SAN FRANCISCO UNIFIED SCHOOL DISTRICT
FACILITIES DESIGN & CONSTRUCTION

Bid Package 3
Boiler Replacements
Mission High School and Flynn Elementary School

ADDENDUM NO. 1

PROJECT: **Mission HS**
3750 18th Street
San Francisco, 94114

Flynn ES
3125 Cesar Chavez Street
San Francisco, 94110

DATE: 13 FEBRUARY 2015

OWNER: San Francisco Unified School District
135 Van Ness Avenue
San Francisco, CA 94103

DSA FILE NO.: N/A

DSA APP. NO.: N/A

Notice is hereby given to all prospective bidders that plans and specifications on the subject project are modified as hereinafter set forth. This Addendum shall be attached to and form a part of the plans and specifications. All bidders must acknowledge receipt of this addendum on the Bid Form. In case of difference with previous addenda or communications, this addendum takes precedence.

It is the responsibility of all bidders to notify all subcontractors from whom they request bids and from whom they accept bids of all changes contained in this addendum.

PROJECT MANUAL

Item 1: Section 00010 Table of Contents
Replace Section 00010 with new Section 00010 dated 3/13/2015

Item 2: Add Sections:
01810 General Commissioning Requirements
15900 Instrumentation and Control Performance Specifications
15945 Commissioning of HVAC

END OF ADDENDUM ITEMS

ATTACHMENTS:

Specifications
Sections 00010, 01810, 15900 and 15945

SECTION 00010

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DIVISION 5 – METALS (Not Used)

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APPENDIX A

Hazardous Materials Specifications as prepared by SCA Environmental, Inc. dated February 16, 2015.

END OF SECTION 00010

SECTION 01810

GENERAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

A. Work Included: Provision of materials, installation and testing of:
   1. Scope of systems and equipment to be commissioned.
   2. Commissioning duties and procedures at the site.

1.2 RELATED SECTIONS

A. Division 01, General Requirements applies to this Section.

B. Contents of Division 15 through 16 apply to this Section.

C. In addition, reference the following:
   1. 15945, Commissioning of HVAC

1.3 REFERENCES AND STANDARDS

A. References and Standards per Division 01, General Requirements, and:
   1. 15945, Commissioning of HVAC

B. In addition, meet the following:
   1. Current edition of the ASHRAE Guideline 0, The Commissioning Process.

1.4 SUBMITTALS

A. Submittals as required by Division 01, General Requirements, and:
   1. 15945, Commissioning of HVAC

B. In addition, provide:
   1. Use the following procedure to ensure quick and effective turnaround of submittals for systems to be commissioned.
      a. The Architect forwards one set of submittals for systems to be commissioned to the Commissioning Authority at the same time as the design team.
      b. The Commissioning Authority forwards comments to the design team for consideration in their submittal response.
      c. The design team sends a consolidated response to the submittals and copies the Commissioning Authority.

1.5 QUALITY ASSURANCE

A. Quality assurance as required by Division 01, General Requirements, and:
   1. 15945, Commissioning of HVAC

1.6 WARRANTY

A. Warranty of materials and workmanship as required by Division 01, General Requirements, and:
   1. 15945, Commissioning of HVAC

1.7 DEFINITIONS

A. Commissioning Authority: The Commissioning Authority is the person or entity referred to throughout the Contract Documents as if singular in number who works with the Owner's Representative under a separate Contract.

B. Commissioning:
   1. Commissioning is a process for achieving, verifying, and documenting that performance of a building and its various energy consuming systems meets the Design Engineer's design intent and the Owner's operational needs.
   2. Commissioning includes tests for the operation of equipment and building systems to ensure that they operate as designed by the Design Engineer, and meet the needs of the building throughout the entire range of operating conditions.
   3. Commissioning is a cooperative effort that requires participation by the Owner's Representative, General Contractor, system and equipment installers, building automation system installer, Testing and Balancing Agency, equipment manufacturers" representatives, Architect, Architect's design engineers, and Commissioning Authority.

C. Owner’s Project Requirements (OPR): Document that details the functional requirements and expectations of how the building will be used and operated. This may include project location, goals, cost considerations, equipment manufacturers, and environmental control requirements.

D. Basis of Design (BoD): A document that records concepts, calculations, decisions, and product selections used to meet the OPR and to satisfy applicable regulatory requirements, standards, and guidelines.

E. Commissioning Procedures:
   1. Inspection and testing procedures that are written by the Commissioning Authority for equipment and systems within the scope of commissioning.
   2. Inspection checklists typically address items of installation compliance with design intent and approved submittals.
   3. Functional performance test procedures typically address all sequences for normal and emergency equipment and system operation. These procedures consist of a mix of One-Time Tests and Continuous Measurement.
   4. One-Time Tests: Functional performance tests of equipment and systems that are performed by forcing specific conditions that are intended to trigger specific responses, per the design intent.

F. Continuous Measurements:

1. Functional performance tests of equipment and systems that are performed by observing parameters of normal operation over an extended period. This is typically accomplished by means of the BAS trend logging capabilities, by monitoring with stand-alone data logging equipment, or by some combination of both.
2. Temperature conditions in occupied spaces, control stability, and lighting levels in areas with daylighting controls are three typical subjects of continuous measurement.

G. Commissioning Plan: The document, provided by the Commissioning Authority, that states the required tests for all equipment and systems within the scope of commissioning.

H. Commissioning Meetings: Issues related to commissioning will be discussed as required during regularly scheduled progress meetings.

1.8 PERFORMANCE REQUIREMENTS

A. Testing, inspecting and performance monitoring tasks specified in this Section and in Sections 15945 is the responsibility of the Commissioning Authority, unless specifically indicated otherwise, and not part of the General Construction Contract. These tasks are included in these Sections for the Contractor's information, so the Contractor can understand the standards of system performance that are required and more effectively coordinate with the process of commissioning.

B. The Commissioning Authority will verify for the Owner's Representative that commissioned mechanical, plumbing, electrical, and controls system function interactively and in compliance with the Project design intent, and to facilitate orderly and efficient transfer of building operating systems to the Owner.

C. Commissioning does not relieve the Contractor of Contract obligations.

1.9 EQUIPMENT AND SYSTEMS TO BE COMMISSIONED

A. Systems:
1. HVAC Equipment
2. HVAC Controls.
3. Heating Water System
4. Security Systems

1.10 COMMISSIONING DUTIES

A. Duties of Owner: Provide the OPR to the Architect/Engineer and Commissioning Authority prior to design development.

B. Duties of Architect:
1. Attend commissioning portion of Progress Meetings as necessary, minimum two meetings.
2. Lead the design team in assisting the resolution of deficiencies.

C. Duties of Architect's Mechanical Engineer:
   1. Attend commissioning portion of Project Meetings as necessary, minimum two meetings
   2. At the request of either the Owner's Representative or the Commissioning Authority, review Commissioning Procedures and submit comments to Owner's Representative.
   3. Develop and provide the Basis of Design to Owner and Commissioning Authority prior to 50 percent CD.
   4. Assist in resolution of problems and deficiencies that are discovered during commissioning.
   5. Perform all construction checklists and provide copies of completed signed construction checklists.

D. Duties of Commissioning Authority:
   1. Attend commissioning portion of Project Meetings as necessary, minimum two meetings.
   2. Provide plan to Owner’s representative for review and comment.
   3. Prepare commissioning procedures for each commissioned system based on actual system configuration.
   4. Commissioning Procedures written by Commissioning Authority will include, in field data collection format, the detailed test procedures, test conditions, and criteria for acceptance of test results.
   5. Submit any commissioning procedures that are written by Commissioning Authority to the Owner's Representative for review and approval at least 1 week prior to scheduled field Testing.
   6. Provide personnel experienced in technical aspects of each system to be commissioned for execution of tests.
   7. BAS Sequence Demonstration:
      a. Witness the Control Contractor's demonstration of their sequence tests.
      b. If any of the demonstrated sequences fails to operate per the controls submittal, witness the repeat demonstration after corrective action has been taken.
   8. Execute the Commissioning Procedures.
   9. Prepare and submit Observation Reports and Deficiency Reports as required, but within 3 days of noting any deficiency.
   10. Submit to Owner's Representative a weekly written report of commissioning progress, unresolved deficiencies, and projected inspection, and test schedule during field testing.
   11. Take the lead in timely evaluation of deficiencies, and advise Owner's Representative on resolution.
   12. Assist in resolving commissioned system disputes by performing research to determine the scope of the dispute, and informing the involved parties on possible solutions to disputes.
   13. Prepare a Commissioning Report that includes a summary of overall commissioning process, including deficiencies found, deficiency corrections, unresolved deficiencies, approved equipment and systems, discrepancies between final design intent and as-built systems, completed commissioning checklists, test documentation, and other commissioning documentation.

E. Duties of General Contractor:
   1. Attend commissioning portion of Project Meetings as necessary, minimum four meetings.
   2. Participate in resolution of problems and deficiencies that are discovered during commissioning.
   3. Coordinate and direct system installers in executing their commissioning tasks.
   4. Coordinate with Commissioning Authority on integration of construction and commissioning schedules.
   5. Oversee and perform documentation requirements for all Pre-Functional Checklists.
   6. Notify Commissioning Authority when all the following has been achieved. It is permissible, with prior approval by Commissioning Authority, to provide notification for individual systems as the following are all completed for each system.
      a. All controls point-to-point and sequence checkout is complete.
      b. All test and balancing is complete.
      c. Normal equipment schedules have been activated
      d. All control overrides and temporary valves have been returned to normal automatic' control.
      e. All manual isolation valves have been left open.
      f. Piping and duct systems have been cleaned and tested.
      g. Heating water system is fully operational under normal automatic operation.
      h. Luminaires are installed with operational daylighting controls and occupancy sensors.
      i. Distribution boards, including overcurrent devices, containing breakers over 600 amps, are installed.
      j. Building inspector acceptance of emergency lighting system following their site inspection.
   7. Provide all startup, flushing, pressure testing, etc results/reports for commissioned systems.

F. Duties of Installer's and Manufacturer's Representatives:
   1. Attend commissioning portion of Project Meetings as necessary, minimum two meetings.
   2. Participate in resolution of problems and deficiencies that are discovered during commissioning.
   3. Within 3 months of the award of the Contract, as part of the required submittals for the contract, Contractor submits manufacturer's startup and installation procedures as well as controls point-to-point and sequence checkout and provides in checkset format for each piece of equipment and controls.
   4. Assist Commissioning Authority by completing certain Sections of the Commissioning Procedures.
   5. Commissioning does not relieve installers from obligations to complete Work as required by Contract Documents.

G. Duties of BAS Installer:

1. Attend commissioning portion of project meetings as necessary, minimum two meetings.
2. Review and approve Commissioning Procedures as relevant to controls work.
3. Point-to-Point Checkout:
   a. Perform point-to-point checkout and calibration of all energy management system points.
   b. Document checkout and calibration on forms as approved by mechanical designer, and/or Commissioning Authority.
   c. Submit three copies of the completed point-to-point checkout forms to the Owner's Representative within 5 working days of completion of field checkout. Distribute copies to the Commissioning Authority and the designer.
4. Control Sequence Testing:
   a. Prepare control sequence test procedure forms of a degree of rigor comparable to the Commissioning Authority's Commissioning Procedures.
   b. Submit test procedure forms to the Commissioning Authority for approval at least 2 weeks prior to intended sequence testing. At the contractor's option, it is acceptable to use the Commissioning Authority's Commissioning Procedures, substituting one-time tests for continuous measurement wherever applicable. However, it is still necessary to submit any edited Commissioning Authority Commissioning Procedures as least 2 weeks prior to intended sequence testing.
   c. Submit the completed sequence testing forms to the Owner's Representative. The Owner's Representative distributes copies to the Commissioning Authority and the designer.
5. Submit to Commissioning Authority, prior to Sequence Demonstration, two copies of installed control Drawings, sequence narratives, control wiring diagrams, and program code or block diagrams.
6. Sequence Demonstration:
   a. After completing and documenting all required sequence tests with own staff, demonstrate sequence tests to the Commissioning Authority.
   b. If any of the demonstrated sequences fails to operate per the controls submittal, take corrective action and demonstrate the failed sequence tests to the Commissioning Authority a second time.
   c. If the Control Contractor fails to demonstrate proper sequence operation in any of the second round of sequence tests, the Commissioning Authority's costs for witnessing all further demonstration of that sequence may be assigned to the Control Contractor by the Owner as a deduct to their contracted price. The Control Contractor will not be responsible for costs related to failure due to design or to other factors beyond their control, though it is expected to call any design concerns (and other factors beyond their control that might cause failure) to the attention of the Commissioning Authority and the Owner's Representative.
7. Assist Commissioning Authority with programming of the energy management system for trend logs to support functional performance testing during field testing.
8. Assist Commissioning Authority with execution of the Commissioning Procedures. Commissioning Authority will present test schedule at Progress Meeting at least 1 week ahead of scheduled tests.

9. The Commissioning Authority, acting with Owner authority, may request the Control Contractor to assist with or perform minor loop tuning adjustments, set point and schedule changes, and other similar minor field corrections.
10. Recommended changes to the controls sequences, program code, and recommendations for additional points must go through the Owner's Representative and the designer. The designer is the final authority on all recommended sequence changes, and will submit such changes to the Owner's Representative for implementation.
11. Submit to Owner's Representative, at least 2 weeks prior to Final Completion, two copies of as-built version of points list, including I/O and virtual points, controls Drawings, program printout, and sequence narratives.
12. Participate in resolution of problems and deficiencies that are discovered during commissioning.

H. Duties of Balancer:
1. Attend commissioning portion of Project Meetings as necessary, minimum two meetings.
2. Participate in resolution of problems and deficiencies that are discovered during commissioning.
3. Assist Commissioning Authority with execution of commissioning procedures.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 COMMISSIONING PROCEDURES AT THE SITE

A. Testing Techniques:
1. Each testing procedure may use a variety of techniques. Generally it is preferred to observe new and existing equipment and systems during normal operation.
2. When functional and emergency modes of operation occur rarely or seasonally, if possible, simulate the conditions that trigger these operational modes.
3. Simulation of conditions may involve changing set points, changing schedules, simulating pneumatic system pressures or energy management system voltages and currents, disconnecting power, jumpering contacts, or other such procedures.
4. Whenever temporary adjustments are made, restore the system to its original condition once tests are completed.
5. When testing requires observing equipment operation over an extended period, use the building energy management system's trend logging capabilities or independent monitoring equipment.
6. Do not use the building automation system trend logging in the commissioning process prior to point-to-point checkout by Controls Contractor and approval of point-to-point checkout by Commissioning Authority.

B. Commissioning Documentation:
1. The Contractors are required to perform startup and checkout of their systems (prefunctional testing) and document the results. The Commissioning Authority

will provide electronic forms that may be used by the Contractors. The Contractors may use their own forms if they contain all the required information on the Commissioning Authority's forms, but prior approval must be obtained.
   a. Where numeric data is required, a narrative entry or simple check-off is not acceptable.
   b. Annotate trend logs and monitored data as necessary to clarify meaning, and attach to relevant test reports.
   c. Do not attach irrelevant data to test reports.
2. The Contractor sends the startup and checkout forms to the Commissioning Authority when they are complete and functional. The Contractor sends a "Certificate of Readiness" with the forms which will signal that functional testing can begin.
3. Starting with prefunctional testing, the Commissioning Authority will e-mail an "issues log" weekly to inform the design and construction team of issues that need resolution. The "issues log" will open and close items as they are discovered and resolved until all items are closed.
4. The Commissioning Authority will assemble all the information from the Commissioning Plan (test forms, trend logs, issues log, and basis of design) into a final Commissioning Report.

C. Coordination of Commissioning and Equipment Startup: Do not initiate functional performance testing for equipment or systems in advance of their startup and checkout by affected equipment or system installers and manufacturers' representatives.

D. Test Acceptance Criteria:
1. Acceptance Criteria are the test results that are required before the mode of performance or inspection item in question will be considered acceptable.
2. Any procedures in Specification Sections 15945 that begin with "Verify that..." have an implied acceptance criterion that the sequence as stated is proven to occur and is documented with visual observation notes, measurements, trend logs, and/or monitored data.
3. Acceptance criteria for other functional modes and checklist items are as stated in each Section of the Commissioning Plan.
4. Input will be sought when necessary from the Architect's Engineer to determine if test results indicate compliance with Design Intent.
5. The Commissioning Authority will recommend acceptance or rejection of Commissioned System Work based on test results.

E. Resolution of Deficiencies:
1. Adjust, repair, or replace defective equipment and systems to meet Commissioning Procedure Acceptance Criteria as directed by Owner's Representative.
2. Inform the Owner's Representative and Commissioning Authority of the date for completion of corrective activities.
3. If the date for completion of corrective work passes without resolution of deficiencies, Owner's Representative reserves the right to obtain supplementary services and equipment to correct the problem as indicated in General Conditions.

F. Rechecking and Retesting Charges:
   1. In the event of a second failure of a specific commissioning procedure item or test, the responsible party may be assessed charges by Owner's Representative.
   2. Charges will be based on each party's actual expenses, including normal hourly billing rates for preparation, testing, and travel time, and materials, equipment rental, and travel expenses as applicable.

G. Construction and Acceptance Milestones for Tasks Related to Commissioning:
   1. Equipment, ductwork, and piping installation.
   2. Equipment startup.
   3. Pre-functional Checklists.
   4. Substantial completion.
   5. Point-to-point checkout and sequence testing of controls.
   6. Test and balance.
   7. Commissioning field testing.
   8. Occupant move-in.
   9. Final completion.
   10. Commissioning report submittal.

END OF SECTION

SECTION 15900

INSTRUMENTATION AND CONTROL PERFORMANCE SPECIFICATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. Work Included: Design (including detailed sequence of operations), materials, installation and testing of:
   1. Communications
   2. Operator Interface
   3. Controller Software
   4. BAS Graphics
   5. Building Controllers
   6. Application Specific Controllers
   7. Advanced Application Controllers
   8. Input/Output Interface
   9. Power Supplies and Line Filtering
   10. Control Panels
   11. Auxiliary Control Devices
   12. Wiring and Raceways

B. This is a performance specification and Contractor is responsible for design tasks and engineering.

1.2 RELATED SECTIONS

A. Contents of Division 15, HVAC and Division 01, General Requirements apply to this Section.

1.3 REFERENCES AND STANDARDS

A. References and Standards as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:
   1. Current edition of UL 916 Underwriters Laboratories Standard for Energy Management Equipment, Canada and the US.
   2. Current edition of FCC Part 15, Subpart J, Class A.

1.4 SUBMITTALS

A. Submittals as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, provide:

1. Prepare and submit a detailed schedule of work. Schedule to identify milestones such as equipment submittals, control panel diagrams, color graphic panel displays, Interlock.
2. Wiring diagrams, control program sequence software flow chart diagrams, conduit layout diagrams, device location diagrams, equipment and component deliveries, installation sequencing, controller startup, point to point startup, control programming, sequence testing, commissioning/acceptance testing and training.
3. Submit design drawings, sequences of operation, program listings, software flow charts and details for each typical piece of equipment and system being controlled. No work to be initiated or fabrication of any equipment started prior to the Owner's Representatives return of REVIEWED submittals.
    a. Sequence of Operation: Please note that the sequence of operation included in the design documents is intended only to communicate the Engineers' general control intent and is not to be used as a direct reference for programming of the EMS system. Verbatim duplication of the Engineer's Sequence of Operation on the submittals is discouraged and may result in non-approval of the submittal. Sequence of operation on submittals shall accurately detail the system's intended programming, and shall include details of all enhancements, adjustments, or deviations from the Engineer's sequence of operation. Submitted sequence of operation shall be written with a logical and organized format and flow. Sequence of operation language shall be detailed, clear, and unambiguous. Point descriptors and point nomenclature referenced in the submitted sequence of operation shall match those (to be) actually programmed. As-built submittal Sequence of Operation shall include all modifications to the programming made as a result of any addendum, bulletins, RFI's, change orders, and commissioning.
4. Format: Make each submittal in one complete and contiguous package. Partial or unmarked submittals will be rejected without review.
5. Submit Manufacturers Data as Follows:
    a. Complete materials list of items proposed to be furnished and installed. A complete Bill of Materials, listing materials, components, devices, wire and equipment are required for this work. The Bill of Materials to be separate for each controller on its own page(s) and to contain the following information for each item listed:
        1) Manufacturer's Name and Model number with furnished options highlighted.
        2) Quantity of each by controller location.
        3) Description of product (generic).
        4) Specified item.
        5) Operating range or span.
        6) Operating point or set point.
    b. Manufacturer's specifications and other data required demonstrating compliance with the specified requirements, including but not limited to: Catalog cuts, technical data and descriptive literature on hardware, software, and system components to be furnished.
    c. The data to be clearly marked and noted to identify specific ranges, model numbers, sizes, and other pertinent data. Submit printed manufacturer's

technical product data for each control device furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials and including printed installation instructions and start-up instructions.

d. Unless specifically called for otherwise, provide bound copies of catalog cuts for standard products, not requiring specifically prepared Shop Drawings, for the following:
   1) Wire and Cable, Class II
   2) Face Plates for Devices
   3) Disconnect Switches for Power Control

e. Where more than one item, size, rating or other variations appear on a catalog cut sheet, clearly identify items to be provided. These items to be properly indexed and referenced to identification numbers, designations and/or details on the Drawings.

6. Shop Drawings: Submit shop drawings for each controlled system, depicting the following information:
   a. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves and other control/monitoring devices.
   b. Label each control device with initial setting or adjustable range of control. Label points in schematic diagrams with termination at corresponding controller.
   c. Electrical Wiring: Clearly differentiate between portions of wiring that are factory installed and portions of be field-installed.
   d. Details of control panel faces, including controls, instruments, and labeling.
   e. Interfaces to equipment furnished under other Sections identifying numbers of wires, termination location, voltages and pertinent details. Responsibility for each end of the interfaces to be noted on these drawings whether or not they are a part of this Section.
7. Equipment locations, wiring and piping schematics, details, panel configurations, sizes, damper motor mounting details, valve schedules, and a points list keyed to specific hardware submittals. Control wiring depicted as fully annotated ladder diagrams with terminations identified, completely configured as to the exact panel, wiring, relay, switch, and component configuration.
8. Tag Number Lists: Develop instruments tag number system and submit list for approval. Coordinate methods and number block with the Owner Representative.
9. Format the Shop and Field Drawings to Include:
   a. A Title Sheet containing a drawing list, abbreviations list, symbols list, site and vicinity maps for project location and schedules.
   b. Floor Plans showing proposed device locations and device nomenclatures.
   c. A Riser Diagram illustrating conduit relationships between devices shown on the Floor Plans. Show device nomenclatures.
   d. A Single-Line Diagram for each system showing signal relationships of devices within the system. Show device nomenclatures.
   e. A Wiring Diagram for each assembly, enclosure or free standing device, showing:
      1) The Devices Within
      2) Wiring Connections
      3) Wire Identification
      4) Voltage Levels

5) Fuse Ratings

f. Operations and Maintenance Manuals:
   1) Following approval of Shop Drawings of control equipment and prior to acceptance of control work, prepare Operating and Maintenance manuals describing operating, servicing, and maintenance requirements of control systems and equipment installed under this Section, in accordance the General and Special Conditions of these Specifications.
   2) Information contained in the manual for the above equipment to include the following:
      a) Manufacturer's catalog cuts and printed descriptive bulletins.
      b) Manufacturer's installation, operating, and maintenance instruction booklets. Complete instructions regarding the operation and maintenance of equipment involved.
      c) Instrument calibration certificates.
      d) Parts list and costs.
      e) Complete nomenclature of replaceable parts, list of recommended spare parts for 12 months operation, their part numbers, current cost and name and address of the nearest vendor of replacement parts.
      f) Name, address and telephone number for closest source of spare parts.
      g) Wiring and schematic diagrams.
      h) Include final record copies of shop drawings.
      i) Copy of guarantees and warranties issued for the various items of equipment, showing dates of expiration.
      j) Reduced plans, diagrams, and control schematics.
      k) Copies of test results.
      l) Control System Operating Manual including: point of summary and point data base; complete printout of program listings; magnetic tape CD or DVD backup of Field Control Cabinet programs; cabinet layout; hard copy of graphic screens; hard copy of specified reports.

g. A final Bill of Quantities including a separate schedule for portable equipment, if delivered as part of this work.

h. Performance, Test and Adjustment Data: Comprehensive documentation of performance verification according to parameters specified in these specifications.

i. Record Drawings: Comply with Division 01, General Requirements and Section 15020, HVAC Basic Requirements. Provide complete as-built submittals including "as-programmed" sequence of operation as well as final occupancy schedules.

1.5 QUALITY ASSURANCE

A. Quality assurance as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:

1. Installer Qualifications: Company specializing in performing work of the type specified in this Section with minimum five year's experience in the local area. Installers required to have successfully completed manufacturer's control system factory training.

1.6 WARRANTY

A. Warranty of materials and workmanship as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

1.7 SYSTEM DESCRIPTION

A. Control system referenced throughout specifications and drawings as Building Automation System (BAS), Building Management System (BMS), or Energy Management System (EMS) interchangeably consists of high-speed, peer-to-peer network of DDC controllers, control system server, and/or operator workstation.

B. Control system server and/or operator workstation provides for overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.

C. System supports web browser access to building data. Remote user using standard web browser be able to access control system graphics and change adjustable set points with proper password.

D. Local Area Network (LAN) either 10 or 100 Mpbs Ethernet network.

E. System will consist of open architecture that is capable of:
1. High speed Ethernet communication using TCP/IP protocol
2. LonTalk protocol.

F. Complete temperature control system to be DDC with electronic sensors and electronic/electric actuation valves and dampers.

G. Prepare individual hardware layouts, interconnection drawings, building riser/architecture diagram and sequence of control from the project design data.

H. Design, provide, and install equipment cabinets, panels, data communication network infrastructure (including cables, conduits, outlets, connections, etc.) needed, and associated hardware.

I. Provide complete manufacturer's specifications for items that are supplied. Include vendor name and model number of every item supplied.

J. Provide a comprehensive operator and technician training program as described in these specifications.

K. Provide as-built documentation, operator's terminal software, diagrams, and other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

L. Provide 120V power, voltage power, transformers, etc. for control panels, transformer panels, and BAS devices. Install per Division 16, Electrical specifications. Power for devices within this specification Section are solely the responsibility of the BAS Contractor.

M. Conduit and raceway systems. Provide per Division 16, Electrical specifications.

1.8 SYSTEM PERFORMANCE

A. Performance Standards - System conforms to following minimum standards over network connections:
   1. Graphic Display: Graphic with 20 dynamic points display with current data within 10 seconds.
   2. Graphic Refresh: Graphic with 20 dynamic points update with current data within 8 seconds.
   3. Object Command: Devices react to command of binary object within 2 seconds. Devices begin reacting to command of analog object within 2 seconds.
   4. Object Scan: Data used or displayed at controller or workstation have been current within previous 6 seconds.
   5. Alarm Response Time: Object that goes into alarm be annunciated at workstation within 45 seconds.
   6. Program Execution Frequency: Custom and standard applications be capable of running as often as once every 5 seconds. Select execution times consistent with mechanical process under control.
   7. Performance: Programmable controllers be able to completely execute DDC PID control loops at frequency adjustable down to once per second. Select execution times consistent with mechanical process under control.
   8. Multiple Alarm Annunciation: Each workstation on network receive alarms within 5 seconds of other workstations.

B. Reporting Accuracy: System reports values with minimum end-to-end accuracy listed in Reporting Accuracy Table below.
   1. Reporting Accuracy Table:

Measure Variable	**Reported Accuracy**
Space Temperature	Plus or Minus 1 degree F
Ducted Air	Plus or Minus 1 degree F
Outside Air	Plus or Minus 2 degrees F
Dew Point	Plus or Minus 3 degrees F
Delta-T	Plus or Minus 0.25 degree F
Water Temperature	Plus or Minus 1 degree F

C. Control Stability and Accuracy. Control loops maintain measured variable at set point within tolerances listed in Control Stability and Accuracy Table below.
   1. Control Stability and Accuracy Table:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	Plus or minus 0 inch wg	0-6 inch wg
	Plus or minus 0.01 inch wg	-0.1 to 0.1 inch wg
Airflow	Plus or minus 10 percent of full scale	
Space Temperature	Plus or minus 2 degrees F	
Duct Temperature	Plus or minus 3 degrees F	

PART 2 - PRODUCTS

2.1 MANUFACTURERS/INSTALLERS

A. Tridium Inc. - Lon based Circon

2.2 COMMUNICATIONS

A. Each controller to have communication port for connection to operator interface.
   1. Internetwork operator interface and value passing to be transparent to internetwork architecture.
   2. Operator interface connected to controller to allow operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, reports, system software, and custom programs to be viewable and editable from each internetwork controller.

B. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers to be readable by each controller on internetwork.

C. Workstations, Building Control Panels and Controllers with real-time clocks use time synchronization service. System automatically synchronize system clocks daily from operator-designated device via internetwork. System automatically adjust for daylight savings and standard time as applicable.

2.3 OPERATOR INTERFACE

A. Operator Interface. Existing PC-based workstation residing on high-speed network. Existing system meets LONWORKS standards and is an Niagra Framework system front end.

B. Integration:
   1. General: The Building Management System (BMS) shall be a new LONWORKS system that is completely integrated with the existing Niagra Framework Operator Interface "Front End". The new system shall match the existing

graphics, schedules, nomenclature, alarms, security, and trends. Communication shall be bidirectional for command of the system from either the new or the existing. Gateways are unacceptable. Third-party integrations are unacceptable.

2. Dynamic Color Graphics:
   a. New graphics to match existing graphics used for existing buildings on existing operator interface.
   b. Real-time color graphic displays dynamic and able to update displays.
   c. Provide operator ability to change values (setpoints) and states in system controlled equipment directly from graphic display.
   d. Provide custom graphics to portray systems installed.
3. System Applications:
   a. Integrate the following applications at Operator Interface "Front End":
      1) Automatic System Database Save and Restore. Store on hard disk copy of current database of each Building Controller. This database automatically updated whenever change is made in any system panel.
      2) Manual Database Save and Restore. System operator able to manually save or clear database and initiate download of specified database from/to any panel.
      3) System Configuration. Provide method of configuring system to allow for changes or additions by users and performs following tasks:
         a) Create, delete or modify control strategies.
         b) Add/delete objects to system.
         c) Tune control loops through adjustment of control loop parameters.
         d) Enable or disable control strategies.
         e) Generate hard copy records of control strategies on printer.
         f) Select points to be alarmed and define alarm state.
         g) Select points to be trended and initiate automatic recording of values.
         h) Start/Stop binary objects and adjust analog objects.
      4) Security: Operator required to log on to system with user name and password in order to view, edit, add, or delete data. System security selectable for each operator.
      5) System Diagnostics: System automatically monitor operation of network connections, building management panels, and controllers. Failure of any device to be annunciated.
      6) Alarm Indication and Handling:
         a) Provide visual means of alarm indication. Alarm indication becomes highest priority regardless of application(s) running.
         b) Provide and archive log of alarm messages to hard drive. Alarm messages to include description of event-initiating object, source, location and time/date of alarm.
      7) Trend Logs: Operator able to define custom trend log for any data object and include interval, start time, and stop time. Trend data sampled and stored on building controller panel, be archived on hard disk, and be retrievable for use in spreadsheets and standard database programs.
         a) System server to periodically gather historically recorded data stored in the building controllers and archive the information.

Archived files to be appended with new sample data, allowing samples to be accumulated.

b) Software to be included that is capable of graphing the trend logged object data. Software capable of creating two-axis (x,y) graphs that display object values relative to time.

c) Operator able to change trend log setup information. This includes the information to be logged as well as the interval at which it is to be logged. Input, output, and value object types in the system may be logged. Provide operations password protected. Setup and viewing may be accessed directly from any and all graphics on which object is displayed.

d) BAS Contractor shall enable trending for any and all system points (physical or virtual) as directed by the Engineer, Owner or Commissioning Authority (CxA). There will be no limit on the number of trended points the BAS Contractor is to set up. BAS Contractor will modify trend setup parameters as directed by the CxA during testing. BAS Contractor shall be proactive and enable trending for all major system points during system startup/programming. BAS Contractor is not to wait for direction to begin trending points. Trend data for each point shall be archived on the main server for a minimum of one year. Trend data archiving shall be enabled immediately upon trend setup, or as soon as communication between the field panel and sever is established. Trend data uploads from field panel to server shall be set up to be automatically performed with sufficient frequency to ensure no data gaps or loss of trend data.

8) Standard Reports: Standard system reports provided for this project. Provide ability for Owner to readily customize these reports for this project:
   a) Objects: System (or subsystem) objects and their current values.
   b) Logs:
   c) Alarm History
   d) System Messages
   e) System Events
   f) Trends

9) Electrical, Gas, and Weather Report:
   a) Periodically gather energy log data stored in the field equipment and archive the information. Archive files appended with new data, allowing data to be accumulated.
   b) Operator able to change the energy log setup information as well. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. Meters monitored by the system may be logged.
   c) System to display archived data in tabular format form for both consumption and peak values. Data shown in hourly, daily, weekly, monthly and yearly formats. In each format the user able to select a specific period of data to view.

d) Electrical Meter Report: Provide monthly report showing daily electrical consumption and peak electrical demand with time and date stamp for each building meter and for each electrical sub-meter on individual building panels, circuits, equipment (such as chillers), and variable frequency drives. Provide an annual (12-month) report showing monthly electrical consumption and peak electrical demand with time and date stamp for each individual meter.

e) Gas Meter Report: Provide monthly report showing daily natural gas consumption for each meter and sub-meter. Provide annual (12-month) report that shows monthly consumption for each meter.

f) Weather Data Report: Provide monthly report showing daily minimum, maximum, and average outdoor air temperature. Provide annual (12-month) report showing minimum, maximum, and average outdoor air temperature for month.

4. Interfaces:
   a. Interfaces to Third Party Systems: BAS connects to third party systems (boilers, rooftop AC units, etc.). Communication protocol specified for third party system, and BAS provides compatible protocol to assure proper two way communication. Points, alarms, and commands displayed on BAS as indicated.

2.4 CONTROLLER SOFTWARE

A. Furnish following applications software for building and energy management. Software applications reside and operate in system controllers. All software to be manufacturer's most current version at the time of installation. All software and associated functions (scheduling, optimum start/stop, etc.) noted in this specification are to be configured and enabled for this project. Incorporate into sequence of operation submittals for review prior to installation.

B. Scheduling: Provide capability to schedule each object or group of objects in system. Coordinate schedule with Owner and program accordingly. Each schedule consists of:
   1. Operator's workstation to show information in easy-to-read daily format. Priority for scheduling: Events, holidays and daily with events being the highest.
   2. Holiday and special event schedules to display data in calendar format. Operator able to schedule holidays and special events directly from these calendars.
   3. Operator able to change information for a given weekly or exception schedule if logged on with the appropriate security access.

C. Optimum Start/Stop: Provide software and program system to start equipment on sliding schedule based upon indoor and outdoor conditions. Determine minimum time of HVAC system operation needed to satisfy space environmental requirements and also determine earliest possible time to stop mechanical systems (i.e. hut down cooling/heating and only provide ventilation one hour prior to scheduled unoccupied period.) Optimum start/stop program operates in conjunction with scheduled start/stop and night setback programs.

D. Alarms:
   1. Operator's workstation to provide visual means of alarm indication. The alarm dialog box to always become the top dialog box regardless of the application(s), currently running.
   2. System to provide log of alarm messages. Alarm log to be archived to the hard disk of the system operator's terminal. Each entry to include a description of the event-initiating object generating the alarm. Entry to include time and date of alarm occurrence.
   3. Alarm messages in user-definable text and entered via remote communication.
   4. Each binary object set to alarm based on operator-specified state.
   5. Each analog object have both high and low alarm limits.
   6. Alarms must be able to be automatically and manually disabled.
   7. Alarms be routed to appropriate workstations based on time and other conditions. An alarm able to start programs, print, be logged in event log, generate custom messages, and display graphics.
   8. System have ability to dial out in event of alarm.

E. Maintenance Management: System monitors equipment status and generate maintenance messages based upon user-designated run-time, starts, and/or calendar date limits. Coordinate settings with District.

F. Sequencing: Provide application software based upon sequences of operation specified to properly sequence designated systems. Provide all points to achieve specified sequences.

G. Staggered Start: This application prevents controlled equipment from simultaneously restarting after a power outage. Order in which equipment (or groups of equipment) is started, along with time delay between starts to be user-selectable.

H. Energy Calculations: Provide software to allow instantaneous power (9e.g. kW) or flow rates (e.g. L/s (gpm)) to be accumulated and converted to energy usage data.

I. Anti-Short Cycling: Binary output objects protected from short cycling by allowing minimum on-time and off-time to be selected.

J. On/Off Control with Differential: Provide algorithm that allows binary output to be cycled based on controlled variable and set point. Algorithm direct-acting or reverse-acting and incorporate adjustable differential.

K. Run-Time Totalization: Provide software to totalize run-times for binary input objects.

2.5 BAS GRAPHICS

A. Develop customized graphics showing the project building(s) and their floor plans, mechanical, and electrical equipment, flow and control diagrams, and other relevant features on Workstation graphic screens. Associated input, output, and virtual objects (e.g., temperature & pressure set points) listed in the Sequence of Operation, and shown on the Input/Output Objects List included in the graphic screens and bound to

the database. Real-time value of objects updated on the display of each graphic automatically. For projects where existing campus and/or building controls systems exist, replicate graphics used in the existing BAS graphics screens.

B. Graphics to have links to the Print function and to display a Standard Legend in the corner of the graphic. Graphics, except pop-ups, to have the date and time displayed in the upper corner of the graphic. Each graphic titled.

C. Weather: Graphics, except pop-ups, to have the outdoor temperature and humidity in the upper corner of the graphic.

D. Alarms: System and component summary alarms located near the top of each relevant graphic screen. Provide links to the associated system/component as part of these tags to assist trouble shooting. Other alarms placed near the associated system/device as depicted in the graphic. Provide text and color of information tags that describe each object and alarm value consistent with a graphics color legend.

E. The Following Graphics Provided as a Minimum:
   1. A building graphic, typically a photograph of the building, with links to each floor plan and other links as defined below.
   2. A central plant graphic with equipment (boilers, etc.), temperature sensors, pressure sensors, flow sensors and refrigeration leak detectors. The central plant graphic to have links to each building on the campus.
   3. Central equipment such as air handler, supply fans, and exhaust fans.
   4. Floor plans of each floor, with temperature sensors, pressure sensors, temperature control zones, heating/cooling zones, ventilation zones, and supply air zones identified. Rooms grouped on a graphic only to the extent that detailed and complete sensing information can be comfortably viewed by an operator and the bound points updated in less than 10 seconds. Each zone to have a temperature symbol that changes color over the range from low (blue) through normal (green) to high (red) and indicate an alarm (flashing red). The zone temperature and or pressure symbol(s) to be a link to a zone control pop-up graphic. Individual floor plan graphics to provide links to related mechanical systems. The mechanical room plan graphics to show the relative location of, and provide links to, either the equipment pop-up or flow and control graphic for mechanical equipment monitored or controlled by the BAS.
   5. Pop-up graphics provided for each zone control system showing a flow diagram and related monitoring & control points and system parameters. Pop-up graphics provided for each piece of equipment that is not shown on a flow and control graphic.
   6. Flow and control diagrams for each system including but not limited to central plant, fan coils, generators, packaged equipment, chilled water systems, heating hot water systems, heat exchangers, pumps, storage tanks, zone terminal units, isolation room systems, smoke damper status, combination fire and smoke dampers status, ventilation systems. The flow and control graphics to have parameters grouped in the lower portion of the graphics. Standard equipment graphics used. Pumps, fans, dampers and other elements to dynamically indicate their state (i.e. pumps and fans to rotate when on and damper positions to dynamically adjust and be shown in their current position, etc.). System flow

and control graphics displayed in a general left to right flow or loop arrangement. Return and exhaust air flow shown on top and return water shown on the bottom of the graphic.

7. Individual equipment/component screens showing sensing and control information available for each device provided.

F. Penetration: The graphic interface to consistently apply a convention whereby a left-click to always penetrate to more detailed information. The text windows to represent the deepest level of penetration. A right-click to always produce a menu of options that are specific to the item selected.

G. Navigation: Graphics organized to provide a "branching structure" that allows an operator to move from a "macro view" to a "micro view" and return. These links to other associated graphics, or allow a return to a previous macro view, provided and arranged horizontally along the bottom of each graphic screen. From left to right, the graphic links as follows: site/building map, building/trailer floor plans, and major mechanical systems at each building. Pop-up right click menus provided as needed on the lower button bar to allow for uncluttered navigation.

H. Clutter Minimization: Each graphic to have separate check boxes in the lower right corner that show/hide set points, alarms/safeties, and devices/equipment.

I. Templates: To the maximum extent possible, use standard graphics as templates to provide a consistent look throughout the interface.

J. Color Scheme: The graphics to use dynamic color changes to communicate equipment type, or object status consistent with the graphics color legend.

K. Symbols and Animations: Fans, pumps, dampers, coils, and generation equipment to be dynamic symbols indicating rotation, state, or position, movement, flow, etc.

L. Macros: When macros are used to add functionality to the graphics, detailed documentation provided.

M. Configure Mode: Access to “Configure Mode” for editing of the graphics password protected to prevent unauthorized changes to the graphics. This password supplied to the appropriate personnel.

N. Graphics Version: Graphics provided in the most current format available at time of control system programming.

O. Points and graphics checked for the proper binding and graphic programming, settings to ensure that the correct system, location, point values and dynamics are shown in the proper location and rotate in the proper directions.

P. After graphics have been accepted, provide, on a CD ROM in an agreed upon file structure. If the graphics have active-x controls or other files that must be placed outside the graphics folder structure a set-up program provided on the disk to place the files in the correct locations.

2.6 BUILDING CONTROLLERS

A. General: Provide adequate number of building controllers to achieve performance specified. Panels to meet the following requirements.
   1. Building Automation System (BAS) to be composed of one or more independent, stand-alone, microprocessor-based building controllers to manage global strategies described in Controller Software Section.
   2. Provide sufficient memory to support operating system, database, and programming requirements.
   3. Share data between networked building controllers.
   4. Distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
   5. Controllers that perform scheduling have real-time clock.
   6. Continually check status of its processor and memory circuits and if abnormal operation is detected, controller:
      a. Assume predetermined failure mode.
      b. Generate alarm notification.

B. Communication:
   1. Each building controller resides on network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and performs routing to network of custom application and application specific controllers.
   2. Controller provides a service communication port for connection to a portable operator's terminal.

C. Environment:
   1. Controllers used outdoors and/or in wet ambient conditions mounted within NEMA waterproof enclosures and rated for operation at 0 degrees F to 150 degrees F.
   2. Controllers used in conditioned space be mounted in NEMA dust-proof enclosures and rated for operation at 32 degrees F to 120 degrees F.

D. Serviceability: Provide diagnostic LEDs for power, communication, and processor. Wiring connections be made to modular terminal strips or to termination card connected by ribbon cable.

E. Memory: Building controller maintains BIOS and programming information in event of power loss for at least 72 hours.

F. Immunity to power and noise. Controller able to operate at 90 percent to 110 percent of nominal voltage rating and performs an orderly shutdown below 80 percent nominal voltage. Operation be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 3-feet.

G. Controller to have a battery to provide power for orderly shutdown of controller and storage of data in nonvolatile flash memory. Battery backup to maintain real-time clock functions for a minimum of 10 days.

2.7 APPLICATION SPECIFIC CONTROLLERS

A. Application specific controllers (ASCs) are microprocessor-based DDC controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers to be fully programmable using graphical programming blocks.
   1. ASC controllers communicates with other devices on internetwork.
   2. Each ASC capable of stand-alone operation without being connected to network.
   3. Each ASC will contain sufficient I/O capacity to control target system.
   4. Application controllers to include universal inputs with minimum 10-bit resolution that accept thermistors, 0-10VDC, 0-5 VDC, 4-20 mA and dry contact signals. Any input on a controller may be either analog or digital with at least 1 input that accepts pulses. Controller to also include support and modifiable programming for interface to intelligent room sensor with digital display. Controller to include binary and analog outputs on board. Provide analog outputs switch selectable as either 0-10VDC or 0-20mA. Software to include scaling features for analog outputs. Application controller to include 24VDC voltage supply for use as power supply to external sensors.
   5. Program sequences stored on board application controller in EEPROM. No batteries needed to retain logic program. Program sequences executed by controller 10 times per second and capable of multiple PI and PID loops for control of multiple devices. Calculations completed using floating-point math and system to support display of information in floating-point nomenclature at operator's terminal. Programming of application controller completely modifiable in the field over installed BAS LANs or remotely via modem interface. Operator to program logic sequences by graphically moving function blocks on screen and tying blocks together on screen.
   6. Application controller to include support for room sensor. Display on room sensor programmable at application controller and include an operating mode and a field service mode. Provide button functions and display data programmable to show specific controller data in each mode based on which button is pressed on the sensor. See sequence of operation for specific display requirements at intelligent room sensor.

B. Communication:
   1. Controller resides on network using MS/TP Data Link/Physical layer protocol.
   2. Each controller connected to building controller.
   3. Each controller capable of connection to laptop computer or portable operator's tool.

C. Environment:
   1. Controllers used outdoors and/or in wet ambient conditions mounted within NEMA waterproof enclosures and rated for operation at 0 degrees F to 150 degrees F.
   2. Controllers used in conditioned space mounted in NEMA dust-proof enclosures and rated for operation at 32 degrees F to 120 degrees F.

D. Serviceability: Provide diagnostic LEDs for power, communication, and processor.

E. Memory: ASC use nonvolatile memory and maintains BIOS and programming information in event of power loss.

2.8 ADVANCED APPLICATION CONTROLLERS

A. General:
1. Expandable application controller capable of providing control strategies for the system based on information from any or all connected inputs. Provide program implementing these strategies completely flexible and user definable. Provide program execution of controller a minimum of once per second.
2. Programming: Object-oriented using control program blocks. Controller to support a minimum of 500 Analog Values and 500 Binary Values. Each and every analog and binary value to support standard specified protocol priority arrays.
3. Provide means to graphically view inputs and outputs to each program block in real-time as program is executing. This function may be performed via the operator's terminal or field computer.
4. Controller to have adequate data storage to ensure high performance and data reliability. Battery to retain static RAM memory and real-time clock functions for a minimum of 1.5 years (cumulative). Provide field-replaceable battery (non-rechargeable) lithium type. Unused battery life: 10 years.
5. The onboard, battery-backed real time clock must support schedule operations and trend logs.
6. Global control algorithms and automated control functions should execute via 32-bit processor.
7. Controller to include both on-board Ethernet specified protocol communication over twisted pair cable (UTP) and to include specified protocol IP communication. In addition, controller to include specified protocol PTP connection port.
8. The base unit of the controller to host up to 8 expansion modules with various I/O combinations. These inputs and outputs to include universal 12-bit inputs, binary triac outputs, and 8-bit switch selectable analog outputs (0-10V or 0-20 mA). Inputs to support thermistors, 0-5VDC, 0-10VDC, 4-20mA, dry contacts and pulse inputs directly.
9. Outputs must have onboard Hand-Off-Auto switches and a status indicator light. HOA switch position to be monitored. Each analog output to include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position.
10. The position of each and every HOA switch to be available system wide as a specified protocol object. Expandable Controller to provide up to 176 discreet inputs/outputs per base unit.

B. Schedules: Each controller to support a minimum of 50 Schedule Objects.

C. Logging Capabilities: Each controller to support a minimum of 200 trend logs. Any object in the system (real or calculated) may be logged. Sample time interval adjustable at the operator's workstation.

D. Alarm Generation:
   1. Alarms may be generated within the system for any object change of value or state either real or calculated. This includes things such as analog object value changes, binary object state changes, and various controller communication failures.
   2. Alarm log provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site via remote communications.
   3. Controller must be able to handle up to 200 alarm setups stored as event enrollment objects - system destination and actions individually configurable.

2.9 INPUT/OUTPUT INTERFACE

A. Input/output points protected such that shorting of point to itself, to another point, or to ground will cause no damage to controller. Input and output points protected from voltage up to 24 V.

B. Binary inputs (BI or DI) allow monitoring of On/Off signals from remote devices. Binary inputs sense “dry contact” closure without external power (other than that provided by controller) being applied.

C. Pulse accumulation input objects accept up to 10 pulses per second for pulse accumulation.

D. Analog inputs (AI) allow monitoring of low-voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals (thermistor, RTD).

E. Binary outputs (BO or DO) provide for On/Off operation or pulsed low-voltage signal for pulse width modulation control. Binary outputs on building and custom application controllers have three-position (On/Off/Auto) override switches and status lights. Outputs selectable for either normally open or normally closed operation.

F. Analog outputs (AO)provide a modulating signal for control of end devices. Outputs provide either a 0 to 10 VDC or a 4 to 20 mA signal as required to provide proper control of the output device. Analog outputs on building controllers have status lights and two-position (AUTO/MANUAL) switch and adjustable potentiometer for manual override. Analog outputs not exhibit drift of greater than 0.4 percent of range per year.

G. Tri-State Outputs. Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices limited to zone control and terminal unit control applications (VAV terminal units, duct-mounted heating coils, zone dampers, radiation, etc.). Control algorithms run zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

2.10 POWER SUPPLIES AND LINE FILTERING

A. Control transformers UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in both primary and secondary circuits. Limit connected loads to 80 percent of rated capacity.

B. DC power supply output match output current and voltage requirements. Unit operates between 32 degrees F and 120 degrees F.

C. Line voltage units UL listed and CSA approved.

D. Power line filtering. Provide transient voltage and surge suppression for workstations and controllers.

2.11 CONTROL PANELS

A. Control Panels:
   1. Enclosures may be NEMA 1 when located in a clean, dry, indoor environment. Indoor enclosures to be NEMA 12 when installed in other than a clean environment. Outdoor enclosures must be NEMA 3R. Provide (hinged door) key-lock latch and removable subpanels. Single key common to field panels and subpanels. In existing campus or building settings, key lock to match existing keys.
   2. Interconnections between internal and face-mounted devices prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections UL listed for 600 volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection individually identified per control drawings.
   3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.
   4. Provide laminated plastic nameplates for enclosures in any mechanical room or electrical room labeled with TCP number. Laminated plastic to be 1/8-inch thick sized appropriately to make label easy to read.

2.12 AUXILIARY CONTROL DEVICES

A. Temperature Instruments:
   1. Low-voltage or Line-voltage Thermostats: Bimetal-actuated, snap acting SPDT contact, enclosed, UL listed for electrical rating, exposed set point adjustment on cover with heat anticipator. Thermostat operates within 55 degrees F to 85 degrees F set point range, with 2 degrees F maximum differential.
   2. Averaging Duct Temperature Sensors: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F, consisting of array of single point sensing elements, securely mounted in duct or plenum; operating range 20-120 degrees F; linear signal; 1-foot element per 2 SF of duct cross Sectional area. Use when duct is 9 SF or larger or where air is subject to temperature stratification.

3. Probe Duct Temperature Sensors: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F, consisting of single point sensing elements, securely mounted in duct or plenum; operating range 20-120 degrees F; linear signal; 24-inch rigid probe. Use where duct is less than 9 SF cross Sectional area.
4. Outside Air Temperature Sensor: Thermistor or platinum RTD element with accuracy of plus or minus 0.5 degrees F at 32 degrees F; Range -58 to 120 degrees F, single element, linear, with weather and sun shield for exterior mounting.
5. Low Temperature Limit Thermostat: Minimum 20 foot capillary sensing element, triggering on low temperature as sensed by any 12-inch segment; snap acting, normally open contacts, manual reset, line voltage.
6. Liquid Immersion Temperature Sensor: Thermistor or platinum RTD element, with accuracy of plus or minus 0.5 degrees F at 32 degrees F, stainless steel well and assembly, range 30 to 250 degrees F.

B. Motorized Control Dampers:
1. Performance: Maximum leakage of 3 CFM/SF at 1-inch WG differential pressure, AMCA Class 1A, maximum pressure rating of 13-inch WG differential pressure, maximum velocity of 6,000 fpm, -72 degrees F to 275 degrees F temperature rating.
2. Multi-blade type, except where either dimension is less than 10-inch single blade may be used. Maximum blade length to be 48-inch.
3. Provide parallel blades for modulating mixing service and opposed blades for throttling service.
4. Blades to be interlocking; minimum 16 gauge galvanized steel; compression type edge seals and side seating stops. In copper, aluminum and stainless steel duct work, damper material matches duct work material.
5. Damper blades be reinforced, have continuous full length axle shafts, axle to axle linkage, and/or operating “jackshafts” as required to provide coordinated tracking of blades.
6. Bearings: Self lubricating stainless steel sleeve or Celcon bearing.
7. Dampers over 25 SF in area to be in two or more Sections, with interconnected blades.
8. Provide remote damper blade position status with binary input.
9. Tested in accordance with AMCA Standard No. 500.

C. Motorized Control Valves:
1. Body pressure rating and connection type construction conforms to pipe, fitting and valve schedules.
2. Fluid valve close-off ratings and spring ranges operates at maximum flows and maximum available pump heads scheduled without leakage.
3. Screwed ends except 2-1/2-inch and larger valves with flanged ends.
4. Steam valve close-off ratings operates at 150 percent of steam pressure without leakage.
5. Modulating Control Valves:
   a. 2-inch and smaller fail-in-place characterized ball valves; ANSI 250 body rating; bronze body and stainless steel trim.

b. 2-1/2-inch and larger cast iron ANSI Class 125, Other with guided equal percentage plug; PTFE packing.

6. Fluid three-way valves globe valves with linear plug with composition disc for tight shutoff.
7. Pressure drop equal to twice pressure drop through heat exchanger (load), 50 percent of pressure difference between supply and return mains, or 5 PSI, whichever is greater, except two-position valves be line size.
8. Bubble-tight line size butterfly valves acceptable on 2-1/2-inch lines and above for two-position action only; cast iron body; aluminum bronze disc; EPDM seat, 200 PSI wg
9. Steam Valves: Body and trim materials in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service. Sizing Criteria:
   a. Two-Position Service: Pressure drop 10 percent to 20 percent of inlet PSIG.
   b. Modulating Service: 15 PSIG or less; pressure drop 80 percent of inlet PSIG.

D. Electric Damper/Valve Actuators:
1. Provide mechanical or electronic stall protection for each actuator.
2. Where indicated provide internal mechanical, spring-return mechanism or provide uninterruptible power supply (UPS). Non-spring-return actuators have external manual gear release to position damper/valve when actuator is not powered.
3. Proportional actuators accepts 0 to 10 VDC or 0 to 20 mA control signal and provide 2 to 10 VDC or 4 to 20 mA operating range.
4. Actuator sized for torque required plus 25 percent; UL or CSA listed; electronic current overload protection.

E. Relays:
1. Control relays UL listed plug-in type with dust cover and LED “energized” indicator. Contact rating, configuration, and coil voltage be suitable for application.
2. Time delay relays UL listed solid-state plug-in type with adjustable time delay. Delay adjustable plus or minus 200 percent (minimum) from set point or as indicated. Contact rating, configuration, and coil voltage be suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.

F. Override Timers: Override timers spring-wound line voltage, UL Listed, with contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless otherwise specified. Timer suitable for flush mounting on control panel face and located on local control panels or where shown.

G. Current Transmitters:
1. AC current transmitters be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4 to 20 mA two-wire output. Unit ranges 10 A full scale, with internal zero and span adjustment and plus or minus 1 percent full-scale accuracy at 500 ohm maximum burden.

2. Transmitter meets or exceeds ANSI/ISA S50.1 requirements and UL/CSA recognized.
3. Unit split-core type for clamp-on installation on existing wiring.

H. Current Transformers: AC current transformers UL/CSA recognized and completely encased (except for terminals) in approved plastic material; plus or minus 1 percent accuracy at 5 A full-scale.

I. Voltage Transmitters: AC voltage; self-powered single-loop (two-wire) type; 4 to 20 mA output with zero and span adjustment; UL/CSA recognized at 600 VAC rating and meet or exceed ANSI/ISA S50.1. Ranges include 100 to 130 VAC, 200 to 250 VAC, 250 to 330 VAC, and 400 to 600 VAC full-scale, adjustable, with plus or minus 1 percent full-scale accuracy with 500 ohm maximum burden.

J. Voltage Transformers: AC voltage transformers UL/CSA recognized, 600 VAC rated; built-in fuse protection; suitable for ambient temperatures of 40 degrees F to 130 degrees F; plus or minus 0.5 percent accuracy at 24 VAC and a 5 VA load.

K. Power Monitors: Selectable rate pulse output for kWh reading; 4-20 mA output for kW reading; N.O. alarm contact; ability to operate with 5.0 amp current inputs or 0-0.33 volt inputs; plus 1.0 percent full-scale true RMS power accuracy; plus 0.5 Hz, voltage input range 120-600 V, and auto range select; NEMA 1 enclosure. Current transformers having a 0.5 percent FS accuracy, 600 VAC isolation voltage with 0-0.33 V output. If 0-5 A current transformers are provided, a three-phase disconnect/shorting switch assembly is required.

L. Overflow Switch: Insertion flow sensor, brass, impeller flow design with analog transmitter unit. Data Industrial Model 220BR.

M. Ultrasonic Level Transmitter: Non-contact measuring device for liquid level; distance ranges from 4-feet to 32-feet; fail-safe intelligence with diagnostic feedback for troubleshooting; automatic temperature compensation; 24VDC; accuracy plus 0.15 percent of span in air. Kele LU Series.

2.13 WIRING AND RACEWAYS

A. General: Provide copper wiring, plenum cable, and raceways as specified in applicable Sections of Division 16, Electrical.

B. Insulated wire to be copper conductors, UL labeled for 90 degrees C minimum service.

C. Field and Subfield Panels: Voltage in panels not exceed 120 volts.

D. Motor Control Centers: Responsibility for correct voltage of holding coils and starter wiring in pre-wired motor control centers interfacing with automatic controls is included hereunder.

E. Wiring for BAS systems communications buses two conductor minimum 18 gauge foil-shielded, stranded twisted pair cable rated at 300 VDC or more than 80 degrees C.

PART 3 - EXECUTION

3.1 DEMOLITION

A. Graphics and Programming: Remove symbols from control system graphics associated with deleted terminal elements. Modify programming code to delete alarms, control loops, etc.

B.

3.2 EXAMINATION

A. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.

B. Notify the Owners' representative in writing of conditions detrimental to the proper and timely completion of the work.

C. Do not begin work until unsatisfactory conditions are resolved.

3.3 CONTROL SYSTEM CHECKOUT AND TESTING

A. Testing completed before Owner's representative is notified of system demonstration.

B. Calibrate and prepare for service of instruments, controls, and accessory equipment furnished under this specification.

C. Verify that control wiring is properly connected and free of shorts and ground faults.

D. Enable control systems and verify calibration and operation of input and output devices.

E. Verify that system operation adheres to sequences of operation.

F. Commissioning and Verification: In addition to commissioning requirements specified elsewhere, provide the following commissioning on the HVAC instrumentation and controls system:
   1. Control systems completely commissioned to ensure aspects of the system are operating as intended and at optimum tuning.
   2. Wiring connections verified and traced from field device to panel to ensure proper connections.
   3. Measured values verified by a hand held calibrated device to validate that value indicated by the control system is in fact the actual measured value.
   4. Loops properly tuned to obtain the desired control value. Each loop to be "upset" and put back in control to demonstrate its ability to stabilize quickly.

5. Provide a final point-by-point report submitted that indicates the date of each verification, the results, and initialed on each page by the person performing the reading.

3.4 ACCEPTANCE TESTING AND TRAINING

A. Site Testing:
   1. Contractor provides personnel, equipment, instrumentation, and supplies necessary to perform testing. Owner or Owner's representative will witness and sign off on acceptance testing.
   2. Contractor demonstrates compliance of completed control system with Contract Documents. Using approved test plan, physical and functional requirements of project demonstrated.

3.5 WIRING

A. Provide electrical wiring required to control systems specified in this Section. Control and interlock wiring complies with national, state and local electrical codes and Division 16, Electrical of this specification.

B. Power wiring required for building control panel(s) to be dedicated circuit(s).

C. Verify location of operator work station with Owner prior to installation.

D. NEC Class 1 (line voltage) wiring UL Listed in approved raceway according to NEC and Division 16, Electrical requirements.

E. Low-voltage wiring meets NEC Class 2 requirements. (Low-voltage power circuits subfused when required to meet Class 2 current limit.)

F. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL Listed for intended application.

G. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for purpose of interfacing (e.g., relays and transformers).

H. Where Class 2 wiring is run exposed, wiring is to be run parallel along surface or perpendicular to it and tied at 10 foot intervals.

I. Where plenum cables are used without raceway, supported from structural members. Cables not to be supported by ductwork, electrical raceways, piping, or ceiling suspension systems.

J. Wire-to-device connections made at terminal block or terminal strip. Wire-to-wire connections at terminal block.

K. Maximum allowable voltage for control wiring 24 V. If only higher voltages are available, provide step-down transformers.

L. Wiring installed as continuous lengths, with no splices permitted between termination points.

M. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at penetrations.

N. Include one pull string in each raceway 1-inch or larger.

O. Control and status relays are to be located in designated enclosures. Enclosures include packaged equipment control panels unless they also contain Class 1 starters.

P. Install raceway to maintain a minimum clearance of 6-inches from high-temperature equipment (e.g., steam pipes or flues).

Q. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

R. Install insulated bushings on raceway ends and openings to enclosures. Seal top end of vertical raceways.

S. Flexible metal raceways and liquid-tight, flexible metal raceways not-to-exceed 3-feet in length and be supported at each end. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways to be used.

T. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway Sections joined with couplings. Terminations made with fittings at boxes.

U. Input and output terminations to be labeled at the controller to identify if they are AI, DI, AD, DO, and function (i.e. pump start, OM Sensor.)

3.6 COMMUNICATION WIRING

A. Follow manufacturer's installation recommendations for communication cabling.

B. Verify integrity of network following cable installation.

C. Communication wiring unspliced length when that length is commercially available; labeled to indicate origination and destination data.

D. Grounding of coaxial cable in accordance with NEC regulations article on “Communications Circuits, Cable, and Protector Grounding.”

3.7 INSTALLATION OF AUXILIARY CONTROL DEVICES

A. General:
   1. Install sensors in accordance with manufacturer's recommendations.
   2. Room sensors installed on concealed junction boxes properly supported by wall framing.
   3. Low-limit sensors used in mixing plenums installed in a serpentine manner horizontally across duct.
   4. Install outdoor air temperature sensors on north facing wall or screen, complete with sun shield at designated location.

B. Flow Switch: Use correct paddle for pipe diameter. Adjust flow switch in accordance with manufacturer's instructions.

C. Actuators:
   1. General:
      a. Mount and link control damper actuators according to manufacturer's instructions.
      b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
   2. Actuator Mounting for Damper and Valve Arrangements to Comply with the Following:
      a. Damper Actuators: Do not install in the air stream.
      b. Use a weather proof enclosure (clear and see through) if actuators are located outside.
      c. Damper or valve actuator ambient temperature not-to-exceed 122 degrees F through any combination of medium temperature or surrounding air. Provide appropriate air gaps, thermal isolation washers or spacers, standoff legs, or insulation as necessary. Mount per manufacturer's recommendations.
      d. Actuator cords or conduit to incorporate a drip leg if condensation is possible. Do not allow water to contact actuator or internal parts. Location of conduits in temperatures dropping below dew point to be avoided to prevent water from condensing in conduit and running into actuator.
      e. Damper mounting arrangements to comply with the following:
         1) Furnish and install damper channel supports and sheet metal collars.
         2) Jack shafting of damper Sections not allowed.
         3) Multi-Section dampers arranged so that each damper Section operates individually. Provide one electronic actuator direct shaft mounted per Section.
      f. Size damper Sections based on actuator manufacturers specific recommendations for face velocity, differential pressure and damper type. In general: Damper Section not-to-exceed 24 ft-sq. with face velocity 1500 FPM.
      g. Multiple Section dampers of two or more arranged to allow actuators to be direct shaft mounted on the outside of the duct.

h. Multiple Section dampers of three or more Sections wide arranged with a 3-sided vertical channel (8-inch wide by 6-inch deep) within the duct or fan housing and between adjacent damper Sections. Vertical channel anchored at the top and bottom to the fan housing or building structure for support. Connect sides of each damper frame to the channels. Holes in the channel to allow damper drive blade shafts to pass through channel for direct shaft mounting of actuators. Face open side of channel downstream of the airflow, except for exhaust air dampers.

i. Multiple Section dampers to be mounted flush within a wall or housing opening to receive either vertical channel supports as described above or sheet metal standout collars. Sheet metal collars (12-inch minimum) to bring each damper Section out of the wall to allow direct shaft mounting of the actuator on the side of the collar.

D. Control Valve:

1. Valves installed in accordance with manufacturer's recommendations.
2. Slip-stem control valves installed so that stem position is not more than 60 degrees from vertical up position. Ball type control valves installed with stem in horizontal position.
3. Control valves accessible and serviceable.
4. Install isolation valves so that control valve may be serviced without draining supply/return side piping system. Install unions at connections to screw-type control valves.

E. Control Damper:

1. Dampers installed in accordance with manufacturer's instructions. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.
2. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.8 SEQUENCES OF OPERATION AND POINTS LISTS

A. Where local energy code dictates certain sequences (such as night setback, night flush, pressure and temperature reset, terminal unit sequences, etc.), the sequences are not repeated in the documents. It is not the intent of this specification or documentation to reiterate the energy code. Provide all energy code mandated sequences and document in sequence of operations submittals at no additional cost to the Owner. Provide all required points to achieve the appropriate sequences.

B. See control diagrams and sequences on drawings.

POINTS LIST	**ANALOG IN**	**ANALOG OUT**	**DIGITAL IN**	**DIGITAL OUT**	**ALARMS**
Damper Open/Close				X	
Fire Alarm Signal			X		

END OF SECTION

SECTION 15945

COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Work included:
1. Definitions, warranties, test equipment requirements, and mechanical commissioning requirements.

1.2 RELATED SECTIONS

A. Contents of Division 15, HVAC and Division 01, General Requirements apply to this Section.

B. In addition, reference the following:
1. Section 01810, General Commissioning Requirements.
2. Division 01 Section 'LEED Requirements' for additional LEED Requirements.

1.3 REFERENCES AND STANDARDS

A. References and Standards per Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:
1. Current edition of ASHRAE Guideline 0, The Commissioning Process.

1.4 SUBMITTALS

A. Submittals as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, provide:
1. Certificates of readiness.
2. Certificates of completion of installation, prestart, and startup activities.
3. Operation and Maintenance Manuals.
4. Test reports.
5. Control Drawings Submittal
   a. Provide a key to abbreviations.
   b. Provide graphic schematic depictions of the systems and each component.
   c. Include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
   d. Provide a full points list with at least the following included for each point:
      1) Controlled system
      2) Point abbreviation
      3) Point description

4) Display unit
5) Control point or set point (Yes / No)
6) Monitoring point (Yes / No)
7) Intermediate point (Yes / No)
8) Calculated point (Yes / No)

6. Architect forwards one set of submittals for systems to be commissioned to Commissioning Agent at same time as design team.
7. Commissioning Agent forwards comments to design team for consideration in their submittal response.
8. Design team sends consolidated response to submittals and copies to Commissioning Agent.

1.5 QUALITY ASSURANCE

A. Quality assurance as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, meet the following:
1. Test Equipment Calibration Requirements: Contractors will comply with test manufacturer's calibration procedures and intervals. Recalibrate test instruments immediately after instruments have been repaired resulting from being dropped or damaged. Affix calibration tags to test instruments. Furnish calibration records to Commissioning Authority upon request.

1.6 WARRANTY

A. Warranty of materials and workmanship as required by Section 15020, HVAC Basic Requirements and Division 01, General Requirements.

B. In addition, provide:
1. Commissioning, inspecting, and testing will not modify terms or time periods of mechanical equipment, systems, and controls warranties including related equipment and systems, and adjacent work.
2. Control system warranty period starts from date of Commissioning Agent acceptance.

1.7 COORDINATION

A. Reference Section 01810 for requirements pertaining to coordination during the commissioning process.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. Provide standard testing equipment required to perform startup, initial checkout and functional performance testing for the equipment being tested. For example, the mechanical contractor of Division 15, HVAC will ultimately be responsible for standard testing equipment for the HVAC&R system and controls system in Division 15, HVAC,

except for the equipment specific to and used by TAB in their commissioning responsibilities. Provide a sufficient quantity of two-way radios by each subcontractor.

B. Include special equipment, tools and instruments (specific to a piece of equipment and only available from vendor) required for testing in the base bid price to the Owner and leave on site, except for stand-alone data logging equipment that may be used by the Commissioning Authority.

C. Manufacturer of equipment to provide proprietary test equipment and software required for programming and/or start-up, whether specified or not. Manufacturer provides the test equipment, demonstrates its use, and assists in the commissioning process as needed. Proprietary test equipment (and software)become the property of the Owner upon completion of the commissioning process.

D. Data logging equipment and software required to test equipment will be provided by the Commissioning Authority, and will not become the property of the Owner.

E. Use only testing equipment of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the specifications. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers have a certified calibration within the past year to an accuracy of 0.5 degree F and a resolution of plus or minus 0.1 degree F. Pressure sensors have an accuracy of plus or minus 2.0 percent of the value range being measured (not full range of meter) and have been calibrated within the last year.

PART 3 - EXECUTION

3.1 GENERAL DOCUMENTATION REQUIREMENTS

A. With assistance from the installing contractors, the Commissioning Authority will prepare prefunctional checklists for commissioned components, equipment, and systems

B. Red-Lined Drawings:
   1. Verify equipment, systems, instrumentation, wiring and components are shown correctly on red-lined drawings.
   2. Preliminary red-lined drawings must be made available to the Commissioning Team for use prior to the start of Functional Performance Testing.
   3. Changes, as a result of Functional Testing, must be incorporated into the final as-built drawings, which will be created from the red-lined drawings.
   4. The contracted party, as defined in the Contract Documents will create the as-built drawings.

C. Operation and Maintenance Data:
   1. Contractor will provide a copy of O&M literature within 45 days of each submittal acceptance for use during the commissioning process for commissioned equipment and systems.
   2. The Commissioning Authority will review the O&M literature once for conformance to project requirements.

3. The Commissioning Authority will receive a copy of the final approved O&M literature once corrections have been made by the Contractor.

D. Demonstration and Training:
1. Contractor will provide demonstration and training as required by the specifications.
2. A complete training plan and schedule must be submitted by the contractor to the Commissioning Authority four weeks prior to any training.
3. A training agenda for each training session must be submitted to the Commissioning Authority one week prior the training session.
4. Notify the Commissioning Authority at least 72 hours in advance of scheduled tests so that testing may be observed by the Commissioning Authority and Owner's representative. Provide a copy of the test record to the Commissioning Authority, Owner, and Architect.
5. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain specific equipment.
6. Train Owner's maintenance personnel on procedures and schedules for starting and stopping, trouble shooting, servicing, and maintaining equipment.
7. Review data in O&M Manuals.

3.2 CONTRACTOR'S RESPONSIBILITIES

A. Mechanical, Controls and TAB Contractors. The commissioning responsibilities applicable to each of the mechanical, controls and TAB contractors of Division 15, HVAC are as follows (references apply to commissioned equipment only):
1. Perform commissioning tests at the direction of the Commissioning Authority.
2. Attend construction phase controls coordination meetings.
3. Attend testing, adjusting, and balancing review and coordination meetings.
4. Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection as directed by the Commissioning Authority.
5. Provide information requested by the Commissioning Authority for final commissioning documentation.
6. Include requirements for submittal data, operation and maintenance data, and training in each purchase order or subcontract written.
7. Prepare preliminary schedule for mechanical system orientations and inspections, operation and maintenance manual submissions, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, testing and balancing and task completion for owner. Distribute preliminary schedule to commissioning team members.
8. Update schedule as required throughout the construction period.
9. During the startup and initial checkout process, execute the related portions of the prefunctional checklists for commissioned equipment.
10. Assist the Commissioning Authority in verification and functional performance tests.
11. Gather operation and maintenance literature on equipment, and assemble in binders as required by the specifications. Submit to Commissioning Authority 45 days after submittal acceptance.

B. Coordinate with the Commissioning Authority to provide 48 hour advance notice so that the witnessing of equipment and system start-up and testing can begin.

C. Notify the Commissioning Authority a minimum of 2 weeks in advance of the time for start of the testing and balancing work. Attend the initial testing and balancing meeting for review of the official testing and balancing procedures.

D. Participate in, and schedule vendors and contractors to participate in the training sessions.

E. Provide written notification to the Construction Manager/General Contractor (CM/GC) and Commissioning Authority that the following work has been completed in accordance with the Contract Documents, and that the equipment, systems, and sub-system are operating as required.
   1. HVAC&R equipment including fans, air handling units, ductwork, dampers, terminals, and other equipment furnished under this Division.
   2. Fire stopping in the fire rated construction, including fire and smoke damper installation, caulking, gasketing and sealing of smoke barriers.
   3. Fire detection and smoke detection devices furnished under other divisions of the specification.

F. Equipment supplier to document the performance of his equipment.

G. Test, Adjust and Balance Contractor:
   1. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
   2. Participate in verification of the testing and balancing report, which will consist of repeating measurements contained in the testing and balancing reports. Assist in diagnostic purposes when directed.

H. Provide training of the Owner's operating staff using expert qualified personnel, as specified.

I. Equipment Suppliers:
   1. Provide requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner, to keep warranties in force.
   2. Assist in equipment testing per agreements with contractors.
   3. Provide information requested by Commissioning Authority regarding equipment sequence of operation and testing procedures.

J. Reference Section 01810, General Commissioning Requirements for additional contractor responsibilities.

3.3 OWNER'S RESPONSIBILITIES

A. Reference Section 01810, General Commissioning Requirements for Owner's Responsibilities.

3.4 DESIGN PROFESSIONAL'S RESPONSIBILITIES

A. Reference Section 01810, General Commissioning Requirements for Design Professional's Responsibilities.

3.5 RESPONSIBILITIES

A. Reference Section 01810, General Commissioning Requirements for Commissioning Authority's Responsibilities.

3.6 TESTING PREPARATION

A. Certify in writing to the Commissioning Authority that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.

B. Certify in writing to the Commissioning Authority that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

C. Certify in writing that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.

D. Place systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

E. Inspect and verify the position of each device and interlock identified on checklists.

F. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.

G. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the Commissioning Authority.

3.7 TESTING, ADJUSTING AND BALANCING VERIFICATION

A. Prior to performance of Testing, Adjusting and Balancing work, provide copies of reports, sample forms, checklists, and certificates to the Commissioning Authority.

B. Notify the Commissioning Authority at least 10 days in advance of testing and balancing Work, and provide access for the Commissioning Authority to witness testing and balancing Work.

C. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the Commissioning Authority.

1. The Commissioning Authority will notify testing and balancing subcontractor 10 days in advance of the date of field verification. Notice will not include data points to be verified.
2. Testing and balancing subcontractor to use the same instruments (by model and serial number) that were used when original data were collected.
3. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items to result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB to result in rejection of final testing. Variations in background noise must be considered.
4. Remedy the deficiency and notify the Commissioning Authority so verification of failed portions can be performed.

3.8 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the Commissioning Authority.

B. Scope of HVAC&R testing to include entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing to include measuring capacities and effectiveness of operational and control functions.

C. Test operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

D. The Commissioning Authority along with the HVAC&R contractor, testing and balancing Subcontractor, and HVAC&R Instrumentation and Control Subcontractor to prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.

E. Tests will be performed using design conditions whenever possible.

F. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the Commissioning Authority and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

G. The Commissioning Authority may direct that set points be altered when simulating conditions is not practical.

H. The Commissioning Authority may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are not practical.

I. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

J. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.9 HVAC&R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

A. Equipment Testing and Acceptance Procedures: Testing requirements are specified in individual Division 15, HVAC Sections. Provide submittals, test data, inspector record, and certifications to the Commissioning Authority.

B. HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 15, HVAC Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls." Assist the Commissioning Authority with preparation of testing plans.

C. Pipe System Cleaning, Flushing, Hydrostatic Tests, and Chemical Treatment: Test requirements are specified in Division 15, HVAC Piping Sections. HVAC&R Contractor to prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the Commissioning Authority. Plan to include the following:
   1. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Provide drawings keyed to pipe zones or sectors formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.
   2. Description of equipment for flushing operations.
   3. Minimum flushing water velocity.
   4. Tracking checklist for managing and ensuring that pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

D. HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, steam, and hydronic distribution systems; special exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.

E. The work included in the commissioning process involves a complete and thorough evaluation of the operation and performance of components, systems and sub-systems. Evaluate the following equipment and systems:
   1. HVAC Equipment and Systems (all)
   2. Boiler
   3. Building Automation System
   4. Pumps

3.10 DEFICIENCIES/NONCONFORMANCE, COST OF RETESTING, FAILURE DUE TO MANUFACTURER DEFECT

A. Reference Division 01, General Requirements for requirements pertaining to deficiencies/nonconformance, cost of retesting, or failure due to manufacturer defect.

3.11 OPERATION AND MAINTENANCE MANUALS

A. The Operation and Maintenance Manuals to conform to Contract Documents requirements as stated in Division 15, HVAC.

B. Provide an updated as-built version of the control drawings and sequences of operation in the final controls O&M manual submittal.

3.12 TRAINING OF OWNER PERSONNEL

A. Mechanical Contractor's Training Responsibilities:
   1. Provide the Commissioning Authority with a training plan two weeks before the planned training.
   2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, HVAC equipment (i.e. pumps, heat exchangers, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.)
   3. Training starts with classroom sessions followed by hands-on training on each piece of equipment to illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
   4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
   5. The appropriate trade or manufacturer's representative provides the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of modes of operation of the specific piece of equipment are required. More than one party may be required to execute the training.
   6. Controls contractor to attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
   7. The training sessions follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
   8. Training Includes:
      a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
      b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed

and spare parts inventory suggestions. Training to include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.

c. Discussion of relevant health and safety issues and concerns.
d. Discussion of warranties and guarantees.
e. Common troubleshooting problems and solutions.
f. Explanatory information included in the O&M manuals and the location of plans and manuals in the facility.
g. Discussion of any peculiarities of equipment installation or operation.

9. Schedule training after functional testing is complete, unless approved otherwise by the Owner.

B. Controls Contractor's Training Responsibilities:

1. Provide the Commissioning Authority and A/E with a training plan four weeks before the planned training.
2. Provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on the capabilities of the control system.
3. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals include detailed description of the subject matter for each session. Manuals to cover control sequences and have a definitions section that fully describes relevant words used in the manuals and in software displays. Manuals will be approved by the Commissioning Authority and A/E. Deliver copies of audiovisuals to the Owner.
4. The trainings will be tailored to the needs and skill-level of the trainees.
5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. Owner to approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. Attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. Three Training Sessions, as Follows:
   a. Training I - Control System. The first training consists of 8 hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
   b. Training II - Building Systems. The second session held on-site for a period of 8 hours of actual hands-on training after the completion of system commissioning. The session includes instruction on:
      1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including

HVAC systems, lighting controls and any interface with security and communication systems.

2) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing set points and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
3) Trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
4) Completely discuss every screen, allowing time for questions.
5) Use of keypad or plug-in laptop computer at the zone level.
6) Use of remote access to the system via phone lines or networks.
7) Setting up and changing an air terminal unit controller.
8) Graphics generation
9) Point database entry and modifications
10) Understanding DDC field panel operating programming (when applicable)

c. Training III - The third training will be conducted on-site six months after occupancy and consist of 8 hours of training. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

END OF SECTION