DIVISION 23: HEATING, VENTILATING, AND AIR-CONDITIONING

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SECTION 230501 – COMMON HVAC REQUIREMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and General Provisions of Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Furnish labor, materials, and equipment necessary for completion of work as described in Contract Documents.

B. It is the intent of these specifications that the systems specified herein are to be complete and operational before being turned over to the owner. During the bidding process, the contractor is to ask questions or call to the engineer's attention any items that are not shown or may be required to make the system complete and operational. Once the project is bid and the contractor has accepted the contract, it is his responsibility to furnish and install all equipment and parts necessary to provide a complete and operational system without additional cost to the owner.

C. Furnish and install fire stopping materials to seal penetrations through fire rated structures and draft stops.

D. Includes But Not Limited To:
   1. General procedures and requirements for HVAC.

E. Related Sections:
   1. Section 23 0593: Testing, Adjusting, and Balancing for HVAC.

1.3 SUBMITTALS

A. Substitutions: By specific designation and description, standards are established for specialties and equipment. Other makes of specialties and equipment of equal quality will be considered provided such proposed substitutions are submitted to the Architect for his approval, complete with specification data showing how it meets the specifications, at least 5 working days prior to bid opening. A list of approved substitutions will be published as an addendum.
   1. Submit a single copy of Manufacturer's catalog data including Manufacturer's complete specification for each proposed substitution.
   2. The Architect or Engineer is to be the sole judge as to the quality of any material offered as an equal.

B. Product Data, Shop Drawings: Within 30 days after award of contract, submit 10 sets of Manufacturer's catalog data for each manufactured item.
   1. Literature shall include enough information to show complete compliance with Contract Document requirements.
   2. Mark literature to indicate specific item with applicable data underlined.
   3. Information shall include but not be limited to capacities, ratings, type of material used, guarantee, and such dimensions as are necessary to check space requirements.
   4. When accepted, submittal shall be an addition to Contract Documents and shall be in equal force. No variation shall be permitted.
   5. Even though the submittals have been accepted by the Engineer, it does not relieve the contractor from meeting all of the requirements of the plans and specifications and providing a complete and operational system.

C. Drawings of Record: One complete sets of blue line mechanical drawings shall be provided for the purpose of showing a complete picture of the work as actually installed.
   1. These drawings shall serve as work progress report sheets. Contractor shall make notations neat and legible therein daily as the work proceeds.
   2. The drawings shall be kept at the job at a location designated by the Mechanical Engineer.
   3. At completion of the project these "as-built" drawings shall be signed by the Contractor, dated, and returned to the Architect.

D. Operating Instructions and Service Manual: The Mechanical Contractor shall prepare 2 copies of an Operation and Maintenance Manual for all mechanical systems and equipment used in this project. Manuals shall be bound in hard-backed binders and the front cover and spine of each binder shall indicate the name and location of the project. Use plastic tab indexes for all sections. Provide a section for each different type of equipment item. The following items shall be included in the manual, together with any other pertinent data. This list is not complete and is to be used as a guide.
   1. Provide a master index at the beginning of the manual showing all items included.
   2. The first section of the manual shall contain:
      a. Names, addresses, and telephone numbers of Architect, Mechanical Engineer, Electrical Engineer, General Contractor, Plumbing Contractor, Sheet Metal Contractor, and Temperature Control Contractor.
      b. List of Suppliers which shall include a complete list of each piece of equipment used with the name, address, and telephone number of vendor.
      c. General Description of Systems including –
         1) Location of all major equipment
         2) Description of the various mechanical systems
         3) Description of operation and control of the mechanical systems
         4) Suggested maintenance schedule
      d. Copy of contractor's written warranty
   3. Provide a copy of approved submittal literature for each piece of equipment.
   4. Provide maintenance and operation literature published by the manufacturer for each piece of equipment which includes: oiling, lubrication and greasing data; belt sizes, types and lengths; wiring diagrams; step-by-step procedure to follow in putting each piece of mechanical equipment in operation.
   5. Include parts numbers of all replaceable items.
   6. Provide control diagram and operation sequence, along with labeling of control piping and instruments to match diagram.
   7. Include a valve chart indicating valve locations.

E. Include air balance and/or water balance reports.

1.4 SUBMITTALS FOR COMMON HVAC REQUIREMENTS

A. Samples: Sealer and gauze proposed for sealing ductwork.

B. Quality Assurance / Control:
   1. Manufacturer’s installation manuals providing detailed instructions on assembly, joint sealing, and system pressure testing for leaks.
   2. Specification data on sealer and gauze proposed for sealing ductwork.

C. Quality Assurance
   1. Requirements: Construction details not specifically called out in Contract Documents shall conform to applicable requirements of SMACNA HVAC Duct Construction Standards.
   2. Pre-Installation Conference: Schedule conference immediately before installation of ductwork.

1.5 QUALITY ASSURANCE

A. Requirements of Regulatory Agencies:
   1. Perform work in accordance with applicable provisions of local and state Plumbing Code, Gas Ordinances, and adoptions thereof. Provide materials and labor necessary to comply with rules, regulations, and ordinances.
   2. In case of differences between building codes, state laws, local ordinances, utility company regulations, and Contract Documents, the most stringent shall govern. Promptly notify Architect in writing of such differences.

B. Applicable Specifications: Referenced specifications, standards, and publications shall be of the issues in effect on date of Advertisement for Bid.
   1. "Heating, Ventilating and Air Conditioning Guide" published by the American Society of Heating and Air Conditioning Engineers.
   2. "Engineering Standards" published by the Heating, Piping, and Air Conditioning Contractors National Association.
   3. "2015 International Building Code", "2015 International Mechanical Code", “2015 International Plumbing Code” and "2015 International Fire Code" as published by the International Conference of Building Officials.
   4. "National Electrical Code" as published by the National Fire Protection Association.
   5. "2015 International Energy Conservation Code ".

C. Identification: Motor and equipment name plates as well as applicable UL and AGA labels shall be in place when Project is turned over to Owner.

1.6 INSPECTIONS AND PERMITS

A. Pay for permits, fees, or charges for inspection or other services. Local and state codes and ordinances must be properly executed without expense to Owner and are considered as minimum requirements. Local and state codes and ordinances do not relieve the Contractor from work shown that exceeds minimum requirements.

1.7 ADDITIONAL WORK:

A. Design is based on equipment as described in the drawing equipment schedule. Any change in foundation bases, electrical wiring, conduit connections, piping, controls and openings required by alternate equipment submitted and approved shall be paid for by this division. All work shall be in accordance with the requirements of the applicable sections.

PART 2 - PRODUCTS FOR COMMON HVAC REQUIREMENTS

A. Finishes, Where Applicable: Colors as selected by Architect.

B. Duct Hangers:
   1. One inch 25 mm by 18 ga 1.27 mm galvanized steel straps or steel rods as shown on Drawings, and spaced not more than 96 inches 2 400 mm apart. Do not use wire hangers.
   2. Attaching screws at trusses shall be 2 inch 50 mm No. 10 round head wood screws. Nails not allowed.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Site Inspection:
   1. Examine premises and understand the conditions which may affect performance of work of this Division before submitting proposals for this work.

2. No subsequent allowance for time or money will be considered for any consequence related to failure to examine site conditions.

B. Drawings:
   1. Mechanical drawings show general arrangement of piping, ductwork, equipment, etc, and do not attempt to show complete details of building construction which affect installation. This Contractor shall refer to architectural, structural, and electrical drawings for additional building detail which affect installation of his work.
      a. Follow mechanical drawings as closely as actual building construction and work of other trades will permit.
      b. No extra payments will be allowed where piping and/or ductwork must be offset to avoid other work or where minor changes are necessary to facilitate installation.
      c. Everything shown on the mechanical drawings shall be the responsibility of Mechanical Contractor unless specifically noted otherwise.
   2. Consider architectural and structural drawings part of this work insofar as these drawings furnish information relating to design and construction of building. These drawings take precedence over mechanical drawings.
   3. Because of small scale of mechanical drawings, it is not possible to indicate all offsets, fittings, and accessories which may be required. Investigate structural and finish conditions affecting this work and arrange work accordingly, providing such fittings, valves, and accessories required to meet conditions. Do not scale drawings for locations of equipment or piping. Refer to large scale dimensioned drawings for exact locations.

C. Insure that items to be furnished fit space available. Make necessary field measurements to ascertain space requirements including those for connections and furnish and install equipment of size and shape so final installation shall suit true intent and meaning of Contract Documents.
   1. If approval is received to use other than specified items, responsibility for specified capacities and insuring that items to be furnished will fit space available lies with this Division.
   2. If non-specified equipment is used and it will not fit job site conditions, this Contractor assumes responsibility for replacement with items named in Contract Documents.

3.2 PREPARATION

A. Cut carefully to minimize necessity for repairs to existing work. Do not cut beams, columns, or trusses.
   1. Patch and repair walls, floors, ceilings, and roofs with materials of same quality and appearance as adjacent surfaces unless otherwise shown. Surface finishes shall exactly match existing finishes of same materials.
   2. Each Section of this Division shall bear expense of cutting, patching, repairing, and replacing of work of other Sections required because of its fault, error, tardiness, or because of damage done by it.
   3. Cutting, patching, repairing, and replacing pavements, sidewalks, roads, and curbs to permit installation of work of this Division is responsibility of Section installing work.

3.3 INSTALLATION

A. Arrange pipes, ducts, and equipment to permit ready access to valves, unions, traps, starters, motors, control components, and to clear openings of doors and access panels.

3.4 STORAGE AND PROTECTION OF MATERIALS:

A. Provide storage space for storage of materials and assume complete responsibility for losses due to any cause whatsoever. Storage shall not interfere with traffic conditions in any public thoroughfare.

B. Protect completed work, work underway, and materials against loss or damage.

C. Close pipe openings with caps or plugs during installation. Cover fixtures and equipment and protect against dirt, or injury caused by water, chemical, or mechanical accident.

3.5 EXCAVATION AND BACKFILL

A. Perform necessary excavation of whatever substance encountered for proper laying of all pipes and underground ducts.
   1. Excavated materials not required for fill shall be removed from site as directed by Engineer.
   2. Excavation shall be carried low enough to allow a minimum coverage over underground piping of 5'-0" or to be below local frost level.
   3. Excess excavation below required level shall be backfilled at Contractor's expense with earth, sand, or gravel as directed by Engineer. Tamp ground thoroughly.
   4. Ground adjacent to all excavations shall be graded to prevent water running into excavated areas.

B. Backfill pipe trenches and allow for settlement.
   1. Backfill shall be mechanically compacted to same density as surrounding undisturbed earth.
   2. Cinders shall not be used in backfilling where steel or iron pipe is used.
   3. No backfilling shall be done until installation has been approved by the Engineer.

3.6 COOPERATION

A. Cooperate with other crafts in coordination of work. Promptly respond when notified that construction is ready for installation of work under Division 23000. Contractor will be held responsible for any delays which might be caused by his negligence or failure to cooperate with the other Contractors or crafts.

3.7 SUPERVISION

A. Provide a competent superintendent in charge of the work at all times. Anyone found incompetent shall be removed at once and replaced by someone satisfactory, when requested by the Architect.

3.8 INSTALLATION CHECK:

A. An experienced, competent, and authorized representative of the manufacturer or supplier of each item of equipment indicated in the equipment schedule shall visit the project to inspect, check, adjust if necessary, and approve the equipment installation. In each case, the equipment supplier's representative shall be present when the equipment is placed in operation. The equipment supplier's representative shall revisit the project as often as necessary until all trouble is corrected and the equipment installation and operation is satisfactory to the Engineer.

B. Each equipment supplier's representative shall furnish to the Owner, through the Engineer, a written report certifying the following:
   1. Equipment has been properly installed and lubricated.
   2. Equipment is in accurate alignment.
   3. Equipment is free from any undue stress imposed by connecting piping or anchor bolts.
   4. Equipment has been operated under full load conditions.
   5. Equipment operated satisfactorily.

C. All costs for this installation check shall be included in the prices quoted by equipment suppliers.

3.9 CLEANING EQUIPMENT AND PREMISES

A. Properly lubricate equipment before Owner's acceptance.

B. Clean exposed piping, ductwork, equipment, and fixtures. Repair damaged finishes and leave everything in working order.

C. Remove stickers from fixtures and adjust flush valves.

D. At date of Substantial Completion, air filters shall be new, clean, and approved by Owner's representative.

E. Trap elements shall be removed during cleaning and flushing period. Replace trap elements and adjust after cleaning and flushing period.

3.10 TESTS

A. No piping work, fixtures, or equipment shall be concealed or covered until they have been inspected and approved by the inspector. Notify inspector when the work is ready for inspection.

B. All work shall be completely installed, tested as required by Contract Documents and the city and county ordinances and shall be leak-tight before the inspection is requested.

C. Tests shall be repeated to the satisfaction of those making the inspections.

D. Water piping shall be flushed out, tested at 100 psi and left under pressure of supply main or a minimum of 40 psi for the balance of the construction period.

3.11 WARRANTEE

A. Contractor shall guarantee work under Division 23 to be free from inherent defects for a period of one year from acceptance.
   1. Contractor shall repair, revise or replace any and all such leaks, failure or inoperativeness due to defective work, materials, or parts free of charge for a period of one year from final acceptance, provided such defect is not due to carelessness in operation or maintenance.
   2. In addition, the Contractor shall furnish all refrigeration emergency repairs, emergency service and all refrigerant required due to defective workmanship, materials, or parts for a period of one year from final acceptance at no cost to the Owner, provided such repairs, service and refrigerant are not caused by lack of proper operation and maintenance.

B. In addition to warrantee specified in General Conditions, heating, cooling, and plumbing systems are to be free from noise in operation that may develop from failure to construct system in accordance with Contract Documents.

3.12 SYSTEM START-UP, OWNER'S INSTRUCTIONS

A. Off-Season Start-up
   1. If Substantial Completion inspection occurs during heating season, schedule spring start-up of cooling systems. If inspection occurs during cooling season, schedule autumn start-up for heating systems.
   2. Notify Owner 7 days minimum before scheduled start-up.
   3. Time will be allowed to completely service, test, check, and off-season start systems. During allowed time, train Owner's representatives in operation and maintenance of system.

4. At end of off-season start-up, furnish Owner with letter confirming that above work has been satisfactorily completed.

B. Owner's Instructions
1. Instruct building maintenance personnel and Owner Representative in operation and maintenance of mechanical systems utilizing Operation & Maintenance Manual when so doing.
2. Minimum instruction periods shall be as follows –
a. Mechanical - Four hours.
b. Temperature Control - Four hours.
c. Refrigeration - Two hours.
3. Instruction periods shall occur after Substantial Completion inspection when systems are properly working and before final payment is made.
4. None of these instructional periods shall overlap another.

3.13 PROTECTION

A. Do not run heat pump, air handling units, fan coil units, or other pieces of equipment used for moving supply air without proper air filters installed properly in system.

B. The mechanical systems are not designed to be used for temporary construction heat. If any equipment is to be started prior to testing and substantial completion, such equipment will be returned to new condition with full one year warranties, from date of substantial completion after any construction use. This includes, but is not necessarily limited to: Equipment, filters, ductwork, fixtures, etc.

3.14 COMMON HVAC REQUIREMENTS:

A. INSTALLATION
1. During installation, protect open ends of ducts by covering with plastic sheet tied in place to prevent entrance of debris and dirt.
2. Make necessary allowances and provisions in installation of sheet metal ducts for structural conditions of building. Revisions in layout and configuration may be allowed, with prior written approval of Architect. Maintain required airflows in suggesting revisions.
3. Hangers And Supports:
a. Install pair of hangers close to each transverse joint and elsewhere as required by spacing indicated in table on Drawings.
b. Install upper ends of hanger securely to floor or roof construction above by method shown on Drawings.
c. Attach strap hangers to ducts with cadmium-plated screws. Use of pop rivets or other means will not be accepted.
d. Where hangers are secured to forms before concrete slabs are poured, cut off flush all nails, strap ends, and other projections after forms are removed.
e. Secure vertical ducts passing through floors by extending bracing angles to rest firmly on floors without loose blocking or shimming. Support vertical ducts, which do not pass through floors, by using bands bolted to walls, columns, etc. Size, spacing, and method of attachment to vertical ducts shall be same as specified for hanger bands on horizontal ducts.

B. CLEANING
1. Clean interior of duct systems before final completion.

END OF SECTION 230501

SECTION 230502 - DEMOLITION AND REPAIR

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Under this section remove obsolete piping and mechanical equipment and relocate, reconnect or replace existing piping affected by demolition or new construction. Remove concealed piping abandoned due to demolition or new construction, or cap piping flush with existing surfaces.

1.3 DRAWINGS AND EXISTING CONDITIONS

A. All relocations, reconnections and removals are not necessarily indicated on the drawings. As such, the Contractor shall make adequate allowance in his proposal for this work as no extra charges will be allowed for these items.

PART 2 - NOT USED

PART 3 - EXECUTION

3.1 TEMPORARY CONNECTIONS

A. Where existing piping must remain in service to supply occupied areas during construction, provide temporary piping, connections, and equipment to maintain service to such areas. All shall be performed in a neat and safe manner to prevent injury to the building or its occupants.

3.2 EXISTING TO BE ABANDONED

A. All required drilling, cutting, block-outs and demolition work required for the removal and/or installation of the mechanical system is the responsibility of this Contractor.

B. No joists, beams, girders, trusses or columns shall be cut by any Contractor without written permission from the Architect.

C. The patching, repair, and finishing to existing or new surfaces is the responsibility of this Contractor, unless specifically called for under sections of specifications covering these materials.

D. Disconnect all equipment that is to be removed or relocated. Relocate any existing equipment that obstructs new construction.

3.3 EXISTING TO REMAIN IN USE

A. Where affected by demolition or new construction, relocate, replace, extend, or repair piping and equipment to allow continued use of same. Use methods and materials as specified for new construction.

3.4 MATERIALS AND EQUIPMENT REMOVED

A. All obsolete materials, piping, and equipment shall become the property of the Contractor and be removed from the site promptly.

END OF SECTION 230502

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install identification of equipment and piping as described in Contract Documents.

B. Mechanical Contractor shall touch-up equipment where factory paint has been damaged. Repaint entire item where more than 20 percent of the surface is involved.

C. Primary painting of walls, ceilings, ductwork, piping and plenums is covered in the general painting section of these Contract Documents.

PART 2 - PRODUCTS

2.1 PAINT

A. Benjamin Moore Impervo or equivalent by Paint Manufacturer approved in Section 09 900.

B. Use appropriate primer.

2.2 LABELS

A. Black Formica with white reveal on engraving.

2.3 CODED BANDS

A. Using colored bands and arrows to indicate supply and return, with colored reflective tape, color code all piping installed in this contract at not more than 20-foot intervals, at equipment, at walls, etc., in accordance with ANSI Standards.

B. Approved Manufacturers:
   1. Seton
   2. Craftmark

2.4 PIPE IDENTIFICATION

A. In addition to the colored bands, stencil with black paint in 1/2 inch high letters a symbol and directional arrow for all fluids handled or use Seaton coded and colored pipe markers and arrows to meet ANSI Standards.

2.5 EQUIPMENT IDENTIFICATION

A. Provide an engraved plastic plate for each piece of equipment stating the name of the item, symbol number, area served, and capacity. Label all control components with plastic embossed mechanically attached labels. Sample:
   1. Supply Fan SF-1 - North Classrooms
   2. 10,000 CFM @ 2.5"

2.6 VALVE IDENTIFICATION

A. Make a list of and tag all valves installed in this work.
   1. Valve tags shall be of brass, not less than 1"x2" size, hung with brass chains.
   2. Tag shall indicate plumbing or heating service.

PART 3 - EXECUTION

3.1 APPLICATION

A. Engraved Plates:
   1. Identify thermostats and control panels in mechanical rooms, furnaces, boilers and hot water heating specialties, duct furnaces, air handling units, electric duct heaters, and condensing units with following data engraved and fastened to equipment with screws –
      a. Equipment mark noted on Drawings (i.e., SF-1)
      b. Area served (i.e., North Classrooms)
      c. Capacity (10,000 CFM @ 2.5)

B. Stenciling:
   1. Locate identifying legends and directional arrows at following points on each piping system –
      a. Adjacent to each item of equipment and special fitting.
      b. At point of entry and exit where piping goes through wall.
      c. On each riser and junction.
      d. Every 50 feet on long continuous lines.
   2. Gas, & Valve Identification –
      a. Identify specific pipe contents by stenciling pipe with written legend and placing of arrows to indicate direction of flow.

C. Painting:
   1. Background Color - Provide by continuous painting of piping.

Symbol	Name	Color
LPG	Propane Gas	Yellow
AIR	Air	Blue

   2. Identification stenciling and flow arrows shall be following colors for proper contrast:

Arrows & ID Stenciling	Color Shade of Pipe
White	Red, Grays, & black
Black	Yellows, Oranges, Greens, & White

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Division 23 0501 - Common HVAC Requirements and Basic Mechanical Materials and Methods Sections apply to work of this section.

1.2 SUMMARY SCOPE

A. This Section includes TAB to produce design objectives for the following:
   1. Air Systems.
      a. Furnaces.
      b. Exhaust Fans.
      c. Rooftop Units.

1.3 SUBMITTALS

A. Agency Data:
   1. Submit proof that the proposed testing, adjusting, and balancing agency meets the qualifications specified below. The firm or individuals performing the work herein specified may not be the installing firm.

B. Engineer and Technicians Data:
   1. Submit proof that the Test and Balance Engineer assigned to supervise the procedures, and the technicians proposed to perform the procedures meet the qualifications specified below.

C. Procedures and Agenda: Submit a synopsis of the testing, adjusting, and balancing procedures and agenda proposed to be used for this project.

D. Sample Forms: Submit sample forms, if other than those standard forms prepared by the AABC or NEBB are proposed.

E. Certified Reports: Submit testing, adjusting, and balancing reports bearing the seal and signature of the Test and Balance Engineer. The reports shall be certified proof that the systems have been tested, adjusted, and balanced in accordance with the referenced standards; are an accurate representation of how the systems have been installed; are a true representation of how the systems are operating at the completion of the testing, adjusting, and balancing procedures; and are an accurate record of all final quantities measured, to establish normal operating values of the systems. Follow the procedures and format specified below.
   1. Draft Reports: Upon completion of testing, adjusting, and balancing procedures, prepare draft reports on the approved forms. Draft reports may be hand written, but must be complete, factual, accurate, and legible. Organize and format draft reports in the same manner specified for the final reports. Submit 2 complete sets of draft reports. Only 1 complete set of draft reports will be returned.
   2. Final Report: Upon verification and approval of draft reports, prepare final reports, type written, and organized and formatted as specified below. Submit 4 complete sets of final reports.
   3. Report Format: Report forms shall be those standard forms prepared by the referenced standard for each respective item and system to be tested, adjusted, and balanced. Bind report forms complete with schematic systems diagrams and other data. Divide the contents of the binder into the below listed divisions, separated by divider tabs:
      a. General Information and Summary

b. Air Systems
c. Temperature Control System Verification.

F. Report Contents: Provide the following minimum information, forms, and data:
1. General information and Summary: Inside cover sheet to identify testing, adjusting, balancing agency, Contractor, Owner, Engineer, and Project. Include addresses and contact names and telephone numbers. Also include a certification sheet containing the seal and name, address, telephone number, and signature of the Certified Test and Balance Engineer. Include in this division a listing of the instrumentation used for the procedures along with the instrument calibration sheet.
2. The remainder of the report shall contain the appropriate forms containing as a minimum, the information indicated on the standard report forms prepared by the AABC or NEBB, for each respective item and system. Prepare a schematic diagram for each item of equipment and system to accompany each respective report form. The report shall contain the following information, and all other data resulting from the testing, adjusting, and balancing work:
a. All nameplate and specification data for all air handling equipment and motors.
b. Actual metered running amperage for each phase of each motor on all pumps and air handling equipment.
c. Actual metered voltage at air handling equipment (phase-to-phase for all phases).
d. Fan RPM for each piece of air handling equipment.
e. Total actual CFM being handled by each piece of air handling equipment.
f. Actual CFM of systems by rooms.
3. Certify that all smoke and fire dampers operate properly and can be reset under actual system operating conditions.

G. Calibration Reports:
1. Submit proof that all required instrumentation has been calibrated to tolerances specified in the referenced standards, within a period of six months prior to starting the project.

1.4 CERTIFICATION

A. Agency Qualifications:
1. Employ the services of a certified testing, adjusting, and balancing agency meeting the qualifications specified below, to be the single source of responsibility to test, adjust, and balance the building mechanical systems identified above, to produce the design objectives. Services shall include checking installations for conformity to design, measurement, and establishment of the fluid quantities of the mechanical systems as required to meet design specifications, recording and reporting the results, and operation of all systems to demonstrate satisfactory performance to the owner.
2. The testing, adjusting, and balancing agency certified by National Environmental Balancing Bureau (NEBB) or Associated Air Balance Council (AABC) in those testing and balancing disciplines required for this project, and having at least one person certified by NEBB or AABC as a Test and Balance supervisor, and a registered professional mechanical engineer, licensed in the state where the work will be performed.

B. Codes and Standard:
1. NEBB: “Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.”
2. AABC: “National Standards for Total System Balance.”
3. ASHRAE: ASHRAE Handbook, 1984 Systems Volume, Chapter 37, Testing, Adjusting, and Balancing.

1.5 PROJECT CONDITIONS

A. Systems Operation: Systems shall be fully operation and clean prior to beginning procedures.

1.6 SEQUENCING AND SCHEDULING

A. Test, adjust, and balance the air systems before hydronic, steam, and refrigerant systems within +10% to -5% of contract requirements.

B. The report shall be approved by the Engineer. Test and balance shall be performed prior to substantial completion.

PART 2 - NOT USED

PART 3 - EXECUTION

3.1 PRELIMINARY PROCEDURES FOR AIR SYSTEM BALANCING

A. Before operating the system, perform these steps.
   1. Obtain design drawings and specifications and become thoroughly acquainted with the design intent.
   2. Obtain copies of approved shop drawings of all air handling equipment, outlets (supply, return, and exhaust) and temperature control diagrams.
   3. Compare design to installed equipment and field installations.
   4. Walk the system from the system air handling equipment to terminal units to determine variations of installation from design.
   5. Check filters for cleanliness and to determine if they are the type specified.
   6. Check dampers (both volume and fire) for correct and locked position. Check automatic operating and safety controls and devices to determine that they are properly connected, functioning, and at proper operating setpoint.
   7. Prepare report test sheets for both fans and outlets. Obtain manufacturer's outlet factors and recommended procedures for testing. Prepare a summation of required outlet volumes to permit a cross-check with required fan volumes.
   8. Determine best locations in main and branch ductwork for most accurate duct traverses.
   9. Place outlet dampers in the full open position.
   10. Prepare schematic diagrams of system "As-Built" ductwork and piping layouts to facilitate reporting.
   11. Lubricate all motors and bearings.
   12. Check fan belt tension.
   13. Check fan rotation.

3.2 MEASUREMENTS

A. Provide all required instrumentation to obtain proper measurements, calibrated to the tolerances specified in the referenced standards. Instruments shall be properly maintained and protected against damage.

B. Provide instruments meeting the specifications of the referenced standards.

C. Use only those instruments which have the maximum field measuring accuracy and are best suited to the function being measured.

D. Apply instrument as recommended by the manufacturer.

E. Use instruments with minimum scale and maximum subdivisions and with scale ranges proper for the value being measured.

F. When averaging values, take a sufficient quantity of readings which will result in a repeatability error of less than 5%. When measuring a single point, repeat readings until 2 consecutive identical values are obtained.

G. Take all readings with the eye at the level of the indicated value to prevent parallax.

H. Use pulsation dampeners where necessary to eliminate error involved in estimating average of rapidly fluctuation readings.

I. Take measurements in the system where best suited to the task.

3.3 PERFORMING TESTING, ADJUSTING, AND BALANCING

A. Perform testing and balancing procedures on each system identified, in accordance with the detailed procedures outlined in the referenced standards. Balancing of the air systems and hydronic systems shall be achieved by adjusting the automatic controls, balancing valves, dampers, air terminal devices, and the fan/motor drives within each system.

B. Cut insulation, ductwork, and piping for installation of test probes to the minimum extent necessary to allow adequate performance of procedures.

C. Patch insulation, ductwork, and housings, using materials identical to those removed.

D. Seal ducts and piping, and test for and repair leaks.

E. Seal insulation to re-establish integrity of the vapor barrier.

F. Adjust timing relays of environmental equipment motor reduced voltage starters to the optimum time period for the motor to come up to the maximum reduced voltage speed and then transition to the full voltage speed to prevent damage to motor, and to limit starting current spike to the lowest possible and practical.

G. Mark equipment settings, including damper control positions, valve indicators, fan speed control levers, and similar controls and devices, to show final settings. Mark with paint or other suitable, permanent identification materials.

H. Retest, adjust, and balance systems subsequent to significant system modifications, and resubmit test results.

3.4 RECORD AND REPORT DATA

A. Record all data obtained during testing, adjusting, and balancing in accordance with, and on the forms recommended by the referenced standards, and as approved on the sample report forms.

B. Prepare report of recommendations for correcting unsatisfactory mechanical performances when system cannot be successfully balanced.

C. Report shall be certified and stamped by a registered professional mechanical engineer employed by the agency and licensed in the state where the work will be performed.

D. Engineer is to provide a floor plan and test and balance contractor to include the plan in test and balance report and identify actual cfm on drawing or number the diffusers to match report.

3.5 DEMONSTRATION

A. If requested, testing, adjusting, and balancing agency shall conduct any or all of the field tests in the presence of the engineer.

B. Agency shall include a maximum of one (1) call back to the project within the one year warranty period to make additional adjustments if requested by the engineer.

END OF SECTION 230593

SECTION 230712 - MECHANICAL INSULATION AND FIRE STOPPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install mechanical insulation and fire stopping as described in Contract Documents including but not limited to the following:
   1. Ductwork Insulation
   2. Fire Stopping

1.3 QUALITY ASSURANCE

A. Insulation shall have composite (insulation, jacket or facing and adhesive used to adhere facing or jacket to insulation) fire and smoke hazard ratings as tested by Procedure ASTM E-84, NFPA 255 and UL 723 not exceeding: Flame Spread of 25 and Smoke Developed of 50.

B. Insulation Contractor shall certify in writing, prior to installation, that all products to be used will meet the above criteria.

C. Accessories, such as adhesives, mastics, cements, and tapes, for fittings shall have the same component ratings as listed above.

D. Products, or their shipping cartons, shall bear a label indicating that flame and smoke ratings do not exceed above requirements.

E. Any treatment of jacket or facings to impart flame and smoke safety shall be permanent.

F. The use of water-soluble treatments is prohibited.

END OF SECTION 230712

SECTION 230716 - DUCTWORK INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install insulation on air ducts outside building insulation envelope as described in Contract Documents.

B. Furnish and install insulation on fresh air ducts and combustion air ducts within building insulation envelope as described in Contract Documents.

C. Furnish and install insulation on other air ducts where indicated on Drawings.

PART 2 - PRODUCTS

2.1 INSULATION

A. 1-1/2 inch thick fiberglass with aluminum foil scrim kraft facing and have a density of one lb/cu ft.

B. Approved Manufacturers:
   1. Manville Microlite FSK
   2. CSG Type IV standard duct insulation
   3. Owens-Corning FRK
   4. Knauf (Duct Wrap FSK)

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct wrap in accordance with Manufacturer's recommendations.

B. Do not compress insulation except in areas of structural interference.

C. Completely seal joints.

END OF SECTION 230716

SECTION 230717 – ROUND SUPPLY DUCT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install round supply duct insulation as described in Contract Documents.

1.3 QUALITY ASSURANCE

A. Insulation shall be UL rated with FSK (foil-skrim-kraft) facing.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Fiberglass blanket insulation

B. Approved Manufacturers:
   1. Johns-Manville R-4 Microlite (R-4 does not include the vapor barrier material).
   2. Owens-Corning faced duct wrap insulation FRK-25 ED-150
   3. Certainteed Standard Duct Wrap.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Insulate round air supply ducts.

B. Facing shall overlap 2" at joints and shall be secured with outward clinch staples on 4" centers.

C. Ducts over 30" in width shall have spot application of adhesive, weld pins or metal screws and caps on not more than 18" centers applied to underside.

D. 3" wide vapor barrier paper shall be applied over seams and sealed with vapor barrier adhesive.

E. Insulate attenuators.

F. Insulate high and low pressure flex ducts.

END OF SECTION 230717

SECTION 230718 - DUCT LINING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install acoustic lining in following above ground metal ductwork as described in Contract Documents unless detailed otherwise:
   1. Outside air
   2. Supply air
   3. Return air
   4. Mixed air
   5. Transfer air
   6. Relief air
   7. Elbows, fittings, and diffuser drops greater than 12 inches in length.

1.3 SYSTEM DESCRIPTION

A. Duct dimensions shown on Drawings are for free area inside insulation. Allowance must be made for insulation, where applicable.

1.4 RATINGS:

A. Material shall have maximum air friction correction factor of 1.10 at 1000 FPM velocity and have a minimum sound absorption coefficient NRC of .60.

PART 2 - PRODUCTS

2.1 DUCT LINER

A. One inch thick, 1-1/2 lb density fiberglass, factory edge coated.

B. Duct lining materials are to meet the requirements of UL 181 for mold, humidity, and erosion resistance.

C. Approved Manufacturers:
   1. Certainteed Ultralite 150 Certa Edge Coat
   2. Knauf - Type M
   3. Manville - Lina-Coustic
   4. Owen Corning Fiberglas - Aeroflex

2.2 ADHESIVE

A. Water Base Type:
   1. Cain - Hydrotak
   2. Duro Dyne - WSA
   3. Kingco - 10-568
   4. Miracle - PF-101
   5. Mon-Eco - 22-67
   6. Techno Adhesive - 133

B. Solvent Base (non-flammable) Type:
   1. Cain - Safetak
   2. Duro Dyne - FPG
   3. Kingco - 15-137
   4. Miracle - PF-91
   5. Mon-Eco - 22-24
   6. Techno Adhesive - 'Non-Flam' 106

C. Solvent Base (flammable) Type:
   1. Cain - HV200
   2. Duro Dyne - MPG
   3. Kingco - 15-146
   4. Miracle - PF-96
   5. Mon-Eco - 22-22
   6. Techno Adhesive - 'Flammable' 106

2.3 FASTENERS

A. Adhesively secured fasteners not allowed.

B. Approved Manufacturers:
   1. AGM Industries Inc - "DynaPoint" Series DD-9 pin
   2. Cain
   3. Duro Dyne
   4. Omark dished head "Insul-Pins"
   5. Grip nails may be used if each nail is installed by "Grip Nail Air Hammer" or by "Automatic Fastener Equipment" in accordance with Manufacturer's recommendations.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install mat finish surface on air stream side. Secure insulation to cleaned sheet metal duct with continuous 100% coat of adhesive and with 3/4 inch long mechanical fasteners 12 inches on center maximum unless detailed otherwise on Drawings. Pin all duct liner.

B. Accurately cut liner and thoroughly coat ends with adhesive. Butt joints tightly. Top and bottom sections of insulation shall overlap sides. If liner is all one piece, folded corners shall be tight against metal. Ends shall butt tightly together.

C. In casings and plenums further contain insulation with wire mesh.

3.2 FIELD QUALITY CONTROL

A. If insulation is installed without longitudinal and end joints butted together, installation will be rejected and work removed and replaced with work that conforms to this Specification.

B. Insulation shall be installed in accordance with Duct Liner Application Standard SMACNA Manual 15.

3.3 ADJUSTING, CLEANING

A. Keep duct liner clean and free from dust. At completion of project, vacuum duct liner if it is dirty or dusty.

END OF SECTION 230718

SECTION 230800 – FIRE STOPPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install fire stopping as described in Contract Documents.

1.3 QUALITY ASSURANCE

A. Fire stopping material shall meet ASTM E814, E84 and be UL listed.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Material shall be flexible, long lasting, intumescent acrylic seal to accommodate vibration and building movement.

B. Caulk simple penetrations with gaps of 1/4" or less with:
   1. Dow Corning Fire Stop Sealant
   2. Pensil 300

C. Caulk multiple penetrations and/or penetrations with gaps in excess of 1/4" with:
   1. Dow Corning Fire Stop Foam
   2. Pensil 200
   3. IPC flame safe FS-1900
   4. Tremco “Tremstop 1A”

PART 3 - EXECUTION

3.1 INSTALLATION

A. Follow manufacturer's installation instructions explicitly.

B. Seal penetrations of ductwork, piping, and other mechanical equipment through one-hour and two-hour rated partitions as shown on Architectural and Mechanical Drawings.

C. Install fire stopping material on clean surfaces to assure adherence.

END OF SECTION 230800

SECTION 230953 - DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.01 DIRECT DIGITAL CONTROL (DDC) SYSTEM DESCRIPTION

A. Intent. The System Contractor shall supply and install a complete Direct Digital Control (DDC) System as required to accomplish the specified Sequences of Operation for control of heating, ventilating, air-conditioning, and other building equipment and systems as described in this specification.

1.02 SYSTEM REQUIREMENTS

A. BACnet®. The control system shall consist of a high-speed, peer-to-peer internetwork of ANSI/ASHRAE Standard 135 native BACnet devices. The control system shall also incorporate input/output devices, mechanical/electrical automatic temperature control devices, enclosures, interconnecting conduit, and cabling.

B. Performance Monitoring. The System shall provide the specified performance monitoring functionality, including required monitoring points and performance metrics, system accuracy, data acquisition and data management capabilities, as well as all required graphical and data displays.

C. Browser-Based User Interface. The System shall support a Browser-based User Interface (BUI) to the System data. An Operator using a standard web browser shall be able to access the control system graphics and change adjustable setpoints.

1.03 SYSTEM ARCHITECTURE

A. BACnet internetwork. The System as provided and installed under this specification shall comprise a BACnet internetwork with a multitiered architecture.

1. All communication shall conform to ANSI/ASHRAE Standard 135: BACnet.

B. Tier 3 Field Level Communication Network (FLCN). This network architecture tier comprises the primary field level infrastructure for the connection of unitary equipment.

1. Tier 3 FLCNs shall be BACnet networks comprised of:

a. Unitary BACnet controllers and devices,

b. Embedded BACnet equipment controllers, and

c. Device-level integration.

2. Tier 3 FLCNs shall use one the following BACnet data links only:

a. BACnet/IP: ANSI/ASHRAE Standard 135 Annex J.

b. B/VPN: BACnet Virtual Private Network.

c. ISO 8802-3 (Ethernet): ANSI/ASHRAE Standard 135.7.

d. Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.

C. Tier 2 Building Level Communication Network (BLCN). This network architecture tier comprises the primary building-level infrastructure for the connection of building- and facility-level systems, and FLCNs.

1. Tier 2 BLCNs shall be BACnet networks comprised of:
    a. Building-level BACnet controllers,
    b. Building-level data archival and analytics,
    c. Local workstations and operator interfaces,
    d. System-level integration,
    e. Routers for the interconnection of FLCNs, and
    f. Building-level BUI.
2. Tier 2 BLCNs shall use one the following BACnet data links only:
    a. BACnet/IP: ANSI/ASHRAE Standard 135 Annex J.
    b. B/VPN: BACnet Virtual Private Network.

D. Tier 1 Enterprise Level Communication Network (ELCN). This network architecture tier comprises the primary enterprise-level infrastructure for the connection of BLCNs.
1. The Tier 1 ELCN shall be a BACnet Wide Area Network (WAN) comprised of:
    a. BLCNs,
    b. Enterprise-level data archival and analytics,
    c. Facility-level integration, and
    d. High-level BUI.
2. The Tier 1 ELCN shall use one the following BACnet data links only:
    a. BACnet/IP: ANSI/ASHRAE Standard 135 Annex J.
    b. B/VPN: BACnet Virtual Private Network.

1.04 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Provide, supervise, and coordinate the installation of components supplied under this Section but installed under other divisions of the specification.

B. Automatic control valves, thermowells, liquid/gas flow switches, liquid/gas flow meters, and energy meters are to be installed by the contractor responsible for the installation of the applicable piping system(s).

C. Automatic control dampers, airflow measuring stations, and duct-mounted airflow sensors and devices are to be installed by the contractor responsible for the installation of the applicable associated duct and/or mechanical system(s).

D. Electrical power and energy meters shall be installed by the contractor responsible for the installation of the associated electrical power system.

E. All line-voltage thermostats and/or System components shall be installed by the contractor responsible for the installation of the associated electrical power system.

F. Air Terminal Unit (ATU) devices with integral damper operators are to be installed by the contractor responsible for installation of the air terminal units.

1.05 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

A. Low-voltage sensors and components that are integral to the System as specified but supplied under other divisions of the specification shall be installed under this Section.

1.06 RELATED SECTIONS

A. The General Conditions of the Contract, the Supplementary Conditions, and General Requirements of the project are part of this specification and shall be used in conjunction with this section as part of the Contract Documents.

B. Submittal Procedures.

C. Heating, Ventilating, and Air Conditioning (HVAC).

D. Electrical.

E. Electronic Access Control and Intrusion Detection.

F. Electronic Detection and Alarm.

1.07 QUALITY ASSURANCE

A. The DDC System Manufacturer shall be engaged full-time and shall have been engaged full-time for a minimum of ten (10) years, in the manufacture of equipment and devices of the scope, size, and service consistent with the requirements for this project.

B. The System Manufacturer shall operate a Quality Management System that is formally certified to be in compliance with ISO 9001:2015.

C. System controllers provided under this specification must be manufactured in compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronics equipment (RoHS 2).

D. The System Contractor shall specialize, and have a minimum of five (5) years of experience in, the design, installation, programming, and operation of Systems consistent with the scope, size, and service specified; and shall:

1. Be an officially authorized representative of the System Manufacturer with an established relationship of not less than three (3) years.

2. Assign to the project technicians and engineers who are officially trained and certified by the System Manufacturer in the design, installation, programming, and operation of the System components.

a. Upon request, the System Contractor shall present certifications of completed training including hours of instruction and course outlines for all technicians and engineers assigned to, and/or otherwise employed on, the project.

E. The BACnet internetwork shall be based upon, and installed according to, the System Manufacturer’s standard integrated hardware and software product design and in accordance with the System Manufacturer’s installation and application documentation.

1.08 CODES AND STANDARDS

A. Workmanship, materials and equipment together with the resultant complete and operational System shall be in compliance with the Authorities Having Jurisdiction (AHJ) for the project and the most restrictive of applicable local, state, and federal codes and ordinances in cooperation with these plans and specifications. At a minimum, the installation shall comply with the current editions in effect thirty (30) days prior to receipt of bids of the following applicable codes:

1. ANSI/ASHRAE Standard 135: BACnet - A Data Communication Protocol for Building Automation and Control Networks.
2. National Electric Code (NEC).
3. Canadian Electrical Code, Part 1 (CSA C22.1-12).
4. International Building Code (IBC).
5. International Mechanical Code (IMC).
6. Underwriters Laboratories (UL).
    a. UL-916 – Energy Management Systems (EMS).

1.09 SYSTEM PERFORMANCE

A. Performance Standards. The System shall conform to the following minimum performance standards using the project-deployed, normal-service, production hardware, firmware, software, and network connections:

1. Graphic Display. A minimum of 50 dynamic real-time data points shall be displayed within 10 seconds of the request and shall refresh with current data within 5 seconds.
2. Operator Command. The maximum time between the command of a binary or analog object by the operator and the reaction initialization by the device shall be 2 seconds.
3. Object Command. Devices shall respond to automatic command of a binary or analog object within 2 seconds.
4. Object scan. Changes of state or analog values shall be transmitted such that reporting of a value is never more than 15 seconds old and is reported within 15 seconds of a change in value.
5. Alarm Response. The maximum amount of time from when an object goes into alarm until it is annunciated at the workstation shall not exceed 20 seconds.
    a. Each workstation on the network shall receive alarms within 5 seconds of other workstations.
6. Program Execution. All programs in all DDC devices shall be able to execute at a minimum of at least one time every second. Program execution time shall be configurable to be consistent with the process under control.
7. Control Loop Performance. All DDC devices shall be able to execute control loops at a frequency at least one time every second. The controller shall update the process value and output generated by this calculation at this same frequency at a minimum or as appropriate for the mechanical process under control.

B. Environmental Conditions. All System components provided under this specification shall operate under ambient environmental conditions of -20°C (-4°F) to 55°C (131°F) dry-bulb and 10% to 90% relative humidity, non-condensing at a minimum. Sensors and control elements shall be constructed of materials suitable and rated for the media sensed under the ambient environmental temperature, pressure, humidity, and vibration conditions typical for the installed location.

C. Power Conditions. Networked components of the System shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%.

D. Reporting Accuracy. System shall report values with minimum end-to-end accuracy as listed in Table 1 through Table 5.

E. Control Stability and Accuracy. Control applications shall maintain process variables at setpoint within the tolerances listed in Table 1 through Table 5.

1. Combined system repeatability of sensors, controllers, and readout devices for a particular application shall be ±2% of full scale of the operating range.

2. Repeatability of overall combined system of sensor, controller, and readout device in a control loop application will be ±5% of full scale of the operating range.

3. Long-term electronic drift shall not exceed 0.4% per year.

TABLE 1: SENSOR, METER, & VALUE REQUIRED ACCURACIES

TAG	SENSOR	TYPE	SENSOR DETAILS	REQUIRED END-TO-END ACCURACY	DISPLAY RESOLUTION	REFRESH INTERVAL (MIN)	TREND INTERVAL (MIN)	REQUIRED CONTROL ACCURACY
S1	Outdoor Ambient dry-bulb temperature.	AI	10K-ohm, NTC, thermistor. Locate in weather station or ventilated enclosure in fully shaded location away from thermal mass bodies.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	10	±1.0°C (±2.0°F)
S2	Outdoor Ambient wet-bulb temperature.	AI	Locate in weather station or ventilated enclosure in fully shaded location away from thermal mass bodies.	±0.3°C (±0.54°F)	0.1°C (0.18°F)	1	10	±1.5°C (±3.0°F)
S3	Dewpoint	AI	Chilled mirror, infrared, capacitive.	±1.5°C (±3.0°F)	0.1°C (0.18°F)	1	10	±1.5°C (±3.0°F)
S4	Facility, main natural gas meter	BI	Positive displacement – pressure compensated; continuous output.	±1% reading, >10:1 turndown	0.05 L/s (0.1 scfm)	1	1	0.05 L/s (0.1 scfm)
S5	Natural gas flow rate	AI/BI	Positive displacement – pressure compensated; continuous output.	±2% reading, >10:1 turndown	0.05 L/s (0.1 scfm)	1	1	0.05 L/s (0.1 scfm)
S6	Facility, main power meter	AI/BI	True RMS to 50th harmonic.	±1% reading	0.1 kW	1	1	0.1 kW
S7	Electric power submeter	AI/BI	True RMS to 50th harmonic.	±1% reading	0.001 kW	1	1	0.001 kW
S8	Space temperature	AI	10K-ohm, NTC, thermistor.	±0.3°C (±0.54°F)	0.1°C (0.18°F)	1	10	±0.5°C (±1.0°F)
S9	Carbon dioxide (CO_2)	AI	Nondispersive infrared sensor.	±30 ppm to ±5% of reading	50 ppm	1	1	40 ppm
S10	Carbon Monoxide (CO)	AI	Electrochemical sensor.	±5 ppm	50 ppm	1	1	50 ppm
S11	Air pressure (duct)	AI		±25 Pa (±0.1 inwc)	125 Pa (0.5 inwc)	1	1	25 Pa (0.1 inwc)
S12	Air pressure (space)	AI		±3 Pa (±0.01 inwc)	3 Pa (0.01 inwc)	1	1	±3 Pa (±0.01 inwc)

S13	Water pressure	AI		±2% of reading	7 kPa (1 psi)	1	1	3.5 kpa (0.5 psi)

TABLE 2: SENSOR, METER, & VALUE REQUIRED ACCURACIES (*CONTINUED*)

TAG	SENSOR	TYPE	SENSOR DETAILS	REQUIRED END-TO-END ACCURACY	DISPLAY RESOLUTION	REFRESH INTERVAL (MIN)	TREND INTERVAL (MIN)	REQUIRED CONTROL ACCURACY
S14	Water temperature	AI	10K-ohm, NTC, thermistor.	±0.5°C (±1.0°F)	0.1°C (0.18°F)	1	1	±1.5°C (±3.0°F)
S15	Δ Temperature	AI	10K-ohm, NTC, thermistor.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	1	±0.2°C (±0.36°F)
S16	Relative Humidity (RH)	AI		±5% RH	5%	1	1	±5% RH
S17	Heating hot water flow	AI		±2% of reading	1000 l/s (5 gpm)	1	1	±0.032 l/s (±0.5 gpm)
S18	Air temperature (ducted; not specified elsewhere)	AI	10K-ohm, NTC, thermistor.	±0.5°C (±1.0°F)	0.1°C (0.18°F)	1	1	±1.5°C (±3.0°F)
S19	Electrical (A, V, W, PF; not specified elsewhere)	AI/BI	True RMS, three-phase, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1% of full-scale	0.1	1	1	0.001 kW
S20	Chiller power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading	0.01 kW	1	1	0.001 kW
S21	Primary chilled water pump power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading; ±3%VFD reading	0.01 kW	1	1	0.001 kW
S22	Chilled water condenser water pump power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum	±1.5% of reading; ±3%VFD reading	0.01 kW	1	1	0.001 kW

			resolution if pulse output.					

TABLE 3: SENSOR, METER, & VALUE REQUIRED ACCURACIES (*CONTINUED*)

TAG	SENSOR	TYPE	SENSOR DETAILS	REQUIRED END-TO-END ACCURACY	DISPLAY RESOLUTION	REFRESH INTERVAL (MIN)	TREND INTERVAL (MIN)	REQUIRED CONTROL ACCURACY
S23	Cooling tower fan power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading; ±3%VFD reading	0.01 kW	1	1	0.001 kW
S24	Secondary chilled water pump power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading; ±3%VFD reading	0.01 kW	1	1	0.001 kW
S25	Chilled water supply temperature	AI	10K-ohm, NTC, thermistor (matched with S26).	±0.5°C (±1.0°F)	0.1°C (0.18°F)	1	1	±0.5°C (±1.0°F)
S26	Chilled water return temperature	AI	10K-ohm, NTC, thermistor (matched with S25).	±0.5°C (±1.0°F)	0.1°C (0.18°F)	1	1	±0.5°C (±1.0°F)
S27	Chilled water plant flow rate	AI	Full-bore magnetic flowmeter (preferred); hot-tapped insertion flowmeter (alternate).	±0.75% of reading ±2.0% of reading	0.005 l/s (0.1 gpm)	1	1	±0.75 of reading ±2.0 of reading
S28	AHU supply fan airflow	AI	Vortex shedding sensor on fan inlet.	±5% of reading down to 0.75 m/s (150 fpm)	0.05 l/s (0.1 cfm)	1	1	±5% of reading down to 0.75 m/s (150 fpm)
S29	Airflow (measuring stations)	AI	Electronic or differential pressure.	±5% of reading	47 l/s (100 cfm)	1	1	±5% of reading

S30	Airflow (terminal)	AI	Electronic or differential pressure.	±10% of reading	47 l/s (100 cfm)	1	1	±10% of reading
S31	Airflow (pressurized spaces)	AI	Electronic or differential pressure.	±3% of reading	24 l/s (50 cfm)	1	1	±3% of reading

TABLE 4: SENSOR, METER, & VALUE REQUIRED ACCURACIES (*CONTINUED*)

TAG	SENSOR	TYPE	SENSOR DETAILS	REQUIRED END-TO-END ACCURACY	DISPLAY RESOLUTION	REFRESH INTERVAL (MIN)	TREND INTERVAL (MIN)	REQUIRED CONTROL ACCURACY
S32	AHU supply fan power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading; ±3%VFD reading	0.1 kW	1	1	0.001 kW
S33	AHU return fan power	AI/BI	True RMS, three-phase, integrated equipment, stand-alone analog or pulse output or network meter; use maximum resolution if pulse output.	±1.5% of reading; ±3%VFD reading	0.1 kW	1	1	0.001 kW
S34	AHU discharge air temperature	AI	10K-ohm, NTC, thermistor.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	10	±0.5°C (±1.0°F)
S35	AHU mixed air temperature	AI	10K-ohm, NTC, thermistor. Use averaging sensor located in AHU mixed air section installed in a serpentine manner vertically across the duct.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	10	±0.5°C (±1.0°F)
S36	AHU return air temperature	AI	10K-ohm, NTC, thermistor. Locate upstream of AHU return air damper.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	10	±0.5°C (±1.0°F)
S37	AHU outdoor air damper position	AO		N/A	0.1%	1	10	0.1%
S38	AHU return air damper position	AO		N/A	0.1%	1	10	0.1%

S39	Whole-facility total water flow rate	AI	Hot-tapped insertion flowmeter.	±2% of reading >20:1 turndown	0.005 l/s (0.1 gpm)	1	1	0.005 l/s (0.1 gpm)
M1	Whole-facility peak power	AI/BI	Maximum of measured value S6 over a specified time interval.	±1%	0.1 kW	1	10	1 kW
M2	Whole-facility area-normalized electric energy use intensity	AV	Measured value S6 divided by a constant (C1) equal to building area in m^2 (ft^2).	±1%	1.8 kWh/m^2 (0.1 kWh/ft^2)	1	10	±1%

TABLE 5: SENSOR, METER, & VALUE REQUIRED ACCURACIES (*CONTINUED*)

TAG	SENSOR	TYPE	SENSOR DETAILS	REQUIRED END-TO-END ACCURACY	DISPLAY RESOLUTION	REFRESH INTERVAL (MIN)	TREND INTERVAL (MIN)	REQUIRED CONTROL ACCURACY
M3	Whole facility natural gas heat rate	AV	Measured value S4 divided by a constant (C2) equal to 0.01 therm/standard cubic feet.	±1.5%	1.8 kW/s (0.1 therms/min)	1	10	±1.5%
M4	Whole-facility area-normalized gas energy use intensity	AV	Calculated value M3 integrated over a specified interval divided by a constant (C1) equal to building area in m^2 (ft^2).	±1.5%	315 kWh/m^2 (0.1 therms/ft^2)	1	10	±1.5%
M5	Average daily outdoor ambient temperature	AV	Average of instantaneous measured value(s) S1.	±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	10	±0.5°C (±1.0°F)
M6	Chilled water plant chilled water ΔT	AV	Calculated difference between measured values S25 – S26; sensors must be matched pair.	2% of reading or ±0.2°C (±0.36°F)	0.1°C (0.18°F)	1	1	0.1°C (0.18°F)
M7	Chilled water plant power	AV	Sum of measured values S20, S21, S22, S23, S24.	±1.5%	0.1 kW	1	10	±1 kW
M8	Chilled water loop thermal cooling output	AV	Calculated value M6 multiplied by measured value S27 multiplied by a constant (C3) equal to 1.0 kW (500 min-tons/°F-gal).	±3%	0.3 kW	1	10	±3%
M9	Chilled water plant efficiency	AV	Calculated value M7 divided by calculated value M8.	±4%	0.03 COP (0.01 kW/ton)	1	10	±4%
M10	Total AHU power	AV	Sum of calculated values S32x.	±1.5%	0.1 kW	1	10	±1.5%

M11	Total AHU flow	AV	Sum of calculated values S28x.	±5%	0.05 l/s (0.1 cfm)	1	10	±5%
M12	Total AHU specific power	AV	Calculated value M10 divided by calculated power M11.	±6%	0.0002 kW/(l/s) 0.0001 kW/cfm	1	10	±6%
M13	AHU percentage outdoor air	AV	Instantaneous difference of measured values (S35-S36)/(S1-S36).	N/A	0.1%	1	1	0.1%

1.10 SUBMITTALS

A. Submittals must be prepared and submitted in compliance with all General Conditions of the Contract, Supplementary Conditions, and General Requirements of the project and in conjunction with the requirements of this section.

B. No work may begin on any segment of this project until submittals have been successfully reviewed and approved for conformity with the design intent.

C. All submittals and documentation including complete System engineering design submittal & drawings, project record documents, application engineering documents, and Operation & Maintenance manuals shall be submitted electronically in the form of an ISO 32000 Portable Document Format (PDF).

1. All control schematics, wiring diagrams, riser diagrams, etc. shall be formatted for ANSI B (279 mm x 432 mm; 11" x 17") or A3 paper size (297 mm x 420 mm).

2. All other documentation may be formatted for ANSI A (216 mm x 279 mm; 8.5" x 11") or A4 (210 mm x 297 mm).

D. Submit in writing and so delineated at the beginning of each submittal, known conflicts, substitutions, and deviations from requirements of Contract Documents. Deviation from Contract Documents must be approved by Owner and/or Contracting Officer prior to award of contract.

E. Each submitted piece of literature and drawing shall clearly reference the applicable specification section and/or drawing that the submittal responds to.

1. General catalogue sheets shall not be acceptable as cut sheets.

F. Submittal documentation and drawings shall consistently use the same abbreviations, symbols, nomenclature, and identifiers. Each control system element shall be assigned a unique identifier pursuant with the Contract Documents.

G. Submittal documentation and drawings shall have at the beginning an index and design drawing legend.

1. Index shall list all design drawings and elements including the drawing number, sheet number, drawing title, etc.

2. Legend shall show and describe all symbols, abbreviations, and acronyms used on the design drawings.

H. System Hardware Submittals. Submit the following at a minimum:

1. A complete Bill of Materials of all equipment, controllers, devices, and sensors to be provided and/or used indicating unique equipment identifier, unique device identifier, manufacturer, model number, and quantity.

2. A Protocol Implementation Conformance Statement (PICS) including a BACnet Interoperability Building Block (BIBB) table for each DDC device included in the submittal.

3. Manufacturer's technical data including product specification sheets, performance curves, and installation/maintenance instructions. When manufacturer's cut sheets apply to a product series rather than a specific product,

the data specifically applicable to the project shall be highlighted or clearly called out by other means.

4. Schematic diagrams for all field sensors and controllers providing floor plans indicating the locations of all sensors, devices, and temperature control panels.

5. Control enclosure details for each enclosure including panel identifier, location, physical lay-out, dimensions, instrumentation, labels, etc.

6. Wiring diagrams and schematics for each control enclosure showing power source for each panel, secondary power, and network termination as well as all individual terminations, terminal numbers, point type, and mnemonic/name.

7. Wiring diagrams for all packaged equipment, motor starters, relay wiring, equipment interlock, safety circuits, etc. clearly indicating all interconnecting wiring and termination of all conductors and cables including labels of all cables and point mnemonics.

8. Wiring diagrams and schematics for each sensor.

I. Controlled System Submittals.

1. Riser diagram showing the physical lay-out of the entire internetwork.

2. Riser diagram for each individual BACnet network including the ELCN, and each BLCN and FLCN including:

a. Data link with physical characteristics and configuration.

b. Each BACnet networked DDC device including location, service, device instance, MAC address, and network number.

c. Each IP networking device including location, service, and IP address.

d. Location of all interface devices including network interface jacks and workstation connections.

e. Location of all MS/TP network termination points and End-of-Line (EOL) terminations.

3. A schematic control flow diagram of each controlled system showing actual physical configuration and location of all control elements including each hardware point type, controller, and mnemonic.

4. A schematic wiring diagram of each controlled system showing actual physical wiring and termination of all control elements including each hardware point type, controller, mnemonic, and terminal number.

5. An instrumentation list for each controlled system displaying each control element, name, manufacturer, model, and product data sheet number in a tabular format.

6. A complete description of the operation of the System including a specific Sequence of Operation for each controlled system. Sequences of Operation shall:

a. Reference the submitted schematic of the controlled system.

b. Refer to equipment and control devices by their specific unique identifiers pursuant with the Contract Documents and the System submittal package.

c. Clearly represent actual application programming methodology and functional control operation not merely a copy of the Contract Document specified sequence of control.

d. Include a concise description of functional system operation under specified normal and failure conditions.

e. Include a complete hardware input and output (I/O) points schedule identifying for each point its instance, type, name/mnemonic, controller, equipment/function, location, termination, override, alarm, and display criteria.

7. Operational deviation from the specified Sequences of Operation as outlined in Contract Documents shall not be permitted under any circumstances without prior written approval by the Owner, Engineer, or Contracting Officer.

8. A schedule of all control valves. This shall include the unique equipment identifier, valve size, dimensions and installation/maintenance clearance, model number (including pattern and connections), close-off rating, flow, CV, pressure drop, pressure rating, and location. The valve schedule shall also contain actuator selection data supported by calculations of the force required to move, close, and seal the valve at design conditions.

9. A schedule of all control dampers. This shall include the unique equipment identifier, unique damper identifier, damper size, pressure drop, blade configuration, orientation and axis of frame, blade rotation, location and selection criteria of actuators, nominal and actual sizes, manufacturer, and model number. The Damper Schedule shall include the AMCA 500-D maximum leakage rate at the operating static-pressure differential.

J. Schedules.

1. Provide a schedule of work indicating at a minimum the intended sequence of work, start dates and durations for individual activities, delivery dates for major materials and equipment including anticipated lead times, and milestones indicating possible restraints on work by other trades or construction delays.

K. Project Record Documentation.

1. Upon completion of installation and System commissioning activities submit record (as-built) documents for review to include:

a. Testing and commissioning reports and checklists.

b. Operation and Maintenance (O&M) manuals.

c. As-built revisions of all submittal data updated to reflect actual field conditions, architecture and execution.

d. Names and 24-hour contact information for installing contractors and service representatives.

e. Operator's manual with administrator and operator level credentials and procedures for operating the System including logging-on/off, handling alarms, generating points reports, trending data, overriding automatic control, changing setpoints, and control variables.

f. Programming manual describing the programming language structure and syntax.

g. Engineering manual describing database management and modification.

h. Installation and maintenance manuals describing how to install and configure new hardware as well as how to perform routine preventative maintenance and calibration together with corrective diagnostic troubleshooting procedures.

i. Documentation of all programs created including setpoints, tuning parameters, and final database.

j. Complete system database as functional after system commissioning and functional testing including all graphics and images used by and/or created for System on electronic format as accepted by the Owner.

k. Final Bill of Material with all installed parts, manufacturers, manufacturers' part numbers, and ordering information.

l. A schedule of recommended spare parts with part numbers and supplier.

m. All original-issue installation and maintenance manuals, user guides, and other documentation provided with all hardware and software provided as a part of this specification.

n. Licenses, guarantees, and warrantee documentation for all equipment and systems.

L. Training.

1. Provide training course outline and curricula at least six (6) weeks prior to training. Engineer and/or Owner shall modify the curricula as necessary to meet the Owner's Project Requirements (OPR). Revised curricula shall be returned no later than three (3) weeks prior to the training.

1.11 WARRANTY

A. The System Manufacturer shall warranty all DDC controllers to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of five (5) years at a minimum.

1. Sensors and field components integral to DDC controllers shall be warrantied to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of one (1) years at a minimum.

B. The System Contractor shall warranty the installation of all other DDC materials and labor to be free of defects under normal expected service and use for a period of one (1) year from the date of final acceptance.

1.12 OWNERSHIP OF PROPRIETARY MATERIAL

A. Upon project acceptance all software and documentation delivered as a part of this specification shall become the exclusive property of the Owner; including but not limited to: all graphics, record drawings, database, application programming code, and documentation.

PART 2 - PRODUCTS

2.01 PRODUCT REQUIREMENTS

A. The System as provided and installed under this specification shall be comprised of BACnet devices including controllers, routers, operator workstations, operator displays, and supervisory software from a single manufacturer and product line or product family.

1. The System Manufacturer product line selected shall be the most current and complete offering and shall currently be actively manufactured and supported and shall have been installed in a minimum of 25 installations at the time the bid date for this project.

    a. This project shall not be used as a test site. First release and test version hardware, software, and firmware shall not be implemented on this project under any circumstances.

2. The entirety of the System Manufacturer product line selected shall be designed and deployed specifically with standard provisions for integral backwards compatibility and extensibility.

    a. System Manufacturer shall certify that System devices, and spare or equivalent components shall be readily available for a minimum of five (5) years after the completion and final acceptance of this project.

    b. System Manufacturer shall certify that its own DDC product line in its entirety, and as was in mainstream service ten (10) years prior to the bid date for this project, are still supported. Support shall include complete viability and compatibility of the legacy components with the current mainstream product line; and availability of replacement or equivalent compatible components and/or repair services.

3. OEM and/or private-labelled controllers or software manufactured or developed by a third-party and labelled or otherwise represented as being a product of the System Manufacturer shall not be accepted under this specification.

4. Non-networked system components specified in this section (including sensors, valves, dampers, etc.) need not be manufactured by the System Manufacturer.

2.02 COMMUNICATION

A. BACnet. The System as provided and installed under this specification shall comprise a BACnet internetwork.

1. All communication between System devices, including operator workstation and operator display communication, provided and/or installed under this specification shall conform to ANSI/ASHRAE Standard 135, BACnet using native BACnet communications.

    a. All devices shall utilize a native BACstack embedded at the media access controller level.

2. Devices that require translation of data, gateways, or mapping of any kind for communication between System devices shall not be acceptable.

B. BTL. All System devices provided and installed under this specification shall be tested, certified, clearly stamped, and listed by the BACnet Testing Laboratories (BTL) a minimum of 30 days prior to the bid date for this project.

1. BTL product listings are available from BACnet International (http://www.bacnetinternational.net/btl/).

C. Extensibility. The System shall be modular in nature and implemented in such a manner that it can be expanded in functionality and in capacity to at least twice the required hardware through the addition of controllers, devices, and wiring. Expansion shall not require operator interface hardware additions, software revisions, firmware revisions, or additional licensing.

2.03 AUTOMATIC CONTROL ACTUATORS

A. Electric Actuation. Unless otherwise specified or scheduled, all control actuators shall be electric/electronic direct-coupled type.

1. Actuators shall have a means for reversing drive direction and a manual override accessible at the front cover.

2. The actuator shall have electronic overload or stall protection to prevent damage to the actuator throughout rotation. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.

3. Spring Return. Where shown, for power-failure or safety applications, an internal mechanical spring-return mechanism shall be built-in to the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable.

    a. All mechanical equipment with direct introduction of outside air shall require fail-safe spring return actuators.

    b. Terminal equipment without direct introduction of outside air are permitted to have actuators that maintain their last commanded position when power is lost to the actuator.

4. Clutch/Gear Release. All non-spring return actuators shall have an external manual clutch/gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 7 Nm (60 in-LB) torque capacity shall have a manual crank for this purpose.

5. Modulating Actuators. Unless otherwise specified or scheduled, all modulating actuators shall be positive positioning and accept a 0-10 VDC or 0-20 mA control signal and provide an operating range of 2-10 VDC or 4-20 mA.

6. Position Feedback. All actuators shall feature a visual position feedback indicator. All non-terminal unit actuators shall provide a 2-10 VDC or 4-20 mA feedback signal.

7. Power. All 24 VAC/VDC actuators shall operate on Class 2 circuits.

8. Enclosure. Actuator casing and/or enclosures shall be appropriate to the application.

    a. Actuators used in or near outdoor air streams shall have IEC IP21 (NEMA 2) housings.

    b. Actuators exposed to moisture, in wet mechanical rooms, or located outdoors shall be meet IEC IP66 (NEMA 4X) requirements or as directed by the AHJ.

B. Where expressly specified or scheduled to be used, pneumatic damper/valve actuators and positioners shall comply with the following minimum requirements:

1. Pneumatic actuators shall be piston-rolling diaphragm type or diaphragm type with easily replaceable, beaded, molded neoprene diaphragm.

2. Actuator housings may be molded or diecast zinc or aluminum.

    a. Exception: Actuator housings for terminal unit zone control dampers or valves may be of high-impact plastic construction with an ambient temperature rating of 10-60°C (50-140°F) minimum. However, any plastic devices located in return air (ceiling) plenums shall be isolated from plenums with an auxiliary metal enclosure having a quick-opening access panel.

3. Actuator size and spring ranges selected shall be suitable for intended application.

4. Rate pneumatic actuators for a minimum 140 kPa (20 psig).

5. Damper actuators shall be selected in accordance with manufacturer's recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control under design flow and pressure conditions.

    a. Furnish a separate actuator for each damper section.

6. Valve actuators shall provide tight close-off at design system pressure and shall provide smooth modulation at design flow and pressure conditions.

7. On sequencing applications, valve and damper actuators shall be sized for a maximum of 14 kPa (2 psi) shift in nominal spring range. Spring ranges shall be selected to prevent overlap or positive positioners shall be provided.

8. Positive positioners to have the following performance characteristics:

    a. Linearity: ±10% of output signal span.

    b. Hysteresis: 3% of the span.

    c. Response: 1.75 kPa (1/4 psi) input change.

d. Maximum pilot signal pressure: 140 kPa (20 psi).

e. Maximum control air supply pressure: 420 kPa (60 psi).

9. Positive positioners shall be provided on actuators for inlet vane control and on any other actuators where required to provide smooth modulation or proper sequencing.

a. Positive positioners shall be high-capacity force balance relay type with suitable mounting provisions and position feedback linkage tailored for each actuator.

b. Positive positioners shall use full control air pressure at any point in stem travel to initiate stem movement or to maintain stem position. Positioners shall operate on a 20-100 kPa (3-15 psi) input signal unless otherwise required to satisfy the control sequences of operation.

2.04 TEMPERATURE DEVICES

A. Analog Temperature Sensors. Analog temperature sensors shall be precision element thermistor type.

B. Duct Sensors. Duct temperature sensors shall include junction box for wiring connections and gasket to prevent air leakage and vibration noise.

1. Single point duct temperature sensor probe shall consist of 316 stainless steel extending to the center of the duct.

2. Averaging duct temperature sensor shall consist of a copper or stainless-steel averaging element. Averaging sensors shall be a minimum of 1.5 m (5') in length per 1 m^2 (10 ft^2) of duct cross sectional area.

3. Immersion Sensors. Liquid immersion temperature sensor shall be provided with a separable stainless steel well. The well must be designed to be consistent and appropriate with the system operating pressure and velocity.

4. Space Sensors. Space temperature sensor shall consist of an element within a ventilated cover aesthetically pleasing and specifically designed for permanent installation in a finished, occupied space.

a. In private and semi-private spaces that serve full-time or full-time-equivalent occupants including but not limited to offices, work rooms, meeting rooms, conference rooms, etc., space sensors shall be provided with setpoint adjustment and occupancy bypass. Bypass not required in zones with occupancy sensors or applications that are constantly occupied.

b. In public spaces without full-time or full-time-equivalent occupants including but not limited to lobbies, hallways, atriums, break rooms, cafeterias, restrooms, theaters, gymnasiums, mechanical spaces, plenums, etc., simple temperature sensor without setpoint or bypass shall be provided.

c. Sensors with operator interface keypads and displays shall be provided as indicated or scheduled elsewhere.

5. Outdoor Air Temperature. Outdoor air temperature sensor shall consist of a single device sensor, ventilated non-metallic sun shield, utility box for terminations, and watertight gasket to prevent water seepage.

6. Differential Temperature. Provide matched sensors for differential temperature applications.

7. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL-Listed, vapor pressure type, with an element of 6 m (20') minimum length.

    a. Provide one (1) low-limit thermostat for each 2 m^2 (20 ft^2) of coil face.

    b. Low-limit thermostat shall respond to the lowest temperature sensed in by any 30 cm (12") section of the element.

    c. Low-limit thermostats shall be manual-reset, DPDT-style with a minimum of one (1) normally-open contact and one (1) normally-closed contact.

8. High-Limit Thermostats. High-limit airstream thermostats shall be UL-Listed, bimetal-operated, manual reset type.

9. Low-voltage Thermostats. Low-voltage thermostats shall be 24 VAC, bimetal-operated or electronic type with adjustable fixed anticipation heater, concealed setpoint adjustment 13-30˚C (55-85˚F) setpoint range, 1˚C (2˚F) maximum differential and vented ABS plastic housing.

10. Line-voltage Thermostat. Line-voltage thermostats shall be UL-Listed bi-metal actuated, open contact type, enclosed, snap-switch type or equivalent solid-state type with adjustable of fixed anticipation heater, concealed setpoint adjustment 13-30˚C (55-85˚F) range, 1˚C (2˚F) maximum differential, and vented ABS plastic housing.

2.05 CURRENT TRANSMITTERS

A. AC Current Transmitters. AC current transmitters shall be UL-Listed self-powered, combination split-core current transformer type with two-wire voltage (0-5 VDC, 1-5 VDC, 0-10 VDC, 2-10 VDC) or current (4-20 mA) output.

    1. Ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A full-scale with internal zero and span adjustment and ±1% full-scale accuracy at 500-ohm maximum burden.

    2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA certified.

B. Current Transformers. Current transformers shall be UL/CSA recognized, split-core and completely encased (except for terminals) in approved plastic material. Transformers shall be selected for ±1% accuracy at 5 A full-scale output.

2.06 CURRENT SWITCHES

A. Current Switches. Current-operated switches shall be UL-Listed self-powered, solid-state, split-core type with adjustable trip current, status LED, and dry-contact output.

B. Security. Each System software user shall be required to log-on to the application/system using with a unique user name and password to view, edit, add, or delete data.

1. Operators shall be assigned unique user accounts for System software applications (applicable to their role) at the direction of the Owner.

2. Utilizing user accounts with multilayered security controls, the permissions configured for each individual operator will restrict/permit day-to-day operations and system configuration.

    a. All operations required in this specification shall be subject to the permissions as assigned to each individual operator.

3. The Owner shall be provided with administrator-level credentials that shall have the ability to configure credentials for all operators.

4. User accounts shall be configured such that each operator shall be automatically logged-off of the system after a configurable period of inactivity.

5.

2.07 PROGRAMMING

A. Memory. Each component of the System shall be provided with sufficient internal memory for the specified Sequences of Operation and data logging with a minimum of 25% of available memory remaining free for future use.

B. Current Versions. At time of acceptance, all operating systems, BACnet internetwork software, hardware, and firmware shall be the latest official release version available.

C. Commonality. Every DDC device provided under this specification shall be programmed by one (1) B-AWS application using one (1) common programming language and methodology.

D. Object Naming. Unless otherwise specified, the System shall be programmed using a standard naming convention. All BACnet objects shall be provided with a native-language name consistent with this specification clause using the standard object Name property. Object names shall be modular in design, allowing easy operator interface without the use of a written object index. Unless the Owner provides a naming convention prior to project submittal, use the following naming convention when programming the database: AA-BBBBCCC-DDDDEE where:

    1. AA is used to designate the service location (e.g., room, floor, building, etc.).

    2. BBBB is used to designate the mechanical system with which the object is associated (e.g., AH, CHWS, HTG, CLG, LTG, etc.).

E. Graphical User Interface. Provide a graphical user interface (GUI) consistent with the requirements of this specification and the Sequences of Operation. At a minimum:

    1. All physical hardware, sensors, control devices, and setpoints shall be visible in a graphical format.

    2. Provide dynamic graphics for all mechanical systems and/or each individual piece of mechanical equipment.

    3. Provide a floorplan of the facility that displays all thermal zone temperatures and provides links to all thermal zones and mechanical equipment.

4. In additional to dynamic equipment graphics, provide a tabular summary of all terminal unit equipment including, at a minimum, the present values of:

    a. Primary process variables and setpoints (e.g., room temperature and setpoint).

    b. Control response (e.g., damper or valve position, fan speed, etc.).

    c. Occupancy mode.

    d. Operational Mode.

    e. Critical Alarm status.

F. Alarms. All alarming in the System shall be performed exclusively using standard BACnet alarm and event objects and services.

1. All hardware inputs and outputs shall be configured with alarms using dynamic thresholds, switching differential, and delays appropriate to the functional operational mode and per the specified Sequence of Operation to prevent nuisance alarm notification.

2. Alarms and events shall be classified according to the project Sequence of Operation and per the direction of the Owner to include the following classifications at a minimum:

    a. Maintenance notifications,

    b. Operational deviations and/or performance warnings, and

    c. Critical equipment failure alarms.

3. Alarm Messages. Alarm messages shall be programmed to use the native language name for the object in alarm in such a way that the source, location, and nature of the alarm is easily understood without relying upon mnemonics or object instances.

    a. Alarm messages shall be fully customizable by the Operator in size, content, behavior, and sound.

4. At the direction of the Owner, operators must be notified of critical alarms and events remotely via e-mail or text message.

G. Schedules. All scheduling shall be performed using standard BACnet Schedule and BACnet Calendar objects.

1. BACnet Schedule objects shall be configured to directly command any BACnet object in the internetwork without requiring custom programming.

H. Trend Logs. The System shall be programmed to automatically record System object values in standard BACnet Trend Log objects.

1. Every analog hardware point shall be trended.

2. Every binary hardware point shall have runtime and cycle times logged.

3. At a minimum, all software setpoints, control loops, and operational modes shall be trended and/or logged.

4. Interrelated objects shall be logically grouped into Trend Log Multiple objects for individual mechanical and building systems.

5. Unless otherwise scheduled, initial log intervals shall be once every 15 minutes.

6. Runtime data for binary objects shall include at a minimum (for the previous 100 transitions for each object):

    a. Total runtime today.

    b. Total accumulated runtime.

    c. Changes of state today.

    d. Total accumulated changes of state.

    e. Timestamp and duration for each change of state.

I. BACnet Priorities. The system shall observe the following standard BACnet command priorities (from highest to lowest):

1. Manual Smoke Control and Life Safety (Priority Level 1).

2. Automatic Smoke Control and Life Safety (Priority Level 2).

3. Critical Equipment Control (Priority Level 5).

4. Minimum On/Off (Priority Level 6).

5. Manual Operator Command (Priority Level 8).

6. Energy Management (Priority Level 9).

7. Normal Automatic Control (Priority Level 10).

2.08 BACnet ADVANCED OPERATOR WORKSTATION SOFTWARE (B-AWS)

A. Use existing High School Energy management system software and license.

2.09 CONTROLLERS

A. Compliance. All controllers provided under this specification shall be provisioned as described in this specification clause and in compliance with all other relevant specification clauses.

B. BACnet Communication. All controllers shall be provisioned to support the following communication requirements at a minimum:

1. Client and Server BACnet Subscribe Change of Value (COV) service.

2. Client and Server BACnet Read Property Multiple (RPM) service.

3. BACnet transmit and receive frame segmentation.

4. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout, and APDU retries.

C. Communication Management. Each controller shall be configured to manage its own BACnet communication transactions to permit distributed devices to access real-time object information for global strategies, monitoring, and alarms. All controller-to-

controller communication shall be peer-to-peer and shall not require a master device, server, or network management device to facilitate communication.

1. No single device may be configured to manage the communication for the entire internetwork.

2. No single device may be configured to manage normal BACnet communication for another device.

3. No device may inherently change the payload (e.g., change the write priority) of a BACnet frame in transit or while being routed.

4. Standard BACnet routing from one network to another network in the internetwork by a BACnet router is acceptable.

5. The contractor must be prepared to demonstrate, upon request, that all BACnet communication is being managed by the originating client and destination server devices.

D. Local Database. All logic required to perform the specified Sequences of Operation, trending, and alarming as outlined in this specification shall reside in each individual controller.

1. Each controller shall execute all specified local control strategies without reliance upon any other device indefinitely in the event of communication failure.

    a. Trim-and-respond and/or demand-based reset control logic shall be programmed with functional fail-safe parameters for stand-alone operation in the event that network objects such as outdoor air temperature, space temperatures, or terminal loads are not available.

2. Controllers that require any level of supervisory server software or hardware or any external platform to manage database execution or network management shall not be permitted as a part of the System provided pursuant with this specification.

E. Controller Selection. Each mechanical system or piece of equipment shall be provided with one dedicated controller with sufficient memory and hardware points necessary to satisfy the specified Sequence of Operation and to comply with the requirements of all applicable System specifications.

1. All physical inputs and outputs necessary to satisfy the specified Sequence of Operation shall be physically connected to the controller executing the control logic.

    a. Objects used for trim-and-respond and/or demand-based reset control such as outdoor air temperature, space temperatures, or terminal loads shall not be required to be hosted on the controller executing the control logic.

2. Multiple pieces of mechanical equipment comprising one mechanical system (e.g., multiple pumps in a pumping system, or chillers in a chilled water system, etc.) may be controlled by a single controller provided all the hardware points associated with all the equipment are physically connected to the controller executing the control logic.

3. Distributed control of one piece of mechanical equipment shall not be performed by multiple controllers.

F. Serviceability. All wiring connections shall be made to field-removable, modular terminal strips.

G. Online Database Manipulation. All controllers must support online modification of individual objects (including but not limited to inputs, outputs, values, loops, schedules, programs, graphical displays, and logs) in real-time while operational without impacting other elements of the database or the functionality of the controller.

1. Creating, deleting, and/or modifying an object shall not require downloading the entire database to the controller. Excepting for the objects being manipulated, it shall not interrupt the operation of the controller.

2. Compiling one program shall not affect the execution of other programs.

3. Manipulation of database objects shall not impact the ability of the operator to access/use the GUI.

H. Operator Override. All controllers shall support operator-initiated timed overrides of hardware and software objects.

1. When the operator-configured override period has expired, the controller shall automatically return the object to the automatic state without any additional action on the part of the Operator.

2. The timed override functionality shall exist entirely in the controller. A workstation shall not be required for the execution of the override period nor for returning the object to automatic.

I. Updates. The operator shall have the ability to update the operating system firmware of any controller provided under this specification at any time after installation, utilizing the BACnet internetwork.

1. Operating system firmware that requires chip replacement or flash modification shall be strictly prohibited.

2.10 FIELD-LEVEL OPERATOR DISPLAY

A. Compliance. Field-level operator displays shall be provisioned as described in this specification article and in compliance with all other relevant specification clauses.

1. Field-level operator displays shall be required to comply with all the requirements for field-level equipment controllers in addition to those prescribed in this specification clause.

B. Provide one (1) field-level operator display integral to each building-level equipment controller as required per the contract documents, drawings, equipment schedules, and/or as follows:

1. All mechanical equipment and systems with a common application shall be provided with the same controller model.

C. BACnet Device Profile. Field-level operator displays shall be certified and Listed by the BACnet Testing Laboratories (BTL) in compliance with the minimum requirements of

ANSI/ASHRAE Standard 135-2012 Revision 14 Annex L a minimum of 30 days prior to the bid date for this project as follows:

1. BACnet Building Controller (B-BC), and
2. BACnet Operator Display (B-OD).

D. Integral Operator Display. Field-level operator displays as provided shall deliver a high-level operator interface environment through an integrated full-color, touch screen display in compliance with the product clause requirements and according to the following minimum criteria:

1. The display environment shall be operator-adjustable including:
    a. Backlighting.
    b. Brightness.
    c. Color scheme.
    d. Degrees Fahrenheit/Celsius.
    e. Language.
    f. Audible alarm notification.
    g. Display time-out/always-on.
2. The operator display shall be provisioned such that the engineering units and language shall be selectable by the operator from the display or dynamically assignable through system-level interfaces (e.g., Graphical User Interfaces (GUIs), Browser-based User Interfaces (BUIs), mobile device apps, etc.). The following languages must be provisioned at a minimum:
    a. English,
    b. French,
    c. Spanish,
    d. German,
    e. Italian,
    f. Portuguese, and
    g. Simplified Chinese.
3. The operator display shall be configured with a multilayer password-protection.
    a. Password, passcode, or PIN shall be configured to restrict/permit day-to-day operations and system configuration.
    b. Each display shall be shown or hidden based upon the operator password.
    c. An administrator shall be provided with the ability to apply security to permit/restrict modification of each individual object on any display.

d. The operator display shall be configured such that each operator shall be automatically logged-off after a configurable period of inactivity.

4. The operator display shall be provisioned to deliver the following:

a. A minimum of 32 separate displays/screens each supporting a minimum of 32 objects for a total display of a minimum of 1024 objects.

b. The operator shall have the ability to command the present value of all hardware and software objects in the local device as an automatic write, permanent override, or temporary override using standard BACnet priorities.

c. The operator shall have the ability to command the present value of a minimum of 256 objects from the BACnet Internetwork as an automatic write, permanent override, or temporary override using standard BACnet priorities.

d. The operator shall have the ability to view/modify BACnet Schedule objects.

e. The operator shall have the ability to view BACnet Trend Log objects.

f. The operator shall have the ability to view/modify BACnet Alarms. Unacknowledged alarms shall be annunciated with a clearly discernable display indication (e.g., icon, color-change, etc.) and operator-configurable audible notification.

5. The operator shall have the ability to initiate timed overrides of hardware and software objects with configurable override periods via the operator display.

a. When the override period has expired, the controller shall automatically return the object to the automatic state without any additional action on the part of the operator.

b. All manual operator commands shall be performed using BACnet priorities and properties.

c. The operator display shall be programmed to indicate objects that are presently manually overridden.

d. For timed overrides, the operator display shall be programmed to show the amount of time remaining until the object reverts to automatic.

e. The timed override functionality shall exist entirely in the controller. A workstation shall not be required for the execution of the time nor for returning the object to automatic.

2.11 TERMINAL UNIT CONTROLLERS

A. Compliance. shall be provisioned as described in this specification article and in compliance with all other relevant specification clauses.

B. Provide one (1) dedicated controller for each terminal unit.

1. All terminal units with a common application shall be provided with the same unitary controller model and manufacturer.

C. BACnet Device Profile. Terminal unit controllers shall be certified and Listed by the BACnet Testing Laboratories (BTL) in compliance with the minimum requirements of ANSI/ASHRAE Standard 135-2012 Revision 14 Annex L a minimum of 30 days prior to the bid date for this project as follows:

1. BACnet Building Controller (B-BC).

D. BACnet Network Architecture. Terminal unit controllers shall be installed on the following network and data link:

1. Tier 3 Field Level Communication Network (FLCN).

a. Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.

E. BACnet Communication. All terminal unit controllers shall be provisioned to support the following communication requirements:

1. A minimum of 64 BACnet client network read requests and/or COV subscriptions and a minimum of 32 BACnet client network write requests and/or COV server notifications.

F. Physical Networking. All terminal unit controllers provided under this specification are required to be provisioned on the following physical communication network:

1. One (1) TIA-485 port @ 76.8 Kbps.

G. Protocol. All terminal unit controllers provided under this specification are required to be provisioned using the following communication protocols and data link:

1. ANSI/ASHRAE Standard 135: BACnet.

a. One (1) Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.

H. Hardware. Terminal unit controllers shall be installed and/or provisioned per the following requirements:

1. Air Terminal Unit Controller Actuators. All air terminal unit controllers shall be provided with damper actuators that comply the following at a minimum:

a. Brushless DC motors with a minimum of 45 in-lb (5 Nm) of torque.

b. Damper position feedback must be provided to the terminal unit controller as an analog input. Software calculated damper position based upon output active drive time is not acceptable.

c. Damper-end/actuator-clutch switch feedback must be provided to the controller as a binary input to indicate that the actuator is at the end of the field-adjusted stroke. Switch must prove at 0% and 100% of the field-adjusted stroke of the damper. Software calculated damper position based upon output active drive time is not acceptable.

d. Actuator rotation defining the drive-to-open direction of the actuator must be software-selectable via the BACnet internetwork by the Operator.

2. Air Terminal Unit Controller Differential Velocity Sensor. All air terminal unit controllers shall be provided with differential velocity sensors for measuring airflow that comply with the following at a minimum:

    a. ±0-500 Pa (±0-2 inwc) sensing range.

    b. Zero-point accuracy of 0.1 Pa (0.0008 inwc).

    c. Resolution of 0.122 Pa (0.0005 inwc).

    d. Span accuracy of 3% of measured value.

I. Air Terminal Unit Controller Test & Balance Calibration (T&B). Air terminal unit airflow sensor calibration shall be performed using the operator interface of the local zone communicating temperature sensor, a dedicated handheld configuration tool connected to each individual air terminal unit controller, or using the GUI.

1. Where software and/or dedicated applications are required for airflow sensor calibration, the following must be provided to the Owner as a part of this specification at a minimum:

    a. One (1) dedicated hardware platform to host the T&B and airflow calibration software and/or application independent from and in addition to any requirement for an operator workstation with a five (5) year warranty.

    b. All software updates and support for five (5) years from the completion and acceptance of the project T&B report.

2.12 SPACE-MOUNTED TERMINAL UNIT CONTROLLERS

A. Compliance. Space-mounted terminal unit controllers shall be provisioned as described in this specification article and in compliance with all other relevant specification clauses.

B. Provide one (1) space-mounted terminal unit controller for each terminal unit as expressly required per the contract documents, drawings, equipment schedules, and/or as follows:

1. All mechanical equipment and systems with a common application shall be provided with the same controller model.

2. The total number of universal inputs and/or outputs connected to a terminal unit controller shall not exceed 4. Systems requiring more than 4 physical inputs and/or outputs shall be controlled by a terminal unit controller or a field-level equipment controller.

C. BACnet Device Profile. All space-mounted terminal unit controllers shall be certified and Listed by the BACnet Testing Laboratories (BTL) a minimum of 30 days prior to the bid date for this project.

D. BACnet Network Architecture. Space-mounted terminal unit controllers shall be installed on the following network and data link:

1. Tier 3 Field Level Communication Network (FLCN).

    a. Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.

E. Physical Networking. All space-mounted terminal unit controllers provided under this specification are required to be provisioned using the following physical communication network:

1. One (1) TIA-485 port @ 76.8 Kbps.

F. Protocol. All space-mounted terminal unit controllers provided under this specification are required to be provisioned such that the following communication protocols and data links are supported:

1. ANSI/ASHRAE Standard 135: BACnet.

a. One (1) Master Slave Token Passing (MS/TP): ANSI/ASHRAE Standard 135.9.

G. Hardware.

1. Integral Operator Display. Each space-mounted terminal unit controller shall be provisioned with a keypad and display to permit low-level operator interface including the following at a minimum:

a. Configurable to display and modify a minimum of ten (10) total object values from any device on the internetwork.

b. Ability to view and modify standard Schedule objects.

2. All space-mounted terminal unit controllers provided under this specification shall be available with all the integral hardware sensors specified in the corresponding Product clause of this specification in a single sensing enclosure.

2.13 COMMUNICATING SPACE SENSORS

A. Warranty. Each communicating space sensor must be warranted by the manufacturer as proven by a certificate from the manufacturer for a period of five (5) years at a minimum.

B. The System shall be configured to actively monitor the communication status and reliability of all communicating sensors.

1. When communication is lost with any communicating sensor, the system shall be configured to generate an alarm and to perform an automatic control strategy fail-safe response until communication is restored.

2. If the system is not capable of performing custom, freely-programmable, and automatic control strategy response as a result of a loss of sensor communication, communicating sensors may not be used.

C. Hardware. Only one (1) communicating space sensor series shall be provided under this specification. The communicating space sensor series of products provided under this specification must be available with the following the integral hardware at a minimum:

1. Temperature.

2. Setpoint.

3. Relative Humidity.

4. Unoccupied Bypass.

5. PIR Occupancy.
    a. Range: 5m/16’.
6. CO_2.
7. Auxiliary onboard inputs.
    a. Thermistor or dry-contact.
8. Auxiliary onboard outputs.
    a. Dry-contact outputs.
9. Front-lighting or Back-lighting.

D. Tamper-proof. Communicating space sensors provided under this specification shall be available as a stainless-steel or aluminum plate for tamper-proof applications in public spaces, corridors, restrooms, gymnasiums, etc.
    1. Tamper-proof communicating space sensors shall cover a standard, single-device utility box.
    2. Tamper-proof communicating space sensors shall be available with the following the integral hardware at a minimum:
        a. Temperature.
        b. Unoccupied Bypass.

E. Except for in tamper-proof installations, each communicating space sensor shall be provided with a keypad and display to permit low-level operator interface with following features at a minimum:
    1. Configurable to display icons, time, point names and engineering units.
    2. Configurable to display and modify object values from any device on the internetwork.
        a. Provide access to a minimum of ten (10) total object values.
    3. All communicating space sensors shall be configured to allow the operator to select degrees Fahrenheit or degrees Celsius for displaying all temperatures.
    4. All communicating space sensors shall be configured to allow the operator to select the display language. The following languages shall be supported at a minimum:
        a. English.
        b. French.
        c. Spanish.
        d. Portuguese.
        e. German.
        f. Italian.
        g. Simplified Chinese.

2.14 COMMUNICATING DUCT SENSORS

A. Warranty. Each communicating duct sensor must be warranted by the manufacturer as proven by a certificate from the manufacturer for a period of five (5) years at a minimum.

B. The System shall be configured to actively monitor the communication status and reliability of all communicating sensors.

1. When communication is lost with any communicating sensor, the system shall be configured to generate an alarm and to perform an automatic control strategy fail-safe response until communication is restored.

2. If the system is not capable of performing custom, freely-programmable, and automatic control strategy response as a result of a loss of sensor communication, communicating sensors may not be used.

C. Enclosure. Communicating duct sensors provided under this specification shall be available with the following enclosures at a minimum:

1. Galvanized box.

2. Plastic box.

D. Hardware. Communicating duct sensors provided under this specification shall be available with the following the integral hardware at a minimum:

1. Temperature.

a. -40 to 120°C (-40 to 250°F)

b. Duct probe lengths 4” to 18”.

2. Relative Humidity.

a. ±2%.

3. Auxiliary onboard inputs.

a. Thermistor or dry-contact.

4. Auxiliary onboard outputs.

a. Dry-contact outputs.

2.15 WIRELESS TEMPERATURE SENSORS

A. The wireless temperature sensors provided must comply with all relevant sections of this specification.

B. Reliability. The System shall be configured to actively monitor the communication status and reliability of all wireless sensors.

1. When communication is lost with any wireless sensor, the system shall be configured to generate an alarm and to perform an automatic control strategy fail-safe response until communication is restored.

2. If the system is not capable of performing custom, freely-programmable, and automatic control strategy response as a result of a loss of sensor communication, wireless sensors may be not be used.

3. If the System Graphical User Interface (GUI) is not capable of intrinsically monitoring, displaying and alarming signal strength and diagnostics then one (1) signal strength monitoring and diagnosis tool including any necessary software and hardware must be provided for each wireless sensing receiver, each workstation or each building; (whichever is greater) as a part of this specification.

    a. A log of the signal strength for the permanently installed wireless sensing infrastructure including each wireless sensor for a period of at least seventy-two (72) continuous hours with samples at least every two (2) minutes shall be provided to the Owner with the Close-Out documentation.

C. Hardware. All wireless temperature sensors provided under this specification shall be available with the following the integral hardware at a minimum:

1. Temperature.

    a. Minimum 10-bit linear active thermistor.

    b. Minimum sensing range: -8˚C – 39˚C (18˚F – 102˚F).

    c. Resolution: +/- 0.05˚C (0.09˚F).

    d. Accuracy: +/- 0.1˚C (0.18˚F).

2. Setpoint Slider.

3. Bypass.

D. Access Points. Wireless access points shall support the following EnOcean Equipment Profiles (EEPs) at a minimum:

1. 1BS.

2. 4BS.

3. RPS.

E. Installation. Wireless temperature sensors shall be installed in compliance with the following requirements:

1. Wireless temperature sensors shall not be installed further than 30 m (100 ft) line of sight from the access point/receiver.

2. Space mounted wireless components shall not be mounted using metal device boxes, plaster rings or mounting brackets.

3. Wireless access points shall support the ability to transmit and receive.

4. If signal repeaters and/or amplifiers are required by the manufacturer's installation documentation and/or for normal day-to-day operation, a spare repeater and/or amplifier shall be provided for every two (2) repeaters and/or amplifiers installed providing the Owner 50% replacement/redundancy as a part of this specification.

5. Where batteries are required by the manufacturer's installation documentation and/or for normal day-to-day operation; one (1) new battery shall be provided for

each wireless sensor per year for the first five (5) years. Additionally, this contractor shall replace the battery for each wireless sensor annually at a minimum.

a. Where installed batteries have a documented and certified minimum operational life-cycle of five (5) years; this contractor shall test each battery at the conclusion of the first year of operation.

6. Where access points, transmitters and receivers cannot be installed directly in the space, necessary accessories, cabling and/or antennae must be provided for mounting within the space where the wireless sensors are mounted.

7. If wireless device binding requires configuration tools or a software application, a configuration tool or software application must be provided for each wireless sensing receiver, each workstation, or each building as a part of this specification.

a. As a part of this contract and as required by the owner, bindings shall be verified by this contractor a minimum of twice (2) in the first year and at least once for each remaining year of the five (5) year warranty.

2.16 AUTOMATIC CONTROL DAMPERS

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

B. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

C. Install extended shaft or jackshaft according to manufacturer's instructions.

D. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure 6.4 mm (1/4") larger than damper dimensions and shall be square, straight, and level.

E. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8") of each other.

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.

G. Provide a visible and accessible indication of damper position on the drive shaft end.

H. Support ductwork in area of damper when required to prevent sagging due to the weight damper sections.

I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

2.17 AUTOMATIC CONTROL ACTUATORS

A. Mount and link all control actuators according to manufacturer's instructions.

1. Check operation of installed damper/valve and actuator assembly to confirm that actuator modulates smoothly throughout full stroke to both open and closed positions.

2. To compress seats when spring-return actuators are used on normally-closed dampers, power actuator to approximately 5˚ open position, manually close the damper, and then tighten linkages.

B. All actuators shall be direct-coupled unless otherwise scheduled or indicated by manufacturer.

C. Minimum torque and power output requirements of actuators shall not be less than 125% of the required design load.

D. When the associated mechanical system or equipment is not in operation, control actuators shall remain in their "off" positions as indicated in the Sequences of Operation.

E. For automatic control valve actuators, In lieu of a manual positioning device, it will be acceptable for the contractor to provide a full line size bypass around the control valve. Three bypass shut-off valves shall be provided to allow the control valve to be isolated while the bypass allows flow around the control valve.

2.18 TEMPERATURE DEVICES

A. All sensors shall be installed in accordance with the manufacturer's recommendations consistent with acceptable industry standards for performance compliant with the requirements of this specification.

B. Mount sensors rigidly and adequately for the environment within the sensor operates.

C. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor readings. Where necessary due to structural cavities, masonry walls, proximity to exterior openings, unconditioned spaces, etc. insulated mounting base shall prevent temperature of mounting location from affecting sensor temperature reading.

D. Space temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.

E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type.

F. All averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.

G. Low-limit sensors and/or thermostats used in mixing plenums shall be installed in a serpentine manner horizontally across the duct. Each bend shall be supported with a capillary clip. Provide a minimum of 3 m of sensing element for each 1 m^2 (1' of sensing element for each 1 ft^2) of coil area.

H. All pipe-mounted sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid or paste in thermal wells.

1. Assembly shall allow removal of sensor from well without loss of measured medium fluid.

I. Outdoor air sensors shall be mounted outside on a northern exposure as high as serviceable on the building. The sensor shall be mounted within a ventilated enclosure to shield the sensor from the effects of the sun. The sensor location shall be selected such that it may not be affected by artificial and/or mechanical airstreams (i.e., building exhaust, building relief, etc.).

J. In condensing environments use stainless steel sensing element and capillary mounting clips.

K. Sensor guards shall be provided to protect sensor from damage in high-impact and/or high-traffic areas and/or where vandalism is a concern.

L. Sensors shall be manually calibrated on site so that the wiring length and termination does not detract from the specified sensor accuracy.

2.19 CURRENT TRANSMITTERS

A. All transmitters shall be installed in accordance with the manufacturer's recommendations consistent with acceptable industry standards for performance compliant with the requirements of this specification.

B. Mount transmitters rigidly and adequately for the environment within the sensor operates.

C. Where required, ensure that the phase relationship is maintained with corresponding voltage measurements.

D. Ensure that the transmitter coil is correctly oriented between the source and load.

E. Where required, following complete installation, ensure shorting bars are retracted or removed for normal operation.

2.20 CURRENT SWITCHES

A. All switches shall be installed in accordance with the manufacturer's recommendations consistent with acceptable industry standards for performance compliant with the requirements of this specification.

B. Mount switches rigidly and adequately for the environment within the sensor operates.

C. Ensure that the transmitter coil is correctly oriented between the source and load.

2.21 TEMPERATURE CONTROL PANELS

A. Provide laminated nameplates or tags for all control system components.

B. A legible reproduction of the "As-built" application engineering for the system served shall be laminated in clear plastic and mounted within each enclosure.

2.22 POWER SUPPLIES AND LINE FILTERING

A. No loads shall exceed 80% of the faceplate rating for each power supply or transformer.

2.23 WIRING

A. System control wiring shall be performed by professionals in a workmanlike manner consistent with acceptable industry standards for performance and in compliance with the contract documents, Project Electrical System Specifications, the National Electric Code (NEC), CSA C22.1-12 and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ). When non-code compliance requirements of the Electrical System Specifications and this specification section differ, this section shall take precedence.

B. Unless otherwise specified it shall be the responsibility of the Contractor to provide all the NEC/CSA Class 2 (low voltage) wiring necessary to provide a complete System in compliance with the requirements of this specification.

C. All wiring consistent with the definitions of NEC/CSA Class 1 (line voltage) shall be installed in UL-Listed raceway or conduit according to the requirements of the NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.

D. All wiring consistent with the definitions of NEC/CSA Class 2 (low voltage) control wiring shall be sub-fused as required and installed according to the requirements of the NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.

E. Class 2 wiring concealed in accessible locations not installed in UL-Listed raceways or conduit may be used provided that the cable is UL-Listed for the intended application.

    1. When Class 2 wiring is installed exposed, wiring is to be routed parallel or perpendicular (right-angles) with building and/or mechanical lines and neatly tied at 1.5 m (5’) intervals.

    2. Exposed cabling shall be mechanically supported to structural members. Cables shall not be supported by, or anchored to: ductwork, electrical raceways, piping or ceiling suspension systems.

    3. Exposed cabling shall be installed in sleeves where the route passes through walls, floors, and other partitions. Maintain fire, smoke, envelope, and pressure ratings of each space.

F. All wiring in mechanical, electrical or service rooms, or where subject to mechanical damage shall be installed in UL-Listed raceway or conduit.

G. Class 2 wiring shall not be installed in raceways or conduit containing Class 1 wiring. Junction boxes, enclosures, and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays, transformers, CTs, etc.). Refer to the requirements of the applicable code enforcing authorities and AHJ.

    1. NEC Chapter 7 Article 725 – Class 1, Class 2 and Class 3 Remote-Control, Signaling and Power-Limited Circuits.

    2. CSA C22.1-12 Rule 16-212 Separation of Class 2 circuit conductors from other circuits

H. Sizing and selection of raceways, enclosures and conduit shall be the responsibility of the Contractor in keeping with the manufacturer’s recommendations and the requirements of NEC, CSA C22.1-12, the Electrical System Specifications and any/all applicable local codes and/or AHJ.

1. Conceal all raceways and conduit, except within mechanical, electrical, or service spaces.

2. Install raceways and conduit to maintain a minimum clearance of 15 cm (6") from high-temperature equipment (e.g., steam lines, flues, etc.).

3. Secure and support raceways and conduit to the structure per the manufacturer's recommendations. Raceways and conduit may not be hung on flexible straps or tie rods, nor may they be attached to ductwork.

2.24 COMMUNICATION WIRING

A. Communication and network wiring shall adhere to the Wiring article in Part 3 of this specification and the manufacturer's recommendations.

B. Communication wiring shall not be installed in any raceway or conduit with Class 1 or Class 2 wiring.

C. All communication wiring shall be installed as continuous lengths, with no splices permitted between termination points.

D. All communication cabling shall be labelled to indicate origination and destination devices.

E. All communications shielding shall be grounded as per manufacturer's recommendations and in accordance with the NEC/CSA (as applicable).

2.25 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels, shall be labelled at each end within 5 cm (2") of the termination with the BACnet object instance or termination number.

B. Manufacturer's name plates and UL or CSA labels are to be visible and legible after equipment is installed.

C. All labels and identifiers shall match record documents.

2.26 SYSTEM CHECK-OUT AND TESTING

A. All testing listed in this article shall be performed by the Contractor. This testing shall be completed before system demonstration is initiated.

1. The Contractor shall furnish all the necessary labor and test and calibration apparatus required to calibrate and prepare for service all instruments, controls, and accessory equipment provided under this specification.

2. Verify that all control terminations are tight, and all control wiring is proper and free from shorts and faults.

3. Enable normal operational control and verify calibration of all input devices individually according to manufacturer's recommendations.

4. Verify the operation of all output devices including action, normal positions, fail-safe positions, start and span, and travel.

5. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation.

    a. Tune all control loops and optimum start/stop routines.

    b. Check each alarm separately by providing an appropriate signal to trip the alarm.

    c. Trip all safeties and interlocks to verify proper operation and fail-safe response.

B. As each device is tested, a log shall be completed showing the date, technician's initials, and any corrective action taken as a result of operational failures. This log shall be submitted prior to scheduling acceptance demonstration and for inclusion in the final O&M manuals.

2.27 CONTROL ACCEPTANCE AND DEMONSTRATION

A. Prior to acceptance, the System shall undergo a series of performance tests to verify proper operation and compliance with this specification.

B. The tests described in this section are in addition, and subsequent, to the tests necessary for start-up, tuning, debugging, and compliance with the requirements of the Check-out and Testing section of this specification. The Engineer or an appointed representative shall be present at the tests specified in this section and shall be notified ten (10) working days prior to the testing procedures.

C. The Contractor shall provide at least two (2) qualified technical personnel equipped with means for two-way communication to demonstrate the actual operation of all control operations and modes including occupied, unoccupied, seasonal changeover, and emergency/fail-safe operation.

    1. Compliance with this specification shall be demonstrated including all specification sections, schedules, drawings, and Sequences of Operation.

D. Demonstrate operator interface compliance with the requirements of the specification.

E. Additionally, the following shall be demonstrated:

    1. Control loop response shall be proven in the form of trend data in a graphical format displaying the actual response to process variables of each control loop.

        a. Trends shall include the process variable, setpoint, loop output, and physical output position.

        b. Trends shall show the loop's response to a change in setpoint which represents a change in output equal to at least 25% of its full range.

        c. The sampling rate shall be between 10 seconds and 3 minutes.

        d. Leading or following loops shall be required to be tuned by the Contractor.

    2. Operational logs for each system that demonstrate normal operation.

a. Trends shall include the process variable, setpoint, loop output, physical output position, operational mode, and equipment status.

b. Trends shall cover three (3) 48-hour periods with a sampling interval of not more than 10 minutes.

3. At the discretion of the Owner/Engineer trends from a random sampling of 25% of unitary controllers/applications shall be submitted.

4. Database backup of the entire network and database restoration for selected controllers.

F. As each device is tested, a log shall be completed showing the date, technician's initials, and any corrective action taken as a result of operational failures.

G. The Contractor shall display, using a third-party data packet analytical tool, that all System data transmission, including operator interface requests, are being performed using BACnet.

H. Any tests that fail to demonstrate the operational compliance of the System shall be repeated, at a later date, after the issues have been resolved. The System Contractor shall be responsible for any necessary repairs or revisions to successfully complete all tests.

I. Within seven (7) calendar days of successful completion of the tests and documentation described herein the System shall be accepted as complete.

1. Any tests that cannot be performed due to circumstances beyond the control of the Contractor may be performed at the discretion of the Owner after acceptance and as a part of the warranty period.

2.28 CLEANING

A. The Contractor shall clean and remove all debris resulting from his/her activities daily. The Contractor shall remove all cartons, containers, crates, etc. under his/her control as soon as their contents have been removed.

B. At the completion of work in any area the Contractor shall clean all work, equipment, etc. keeping it free from dust, dirt, debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any other factory finish damage shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed or damaged shall be replaced with new material and painted to match the adjacent areas.

2.29 TRAINING

A. The Contractor shall provide instruction on the adjustment, operation and maintenance of the System including all hardware and software provided and installed in compliance with the requirements of this specification.

1. Training shall be performed by a manufacturer's representative and/or instructor or a manufacturer-trained application engineer and/or technician with a minimum of 5-years of experience in the installation, programming and operation of the System.

2. All training equipment and material shall be provided by this Contractor.

B. Training in the operation of the System shall be performed utilizing a BACnet network of working controllers' representative of the installed network and/or the Owner's facility and shall include:

2.30 INSTRUCTIONS TO OTHER CONTRACTORS

A. Control Valve Installation. Control valves shall be installed in accordance with the manufacturer's recommendations and in compliance with this specification.

1. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball type control valves shall be installed with the stem in the horizontal positions.

2. Control valves shall be installed so that they are accessible and serviceable and so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.

3. Isolation valves shall be installed so that the control valve body may be serviced without draining the piping system. Unions or flanges shall be provided at all connections to control valves.

4. Provide tags for all controls valves indicating service and identifier. Secure tags with chain and hook. Identifiers shall match approved control shop drawings.

B. Control Damper Installation. Control dampers shall be installed in accordance with the manufacturer's recommendations and in compliance with this specification.

1. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

2. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Inside clear duct openings shall measure 6 mm (1/4") larger than damper actual outside clear dimensions and shall be square, straight, and level.

3. Individual damper sections as well as entire multiple section assemblies must be completely square and free from racking, twisting, or binding. Diagonal measurements from upper corners to opposite lower corners must be within 3 mm (1/8") of one another.

4. Unless specifically designed for vertical blade orientation, dampers must be installed with blade axis horizontal.

5. Damper blades, shafts, and linkages must operate without binding. On multiple section assemblies, blades must open and close simultaneously.

6. Provide a visible and accessible indication of damper position on the drive shaft end.

7. Support ductwork in area of damper when required to prevent sagging due to damper weight.

8. After installation caulk between frame and duct and/or opening to prevent leakage around perimeter of damper.

2.31 SEQUENCES OF OPERATION

AHU – 1

Operate the fan based on a demand from the space or a Air Quality high level with Occupied setpoints and Unoccupied setpoints. Room sensor shall have a occupied sensor capability built into the sensor with adjustable time delays on, and Off. Maintain a discharge air setpoint that will operate on a slide reset based on an outside Air temperature sensor hard wired into the same AHU controller. Do not rely on the transfer of the outside air. Monitor the status of the fan with an analog Current sensor for fan status and belt loose/ lost belt status. In Heat Mode Stage heaters based on maintaining a Discharge temperature setpoint with a outside air resets and lockouts. Stage heaters with a sample Discharge air temp on a variable time for tuning and preventing all stages coming on. Economizer operation shall operate in Cooling mode controlling to a Mixed air setpoint at the Return air temp compared to the Outside air and only operate when outside Air if lower than return air temperature. If the air quality is above setpoint Modulate economizer to bring in Fresh air needed for air exchange and enable exhaust fans. Air exchange mode may be set to a fixed value on the economizer set during balancing stage of the project. During hot temperatures and the economizer is locked out. Pull a forecast from NOAA and determine if there will be consecutive high temperatures. If higher daytime temperatures are in the forecast, occupy in the evenings if cooling is available and cool space to 4 degrees below setpoint to help with space overheating. allow master schedule to override this function.

UNIT HEATERS

All unit heaters in space Shall all be enabled based on a call from the thermostat. Status the 24v on the ignition module and generate an alarm based on enable command and status of ignition module.

FURNACE

Run furnace operation on a call from the space sensor . Setpoint shall be set by occupied setpoint and unoccupied setpoints with a 2 hour override operation and a 4 degree adjustment. Install MS/TP communication wire in from the last controller daisychain installation is acceptable also. Redline route used. Install a damper actuator on the outside air that will modulate open on a fan command. With a spring return operation to the closed position. Install Discharge air sensor and a analog current sensor for fan status of operation or lock rotor current. Disable heat command if fan status is not sensed.

SECTION 230953

SECTION 233114 - LOW-PRESSURE STEEL DUCTWORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install above-grade ductwork and related items as described in Contract Documents.

PART 2 - PRODUCTS

2.1 DUCTS

A. Fabricate of zinc-coated lockforming quality steel sheets meeting requirements of ASTM 653A/653M, "Specification for Sheet Steel Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock Forming Quality", with G 60 coating.

B. Use of aluminum, non-metallic, or round ducts is not permitted. [Specification writer: Use of aluminum ducts in areas with high chlorine content (eg.: ventilation for pools, spas, etc.) should be considered on a per job basis.]

2.2 DUCT JOINTS

A. Ducts with sides up to and including 36 inches shall be as detailed in the SMACNA manual.

B. Duct sizes over 36 inches shall be fabricated using SMACNA T-24 flange joints or pre-fabricated systems as follows:
   1. Ducts with sides over 36 inches to 48 inches:
      a. transverse duct joint system by Ductmate/25, Nexus, Ward, or WDCI (Lite) (SMACNA "E" or "G" Type connection).
   2. Ducts 48 inches & larger:
      a. Ductmate/35, Nexus, or WDCI (Heavy) (SMACNA "J" Type connection).
   3. Approved Manufacturers:
      a. Ductmate Industries Inc, 10760 Bay Meadows Drive, Sandy, UT 84092 (801) 571-5308
      b. Nexus, Exanno Corp, P O Box 729, Buffalo, NY 14206 (716) 849-0545
      c. Ward Industries Inc, 1661 Lebanon Church Road, Pittsburg, PA 15236 (800) 466-9374
      d. WDCI, P O Box 10868, Pittsburg, PA 15236 (800) 245-3188

2.3 ACCESS DOORS IN DUCTS

A. At each manual outside air damper and at each motorized damper, install factory built insulated access door with hinges and sash locks. Locate doors within 6 inches of installed dampers. Construction shall be galvanized sheet metal, 24 ga minimum.

B. Fire and smoke damper access doors shall have a minimum clear opening of 12" x 12" or as specified on Drawings to easily service fire or smoke damper. Doors shall be within 6 inches of fire and smoke dampers and in Mechanical Room if possible.

C. Identify each door with 1/2" high letters reading “smoke damper” or “fire damper”.

D. Approved Manufacturers:
   1. AirBalance - Fire/Seal #FSA 100
   2. Air Control Products - HAD-10
   3. Cesco-Advanced Air - HAD-10
   4. Elgen - Model 85 A
   5. Kees Inc - ADH-D.
   6. Louvers & Dampers - #SMD-G-F
   7. Nailor-Hart Industries Inc - Series 0831
   8. National Controlled Air Inc - Model AD-FL-1

2.4 FLEXIBLE EQUIPMENT CONNECTIONS

A. 30 oz closely woven UL approved glass fabric, double coated with neoprene.

B. Fire retardant, waterproof, air-tight, resistant to acids and grease, and withstand constant temperatures of 250 deg F.

C. Approved Manufacturers:
   1. Cain - N-100
   2. Duro Dyne - MFN
   3. Elgen - ZLN
   4. Ventfabrics - Ventglas

2.5 CONCEALED CEILING DAMPER REGULATORS

A. Approved Manufacturers:
   1. Cain
   2. Duro Dyne
   3. Metco Inc
   4. Vent-Lock - #666
   5. Young - #303

2.6 VOLUME DAMPERS

A. In Main Ducts:
   1. 16 gauge galvanized steel, opposed blade type with 3/8 inch pins and end bearings. Blades shall have 1/8 inch clearance all around.
   2. Damper shall operate within acoustical duct liner.
   3. Provide channel spacer equal to thickness of duct liner.
   4. Approved Manufacturers:
      a. Air Balance - Model AC-2
      b. Air Control Products - CD-OB
      c. American Warming - VC-2-AA
      d. Greenheck - VCD-1100
      e. NCA, Safe Air
      f. Vent Products - 5100

B. In Sheet Metal Branch Ducts:
   1. Extruded aluminum, opposed blade type. When in open position, shall not extend beyond damper frame.
   2. Maximum blade length 12 inches.
   3. Damper Regulator shall be concealed type with operation from bottom or with 90 deg miter gear assembly from side.
   4. Approved Manufacturers:
      a. Air Control Products - TCD-OB
      b. Air Guide - OB

c. Arrow - OBDAF-207
d. CESCO - CDA
e. Reliable Metals - OBD-RO
f. Tuttle & Bailey - A7RDDM
g. Safe Air
h. Young - 820-AC

C. Dampers above removable ceiling and in Mechanical Rooms shall have locking quadrant on bottom or side of duct. Otherwise, provide concealed ceiling damper regulator and cover plate.

2.7 MOTORIZED OUTSIDE AIR DAMPERS

A. Damper Blades:
1. 18 gauge galvanized steel or equivalent aluminum with replaceable rubber blade edges, 9 inches wide maximum.
2. End seals shall be flexible metal compression type.
3. Opposed blade type.

B. Make provision for damper actuators and actuator linkages to be mounted external of air flow.

C. Approved Manufacturers & Models:
1. Air Balance - AC-2
2. American Warming - VC-2-AAVA
3. Arrow - OBDAF-207
4. Greenheck - VCD-2100
5. Honeywell - D641
6. Johnson - D1300
7. Louvers & Dampers - TSD400
8. Ruskin - CD36 or CD60
9. Safe Air - 610
10. Vent Products - 5800

2.8 BACKDRAFT DAMPER

A. Backdraft blades shall be nonmetallic and shall be neoprene coated fiberglass.

B. Stop shall be galvanized steel screen or expanded metal, 1/2 inch mesh.

C. Frame shall be galvanized steel or extruded aluminum alloy.

D. Approved Models & Manufacturers:
1. Air Control Products - FBD
2. American Warming - BD-15
3. CESCO - FBD 101
4. Ruskin - NMS2
5. Safe Air

2.9 DUCT HANGERS

A. 1" x 18 gauge galvanized steel straps or steel rods as shown on Drawings, and spaced not more than 8 feet apart. Do not use wire hangers.

B. Attaching screws at trusses shall be 1-1/2 inch No. 10 round head wood screws. Nails not allowed.

2.10 DUCT SEALER

A. Cain - Duct Butter or Butter Tak

B. Design Polymerics - DP 1010

C. DSC - Stretch Coat

D. Duro Dyne - S2

E. Hardcast - #601 Iron-Grip or Peel-N-Seal Tape
   1. Kingco - 15-325
   2. Mon-Eco - 44-41
   3. Trans-Continental Equipment Co - Multipurpose Duct Sealant
   4. United - Sheet Metal duct-sealer

PART 3 - EXECUTION

3.1 INSTALLATION

A. Ducts:
   1. Straight and smooth on inside with joints neatly finished unless otherwise directed.
   2. Duct panels through 48 inch dimension having acoustic duct liner need not be crossbroken or beaded.
   3. Crossbreak unlined ducts and duct panels larger than 48 inch or bead 12 inches on center.
   4. Securely anchor ducts to building structure with specified duct hangers attached with screws. Do not hang more than one duct from a duct hanger.
   5. Brace and install ducts so they shall be free of vibration under all conditions of operation.
   6. Ducts shall not bear on top of structural members.
   7. Make duct take-offs to branches, registers, grilles, and diffusers as detailed on Drawings.
   8. Ducts shall be large enough to accommodate inside acoustic duct liner. Dimensions shown on Drawings are net clear inside dimensions after duct liner has been installed.
   9. Properly flash where ducts protrude above roof.
   10. Install internal ends of slip joints in direction of flow. Make joints air tight using specified duct sealer.
   11. Cover horizontal and longitudinal joints on exterior ducts with two layers of Hardcast tape installed with Hardcast HC-20 adhesive according to Manufacturer's recommendations.
   12. Paint ductwork visible through registers, grilles, and diffusers flat black.

B. Install flexible inlet and outlet duct connections to each furnace, fan, fan coil unit, and air handling unit.

C. Install concealed ceiling damper regulators.
   1. Paint cover plates to match ceiling tile.
   2. Damper regulators will not be required for dampers located directly above removable ceilings or in Mechanical Rooms.

D. Provide each take-off with an adjustable volume damper to balance that branch.
   1. Anchor dampers securely to duct.
   2. Install dampers in main ducts within insulation.
   3. Dampers in branch ducts shall fit against sheet metal walls, bottom and top of duct, and be securely fastened. Cut duct liner to allow damper to fit against sheet metal.
   4. Where concealed ceiling damper regulators are installed, provide a cover plate.

E. Install grilles, registers, and diffusers. Level floor registers and anchor securely into floor.

F. Air Turns:
   1. Permanently installed, consisting of single thickness curved metal blades with one inch straight trailing edge to permit air to make abrupt turn without appreciable turbulence, in 90 degree elbows of above ground supply and return ductwork.
   2. 4-1/2 inch wide minimum vane rail. Do not use junior vane rails.
   3. Double thickness vanes not acceptable.
   4. Quiet and free from vibration when system is in operation. See SMACNA Manual

G. Install motorized dampers

END OF SECTION 233114

SECTION 233316 - FIRE DAMPERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install fire dampers at penetrations of fire rated walls, floors, & ceilings, at ducts, registers, grilles, or louvers as described in Contract Documents.

1.3 QUALITY ASSURANCE

A. Requirements of Regulatory Agencies:
   1. Dampers shall conform to UL and NFPA requirements and bear UL label.
   2. Dampers shall be approved by State Fire Authorities where so required.

1.4 MAINTENANCE MATERIALS

A. Leave six fusible links of each rating type used on Project with Owner.

PART 2 - PRODUCTS

2.1 FIRE DAMPERS

A. Walls & Floors:
   1. Type "B" with 165 deg F link unless otherwise indicated on Drawings.

B. Ceilings:
   1. Radiation type ceiling fire damper with 165 deg F link unless otherwise indicated on Drawings.

C. Approved Manufacturers:
   1. Air Balance Inc
   2. Cesco
   3. Safe Air Inc
   4. Ultra Safe

PART 3 - EXECUTION

3.1 INSTALLATION

A. Fire damper installation shall conform to details shown in SMACNA Fire Damper Guide and as required by manufacturer’s recommendations and local codes.

B. Each fire damper shall have access panel for maintenance and inspection.

C. Locate access panels not more than 6 inches from fire damper they serve.

END OF SECTION 233316

SECTION 233318 - SMOKE DETECTORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Ionization smoke detector mounted in supply air streams or as shown on drawings. Detector to operate on 120 volts AC.

PART 2 - PRODUCTS

2.1 SMOKE DETECTORS

A. Approved Manufacturers & Models:
   1. Series 2650-450 ionization type, duct mounted smoke detector, by Robertshaw
   2. MS Series ionization type duct mounted smoke detector by Air Products Controls Ltd.
   3. Model DH400 ACDC duct mounted smoke detector by System Sensor, a Division of Pittway
   4. Model 0550 duct smoke detector by Maple Chase Co.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install on systems greater than 2000 CFM and interlock with motor control to shut down fan systems upon smoke detection.

B. Install as shown on drawings at each smoke/fire damper location and connect to damper. Provide access door as specified in Section 23 3114. Smoke detectors to be installed within 5' of fire/smoke damper.

END OF SECTION 233318

SECTION 233346 - FLEX DUCT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install supply air branch duct runouts to diffusers as described in Contract Documents.

PART 2 - PRODUCTS

2.1 DUCTS

A. Formable, flexible, circular duct which shall retain its cross-section, shape, rigidity, and shall not restrict air flow after bending.

B. Nominal 1-1/2 inches thick, 3/4 lb/cu ft density fiberglass insulation with air-tight, polyehtylene or polyester core, sheathed in seamless vapor barrier jacket factory installed over flexible assembly.

C. Assembly, including insulation and vapor barrier, shall meet Class I requirement of NFPA 90A and be UL 181 rated, with flame spread of 25 or less and smoke developed rating of 50 or under.

D. Length of flexible ductwork shall not exceed 8'-0".

2.2 APPROVED MANUFACTURERS

A. ANCO-FLEX - 4625

B. Flex-Aire - PF/UPC #090

C. Hart & Cooley - F114

D. Thermaflex - G-KM

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct in fully extended condition free of sags and kinks.

B. Make duct connections by coating exterior of duct collar for 3 inches with duct sealer and securing duct in place over sheet metal collar with 1/2 inch wide metal cinch bands and sheet metal screws.

END OF SECTION 233346

SECTION 233400 - EXHAUST FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install exhaust fans as described in Contract Documents.

1.3 QUALITY ASSURANCES

A. Requirements of Regulatory Agencies:
   1. Bear AMCA seal and UL label.

PART 2 - PRODUCTS

2.1 CEILING MOUNTED EXHAUST FANS

A. Acoustically insulated housings.

B. Sound level rating of 4.6 sones maximum for fan RPM and CFM listed on Drawings.

C. Include chatterproof integral back-draft damper with no metal to metal contact.

D. True centrifugal wheels.

E. Entire fan, motor, and wheel assembly shall be easily removable without disturbing housing.

F. Suitably ground motors and mount on rubber-in shear vibration isolators.

G. Provide wall or roof cap, as required.

H. Approved Manufacturers:
   1. Cook-Gemini
   2. Greenheck Sp
   3. Pace
   4. Penn Zephyr

2.2 ROOF MOUNTED EXHAUST FANS

A. Direct drive or have adjustable pitch V-belt as noted on Drawings.

B. Wheels shall be backward curved and housing shall be removable or hinged aluminum.

C. Isolate motor with vibration dampeners.

D. Provide quiet type back-draft dampers.

E. Insulated, pre-fabricated metal roof curb shall be for flat or sloped roof as shown on Drawings.

F. Approved Manufacturers:
   1. Fans:

a. Penn
b. Centri-Master
c. Cook
d. Greenheck G, GB

2. Standard curbs:
   a. Penn
   b. Cook
   c. Greenheck
3. Sound attenuating curbs:
   a. Penn
   b. Greenheck

PART 3 - EXECUTION

3.1 INSTALLATION

A. Anchor fan units securely to structure or curb.

END OF SECTION 233400

SECTION 233451 – CARBON MONOXIDE EXHAUST SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install monoxide exhaust system as described in Contract Documents.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Monoxide Exhaust:
   1. Overhead system with necessary fans, ducts, fittings and accessories.
   2. Install using high pressure galvanized ductwork, fabricated and installed in accordance with "High Pressure Duct Manual."
   3. Provide flexible exhaust tubes with adaptor and automatic reel system.
   4. Approved Manufacturers:
      a. Apex Rail.
      b. Or Approved Equal.

END OF SECTION 233451

SECTION 233713 - AIR OUTLETS & INLETS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install wall supply registers, transfer grilles, return air grilles, soffit grilles, ceiling diffusers, louvers connected to ductwork, and registers as described in Contract Documents.

PART 2 - PRODUCTS

2.1 GRILLES & REGISTERS

A. Approved Manufacturers:
   1. Price
   2. Anemostat
   3. Krueger
   4. Titus
   5. Tuttle & Bailey

2.2 SPIN-IN FITTINGS

A. Low pressure round take-offs to diffusers shall be made with spin-in fittings. They shall incorporate a manual balancing damper. The damper shall be spring loaded and a positive locking wing nut shall secure the damper position.

B. Approved Manufacturers:
   1. Sheet metal fittings: Genflex DB-1DEL, Hercules

2.3 LOUVERS

A. Extruded aluminum, with blades welded or screwed into frames and 1/2 inch mesh 16 gauge aluminum bird screen.

B. Frames shall have mitered corners.

C. Louvers shall be recessed, flanged, stationary, or removable as noted on Drawings.

D. Approved Manufacturers:
   1. Airolite
   2. American Warming
   3. Arrow
   4. Industrial Louvers
   5. Ruskin
   6. Vent Products

PART 3 - EXECUTION

3.1 INSTALLATION

A. Anchor securely into openings.

B. Install with screws to match color and finish of grilles and registers.

C. Touch-up any scratched finish surfaces.

D. Install in accordance with manufacturer's instructions.

E. Check location of outlets and inlets and make necessary adjustments in position to conform with architectural features, symmetry, and lighting arrangement.

F. Install diffusers to ductwork with air tight connection.

G. Provide balancing dampers on duct take-off to diffusers, and grilles and registers, despite whether dampers are specified as part of the diffuser, or grille and register assembly.

H. Paint ductwork visible behind air outlets and inlets matte black. Refer to Section 09 9000.

END OF SECTION 233713

SECTION 234145 – FURNACE AIR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install furnace vent piping and combustion air intake piping as described in Contract Documents.

PART 2 - PRODUCTS

2.1 AIR PIPING

A. Schedule 40 pipe and fittings meeting requirements of one of following:
   1. ASTM D 1785-89, "Specification for Poly(Vinyl Chloride)(PVC) Plastic Pipe, Schedules 40, 80, and 120."
   2. ASTM D 2661-89, " Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste, and Vent Pipe and fittings."
   3. ASTM D 2665-89a, "Specification for Poly(Vinyl Chloride)(PVC) Plastic Drain, Waste, and Vent Pipe and Fittings."

2.2 PRIMER & CEMENT

A. Meet requirements of ASTM D 2564-88, "Specification for Solvent Cements for Poly(Vinyl Chloride)(PVC) Plastic Pipe and Fittings."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Do not combine furnace drain piping with cooling coil drain piping.

B. Run individual vent and individual combustion intake piping from each furnace to outdoors with location and formation recommended by Furnace Manufacturer. Slope lines downward toward furnaces.

C. Slope combustion chamber drain downward to funnel drain. Anchor to wall with wall clamps, allowing free movement through clamp for expansion.

D. Use vent terminal kit or clamping system provided by Furnace Manufacturer. Install vent and combustion air intake piping at clearance and distances required by Furnace Manufacturer.

E. Attach factory-supplied neoprene coupling to furnace combustion-air inlet connection and secure with clamp.

F. Ensure that factory-supplied perforated metal disc is installed in flexible coupling, unless its removal is required.

END OF SECTION 234145

SECTION 235416 – SEPERATED COMBUSTION PROPANE UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install separated combustion unit heaters as described in Contract Documents.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Provide high-efficiency, separated combustion, propane gas fired unit heaters as manufactured by Reznor. They are to be designed for a fuel use improvement of 25% and engineered for use in building areas with negative pressure and/or extremely dirty or mildly corrosive atmospheres. The use of a factory-installed power venter to draw combustion air from outside is to prevent dirt, lint, dust, or other contaminants present in the heated space from entering the unit. The combustion air supply pipe and flue exhaust pipe shall be run parallel to a factory-supplied (horizontal), (vertical) vent terminal assembly. The vent terminal assembly shall be arranged to provide preheating of the combustion supply air and to allow a single wall or roof penetration.

B. The SC series shall be provided with a 24-volt control transformer, a two-stage, gas control system with a regulated combination redundant gas valve and an intermittent spark pilot with electronic flame supervision (and timed lockout). The SC is to include all limit and safety controls, including a combustion air pressure differential switch to verify proper vent flow before allowing operation of the gas valve.

C. Each unit shall be equipped for use with propane gas and 120/1, volt power supply. The heat exchanger shall be the Reznor Themrocore design of aluminized, E-3 steel and include flared ports (burner air shutters) and a stainless steel insert. The units shall be designed for 80% thermal efficiency.

D. These units are to be propeller fan(s), open drip-proof fan motor(s) with internal overloads, and safety fan guard(s). Horizontal louvers shall be provided for directing air flow. The unit must be arranged for ceiling suspension with threaded hanger connections (and provided with hanger kits). The cabinet shall be constructed of zinc grip steel and finished with baked-on enamel.

E. All separated-combustion unit heaters must be design-certified by the American Gas Association and bear the A.G.A. label.

END OF SECTION 235416

SECTION 235417 – HIGH EFFICIENCY PROPANE GAS FURNACE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install propane gas fired condensing high efficiency furnace as described in Contract Documents.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Fabrication:
   1. Furnaces shall be factory assembled units certified by AGA complete with blower section, furnace section, condensing coil, steel casing, piped, and wired.
   2. Blower section shall consist of cabinet, blower, and motor.
   3. Cabinet shall be of 22 gauge minimum cold rolled steel and have finish coat of baked-on enamel.
   4. Blower shall be Class 1, full DIDW, statically and dynamically balanced.
   5. Filters shall be one inch thick pleated throw-away type as furnished by furnace manufacturer.
   6. Provide furnace with accessory side mounted filter box frame and factory available bottom closure.
   7. Automatic controls:
      a. 100% cut-off safety pilot
      b. Manual gas shut-off valve
      c. 0perating automatic gas valve
      d. Solid state type fan and thermal limit controls
      e. 24 volt transformer
      f. Electronic ignition system
      g. Pressure switch safety for induced draft fan

B. Units:
   1. Blower shall be driven by motor with adjustable pitch V-belt drive or by a multi-speed direct driven motor.
   2. Furnace section shall be enclosed in 22 gauge minimum enameled steel casing lined with foil covered insulation.
   3. Heat exchanger shall be ceramic or glass coated, stainless steel, or 18 gauge aluminized steel with 20 year minimum limited warranty.
   4. Units shall be rated at 93% minimum AFUE (Annual Fuel Utilization Efficiency) calculated in accordance with DOE test procedures.
   5. 2" or 3" intake and exhaust lines to outside with factory furnished combination flue/intake assembly for roof or sidewall.

C. Provide with Web enabled 7 day programmable thermostat equal to Honeywell Prestige.

D. Approved Manufacturers:
   1. Lennox

2. Carrier
3. York
4. Trane

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

A. Quality Assurance: Furnace manufacturer's representative shall start up and check out furnace equipment as follows:
   1. Verify proper gas orifice sizing for altitude.
   2. Clock gas meter for rated input.
   3. Verify and set gas pressure at furnace.
   4. Check and measure temperature rise.
   5. Check safety controls for proper operation.

END OF SECTION 235417

SECTION 235723 - WALL HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 SUMMARY

A. Furnish and install wall heaters as described in Contract Documents.

1.3 QUALITY ASSURANCE

A. Units shall be UL listed and comply with NEC.

PART 2 - PRODUCTS

2.1 MANU FACTURED UNITS – WALL HEATERS

A. Fan type for recess mounting in wall.

B. 20 gauge minimum sheet metal casing.

C. Heating element shall be encased in steel finned casting and protected by thermal switch.

D. Fan motor shall be heavy duty enclosed and permanently lubricated.

E. Fan shall be precision balanced and fan-motor assembly mounted to be vibration free.

F. Units shall be controlled automatically by integral thermostat when heater is in "ON" position.

G. Heater shall have built-in fan delay.

H. Finish - Baked-on enamel.

I. Approved Manufacturers:
   1. Q' Mark AWH-4000 or equal by
   2. Berko
   3. Thermador
   4. Markel

END OF SECTION 235723

SECTION 236220 – ROOFTOP HEATING-COOLING UNIT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, General Provisions of Contract, including General and Supplementary Conditions and Section 23 0501 apply to this Section.

1.2 QUALITY ASSURANCE

A. Unit shall be AGA certified.

1.3 WARRANTY

A. Provide five-year warranty on compressors.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Unit shall be one piece combination air-to-air DX mechanical cooling system and gas fired heating system complete with automatic controls.

B. Equipment shall be shipped completely assembled, pre-charged, piped and wired internally ready for field connections.

C. Roof mounting frame shall be furnished and installed. Frame shall be steel and mate to bottom perimeter of equipment. When flashed into roof, it shall make a unit mounting curb and provide weather-proof duct connection and entry into conditioning area.

D. Power Saver: (Fresh Air Dampers)
   1. Provide complete with all controls and air mixing damper assembly, including fresh air, recirculated air, and exhaust air dampers.
   2. Fresh air section shall be equipped with air filters.
   3. Mixing box sections shall contain low leakage dampers with edge seals and inflatable blade seals.

E. Cooling System:
   1. Coils shall be non-ferrous construction with aluminum fins mechanically bonded to seamless copper tubes.
   2. Condenser coil shall have sub-cooling rows.
   3. Compressor shall be resiliently mounted, have built-in 3-mode crankshaft lubrication, crankcase heater, discharge temperature limiter, current and temperature sensing motor overloads.
   4. Cooling system shall be protected by high and low pressure switches and compressor timed off control.
   5. Provide with hail guard over condenser coil.

F. Heating System:
   1. Automatic controls furnished to give 50/50 2-stage operation.
   2. Cylindrical tube and drum exchanger constructed of Duraglas coated steel or stainless steel.
   3. Stainless steel burner listed for operation at low outdoor air temperatures.

4. Visual inspection of burner flame possible through observation port at rear of heat exchanger.
5. Power vented.

G. Air Movers:
1. Twin centrifugal conditioned air blowers with permanently lubricated ball bearings, adjustable belt drive or direct drive as shown on drawings.
2. Condenser fans shall be direct driven.
3. Motors shall have inherent protection devices.

H. Frame and Casing:
1. Frame shall be welded construction.
2. Casing shall be galvanized panels with baked-on outdoor enamel finish.
3. Entire cabinet shall be insulated with 1" thick fiberglass.
4. Provide coil guards on exposed condenser coils.

I. Furnish two sets of 2" throw away filters.

J. Provide with 7-day programmable thermostat equal to Honeywell T-7350.

K. Approved Manufacturers:
1. Lennox
2. Trane
3. Carrier

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

A. Provide manufacturer's startup and warranty.

END OF SECTION 236220

END OF DIVISION 23