Valves shall be free from material and workmanship defects for a period of 5 years from date of installation.
4. Two Position Control Valves
   a. Control valves shall be globe or ball valves.
   b. Line size full ported valves shall be used to minimize pressure drop.
   c. The valve trim shall utilize a stainless steel ball and stem for all water or glycol solutions up to 60%. For water applications, an optional chrome plated brass ball and brass stem may be used for sizes ¾” and smaller.
   d. Valve bodies shall be nickel-plated, forged brass with female NPT threads. Bodies to 1 ¼” shall be rated at 600 psi and sizes 1 ½” to 3” at 400 psi.
   e. Valves shall have a self-aligning, blowout proof, brass stem with a dual EPDM O-ring packing design. Fiberglass reinforced Teflon seats shall be used.
   f. The valves shall have a four bolt mounting flange to provide a 4 position, field changeable, electronic actuator mounting arrangement.
   g. A non-metallic coupling, constructed of high temperature, continual use material shall provide a direct, mechanical connection between the valve body and actuator. The coupling shall be designed to provide thermal isolation and eliminate

lateral and rotational stem forces. Vent hole shall be provided to reduce condensation build-up.

5. High Performance Butterfly Valves
   a. Butterfly valves shall be ANSI rated, to be determined in accordance with the pressure rating and mechanical piping.
   b. Valves shall be fully lugged and constructed of a carbon steel body.
   c. The seat shall be of RTFE with a soft seat design.
   d. The shaft shall be 17-4 PH SS and the disc shall be 316 SS. Butterfly valves shall have a double offset or double eccentric shaft design to minimize seat abrasion and lower torque.
   e. All valves shall have a metal identification tag attached to the valve body. Information on this tag includes the valve figure number, size, pressure class, materials of construction, and operating pressure and temperatures.
   f. The butterfly valves shall have a three bushing design completely isolating the valve shaft from the body.
   g. The valve actuator shall be electronic with thermally protected capacitor-type reversible motor.
   h. The actuator shall also include a planetary worm combination drive, heater limit switches and wiring terminal blocks.
   i. Housing shall be NEMA 4 with top mounted domed indicator.
   j. Geartrain shall be high alloy steel gear sets, self locking.
   k. All actuators shall be equipped with 2 SPDT, 10VA 250VAC.
   l. Provide valve end switches to indicate positive valve open and positive valve closed status to BMS.
   m. All actuators shall be equipped with manual hand-wheel override.
   n. Butterfly valve, actuator valve combination shall be provided by one manufacturer and carry a five year Warranty.
   o. Steam control shut-off valves:
   p. Steam control shut-off valves shall be single seated with stainless steel trim.
6. Valve Actuators:
   a. Valve actuators shall be electric, and properly selected for the valve body and service. Actuators shall be fully proportioning and be spring return for normally open or normally closed operation as specified.
   b. The controls contractor shall provide control power transformers for valve actuators for low voltage operation as required.
   c. If upon contractor's final sizing of valve and actuators it has been determined that the power required for the assembly exceeds the power available from the BMS control panel, the contractor shall coordinate with the Div. 26 contractor for additional power.
   d. Manufacturer:
      1) Belimo

I. Dampers

1. Motorized Control Dampers

a. Motorized Control Dampers shall have 13 gauge galvanized frames of not less than 3" in width and blades of 16 gauge, or double 22 gauge, galvanized steel and shall be adequately braced to from a rigid assembly where required in galvanized ductwork. Dampers shall have blades not more 8" wide. Linkage and hardware shall be zinc plated steel. Damper blades and rods shall be installed in horizontal position.

b. All dampers shall be of the opposed blade type, and shall be electric motor operated. Dampers shall have continuous elastomer or stainless steel stops to avoid leakage. Bearings shall be oil tight non-ferrous sleeve type. All dampers shall be provided with continuous 3/16" x 1/2" closed cell neoprene gasketing around perimeter of the frame and at interlocking blade edges to form an airtight seal.

c. All dampers shall be constructed to provide a maximum leakage in accordance with ASHRAE/IES 90.1 and tested to ANSI /AMCA Std 500. Submit leakage and flow characteristic data for all dampers.
d. All outside air dampers shall automatically close in the event of a loss of power, unless otherwise noted.
e. Outdoor air applications in costal environments shall be provided with TAMCO SW (saltwater), Ruskin CE or approved equal, construction features
f. Dampers shall be Imperial, Ruskin or approved equal.

~~1. Motorized Control Dampers~~
~~a. Motorized Control Dampers shall have 13 gauge galvanized frames of not less than 3" in width and blades of 16 gauge, or double 22 gauge, galvanized steel and shall be adequately braced to from a rigid assembly where required in galvanized ductwork. Dampers shall have blades not more 8" wide. Linkage and hardware shall be zinc plated steel. Damper blades and rods shall be installed in horizontal position.~~
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~~c. All dampers shall be constructed to provide a maximum leakage of 3-1/2%, with an approach velocity of 1500 fpm when closed against a pressure of 4 inches of water. Submit leakage and flow characteristic data for all dampers.~~
~~d. All outside air dampers shall automatically close in the event of a loss of power, unless otherwise noted.~~
~~e. Dampers shall be Imperial, Ruskin or approved equal.~~

2. Damper Operators:
   a. Damper operators shall be electric, spring return or fail in place, and shall be properly sized so as to stroke the damper smoothly and efficiently throughout its range. Actuator response shall be linear in response to sensed load.
   b. The controls contractor shall provide control power transformers for damper actuators for low voltage operation as required.
3. Damper End Switches
   a. Damper end switches shall comprise of high temperature micro switches, mercury switches are not acceptable.
   b. Damper end switch shall comprise of one switch which closes when the blades are fully open and the second switch closes when the blades are fully closed
   c. Damper end switches shall be provided for each actuator controlled damper section. If more than one end switch is provided for a damper assembly, the wiring of damper section end switches in parallel is acceptable.
   d. Manufacturer: Ruskin

J. Electrical metering devices
1. Division 26 shall provide electrical meters which shall provide inputs to the BMS via a Modbus or BACNET communications protocol. Refer to Section 26 for additional details as to the data being monitored. The interface shall allow for full monitoring of the device encompassing multiple inputs to the BMS.

K. Field Equipment Cabinets:

1. All indoor control cabinets shall be fully enclosed NEMA 1 (minimum, see NEMA rating for enclosures within this specification) construction with (hinged door) key-lock latch and removable sub panels. A single key shall be common to all field panels and sub panels. All transformers, electric relays, manual override switches, etc., shall be mounted within the enclosure and factory wired to terminal strips.

2. Interconnections between internal and face mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600 volt service (or in accordance with line voltage), individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.

L. Test and Calibration Equipment

1. All necessary calibration and testing equipment shall be provided to perform the testing, commissioning and acceptance testing as part of the deliverable.

M. Component Tags

1. Valve Tags:

a. All automatic and manual valves provided by this contractor, shall be identified with 2" diameter brass tags and brass chains. Lettering shall be 1/2" high, stamped and painted black. Automatic valve tags shall be stamped with the letters "AV" and sequentially numbered. Provide valve schedule and sample tags for approval.

2. Sensor Tags:

a. All sensors/instruments shall be identified with 1"x 3" black lamacoid labels with engraved white lettering. Lettering shall be 1/4" high. Provide sensor number, Air handling unit number/pump/source equipment (as relevant), part number and sensor range on tag.

PART 3 - EXECUTION

3.1 BUILDING MANAGEMENT SYSTEM - GENERAL

A. Space mounted devices are to be identical in appearance. All devices shall be mounted under the same style cover.

B. Provide all relays, switches, sources of electricity and all other auxiliaries, accessories and connections necessary to make a complete operable system in accordance with the sequences specified.

C. Install controls so that adjustments and calibrations can be readily made.

D. Mount surface-mounted control devices on brackets to clear the final finished surface on insulation.

E. Conceal control conduit and wiring in all spaces except in the Mechanical Equipment Rooms and in unfinished spaces. Install control conduit and wiring in parallel banks with all changes in directions made at 90 degree angles.

F. Install control valves horizontally with the power unit up. Installation of control valves will be by the Division 23 Contractor.

G. Unless otherwise noted, install wall mounted sensors, thermostats and humidistats at 5'-0" above the finished floor measured to the centerline of the instrument. Submit device locations, mounting heights and details for approval.

3.2 SENSOR TUBING & INSTALLATION

A. Concealed spaces: Tubing shall be copper tubing.

B. Exposed: Where tubing is installed in exposed areas susceptible to damage (i.e., located outdoors, exposed to heavy pedestrian or maintenance traffic), tubing shall be installed in conduit.

3.3 ELECTRICAL INSTALLATION

A. General

1. For conduit support and installation of wires and cables see applicable paragraphs of the latest edition of the NEC.

B. Raceways and Conduit

1. All conduit/cable entry to control panels shall be from the bottom or sides to prevent condensation from draining into electronic equipment contained within.
2. Conduit / EMT percent fill shall not exceed maximum NEC allowable fill.
3. Use liquid tight flexible metal conduit for making connections at instruments and devices mounted on piping or vessels or on equipment subject to vibration.

C. Wiring

1. Line voltage wiring, concealed or exposed, shall be installed in accordance with Division 26, local electrical code and the NEC.
2. Low voltage data transmission wiring, except the primary peer-to-peer communications trunk,

    a. installed in concealed, accessible areas shall be plenum rated cable
    b. installed in exposed areas, such as mechanical equipment rooms, shall be installed in EMT(metal).

3. Peer-to-peer communications including trunk low voltage data transmission and wiring between controllers shall be installed in EMT(metal).
4. Cables for 120/24 VAC wiring and low level signal wiring shall always be run in separate raceways.
5. Wire splices within conduit are prohibited under any circumstances.
6. All smoke control wiring including Fire Alarm System Relay and Monitoring Modules shall be in accordance with Division 26.
7. All wiring shall be in accordance with this specification and Division 26, including tagging, labeling and identification.
8. Controllers shall be provided with a terminal strip for field wiring. All control wiring internal to the panel landing direct on I/O will be done through a terminal strip. Under no circumstances will field wiring be terminated from inputs or outputs direct to the I/O controllers.

D. Contractors' tests shall be scheduled and documented in accordance with the commissioning requirements.

3.4 FIBER COMMUNICATIONS

1. Contractor is to adhere to all Div 27 specifications for all fiber optic scope, including the following specifications;

   a. 271300 - Communications Backbone Cabling
   b. 270528 - Pathways for Communications Systems

2. Contractor shall make use of ICT contractor provided raceways where ever possible, refer to T-400 series drawings for design intent of raceway systems.

3.5 SEQUENCE OF OPERATIONS

A. AHU-01 - 100% Outside Air Unit – Cooling Coil and Electrical Heating Coil

1. General (Normal Position)

   a. Cooling coil control valve, modulating type, normally closed, fail last position.
   b. Electric Heating coil **normally off.** ~~control valve, modulating type, normally closed, fail closed.~~
   c. Supply fan, VFD – typical of 4, normally off.

2. Hardwired Safeties and Alarms:

   a. Safeties shall be enabled at all times.

      1) The FAS shall stop the supply fans on a smoke condition via hardwired interlock to the supply fan VFD's as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
      2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

   b. Pressure switches shall stop the supply fans via hardwired interlock to the fan starters. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fans shall remain off until the pressure switches are reset manually.

      1) Low suction air pressure switch installed upstream of the supply fans and downstream of the closest damper will stop the supply fans when duct pressure decreases below design.
      2) High supply fan discharge air pressure switch installed downstream of the supply fans and upstream of the closest damper will stop the supply fans when duct pressure exceeds design.

3. System Off:

   a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

   a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
   b. When the system is commanded on the supply fans shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
   c. After the supply fans' status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

   a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
   b. The BMS shall modulate the cooling coil control valve and the electric ~~reheat~~ coil to maintain the supply air setpoint (adjustable);

      1) Supply air dew point of 46F (+ 2 / - 2 F)
      2) Supply air dry bulb of 69F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

   a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

   a. Maintenance alarms are generated at the operator workstation when:

      1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
      2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
      3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

B. AHU-02 - 100% Recirculation Air Unit –Cooling Coil Only

1. General (Normal Position)

   a. Cooling coil control valve, modulating type, normally closed, fail last position.
   b. Supply fan, VFD, normally off.

2. Hardwired Safeties and Alarms:

   a. Safeties shall be enabled at all times.

      1) The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.

2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

b. Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.

3. System Off:

a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
b. When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
c. After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

1) Space dry bulb of 78F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.

3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

C. AHU-03 - 100% Recirculation Air Unit –Cooling Coil Only

1. General (Normal Position)

a. Cooling coil control valve, modulating type, normally closed, fail last position.
b. Supply fan, VFD **– typical of 2**, normally off.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

b. Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.

3. System Off:

a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
b. When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
c. After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.

b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

1) Space dry bulb of 83F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

D. AHU-04 - 100% Outside Air Unit –Cooling Coil

1. General (Normal Position)

a. Cooling coil control valve, modulating type, normally closed, fail last position.
b. Supply fan, VFD – typical of 2, normally off.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the supply fans on a smoke condition via hardwired interlock to the supply fan VFD's as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

b. Pressure switches shall stop the supply fans via hardwired interlock to the fan VFD's. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fans shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fans and downstream of the closest damper will stop the supply fans when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fans and upstream of the closest damper will stop the supply fans when duct pressure exceeds design.

3. System Off:

   a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

   a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
   b. When the system is commanded on the supply fans shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
   c. After the supply fans' status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

   a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
   b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

      1) Supply air dew point of ~~46F~~ **48F** (+ 2 / - 2 F)
      2) Minimum dry bulb temperature of 50F. **The space thermostat(s) readings shall be averaged for the entire space served by AHU-04.** If space drops below 50F, reset supply DBT to 52F (+ 0 / - 2 F).

6. Fire Alarm Shutdown:

   a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

   a. Maintenance alarms are generated at the operator workstation when:

      1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
      2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
      3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

E. AHU-05 - 100% Outside Air Unit – Cooling Coil and Electrical Heating Coil

1. General (Normal Position)

   a. Cooling coil control valve, modulating type, normally closed, fail last position.
   b. Electric Heating coil, **normally off.** ~~control valve, modulating type, normally closed, fail closed.~~
   c. Supply fan, VFD – typical of 4, normally off.

2. Hardwired Safeties and Alarms:

   a. Safeties shall be enabled at all times.

      1) The FAS shall stop the supply fans on a smoke condition via hardwired interlock to the supply fan VFD's as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
      2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

   b. Pressure switches shall stop the supply fans via hardwired interlock to the fan starters. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fans shall remain off until the pressure switches are reset manually.

      1) Low suction air pressure switch installed upstream of the supply fans and downstream of the closest damper will stop the supply fans when duct pressure decreases below design.
      2) High supply fan discharge air pressure switch installed downstream of the supply fans and upstream of the closest damper will stop the supply fans when duct pressure exceeds design.

3. System Off:

   a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

   a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
   b. When the system is commanded on the supply fans shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
   c. After the supply fans' status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

   a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
   b. The BMS shall modulate the cooling coil control valve and the electric ~~reheat~~ coil to maintain the supply air setpoint (adjustable);

      1) Supply air dew point of 46F (+ 2 / - 2 F)
      2) Supply air dry bulb of 69F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

   a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

F. AHU-06 **— 100%** Recirculation Air Unit –Cooling Coil Only

1. General (Normal Position)

a. Cooling coil control valve, modulating type, normally closed, fail last position.
b. Supply fan, VFD, normally off.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

b. Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.

3. System Off:

a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
b. When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.

c. After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

1) Space dry bulb of 70F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

G. AHU-07 – 100% Recirculation Air Unit –Cooling Coil Only

1. General (Normal Position)

a. Cooling coil control valve, modulating type, normally closed, fail last position.
b. Supply fan, VFD, normally off.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.

b. Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.

3. System Off:

a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
b. When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
c. After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

1) Space dry bulb of 83F (+ 2 / - 2 F). The space thermostat(s) readings shall be polled for the maximum temperature and the cooling coil control valve shall modulate to maintain the space air setpoint.

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

H. AHU-08 – 100% Recirculation Air Unit –Cooling Coil Only

1. **General (Normal Position)**

   a. **Cooling coil control valve, modulating type, normally closed, fail last position.**
   b. **Supply fan, VFD, normally off.**

2. **Hardwired Safeties and Alarms:**

   a. **Safeties shall be enabled at all times.**

      1) **The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.**
      2) **Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.**

   b. **Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.**

      1) **Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.**
      2) **High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.**

3. **System Off:**

   a. **When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.**

4. **System Start-Up:**

   a. **The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.**
   b. **When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.**
   c. **After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.**

5. **Normal Mode:**

   a. **The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.**
   b. **The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);**

      1) **Space dry bulb of 70F (+ 2 / - 2 F)**

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
3) Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.

I. AHU-09 – 100% Recirculation Air Unit –Cooling Coil Only

1. General (Normal Position)

a. Cooling coil control valve, modulating type, normally closed, fail last position.
b. Supply fan, VFD, normally off.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the supply fan on a smoke condition via hardwired interlock to the supply fan VFD as well as an additional input to the BMS. All controls shall return to their normal position. A critical alarm shall be raised on the BMS.
2) Fire Smoke Dampers adjacent to the AHU shall be provided with open and closed end switches. End switches proving open shall allow the AHU to be started via hardwired connection to permissive circuit.

b. Pressure switches shall stop the supply fan via hardwired interlock to the fan VFD. A critical alarm shall be raised at the BMS when duct pressure exceeds the switch setpoint (adjustable). All other controls shall return to their normal position. The fan shall remain off until the pressure switches are reset manually.

1) Low suction air pressure switch installed upstream of the supply fan and downstream of the closest damper will stop the supply fan when duct pressure decreases below design.
2) High supply fan discharge air pressure switch installed downstream of the supply fan and upstream of the closest damper will stop the supply fan when duct pressure exceeds design.

3. System Off:

a. When the system is off (status based on proof of airflow via the airflow measuring station), all valves, dampers, and control devices shall be in their normal positions.

4. System Start-Up:

a. The system shall be programmed to be in Normal Mode and shall be programmed for continuous (24/7) operation, or controlled manually via the operator's workstation.
b. When the system is commanded on the supply fan shall start after a 10 second delay (adjustable) and ramped up to minimum speed.
c. After the supply fan status is proven on proof of air flow via the air flow measuring station, the system shall be indexed to the Normal mode.

5. Normal Mode:

a. The AHU shall operate at constant volume; refer to mechanical schedules for airflow setpoints.
b. The BMS shall modulate the cooling coil control valve to maintain the space air setpoint (adjustable);

1) Space dry bulb of 78F (+ 2 / - 2 F)

6. Fire Alarm Shutdown:

a. The Air Handling Unit shall be shutdown via a relay input directly from the Fire Alarm System; the Fire Alarm system shall also send a signal to the BMS.

7. Alarms

a. Maintenance alarms are generated at the operator workstation when:

1) The pre-filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.5 in. w.g. (adjustable) initially as temporary setpoint.
2) The filter pressure drop reaches dirty filter setpoint, refer to mechanical schedule, manufacturer data or use 0.8 in. w.g. (adjustable) initially as temporary setpoint.
~~G.~~ **Leak detection shall be provided by the controls contractor. When water sensor detects presence of water below condensate drip pan, an alarm shall be generated at the BAS.**~~DX Split System AC Units (AC-01 & AC-02 / ACC-01)~~
~~1. The Split Air Conditioning Units system shall be controlled via space thermostat and controller furnished by the unit manufacturer.~~
~~2. Normal Mode:~~
~~a. Controller shall enable and disable fan, and stage compressors as needed to maintain space temperature cooling setpoint of 78F (adjustable).~~
~~b. The BMS shall only monitor space temperature in the area served.~~

~~3. Alarms~~
~~a. Leak detection shall be provided by the controls contractor. If water sensor detects presence of water below unit, an alarm shall be generated at the BAS, and unit shall be de-energized.~~

~~b. If space temperature rises 2F (adjustable) above setpoint for a 10 minute (adjustable) time period, the controller shall disable the unit and generate a general alarm.~~

~~c. If the space temperature drops below 2F (adjustable) below setpoint for 10 minutes (adjustable) time period, an alarm shall be annunciated at the BMS.~~

~~d.~~**3)** ~~The BMS shall monitor dry contact provided by the unit manufacturer. An alarm shall be generated at the BMS upon system alarm/trouble.~~

~~H.~~**J.** Exhaust Fans – (EF-01 & EF-02)

1. General

   a. Fan, starter, normally off.

2. System Off:

   a. When the system is off, fan shall be in normal position as stated above.

3. System Start-Up:

   a. The exhaust fans shall be started/stopped by the BMS based on a time of day schedule or manual command from the BMS workstation. The BMS contractor shall set the initial operations to coincide with the facility occupied times.
   b. On a stop command the fan shall stop.

4. Fire Alarm Shutdown:

   a. The exhaust fans will be shut down via a relay from the Fire Alarm System (FAS) in the event of a fire/smoke event.
   b. The BMS provide a soft shutdown of the unit via BMS programming in order to eliminate nuisance alarm.

5. Alarms

   a. BMS shall monitor FAS shutdown relay and provide an alarm at the BMS.~~,~~

~~I.~~**K.** Exhaust Fan – (EF-05)

1. General

   a. Fan, normally off.
   b. Fire Smoke Damper**s** (~~Two in total~~**As applicable**), normally open, fail close.

2. Hardwired Safeties and Alarms:

   a. Safeties shall be enabled at all times.

      1) The FAS shall stop the fan on a smoke condition via hardwired interlock to the fan starter
      2) Fire Smoke Damper on makeup air opening and fire smoke damper on exhaust duct connected to fan shall each be provided with open end switch. End switch for both fire smoke dampers proving open shall allow the fan to be started via hardwired connection to fan starter.

3. System Off:

a. When the system is off, fan shall be in its normal position as stated above.

4. System Start-Up:

a. The system shall be enabled and started via seasonal / time of day schedule or via a manual command from the BMS workstation.
b. The temperature control loop shall be started.

5. Temperature Control Mode:

a. The fan shall start / stop to maintain space temperature at setpoint (adjustable).

b. The fan shall start / stop to maintain space temperature at setpoint of +10F above ambient (adjustable);

c. If after the operation of the fan for 10 minutes (adjustable) the space temperature is less than that of the setpoint the fan shall be stopped.

6. Fire/Smoke Event:

a. The fan shall be turned off (if not already off) directly via a relay from the Fire Alarm system; the fan shall stay off as long as a Fire Alarm condition is present.

L. Exhaust Fan – (EF-06)

1. General

a. Fan, normally off.
b. Fire Smoke Dampers (As applicable), normally open, fail close.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the fan on a smoke condition via hardwired interlock to the fan starter
2) Fire Smoke Damper on makeup air opening and fire smoke damper on exhaust duct connected to fan shall each be provided with open end switch. End switch for both fire smoke dampers proving open shall allow the fan to be started via hardwired connection to fan starter.

3. System Off:

a. When the system is off, fan shall be in its normal position as stated above.

4. System Start-Up:

a. The exhaust fan shall be started/stopped by the BMS based on a time of day schedule or manual command from the BMS workstation. The BMS contractor shall set the initial operations to coincide with the facility occupied times.
b. On a stop command the fan shall stop.

5. Fire/Smoke Event:

a. The fan shall be turned off (if not already off) directly via a relay from the Fire Alarm system; the fan shall stay off as long as a Fire Alarm condition is present.

M. Exhaust Fan – (EF-07)

1. General

a. Fan, normally off.
b. Fire Smoke Dampers (As applicable), normally open, fail close.

2. Hardwired Safeties and Alarms:

a. Safeties shall be enabled at all times.

1) The FAS shall stop the fan on a smoke condition via hardwired interlock to the fan starter
2) Fire Smoke Damper on transfer air opening and fire smoke damper on exhaust duct connected to fan shall each be provided with open end switch. End switch for both fire smoke dampers proving open shall allow the fan to be started via hardwired connection to fan starter.

3. System Off:

a. When the system is off, fan shall be in its normal position as stated above.

4. System Start-Up:

a. The system shall be enabled and started automatically in event of power outage or via a manual command from the BMS workstation.

b. On a stop command the fan shall stop.

5. Fire/Smoke Event:

a. The fan shall be turned off (if not already off) directly via a relay from the Fire Alarm system; the fan shall stay off as long as a Fire Alarm condition is present.

~~J.~~**N.** Supply Fan – (SF-01)

1. General

a. Fan, normally off.

2. Safeties shall be enabled at all times.

a. The FAS shall stop the fan on a smoke condition via hardwired interlock to the fan starter
b. Fire Smoke Damper adjacent to the fan shall be provided with open end switch. End switch proving open shall allow the fan to be started via hardwired connection to fan starter.

3. System Off:

a. When the system is off, fan shall be in its normal position as stated above.

4. System Start-Up:

a. The system shall be enabled and started via seasonal / time of day schedule or via a manual command from the BMS workstation.

b. The temperature control loop shall be started.

5. Temperature Control Mode:

~~a. The fan shall start / stop to maintain space temperature at setpoint (adjustable).~~

~~b.~~**a.** The fan shall start / stop to maintain space temperature at setpoint of +10F above ambient (adjustable);

~~c.~~**b.** If after the operation of the fan for 10 minutes (adjustable) the space temperature is less than that of the setpoint the fan shall be stopped.

6. Fire/Smoke Event:

a. The fan shall be turned off (if not already off) directly via a relay from the Fire Alarm system; the fan shall stay off as long as a Fire Alarm condition is present.

O. Smoke Exhaust Fans (SEF-XX; Typical for a pair of smoke exhaust fans)

1. General

a. Duty fan, normally on.
b. Standby fan, normally off.
c. Fan system (SEF pairs) shall be interlocked (via BMS) with the corresponding AHU (pairings provided below).
AHU/SEF pairings

1) AHU-01 paired with SEF-01/02.
2) AHU-04 paired with SEF-03/04.
3) AHU-05 paired with SEF-05/06.

2. Normal Mode Operation:

a. The duty fan shall be enabled and started, via the fan starter, by the BMS upon startup of the corresponding AHU; fan system operation shall be interlocked with the AHU through BMS programming.

3. Fire/Smoke Event:

a. Fire Alarm System will override the fan operation via a FAS relay to the starter; refer to Division 26 Drawings & specs for Fire/Smoke mode sequence of operations.

4. Alarms

a. An alarm shall be generated on the BMS if a duty fan is not running, as confirmed by a current sensor status, when commanded to run from/by the BMS.

5. Fan Rotational Program (Normal Mode):

Fan operation assignment shall rotate automatically, from duty to standby fan, on a monthly basis (adjustable) to ensure equal run time for all fans.

a.

b. Operation shall enable rotation only during normal operation.

6. Fan Failure

a. If the duty fan fails or fails to start, the standby fan becomes the duty and an alarm is generated at the BMS operator workstation.

~~K.~~**P.** Primary Chilled Water System

1. General

a. The system shall consist of the following

1) ~~Four~~ **Five** (~~4~~**5**) constant flow chillers, normally off.
2) F**ive**~~our~~ (**5**~~4~~) chilled water isolation valves, isolation type, normally closed.
3) F**ive**~~our~~ (~~4~~**5**) Primary chilled water pumps, constant flow type, normally off.

2. System Off

a. When the system is off, all equipment shall be in its normal position as stated above.

3. Lead Chiller Operation

a. It is expected that the chillers are to be scheduled on to run 24/7 basis or manually enabled by the BMS operator.
b. Each pump is paired to a chiller, and shall be interlocked with the corresponding chiller operation, via the BMS.
c. Once enabled the BMS shall initiate the condenser water system, refer to related sequences for operational details.
d. Once enabled the BMS shall select the lead chiller via the rotational program.
e. The lead chiller supply isolation valves shall be commanded open, and valve status shall prove open via valve end switches.
f. The BMS shall start selected lead chiller pump upon chiller supply water isolation valve open position.
g. When “enabled” by the BMS the chiller’s controller shall maintain a constant chilled water supply temperature setpoint of 42degF +/-1degF (adjustable).
h. Once the primary chilled water loop is operational the secondary chilled water loops shall be enabled. Refer to related sequences section.
i. Once the secondary system is operational the primary chilled water system shall go into primary chilled water control and initiate secondary chilled water control.

4. Primary Chilled Water Control:

a. The primary chilled water system design is that of a constant flow which must always be greater than that of the **variable** secondary chilled water loop.
b. To manage this requirement, lag chillers shall be enabled **and disabled as needed to maintain the flow differentials**.
~~b.~~**c. Any excess primary flow**~~The excess flow~~ shall flow back to the **primary** chilled water return loop via the decoupler thereby ensuring positive flow in the decoupler loop and design chilled water temperature delivery to the secondary chilled water side.

d. The chiller staging shall be in accordance with the sequence:

~~Bypass Flow = Primary Flow – Secondary Flow~~

1) Stage lag chiller on when Bypass Flow < 50 gpm (adjustable) for 5 minutes (adjustable)

2) De-stage lag chiller when Bypass Flow > 50 gpm (adjustable) + rated flow of a single chiller for 5 minutes (adjustable)

~~If~~ **Definition** ~~–~~**: Bypass Flow = Primary Flow – Secondary Flow**

~~c. at any time the Load Run Amps (LRA) exceeds 80% for more than 10 minutes (adjustable) the lag chiller and lag chilled water pump shall be initiated. Refer to Lag Chiller Operation Mode~~

~~5. Lag Chiller Operation Mode~~

~~a. Once initiated the BMS shall initiate a demand limit to the lead chiller (s), limit shall be set to 50% (adjustable) Limit provided to ease continued operation of lead chiller while staging lag chiller. Limit to last only for a period of one minute (adjustable, time to be coordinated with lag startup).~~

~~b.~~**e.** Once ~~enabled~~ **staging is required** the BMS shall the select the ~~subsequent~~ lag chiller via the rotational program.

~~c.~~**f.** The BMS shall enable the lag chiller in the same manner as the lead chiller including the condenser water system.

~~d.~~**g.** The lead and lag chillers shall both run to the same chilled water setpoint and share the cooling load.

~~e.~~**h.** ~~**If at any time the secondary chilled water loop is less than 45% of the primary chilled water loop flow for more than 5 minutes (adjustable**~~Upon low load conditions as noted by either chiller operating at Load Run Amps (LRA) less than 30% for more than 10 minutes (adjustable) ~~)~~ the lag chiller and related pumps shall be destaged. ~~~~Destaging shall consist of turning off the chilled water and condenser pumps, closing the chilled water, condenser water valves and the tower return valves and disabling the lag chiller.

~~6.~~**5.** Alarms

a. an alarm will be generated on the BMS shall be generated if any of the following conditions develop.

1) The expansion tank low pressure condition below setpoint.
2) Chilled water supply temperature is +/- 5 DegF from setpoint.
3) Flow meters register 10% deviation from design flow setpoint.
4) Differential Pressure across chiller chilled water bundle is +/- 3 psi from setpoint

6. Rotational Program:

a. Lead/Lag chillers and pumps operation assignment shall rotate automatically on a weekly basis to ensure equal run time for all chillers and pumps.

b. If a lead chiller or pump fails or fails to start, the lag chiller or pump becomes the lead and an alarm is generated at the BMS operator workstation.

~~L.~~**Q.** Secondary Chilled water system

1. General

   a. The system shall consists of the following

      1) Secondary Chilled Water Pump 1, Lead, VFD driven, 0% off.
      2) Secondary Chilled Water Pump 2, Lag, VFD driven, 0% off.
      3) Secondary Chilled Water Bypass valve, Modulating, normally closed.
      4) Multiple system differential pressure transmitters

2. System Off

   a. When the system is off, all equipment shall be in its normal position as stated above.

3. System Start

   a. It is expected that the chillers are to be scheduled on to run 24/7 basis or manually enabled by the BMS operator.
   b. Once enabled the BMS shall select the lead pump via the rotational program.
   c. When enabled the lead pump shall start and ramped up to minimum speed (Adjustable - initially set to 25%). The system shall then be indexed to pump flow control.

4. Pump Flow Control

   a. The differential pressure sensor indicating the highest demand (refer to mechanical drawings for quantities and locations) shall modulate the lead pump VFD to maintain the differential pressure setpoint (adjustable-coordinate final setpoint with balancing contractor).
   b. If during startup the minimum speed of the pump exceed system differential pressure setpoint, the Minimum Bypass Differential Control mode shall be initiated. See below for sequences.
   c. On a further demand for chilled water when the lead pump VFD approaches 100% speed output the lag pump shall be enabled.
   d. The lead pump shall ramp down and the lag pump shall ramp up in a synchronized manner.
   e. Both lead and lag pump VFD's shall be modulated in unison to maintain the differential pressure setting.
   f. On a drop in chilled water demand when both the lead and the lag pump VFD's have modulated down below 40% speed setting the lag pump shall be disabled.
   g. On a further decrease in demand from the system the lead pump VFD speed shall decrease to maintain differential setpoint. The system shall go into minimum bypass differential control on a further decrease in demand from the system as defined by the following,

      1) The Bypass Valve closed
      2) The lead pump VFD at minimum for 5 minutes (adjustable)
      3) Differential transmitter value is above setpoint by 1 PSI (adjustable)

5. Minimum Bypass Differential Control

   a. The pump VFD shall remain at minimum speed. The bypass valve shall be allowed to modulate to maintain the minimum bypass differential setpoint.

b. Minimum bypass differential control shall be maintained until the following occurs;

1) An increase in demand as noted by the bypass control valve being closed for 5 minutes (adjustable)
2) Differential value is below the minimum bypass differential setpoint by 1 PSI (adjustable).
3) At this time the system shall go back to normal differential pressure control.

~~6. Secondary chilled water Pump Minimum Flow Bypass Control – Pressure Control via BMS~~

~~a. The secondary chilled water pumps shall modulate to maintain the differential setpoint (adjustable). On an increase in demand from the system the duty pump VFD speed shall increase to maintain differential setpoint. On a decrease in demand from the system the duty pump VFD speed shall decrease to maintain differential setpoint. The system shall go into minimum bypass differential control on a further decrease in demand from the system as defined by the following,~~
~~b. The Bypass Valve closed~~
~~c. The pump VFDs at minimum for 5 minutes (adjustable)~~
~~d. Differential transmitter value is above setpoint by 1 PSI (adjustable)~~
~~e. Minimum Bypass Differential Control~~

~~1) The pump VFD shall remain at minimum speed. The minimum bypass valve shall be allowed to modulate to maintain the minimum bypass differential setpoint (equal to the differential setpoint plus 1 PSI (adjustable).~~
~~2) Minimum bypass differential control shall be maintained until the following occurs;~~
~~3) An increase in demand as noted by the bypass control valve being closed for 5 minutes (adjustable)~~
~~4) Differential value is below the minimum bypass differential setpoint by 1 PSI (adjustable).~~
~~5) At this time the system shall go back to normal differential pressure control.~~

~~7.~~**6.** Fire Alarm Shutdown

a. All chillers and pumps will be turned off, and all valves shall be indexed to normal positions (see above) during a Fire Alarm condition.

~~M.~~**R.** Condenser Water System

1. General

a. The condenser water system is comprised of a multistage cooling tower. Primary condenser water pumps circulate condenser water through electric chillers before discharging to 1st stage cooling tower distribution basins. Water falls through the fill and drains to the 1st stage cooling tower collection basins. Secondary condenser water pumps draw from the 1st stage cooling tower collection basins and pump to the 2nd stage cooling tower distribution basins. Water falls through the fill and drains to the 2nd stage cooling tower collection basins. The primary condenser water pumps draw from the 2nd stage cooling tower collection basins and pump to the electric chillers to complete the cycle.
b. The multistage cooling tower is divided into a north and south side. The north side of the cooling tower is sized for 100% condenser water flow from three (3) chillers. The south side of the cooling tower is sized for 100%

condenser water flow from two (2) chillers. The north/south split of the cooling tower allows one side to be taken out of service for maintenance while maintaining a reduced capacity.

c. The system shall consist of the following

1) Five (5) constant flow primary condenser water pumps, VFD driven, 0% off.
2) Side stream filtration system, normally off.
3) Five (5) constant flow condenser water electric chillers, normally off.
4) Five (5) condenser water control valves, isolation type, normally closed.
5) Chemical water treatment system, normally off.
6) Two (2) 1st stage distribution basin control valves, isolation type, normally closed.
7) Two (2) 1st stage distribution basin bypass control valves, isolation type, normally closed.
8) Two (2) 2nd stage distribution basin bypass control valves, isolation type, normally closed.
9) Secondary condenser water pump (SCWP-01), Lead, VFD driven, 0% off.
10) Secondary condenser water pump (SCWP-02), Lag, VFD driven, 0% off.
11) Two (2) 2nd stage distribution basin control valves, isolation type, normally closed.
12) Two (2) makeup water control valves, isolation type, normally closed.
13) Water softener system, normally off.

2. System Off

a. When the system is off, all equipment shall be in its normal position as stated above.

3. Condenser Water System Start/Stop – Initial Operation

a. The 1st and 2nd stage collection basins shall be manually filled to nominal level by makeup water connections prior to initial operation of condenser water system to ensure the condenser water pumps have a reservoir to draw from.
b. The condenser water system shall be enabled to run whenever any chiller is required to operate.
c. Once the condenser water system is enabled the BMS shall select the primary condenser water pump and condenser water isolation valve associated with the selected chiller as determined by the BMS rotational program to provide the condenser water flow required.
d. The BMS shall proceed to:

1) Open the selected chiller's condenser water isolation valve
2) Open the selected 2nd stage distribution basin bypass control valves

e. Upon BMS receipt of the proof of open status from the chiller's isolation valve end switch and the selected 2nd stage distribution basin bypass control valves' end switch, the BMS shall start the selected primary condenser water pump.
f. The BMS shall select the lead secondary condenser water pump as determined by the BMS rotational program to provide the condenser water flow required.

g. Upon BMS receipt of the proof of operation from the primary condenser water pump's current sensor, the BMS shall proceed to:

1) Open the selected 1st stage distribution basin control valves
2) Close the 2nd stage distribution basin bypass control valves
3) Open the selected 2nd stage distribution basin control valves

h. Upon BMS receipt of the proof of open status from the selected 1st stage distribution basin control valves and selected 2nd stage distribution basin control valves, the BMS shall start the lead secondary condenser water pump.

i. When enabled the lead pump shall start and ramp up to minimum speed (Adjustable - initially set to 25%). The system shall then be indexed to 1st stage collection basin level control.

4. 1st Stage Collection Basin Level Control

a. Each 1st stage collection basin section shall be provided with a BMS contractor provided BMS monitoring analog level transmitter.

b. The analog level transmitter shall modulate the lead secondary condenser water pump VFD to maintain the nominal 1st stage collection basin level setpoint (see mechanical drawings for detail).

c. On a further decrease in 1st stage collection basin level below low level when the lead secondary condenser water pump VFD approaches 100% speed (adjustable) output the lag pump shall be enabled.

d. The lead secondary condenser water pump shall ramp down and the lag secondary condenser water pump shall ramp up in a synchronized manner.

e. Both lead and lag secondary condenser water pump VFD's shall be modulated in unison to maintain the nominal 1st stage collection basin level setpoint.

f. On an increase in 1st stage collection basin level above high level when both the lead and the lag secondary condenser water pump VFD's have modulated down below 40% speed (adjustable) setting the lag secondary condenser water pump shall be disabled and the lead secondary condenser water pump VFD shall modulate to maintain the nominal 1st stage collection basin level setpoint.

g. The BMS shall generate the following alarms, level heights to be determined during final commissioning of system by TAB and coordinated with controls contractor.

1) Low-low level alarm (critical alarm)
2) Low level alarm
3) High level alarm
4) High-high level alarm (critical alarm).

h. Level monitoring for alarming purposes shall be limited to the 1st stage collection basin in operation. The BMS shall allow for a collection basin maintenance mode which shall temporarily defeat alarming in a collection basin being maintained.

i. If the water level of any of the active 1st stage collection basins fall below its low-low level:

1) A critical alarm shall be raised on the BMS operator's workstation
2) The lead secondary condenser water pump shall be turned off
3) The selected 1st stage distribution basin control valves shall close

4) The selected 2nd stage distribution basin bypass control valves shall open
5) The selected 2nd stage distribution basin control valves shall close

j. If the water level of any of the active 1st stage collection basins reaches its high-high level:

1) A critical alarm shall be raised on the BMS operator's workstation
2) The lead secondary condenser water pump shall be turned off
3) The selected 1st stage distribution basin control valves shall close
4) The selected 2nd stage distribution basin bypass control valves shall open
5) The selected 2nd stage distribution basin control valves shall close

k. An alarm shall be raised when a collection basin containing water has not been in use for greater than seven days(adjustable), the alarm message shall instruct the operators to drain the basin.

5. 2nd Stage Collection Basin Level Control

a. Each 2nd stage collection basin section shall be provided with a BMS contractor provided BMS monitoring analog level transmitter.
b. The analog level transmitter shall modulate the makeup water control valves to maintain the nominal 2nd stage collection basin level setpoint (see mechanical drawings for detail).
c. The BMS shall generate the following alarms, level heights to be determined during final commissioning of system by TAB and coordinated with controls contractor.

1) Low-low level alarm (critical alarm)
2) Low level alarm
3) High level alarm
4) High-high level alarm (critical alarm).

d. Level monitoring for alarming purposes shall be limited to the 2nd stage collection basin in operation. The BMS shall allow for a collection basin maintenance mode which shall temporarily defeat alarming in a collection basin being maintained.
e. If the water level of any of the active 2nd stage collection basins fall below its low-low level:

1) A critical alarm shall be raised on the BMS operator's workstation
2) All condenser water valves and pumps shall return to normal position described above.

f. If the water level of any of the active 1st stage collection basins reaches its high-high level:

1) A critical alarm shall be raised on the BMS operator's workstation
2) All condenser water valves and pumps shall return to normal position described above.

g. An alarm shall be raised when a collection basin containing water has not been in use for greater than seven days(adjustable), the alarm message shall instruct the operators to drain the basin.

~~1.~~ **Condenser Water System Operation for Staging On Additional Chiller**~~General~~
6.

a. The condenser water system shall be required to increase its total flow output when additional lag chillers are required to operate.
b. The BMS shall select the primary condenser pump and condenser water isolation valve associated with the selected lag chiller as determined by the BMS rotational program to provide the condenser water flow required.
c. The BMS shall be programmed to ensure that the three (3) chillers and their associated primary condenser water pumps connected to the north side of the cooling tower may operate with the cooling tower south side out of service and the two (2) chillers and their associated primary condenser water pumps connected to the south side of the cooling tower may operate with the cooling tower north side out of service.[RP1][CB2]
d. The BMS shall proceed to:

1) Open the lag chiller isolation valve

~~a.~~ **Upon BMS receipt of the proof of open status from the lag chiller's isolation valve end switch and the selected 1st stage distribution basin control valves' end switch, the BMS shall start the selected primary condenser water pump.**~~The condenser water system is designed to operate with a constant condenser water flow through each operating chiller. Each chiller~~
e.
f. When enabled the selected primary condenser water pump shall start and ramp up to required condenser water flow over a 30 second (adjustable) time period.
g. The system shall then be indexed to 1st stage collection basin level control.

7. Condenser Water System Operation for Staging Off a Chiller

a. The selected chiller to be disabled has an associated primary condenser water pump and isolation valve which shall be controlled to support the staging off of the selected chiller.
b. The chiller selected to be turned off shall have its dedicated primary condenser water pump turned off.
~~b.~~ **Once the pump has been turned off the chiller isolation valve shall be closed, and proven closed via the valve end switch.**~~The condenser water system consists of the following:~~
~~c. Four constant flow condenser water pumps, provided with starters~~
~~d. Four constant flow condenser water electric chillers~~
~~e. One cooling tower with means for basin separation into two equal halves.~~
~~f. Four cooling tower return control valves, modulating type, normally closed.~~
~~g. Four chiller condenser water supply isolation valves, two position type, normally closed.~~
~~h. Condenser Water Sand Filtration System~~
~~i. Condenser Water System Start/Stop – Initial Operation~~
~~j. The condenser water system shall be enabled to run whenever any chiller is required to operate.~~
~~k. Once the condenser water system is enabled the BMS shall select the condenser pump and cooling tower return control valve associated with the selected chiller as determined by the BMS rotational program to provide the condenser water flow required.~~
~~l. The BMS shall proceed to open the following valves;~~
~~m. Chiller specific tower return valve~~
~~n. Selected chiller's condenser water isolation valve~~

~~c. Upon BMS receipt of the proof of open status from the chiller's isolation valve end switch and the cooling tower return valve's position feedback, the BMS shall start the selected condenser water pump.~~

~~2. Condenser Water System Operation for Staging On Additional Chiller~~

~~a. The condenser water system shall be required to increase its total flow output when additional lag chillers are required to operate.~~

~~b. The BMS shall select the condenser pump and cooling tower return control valve associated with the selected lag chiller as determined by the BMS rotational program to provide the condenser water flow required.~~

~~c. The BMS shall proceed to open the following valves;~~

~~1) Lag Chiller specific tower return valve~~

~~2) Selected chiller's condenser water isolation valve~~

c. Upon BMS receipt of the proof of open status from the lag chiller's isolation valve end switch and the cooling tower return valve's position feedback, the BMS shall start the selected condenser water pump.

~~d.~~ **The system shall then be indexed to 1st stage collection basin level control.**

d.

~~3.~~ **Proposed Condenser Water System Sequencing**~~Condenser Water System Operation for Staging Off a Chiller~~

8.

a. (1) chiller and (1) primary condenser water pump operate at 100% flow

1) (1) secondary condenser water pump operates at 25% flow
2) Condenser water flow evenly split between north and south side of cooling tower
3) North side operates at 17% flow capacity, south operates at 25% flow capacity

b. (2) chillers and (2) primary condenser water pumps operate at 100% flow

1) (1) secondary condenser water pump operates at 50% flow
2) Condenser water flow evenly split between north and south side of cooling tower
3) North side operates at 33% flow capacity, south operates at 50% flow capacity

c. (3) chillers and (3) primary condenser water pumps operate at 100% flow

1) (1) secondary condenser water pump operates at 75% flow
2) Condenser water flow evenly split between north and south side of cooling tower
3) North side operates at 50% flow capacity, south operates at 75% flow capacity

d. (4) chillers and (4) primary condenser water pumps operate at 100% flow

1) (2) secondary condenser water pumps operate at 50% flow
2) Condenser water flow evenly split between north and south side of cooling tower
3) North side operates at 67% flow capacity, south operates at 100% flow capacity[RP3][CB4]

e. (5) chillers and (5) primary condenser water pumps operate at 100% flow

1) (2) secondary condenser water pumps operate at 62.5% flow
2) Condenser water flow split 60% to north and 40% to south side of cooling tower

f. North side operates at 100% flow capacity, south operates at 100% flow capacity

~~a. General - The selected chiller to be disabled has an associated condenser water pump and cooling tower return valve which shall be controlled to support the staging off of the selected chiller.~~
~~b. The chiller selected to be turned off shall have its dedicated condenser water pump turned off.~~
~~c. Once the pump has been turned off the chiller condenser isolation valve shall be closed, and proven closed via the valve end switch.~~
~~d. The Chiller specific tower return valve shall be closed, and proven closed via position feedback.~~

~~4. Cooling Tower Basin Level Controls and Monitoring~~
~~a. Each cooling tower basin section shall be provided a self contained make up water system.~~
~~b. Each cooling tower basin section shall be provided a contractor provided BMS monitoring analog level sensor. The BMS shall generate the following alarms, level heights to be determined during final commissioning of system by TAB and coordinated with controls contractor.~~
~~1) Low-low level alarm (critical alarm)~~
~~2) High-high level alarm (critical alarm).~~
~~c. The analog level sensors located in the tower basins shall be used to monitor basin levels and determine whether a High-High or Low-Low level has been reached.~~
~~d. Level monitoring for alarming purposes shall be limited to the tower basins in operation. The BMS shall allow for a basin maintenance mode which shall temporarily defeat alarming in a basin being maintained.~~
~~e. If the water level of any of the active basins fall below its low-low level, a critical alarm shall be raised on the BMS operator's workstation.~~
~~f. If the water level of any of the active basins reaches its high-high level switch, a critical alarm shall be raised on the BMS operator's workstation.~~
~~g. An alarm shall be raised when a cooling tower basin containing water has not been in use for greater than seven days(adjustable), the alarm message shall instruct the operators to drain the basin.~~

~~N.~~**S.** Rotational Program:

1. Equipment operation assignment shall rotate automatically on a monthly basis (adjustable) to ensure equal run time for all chillers and pumps.

~~1.~~ **If a lead or lag chiller or pump fails or fails to start, the subsequent lag chiller and pump becomes the lead and an alarm is generated at the BMS operator workstation.**

~~2. If a lead or lag chiller or pump fails or fails to start, the subsequent lag chiller and pump becomes the lead and an alarm is generated at the BMS operator workstation.~~
~~O. Heat Exchanger - N2 Boost Compressors (HX-01/02 & P-01/02)~~
~~1. General~~
~~a. The system shall comprise of the following:~~
~~1) Constant flow Heat Exchangers, HX-01~~
~~2) Constant flow Heat Exchangers, HX-02~~
~~3) Duty Pump P-01, constant flow, balanced by TAB contractor via VFD, normally off.~~
~~4) Duty Pump P-02, constant flow, balanced by TAB contractor via VFD, normally off.~~

5) Modulating Valve, HX-01 Primary side, normally closed, fail in place.
6) Modulating Valve, HX-02 Primary side, normally closed, fail in place.
7) Isolation Valve, HX-02 Secondary side, normally closed, fail open.
8) Isolation Valve, HX-01 Secondary side, normally closed, fail open.
2. System Start-up
a. The system shall be enabled by manual command at the workstation.
b. HX-01 and HX-02 secondary side isolation valves shall be opened.
c. Upon both isolation valves proving open via end switches both duty pumps shall turn on and ramp up to programmed setpoint (Setpoint coordinated with TAB Contractor to design setpoint)
d. Both HX-01 and HX-02 primary side modulating valves shall be modulated to maintain secondary side supply temperature at setpoint (adjustable).
3. Lag Pump Operation
a. Upon failure of either duty pumps the BMS shall generate an alarm at the BMS workstation, shall turn failed pump off and ramp remaining duty pump to 100% / 60Hz to allow for continued operation.
4. Fire Alarm Shutdown
a. All pumps shall be turned off, and all valves shall be indexed to normal positions (see above) during a Fire Alarm condition.
5. Alarms
a. an alarm will be generated on the BMS shall be generated if any of the following conditions develop.
1) Secondary Side water supply temperature is +/- 5 DegF from setpoint.
2) Primary side and secondary side differential pressure across heat exchanger is +/- 3 psi from design setpoint (set initial design setpoint to 5 psi)
3) The expansion tank low pressure condition below setpoint.
P. Heat Exchanger – LBNF Experiment Equipment (HX-03/04 & P-03/04)
1. General
a. The system shall comprise of the following:
1) Constant flow Heat Exchangers, HX-03
2) Constant flow Heat Exchangers, HX-04
3) Duty Pump P-03, constant flow, balanced by TAB contractor via VFD, normally off.
4) Duty Pump P-04, constant flow, balanced by TAB contractor via VFD, normally off.
5) Modulating Valve, HX-03 Primary side, normally closed, fail in place.
6) Modulating Valve, HX-04 Primary side, normally closed, fail in place.
7) Isolation Valve, HX-04 Secondary side, normally closed, fail open.
8) Isolation Valve, HX-03 Secondary side, normally closed, fail open.
2. System Start-up
a. The system shall be enabled by manual command at the workstation.
b. HX-03 and HX-04 secondary side isolation valves shall be opened.
c. Upon both isolation valves proving open via end switches both duty pumps shall turn on and ramp up to programmed setpoint (Setpoint coordinated with TAB Contractor to design setpoint)
d. Both HX-03 and HX-04 primary side modulating valves shall be modulated to maintain secondary side supply temperature at setpoint (adjustable).
3. Alarms
a. an alarm will be generated on the BMS shall be generated if any of the following conditions develop.
1) Secondary Side water supply temperature is +/- 5 DegF from setpoint.
2) Primary side and secondary side differential pressure across heat exchanger is +/- 3 psi from design setpoint (set initial design setpoint to 5 psi)
3)**2.** The expansion tank low pressure condition below setpoint.

Q.**T.** Fuel Oil System Monitoring **(Filtration System and Transfer System)**

1. See Spec 231000 for details on Fuel Oil System.

2. The BMS shall monitor multiple dry contact output alarms from the Fuel Oil System controllers. Refer to approved submittal for number of alarm contacts and/or digital inputs to be monitored by the BMS.

~~2. The BMS will monitor a system alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.~~

3. The BMS will monitor a tank high level alarms, one per tank, through dry contact output from the system and an alarm will be generated on the BMS upon initiation.
4. The BMS will monitor a tank low level alarms, one per tank, through dry contact output from the system and an alarm will be generated on the BMS upon initiation.

~~5. The BMS will monitor a system alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.~~

~~R.~~**U.** Sump Pump Monitoring

1. The system will be provided by Div. 22.
2. The BMS will monitor a system status dry contact output from the system.
3. The BMS will monitor a common alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.

~~3.~~

~~S.~~**V.** Electrical Metering

1. The electrical meters will be provided by Div. 26.
2. The BMS will be integrated with the electrical meters.
3. Integration specifics shall be coordinated with the approved metering submittals, coordinate with Div. 26 for final integration protocols. BMS contractor responsible for all necessary BMS hardware and wiring to support the integration with the BMS.

~~T.~~**W.** Chemical Water Treatment System Monitoring

1. The BMS will monitor status of all Chemical Water Treatment System Pumps.

~~The BMS will monitor a common alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.~~

X. ~~Sand~~Side Stream Filtration System Monitoring

1. The BMS will monitor ~~a common alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation~~status of Side Stream Filtration System Pumps.
2. The side stream filter backwash cycle shall be timed to ensure that it does not coincide with the schedule for the water softener regen waste cycle. This is to ensure the basin gathering this drainage does not receive both flow rates at the same time.

Y. Water Softener System Monitoring

1. The BMS will monitor status of Water Softener System regen waste discharge.
~~1.~~2. The water softener regen waste cycle shall be timed to ensure that it does not coincide with the schedule for the side stream filtration system backwash cycle. This is to ensure the basin gathering this drainage does not receive both flow rates at the same time.

~~U.~~**Z.** Emergency Generators

1. Emergency Generators shall be controlled via the Generator Control System provided by Division 26
2. The BMS shall monitor and annunciate critical alarms from the BMS workstation. Refer to approved submittal for number alarm contacts and/or digital inputs to be monitored by the BMS.

~~V.~~**AA.** Air Compressor System Monitoring

1. The BMS will monitor a common alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.
2. The BMS will be integrated with the air compressors. Integration specifics shall be coordinated with the approved metering submittals, coordinate with Div. 26 for final integration protocols. BMS contractor responsible for all necessary BMS hardware and wiring to support the integration with the BMS.

~~W.~~**BB.** UPS Monitoring **(DIV 23)**

1. The BMS will monitor a common alarm dry contact output from the system and an alarm will be generated on the BMS upon initiation.

CC. Central Lighting Inverter Monitoring

1. All equipment by Div 26.
2. The BMS will be integrated with the Central Lighting Inverter Main Panel.
3. Integration specifics shall be coordinated with the approved metering submittals, coordinate with Div. 26 for final integration protocols. BMS contractor responsible for all necessary BMS hardware and wiring to support the integration with the BMS.
4. The BMS will monitor multiple dry contact alarm outputs from the system; alarms shall be annunciated at the BMS upon initiation.
~~1.~~

~~X.~~**DD.** Water Pressure Reducing Valve

1. The BMS will monitor a digital dry contact output from the system provided flow switch for status monitoring.

3.6 COMMISSIONING, TESTING AND ACCEPTANCE

A. Refer to Division 1 for requirements of controls system testing to be carried out by an independent testing contractor.

B. The installation contractor shall perform a three-phase commissioning procedure consisting of field I/O calibration and commissioning, system commissioning and integrated system program commissioning. Document all commissioning information on commissioning data sheets as contained in this specification or alternatively on commissioning data sheets as provided by the independent controls testing contractor and submitted for review prior to the work being carried out. Commissioning work, which requires shutdown of system or deviation from normal function, shall be performed when the operation of the system is not required. The commissioning must be coordinated with the FRA and construction manager to ensure systems are available when needed. Notify the operating personal in writing of the testing schedule so that authorized personnel from the FRA and construction manager are present throughout the commissioning procedure.

C. Field I/O Calibration and Commissioning

1. Prior to system program commissioning, verify that each control panel has been installed according to plans, specifications and approved shop drawings. Test, calibrate and bring on line each control sensor and device. Commissioning to include, but not be limited to:

   a. Sensor accuracy at 10, 50 and 90% of range.
   b. Sensor range.
   c. Verify analog limit and binary alarm reporting.
   d. Point value reporting.
   e. Binary alarm and switch settings.
   f. Actuator and positioner spring ranges.
   g. Fail safe operation on loss of control signal, electric power, network communications, etc.

2. Record calibration and test data on commissioning data sheets. Sufficient space should be provided near each point name for sign off.

D. System Program Commissioning

1. After control devices have been commissioned (i.e. calibrated, tested and signed off), each DDC program shall be put on line and commissioned. The contractor shall, in the presence of the FRA demonstrate each programmed sequence of operation and compare the results in writing. In addition, each control loop shall be tested to verify proper response and stable control, within specified accuracies. System program test results shall be recorded on commissioning data sheets and submitted for record. Any discrepancies between the specification and the actual performance will be immediately rectified and retested.

E. Integrated System Commissioning:

1. After all DDC programs have been commissioned, the contractor shall verify the overall system performance as specified. Tests shall include, but not be limited to the following:
2. Data communication, both normal and failure modes.
3. Fully loaded system response time.
4. Impact of component failures on system performance and system operation.
5. Time/Date changes.
6. End of month/ end of year operation.
7. Season changeover.
8. Global application programs and point sharing.
9. System backup and reloading.
10. System status displays.
11. Diagnostic functions.
12. Power failure routines.
13. Battery backup.

F. Acceptance Testing

1. Submit for approval, a detailed acceptance test procedure designed to demonstrate step by step testing of all BMS related sequences, systems and equipment, integration with external systems and compliance with contractual requirements. This Acceptance test procedure will take place after the commissioning procedure, in addition to the testing described above the testing will verify that sensors and control devices maintain specified accuracies and the system performance does not degrade over time.

2. Using the commissioning test data sheets, the contractor shall demonstrate all point types as required by FRA/engineer. The contractor shall supply all instruments for testing and turn over same to the FRA after acceptance testing.

   a. All test instruments shall be submitted for approval.

G. Test instrument accuracy

Temperature:	1/4°F or 1/2% full scale, whichever is less.
High Pressure (psi):	1/2 psi or 1/2% full scale, whichever is less.
Low Pressure (in w.c.):	1/2% of full scale
Humidity:	2% RH
Electrical:	1/4% full scale

H. Verification Testing

1. System verification testing is part of the Commissioning Process. Verification testing shall be performed by the contractor and witnessed and documented by the Engineer. The commissioning process requires detailed O&M documentation.

I. For systems being commissioned, training of the FRA's operation and maintenance personnel is required in cooperation with the FRA and the commissioning agent. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the FRA. Refer to division 01 section 019113 commissioning for detailed commissioning requirements.

3.7 CLOSEOUT

A. Substantial Completion Requirements:

1. Provide Final Cleaning immediately prior to Substantial Completion inspection.
2. Corrective Work:

   a. Remove, Repair and Reinstall, or Restore in Place damaged items.
   b. Replace damaged materials or items with New if repair not acceptable to FRA Construction Coordinator.

3. Provide product data to complete Operation & Maintenance Manuals.
4. Submit executed Warranties.

3.8 DEVICE AND INPUT/OUTPUT SCHEDULE

A. Refer to design drawings for device and input/output schedules.

END OF SECTION 230923