Table of Contents

SECTION 23 00 00

HEATING, VENTILATING AND AIR CONDITIONING
(Filed Sub-Bid Required)

PART 1 - GENERAL

1.01 PROVISIONS INCLUDED

A. The Conditions of the Contract including Part A of the Project Manual and Division 1 - General Requirements, apply to the Work under this Section.

B. HVAC Contractor shall be the General Contractor for this project.

SCOPE OF WORK

The work described herein shall be interpreted as work to be done by the HVAC Contractor.

The work covered by this Section of the Specifications includes the furnishing of all labor and materials and in performing all operations in connection with the installation of the HVAC work.

The work includes, but is not limited to, the following:

1. Air Cooled Chillers.
2. Hydronic Pumps.
3. Variable Frequency Drives (Electrical Contractor to install)
4. Hydronic Supply and Return Piping.
5. Hydronic Accessories.
6. Piping Insulation.
7. Dedicated Outdoor Air System.
8. Exhaust Fans.
9. Sheet Metal Ductwork.
10. Grilles, Registers and Diffusers.
11. Ductwork Insulation.
12. Condensate Drain Piping and Pumps.
13. Variable Refrigerant Volume/Flow System (Outdoor Unit, Indoor Units, and Interface with the BMS via).
14. Refrigerant Piping.
15. Automatic Temperature Controls.
    a. ATC Contractor shall write new programming as required to tie in equipment that will be added to the building under this contract. The new equipment is as follows:
        1) Air-Cooled Chillers, Dedicated Outdoor Air System, Condensing Boiler and two (2) boiler pump into the existing control structure. Map alarms and points to be available on the head end. Provide start/stop control, and global points and temperature setpoints.
        2) Two (2) Chilled Water Pumps and Two (2) Heating Hot Water Pumps that will operate in Lead / Lag manner. Each Pump shall be rotated on a bi-weekly basis to even out run time. The chilled water system shall be controlled based on system pressure as the pressure increases the pumps shall decrease output and as the pressure drops the pumps shall increase their output.
    b. Provide outside air dampers and modulating DDC damper actuators, two-way modulating DDC control valves for new and existing FCUs (Installed by the HVAC Contractor).
16. O&M Manuals
17. Operating Instructions (Training on the components and systems).
18. Record Drawings.
19. Staging, Ladders, Scaffolding, Hoists and All Related Equipment.
20. Coring, Cutting and Patching required under this section
21. Firestopping at all penetrations.
22. Finish painting, including painting of supporting steel for mechanical equipment.

23. Coring, Cutting and patching greater than 4-1/2" for other sub-contractors.
24. Flashing and waterproofing of all pipe penetrations through walls.
25. Furnish and install all access panels required under this section.
26. Furnish, install, and flash all roof curbs required under this section (Coordinate work with City's Roofing Contractor).
27. Flashing and waterproofing of all new pipe penetrations through roof (Coordinate work with City's Roofing Contractor)
28. Plumbing work to be done by a Licensed Plumber under the supervision of this contractor is specified under this section and as listed here:
    a. The Plumber shall furnish and install Exhaust Vent and Combustion Air piping, including hangers and supports, associated with new gas fired boiler.
    b. The Plumbing Subcontractor shall furnish and install gas piping, gas train, valves, and hangers associated with new gas connection to new gas fired boiler.
29. Sprinkler Relocation work shall be performed by a licensed sprinkler contractor under the supervision of this contractor.
30. Procure the services of Testing, Adjusting and Balancing Contractor. Organize and schedule other subcontractors as required to perform the work in a timely manner.
31. Commissioning: Work with the Commissioning Agent to provide access, and assistance in providing documentation, testing, and scheduling of other contractors to be available to perform functional testing to provide confirmation that all systems are operating as designed and meet the Owner's Requirements.

1.02 ALTERNANTES

A. ADD ALTERNATE #1 – DDC FRONT END UPDATE

1. The work under this alternate shall include upgrading the Building Management System's front end to the requirements specified in the Building Management Section of the Specification Division 23 00 00.
2. Adding unitary controllers to existing equipment to allow for scheduling, and polling operational points (temperature, valve position, fan speed) provide global points (Outside Air Temperature and Hunidity) and setpoints. Communication Wiring shall be updated as required to conform with the new head-end and all unitary controllers.

B. ADD ALTERNATE #2 – INDOOR FIRING RANGE VENTILATION UPGRADES

1. The work under this alternate shall shall take place in the Indoor Firing Range, and it will include removing the existing exhaust fans and adding a Manufactured HEPA Housing wirh a prefilter rack, which whill sit on a 30" curb, and new fans will be fastened to the top of the HEPA Housing. Downdraft Exhaust Fans, 99.97% HEPA Filerts, Pre-filters, and new motorized dampera.
2. The controls for the existing roof top unit will be revised to control the dampers and exhaust fans in addition to existing roof top unit. Different firing line scenariors will be programed so that the user can toggle a series of switch to change between scenes. Scene control box to be provided by the ATC Contractor and installed in the firing range at the location approved by the Range Master.
3. Electrical contractor will run power on the roof in conduit for the new exhaust fans as shown on the Electrical Drawings.

C. ADD ALTERNATE #3 – SALLYPORT EXHAUST CONTROL UPGRADE

1. The work under this section shall inclued the furnishing and installation of a vehicle exhaust monitoring system similar to INTEC Controls Standalone Gas Controller (PolyGard2 SGC6) or approved equal. That will monitor the sallyport for carbon monoxide (co) and nitric oxidies (nox), that will be used to control the exhaust fans.
2. The existing exhaust fans will be replace with variable speed exhaust fans with EC Motors, and new motorized inlet and outlet dampers will be provide to meet the energy code requirments for positive close-off and leakage rate. ATC Contractor to provide dampers, and two position DDC actuators to be installed by the HVAC Contractor.

3. The controls will be updated to read data from the vehicle exhaust monitoring system, and based on the readings open the motorized inlet and outlet dampers and control the speed of the exhasut fans based on the sampled levels.

1.03 RELATED WORK UNDER OTHER SECTIONS

A. The following work is not included under this Section and shall be performed under the Sections indicated:

1. By the Electrical Subcontractor:
   a. The Electrical Subcontractor shall furnish a duct smoke detector for Dedicated Outside Air System's supply duct. Smoke detectors shall be installed by the HVAC Subcontractor under this Section and wired to an indicator light mounted on the ceiling of the second floor. The light will blink to indicate activation. ATC Sub-subcontractor shall provide control wiring to fan motor.
   b. All power wiring required for the automatic temperature control system Electrical Subcontractor at a minimum shall provide two 120-volt power junction boxes per floor as shown on the drawings. ATC Sub-Contractor to review with the Electrical Contractor if additional required. Automatic temperature control wiring shall be provided by the Automatic Temperature Control Sub-subcontractor under Division 23.
   c. All electrical power wiring and connections and all disconnect switches not provided with or as integral part of the HVAC equipment shall be provided by the Electrical Subcontractor.
   d. Motor starters and VFDs shall be furnished and installed by the HVAC Subcontractor and wired by the Electrical Subcontractor.
   e. Boiler and Burner control wiring shall be provided under this Section by HVAC.
   f. Refer to Electrical specification for more information.

1.04 CODES, ORDINANCES AND PERMITS

A. All material and work provided shall be in accordance with the following codes and standards:
   1. Massachusetts State Building Code (780 CMR 9th Edition – 2015 International Building Code with Massachusetts Amendments and 2015 International Existing Building Code with Massachusetts Amendments)
   2. Massachusetts Mechanical Code (780 CMR 28.00 - 2015 International Mechanical Code (IMC)).
   3. Massachusetts Energy Conversation Code (780 CMR 13.00 - IECC 2018 / ASHRAE 90.1 2016.
   4. 248 CMR 10.00 (2021) Uniform State Plumbing Code (Massachusetts Plumbing Code)
   5. 248 CMR 4.00 National Fuel Gas Code (2012 Edition) with Massachusetts amendments (248 CMR).
   6. 527 CMR 1.00 (2019) Massachusetts Comprehensive Fire Safety Code (2015 NFPA 1 with Massachusetts Amendments))
   7. 527 CMR 12.00 (2020) Massachusetts Electrical Code (2020 NFPA 70 with Massachusetts Amendments).
   8. 522 CMR Board of Boiler Rules – (Pressure Vessel Regulations)
   9. National Fire Protection Association (NFPA).
   10. State Department of Public Safety.
   11. Massachusetts Department of Environmental Protection
   12. Standards of the Underwriters Laboratories (UL).
   13. National Institute of Occupational Safety and Health (NIOSH) (HEW Publication No. (NIOSH) 76-130).
   14. Occupational Safety and Health Act (OSHA) (29 CFR 1910.1025 and 1926.62)
   15. Environmental Protection Agency (73 FR 66964, codified at 40 CFR part 58).

B. Where the contract documents indicate more stringent requirements than the above codes and ordinances, the Contract Documents shall take precedence.

C. All necessary permits, inspections, and approvals are to be obtained and paid for by this Subcontractor. The contractor is responsible for securing all Local permits and inspections as well as State required permits and inspections.

1.05 CONTRACT DRAWINGS AND SPECIFICATIONS

A. The drawings showing layout of the HVAC systems indicate the approximate location of piping, ductwork, equipment and location of services. They are schematic and are not intended to show the exact routing or all fittings required.

The final determination as to the routing shall be governed by structural conditions and other obstructions. No cutting or removal of any wood or concrete members will be allowed, unless approved in writing by the Architect.

B. The right to make any reasonable change in the location of ducts, piping, apparatus and equipment up to the time of roughing-in is reserved by the Architect without involving any additional expense to the Owner.

C. The specifications supplement the drawings and provide specifics pertaining to the methods and material to be used in the execution of the work.

D. Any discrepancies between the drawings and specifications or within the drawings/specifications shall be brought to the attention of the Architect/Engineer for clarifications.

E. HVAC Subcontractor shall read and understand the Contract Documents and submit the bid in accordance therewith. Failure to examine the Contract Documents and site plans shall not relieve the HVAC Subcontractor from any obligation under the bid as submitted.

1.06 SHOP DRAWING AND MATERIALS SCHEDULE

A. Within fifteen days after the date of notice to proceed and before purchasing any materials or equipment, submit for approval a complete list, in three copies or electronically via a construction management program (PROCORE, Premier, eSUB or similar program), of all materials to be incorporated in the work. After the list has been processed, submit complete shop drawings of all equipment. These shop drawing submittals shall be submitted within fifteen days after the processing date of original submittal list.

B. The approval of equipment does not relieve the HVAC Subcontractor from the responsibility for shop drawing errors in details, sizes, quantities, wiring diagram arrangements and dimensions which deviate from the specification, contract drawings and/or job conditions as they exist.

C. Refer to General Requirements for substitution of equipment and submittal of shop drawings. If apparatus or materials are substituted for those specified and such substitution necessitates changes in or additional connections, supports or construction, same shall be provided. The HVAC Subcontractor shall assume cost and entire responsibility thereof.

D. Submit the name(s) and contact information for a minimum of two qualified vendors that are eligible to provide operations and maintenance on the installed HVAC system.

1.07 COORDINATION DRAWINGS

A. The HVAC Subcontractor, the Plumbing Subcontractor, the Electrical Subcontractor and the Fire Suppression Subcontractor shall coordinate all HVAC, plumbing, electrical and sprinkler work with that of each trade, in order to:

1. Avoid interferences between general construction, mechanical, electrical, structural and other specialty trades.
2. Maintain clearances and advise other trades of clearance requirements for operation, repair, removal and testing of equipment.
3. Indicate aisleways and accessways required on coordinated shop drawings for mechanical equipment rooms, electrical rooms and computer rooms.
4. Coordinate location of sleeves and inserts, including setting in place prior to pouring concrete.

B. Subcontractor's Coordination Drawings

1. This Subcontractor for the work of this SECTION shall prepare Coordination Drawings showing all the work of this Section to be installed. The Coordination Drawings shall be not less than 1/4-inch scale for MEP spaces and not less than 1/8-inch scale for other areas. Coordination drawings shall be produced as a digital 3D BIM model. The coordination drawings shall be initiated by the HVAC Subcontractor and then forwarded to the Fire Suppression Subcontractor.
2. The Fire Suppression Subcontractor, after showing all of the Fire Suppression work, shall forward the reproducible coordination drawings to the Plumbing Subcontractor.
3. The Plumbing Subcontractor, after showing all of the Plumbing work, shall forward the reproducible coordination drawings to the Electrical Subcontractor.
4. The sequence of Coordination Drawings shall be HVAC Subcontractor to Plumbing/Fire Suppression Subcontractor to Electrical Subcontractor to General Contractor.

5. The Subcontractor for the work of this SECTION shall attend a series of meetings arranged by the General Contractor to resolve any real or apparent interferences or conflicts with the work of the other contractors or with ceiling heights shown on the drawings.
6. The Subcontractor for the work of this SECTION shall then make adjustments to his work on the Coordination Drawings to resolve any real or apparent interferences or conflicts.
7. After any real or apparent interferences and conflicts have been incorporated into the Coordination Drawings, the Subcontractor shall prepare the final Coordination Drawings and submit to the Construction Manager.
8. The Subcontractor for the work of this SECTION shall not install any of his work prior to the preparation of the final Coordination Drawings. If the work of this SECTION proceeds prior to the final Coordination Drawings, any change to the work to correct the interferences and conflicts which result shall be made by the Subcontractor for the work of this SECTION at no additional cost to the Owner.
9. Coordination Drawings are for the Subcontractor's and Engineer/Architect's use during construction and shall not be construed as replacing any shop, "as-built", or Record Drawings required elsewhere in these Contract Documents.
10. Engineer/Architect's review of Coordination Drawings shall not relieve the Subcontractor for the work of this SECTION from his overall responsibility for coordination of all work performed pursuant to the Contract or from any other requirements of the Contract.

1.08 COOPERATION AND COORDINATION WITH OTHER TRADES

A. The work shall be so performed that the progress of the entire building construction including all other trades, shall not be delayed nor interfered with. Materials and apparatus shall be installed as fast as conditions of the building will permit and must be installed promptly when and as desired.

B. Confer with all other trades relative to location of all apparatus and equipment to be installed and select locations so as not to conflict with work of other Sections. Any conflicts shall be referred immediately to the Architect/Engineer for decision to prevent delay in installation of work. All work and materials placed in violation of this clause shall be readjusted to the Architect's/Engineer's satisfaction, at no expense to the Owner.

C. Where work of this section will be installed in close proximity to work of other sections or where there is evidence that the work of this section will interfere with work of other sections, assist in working out space conditions to make satisfactory adjustment. Prepare and submit for approval 3/8-inch scale or larger working drawings and sections, clearly showing how this work is to be installed in relation to the work of other sections. If the work of this section is installed before coordinating with other trades or so as to cause interference with work of other trades, make changes necessary to protect conditions without extra charge.

D. Keep fully informed as to the shape, size and position of all openings required for all apparatus and give information in advance to build openings into the work. Furnish and set in place all sleeves, pockets, supports and incidentals.

E. All distribution systems which require pitch or slope such as sanitary drains and water piping shall have the right of way over those which do not. Confer with other trades as to the location of pipes, ducts, lights and apparatus and install work to avoid interferences.

F. Where there is evidence that work of this Subcontractor will interfere with the work of other trades, this Subcontractor shall assist in working out space conditions to make satisfactory adjustments.

G. This Subcontractor shall, with the approval of the Engineer and without extra charge, make reasonable modifications in his work as required by structural interferences, or by interference with work of other trades, or for proper execution of the work.

H. If this Subcontractor installs his work before coordinating with other trades and his work causes interference with the work of such other trades, he shall make all necessary changes in his work to correct the condition without extra charge and as directed by the Engineer.

I. This Subcontractor shall protect all materials and work of other trades from damage that may be caused by his work and shall make good any damages so caused.

1.09 RECORD DRAWINGS

A. Provide two sets of black line prints to be used as working record drawings during construction. One set of prints shall be maintained at the job site and shall, at all times, be accurate, clear and complete, showing the actual location of all equipment ducts and piping. The working record drawings shall be available for review at the job site by the Architect's/Engineer's field representative. The marked up As Built Drawings required to be maintained under this section are Drawings M-1.1, M-1.2, M-1.3, M-2.1, M-2.2, M-3.1, M-3.2, M-4.1, M-4.2, M-5.0, M-6.1, M-6.2, M-6.3, M-7, M-8.1, M-8.2, M-8.3.

B. Any addenda sketches, supplementary drawings and change orders issued during the course of construction shall be transferred to the working record drawings.

C. At the completion of all work submit an accurate, checked set of working record drawings. Non-availability of these drawings will postpone the final inspection until the record drawings are available.

D. The HVAC Subcontractor shall incorporate all changes on the original drawings. The Subcontractor shall submit to the designer, disks of drawings on Auto CAD Version latest version with two sets of prints and reproducible drawings. Inaccuracies in Record Drawings, as determined by the designer, shall be corrected.

E. All costs related to these requirements shall be paid for by the HVAC Subcontractor.

1.10 OPERATING INSTRUCTIONS AND MAINTENANCE MANUALS

A. Provide operating instructions to the Owner's designated representatives with respect to operating functions and maintenance procedures for all equipment and systems installed. The cost of providing a manufacturer's representative at the site for instructional purposes shall be included in the contract price. The operating instructions shall be presented in scheduled; pre-arranged formal periods coordinated by the Commissioning Agent. The HVAC Subcontractor shall include in his contract price, the cost for instructions, up to twenty (20) hours, which shall not necessarily be consecutive. The training shall break down as follows eight (8) hours of training on equipment, and eight (8) hours on the controls divided into two sessions. The remain four (4) hours of training will be conducted one month after the final turnover of the systems to the Owner.

1. Documentation: Submit documents for all training materials including as listed below.

   a. Provide a preliminary training schedule to the Commissioning Agent for review.
   b. Provide the Commissioning Agent with training plans two weeks before the planned training.
   c. Provide a training manual for facilities staff or a link if offered through the City's website. Provide a copy of training materials, training date, and attendee list for initial facilities staff training session(s).
   d. Provide training materials for teachers and administrative staff. Provide a copy of training date and attendee list for initial teacher and administrator training session. Also include a signed letter from the principal or superintendent committing to annual training as outlined in the prerequisite.

2. Contractor Responsibilities:

   a. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece equipment including, but not limited to, all HVAC equipment (ex. pumps, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.)
   b. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, and power failure.
   c. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
   d. The HVAC contractor or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all

modes of operation of the specific piece of equipment are required. More than one party may be required to execute the training.

e. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.

f. The training sessions shall follow the agendas submitted and approved by the team.

3. Training Shall Include:

a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.

b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.

c. Discussion of relevant health and safety issues and concerns.

d. Discussion of warranties and guarantees.

e. Common troubleshooting problems and solutions.

f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.

g. Discussion of any peculiarities of equipment installation or operation.

h. The format and training agenda in The HVAC Commissioning Process, ASHRAE Guideline O, is recommended.

i. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.

1) The mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.

2) Training shall occur after functional testing is complete, unless approved otherwise by the Owner.

4. Training Scope:

a. HVAC equipment locations and areas served.

b. Operational/Design intent of equipment and interactions with other equipment or systems

c. Equipment operations; Start-up, Shutdown and Normal operations.

d. Provide DOC system training including Detailed sequence of operations.

e. Review of system drawings and schematics

f. Preventative Maintenance and replacement part sources

g. O&M Manual review

h. Questions and Answers

B. Maintenance Manuals:

1. At the completion of the project, turn over to the Architect/Engineer, two complete manuals containing the following:

a. Complete shop drawings of all equipment.

b. Operation description of all systems.

c. Names, addresses and telephone numbers of all major suppliers of equipment on a separate indexing sheet.

d. Preventive maintenance instructions for all equipment.

e. Spare parts list of all system components.

2. The Subcontractor shall collect the operating instructions, bind them into two complete sets and deliver them to the Architect/Engineer who will check for completeness and deliver them to the Owner. All information shall be in three-ring, loose-leaf binders.

3. All pertinent portions of the training sessions shall be video recorded with copies provided in the O&M manuals.
4. Delivery of the operating and maintenance manuals shall be a condition precedent to final payment.

1.11 GUARANTEE

A. This Subcontractor shall obtain, in the Owner's name, the standard written manufacturer's guarantee for one year or greater of all materials furnished under this section where such guarantees are offered in the manufacturer's published product data. All these guarantees shall be in addition to, and not in lieu of, other liabilities which this Subcontractor may have by law or other provisions of the contract documents.

B. This Subcontractor shall warranty workmanship and materials for a period of not less than one year from the date of substantial completion. Should any defects in materials or workmanship appear during this period, they shall be corrected or replaced by the Subcontractor to the satisfaction of the Architect, and at no expense to the Owner.

1.12 CUTTING, CORING AND PATCHING

A. Cutting and patching through new construction using core drill and measuring larger than 4-1/2 inches in diameter, or 4-4/2 inches by 4-1/2 inches, shall be performed by Trades specializing in the specific surfaces affected, e.g., carpentry, masonry, metals, roofing, except where noted otherwise. Notify the specific Trade(s) of exact locations and sizes for openings required. The extent of masonry walls is shown on the architectural drawings. This Section's Contractor is responsible for reviewing and coordinating with other sub-contractors.

1. Exposed concrete coring: Notify Contractor of exact locations and sizes for all openings required in exposed concrete, to be executed under Section 03 30 00 – Cast-in-Place Concrete.
2. Concrete coring less than 4-1/2 inches: Any new penetration cut through concrete less than 4-1/2 inches in width shall be executed by the specific Trade(s) installing the work.
3. Concrete coring 4-1/2 inches or larger: Notify Contractor of exact locations and sizes for openings larger than 4-1/2 inches in diameter required in concrete, to be executed under Section 03 30 00 – Cast-in-Place Concrete.
4. Masonry openings less than 4-1/2 inches: Any new penetration cut through masonry less than 4-1/2 inches in width shall be executed by the specific Trade(s) installing the work.
5. Masonry openings 4-1/2 inches or larger: Notify Contractor of exact locations and sizes for openings larger than 4-1/2 inches in width required in masonry, to be executed under Division 04 - Masonry, utilizing lintels, furnished per Division 05 - Metals.
6. Exposed gypsum board: Notify Contractor of exact locations and sizes for all openings required in exposed gypsum board, to be executed under Division 09 - Finishes.
7. Concealed gypsum board: Any new penetration cut through concealed gypsum board less than 4-1/2 inches in width shall be executed by the specific Trade(s) installing the work. Cutting and patching larger than 4-1/2 inches in diameter, or 4-4/2 inches by 4-1/2 inches to be executed under Division 09 - Finishes.
8. Notify Architect prior to any cutting or coring larger than 2 inches.

1.13 PERMITS

A. This Subcontractor shall be responsible for obtaining and paying for all permits and inspections required to complete all work described in this section. Refer to The General Conditions of the Contract for Construction for more information on Local and State Permit Requirements.

1.14 STORAGE OF MATERIALS

A. Store materials prior to their installation in the area(s) where designated by the Owner. Be responsible for all stored equipment and materials and protect all installed equipment and materials from damage.

1.15 INSPECTION AND TESTS

A. If inspection of materials installed shows defects, such defective work, materials and/or equipment shall be replaced at no cost to the Owner and the inspection and tests repeated.

B. Make all reasonable tests as required and prove the integrity of all work and leave the entire HVAC installation in correct adjustment and ready to operate.

1.16 ELECTRICAL CHARACTERISTICS

A. In general, and unless specifically indicated otherwise in the specifications or noted on the drawings, all HVAC equipment shall be of the HP, voltage, and phase as indicated on the drawings.

B. Control wiring and conduit for the HVAC systems shall be furnished under this Section. Power wiring, including provisions for disconnect switches not otherwise furnished as an integral part of the mechanical equipment, is under the work of the Electrical Subcontractor.

C. Fractional horsepower motors wired for single phase operation shall have automatic reset overload protection built into the motor.

1.17 DEFINITION OF TERMS

A. "Furnish" or "Supply" means to purchase, procure, acquire and deliver.

B. "Install" means to rig, erect, mount and connect, unless specifically noted otherwise.

C. "Furnish and Install" means to supply, deliver, rig, erect, mount and connect in readiness for operation, unless specifically noted otherwise.

D. "Provide" is synonymous with "Furnish and Install".

E. "Piping" means pipe, tubing, fittings, flanges, unions, valves, strainers, traps, hangers and other accessories related to such piping.

F. "Concealed" means hidden in chases, furred spaces and walls, above ceilings or enclosed in construction.

G. "Exposed" means visible or not installed "Concealed" as defined above.

H. "Approved Equal" or "or equal" means any equipment or material which is approved by the Engineer as equal in quality, durability, appearance, strength, design and performance to the equipment or material originally specified.

I. "Underground" means buried exterior to or within the building.

1.18 SCAFFOLDING AND STAGING

A. All staging, exterior and interior, required to be over eight feet in height, shall be furnished and erected by this Subcontractor and maintained in safe condition by him without charge to and for the use of all trades as needed by them for proper execution of their work, except where specified to the contrary in any filed sub-bid Section of the Specification.

1. Erection and dismantling of staging shall be performed only by trained, certified, and experienced staging personnel qualified to perform such work.
2. Copies of such certifications, clearly indicating qualifications, shall be provided to the Architect prior to commencement of such erecting and dismantling work.

B. Provide, maintain and remove safe and adequate interior and exterior staging, ladders, scaffolding, hoists, and all other related equipment for proper and complete execution of the work of this section in accordance with requirements of the Contract Documents. Staging, scaffolding, hoists and all other related equipment shall comply with all applicable federal, state and local regulations.

C. Staging, ladders, scaffolding, hoists and all other related equipment shall be provided, maintained and removed when no longer required.

1.19 WORK COORDINATION AND JOB OPERATIONS

A. HVAC equipment shall not be installed in congested and possible problem areas without first coordinating the installation of same with the other trades. Relocate HVAC equipment should it interfere with the proper installation of equipment to be installed by the other trades.

B. Particular attention is directed to the coordination of ductwork with the equipment of other trades being installed in and above the ceiling areas. Conflicts in mounting heights and clearances above hung ceilings shall be brought to the attention of the Engineer for a decision before equipment is installed.

C. Furnish to the other trades, all information relative to the portion of the HVAC installation that will affect them, so that they may plan their work and installations accordingly.

1.20 REBATES

A. HVAC Subcontractor shall assist the Owner in obtaining all eligible utility rebates and transferring these rebates to the Owner pertaining to this section.

1.21 DESCRIPTION OF WORK

A. All of the Contract Documents, including Drawings, General Conditions, Supplementary Conditions, and all Sections of Division 01 – General Requirements, apply to the Work of this Section.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS

A. Hot Water, and Chilled Water Piping:

1. Piping 2" diameter and smaller shall be type "L" hard drawn copper tubing with wrought copper fittings.
2. Piping 2-1/2" diameter and larger shall be Schedule 40 black steel pipe, ASTM A-53, Grade B, ERW.

B. Condensate Drain:

1. Copper Pipe: Condensate drain piping shall be Type M copper tubing, sized as indicated on the drawings. Provide P-trap for each condensate drain line connection. Provide clean-outs at each change in direction of piping. Use tees and a 45-degree fitting for a branch line joining a main. Clean-outs shall be made with threaded plug tees. Pitch piping down in direction of flow.
2. Condensate drain from roof-top units shall not be less than 1-1/4" diameter PVC and shall be extended to roof drains.
3. *PVC PIPE IS NOT ALLOWED IN THE ABOVE CEILING RETURN AIR PLENUMS OF THIS BUILDING*

C. Refrigerant Piping:

1. Rigid Copper Refrigerant Pipe: ASTM B819, type #ACR hard drawn or annealed with ASME B16.22 wrought copper fittings. Material shall be Type ACR hard drawn copper tubing with silver solder wrought copper fittings. Tubing shall be specially cleaned and capped for use with refrigerants. Piping shall be sized as recommended by the manufacturer.
2. Pre-insulated line sets: At the discretion of the HVAC subcontractor, manufacturer approved pre-insulated line sets may be used. Lines shall be hung to avoid sagging. Do not allow lines to lay on ceiling system. Pre-Insulated line sets shall be sized and have an insulation thickness as recommended by the equipment manufacturer.

D. Domestic Water Connection (type "L" copper): Material shall be type "L" hard-drawn copper tubing with wrought copper fittings.

E. Gas Piping

1. Gas and gas train vent piping shall be Schedule 40 steel or wrought iron, complying with ANSI Standard B36.10, ASTM A53 or ASTM A106. Fittings shall be threaded malleable iron complying with ASME B16.3. All gas pipe 3" and larger shall be welded. Welding outlet fittings shall conform to ASTM A53. Condensate/sediment traps shall be installed at all points in accordance with the requirements of all applicable Codes, and at the gas inlet of each piece of gas-fired equipment.
2. Joining of steel or wrought iron pipe to dissimilar metals shall be accomplished using dielectric, brass or stainless-steel fittings. The use of a dielectric may require the installation of a bonding jumper between the two metallic pipes. The bonding jumper shall be sized and installed by a licensed electrician.

F. Direct Vent and Combustion Air Piping

1. Direct Vent and Combustion Air Piping to be InnoFlue SW Commercial as manufactured by Centratherm.
2. The vent shall be of the single wall, factory-built type, designed for use in conjunction with Category II, or IV condensing gas fired appliances
3. Maximum continuous flue gas temperature shall not exceed 230 degrees F (110 degrees C).
4. Vent shall be listed for a maximum positive pressure rating of 20" w.c.
5. The vent system shall be continuous from the appliance's flue outlet to the vent termination outside the building. All systems components shall be UL/cUL listed and supplied by the same manufacturer.
6. The vent shall be constructed from Flame Resistant Polypropylene.
7. All systems components such as vent supports, roof or wall penetrations, terminations, appliance connectors and drain fittings required to install the vent system shall be UL/cUL listed and provided by the vent manufacturer.

8. All systems components shall include a factory- installed gasket in their female-end to render the vent air and water tight when the male/female ends are pushed together as per manufacturer's instructions. Vent systems requiring field installed sealants or compounds shall not be acceptable.
9. Vent layout shall be designed and installed in compliance with manufacturer's installation instructions and all applicable local codes.

G. Fittings & Couplings:

1. Fittings for piping 2-1/2" diameter and larger shall be standard welding fittings as manufactured by Tube-Turns, Grinnell, Crane or approved equal. Elbows shall be long radius elbows. Branch connections reducing two sizes or less shall be made with welding tees of the same manufacturer as the fittings. Branch connections reducing more than two sizes shall be made with weldolets, threadolets, or with welding tees. Unless otherwise indicated or approved, all reduction in pipe size shall be made with eccentric reducers. Flanges shall be 150-pound weld neck flanges.
2. Screwed fittings shall be 125-pound cast iron fittings. Unions shall be 150-pound ground joint units. All reducers shall be eccentric reducers.
3. Provide dielectric fittings for all connections between ferrous and non-ferrous piping.
4. Grooved Couplings: At the option of the contractor, piping 2-1/2" and larger may be joined with Victaulic fittings and flanges in lieu of welding. Piping shall be Schedule 40 black steel pipe, ASTM A-53, Grade B, ERW. Victaulic couplings, fittings, supports, valves, strainers and supports shall be installed in strict accordance with the manufacturer's recommendation (Victaulic "Fit-Fittings" will not be accepted).
    a. Grooved coupling shall consist of two or more pieces of ductile or malleable iron with synthetic rubber gaskets with a central cavity pressure responsive design. Coupling bolts and nuts shall be physical properties of ASTM A-183. All couplings shall be Style 07 or equal unless otherwise indicated.
    b. Full size branch connections shall be made with manufactured grooved end tees. Branch connections with locating collar engaging into hole or Style 72 outlet connection shall be used to join grooved pipe branch connections shall be Victaulic Grade "E" EPDM compound with working temperature of -30°F to 230°F.
    c. Flanges shall be Vic-Flange Style 741. Flanges and standard fittings shall be ductile iron conforming to ASTM A-536 9 Grade 65-45-12) or malleable iron conforming to ASTM A-47 Grade 32510, painted with a rust inhibiting modified vinyl alkyd enamel or hot dip galvanized to ASTM A-153 or Zinc Electroplated to ASTM B-633 as required. Unions shall be 150-pound ground joint units. All reducers shall be eccentric reducers.
5. Copper Fittings:
    a. Fittings for copper tubing shall be wrought copper fittings.
    b. At the option of the HVAC Subcontractor, copper piping 2" and under shall be joined with ProPress fittings as manufactured by Viega LLC or approved equal. Piping fittings and components shall be capable of withstanding 150 psig. Working pressure at 200 deg F. Piping and fittings shall be installed per manufacturer's installation instructions. Housing shall be copper or bronze. Sealing element shall be EPDM. Pipe and fittings shall be installed using manufacturer's specific tools and using smart connect technology.
    c. Provide link seals for underground piping as hereinafter specified

2.2 BOLTS, GASKETS AND JOINTS

A. All screwed joints shall be made tight with teflon tape.

B. All flanges shall be faced and drilled to US Standards and fitted with machine bolts of proper number and size, having semi-finished hexagon nuts and a washer under each nut. All flanged joints shall be fitted with Johns-Manville Service, Cranite or Durable ring gaskets.

C. All solder joints shall be made with 95-5 solder and shall make perfect adhesion between pipe tubing and fitting.

D. Provide dielectric fittings for all connections between ferrous and non-ferrous piping.

2.3 HANGERS AND SUPPORTS

A. Provide pipe supports, hangers, and other devices necessary to support firmly and substantially the piping and the apparatus described in the specifications and shown on the drawings. Hangers shall be arranged to maintain the required grading and pitch, to prevent vibration, and to provide for expansion and contraction. All hangers and supports shall be in compliance with seismic requirements of the State Building Code.

B. Where the weight of piping or other apparatus makes it impracticable to support same from the ceiling alone, flange pipe standards shall be installed to support the weight of piping, valves and fittings.

C. Piping shall not be supported from ductwork, breeching, equipment, ceiling suspension systems or other piping.

D. Brackets of approved type may be used along walls.

E. Each vertical line shall be supported at its base using a suitable hanger placed in the horizontal line near the riser.

F. Piping 2-inch diameter and smaller shall be supported by "A" bands with adjustable steel rod with concrete insert or beam clamp. Piping 2-1/2 and above diameter shall be supported by clevis hangers with adjustable steel rod and one concrete insert or beam clamp. Two rod roll hangers shall be used in lieu of the hanger type specified where space limitations necessitate.

G. 1A bands and clevis hangers shall be installed outside the thermal insulation. Provide 18 gauge, 12" long pipe covering protection shields on insulated piping at 1A bands and clevis hangers. Provide galvanized metal shields between pipe hangers and insulation where saddles are not required and where hangers are installed outside of insulation.

H. The maximum spacing between pipe supports shall be in accordance with the latest addition of ANSI/MSS SP-69 & SP-58 Tables 3 & 4. The following excerpts from the tables shall be verified prior to work.

1. Horizonal Steel Pipe:

Nominal Pipe Size (in)	Rod Diameter (in)	Maximum Spacing (ft)
3/8 – 1-1/4	3/8	7
1-1/2	3/8	9
2	3/8	10
2-1/2	1/2	11
3	1/2	12

2. Horizonal Copper Pipe:

Nominal Pipe Size (in)	Rod Diameter (in)	Maximum Spacing (ft)
1/4 – 3/4	3/8	5
1	3/8	6
1-1/4	3/8	7
1-1/2	3/8	8
2	3/8	8
2-1/2	1/2	9
3	1/2	10

These spans apply to straight runs of piping without concentrated loads. Spans shall be shorter as required by changes in direction or by concentrated loads such as strainers, valves, or related items. Supplementary steel shall be furnished and installed as required by ANSI/MSS SP-58.

I. The first three hangers on the suction and on the discharge of each pump shall be provided with Type 30N spring hangers as manufactured by Mason Industries or equal as manufactured by Carpenter and Patterson or Grinnell. The HVAC Contractor shall use necessary means to install all piping and equipment with minimal vibration and sound that is normal to the pumps as verified by the pump manufacturer.

J. Roof pipping supports: Provide corrosion resistant rooftop pipe supports suitable for installation on the architectural roof specified. The supports shall be designed to support gas and refrigeration piping systems, be UV resistant, and be capable of supporting and securing in place the indicated piping. Supports shall be MIFAB C-Port or equivalent by Anvil, Eaton, PHD, or approved equal.

2.4 SLEEVES, INSERTS AND ESCUTCHEONS

A. All piping passing through masonry walls, slabs, floor partitions or other building construction shall be provided with pipe sleeves at least two pipe sizes larger than the pipe passing through them or the insulation jacket on covered pipes. Sleeves shall be flush on either side of masonry walls or partitions. All sleeves in floor slabs shall extend ½" above finished floors. All sleeves shall be standard weight steel pipe.

B. Where exposed pipes pass through floors, finished walls or finished ceilings, they shall be fitted with neat, heavy spun or stamped steel, chrome plated escutcheons, firmly secured to the pipes. In unfinished areas, escutcheons shall be cast iron, split and painted to match the adjacent surfaces. Escutcheons shall be of sufficient outside diameter to amply cover the sleeved openings for the pipe.

C. Where pipes penetrate fire rated assemblies, walls or floors, openings shall be firestopped. At all partition penetrations, walls or floors, openings shall be firestopped per the requirements of Section 07 8413.

2.5 VALVES

A. Furnish and install valves as indicated on the drawings and specified herein. All valves in each class shall be manufactured by the same manufacturer.

B. Isolation Valves: Furnish and install isolation valves as indicated by the drawings and specifications. Isolation valves shall be manufactured by Apollo, Crane, Emerson, Hammond, Neles, Nibco, Victaulic, or approved equal.

1. Ball Valves: Isolating valves on piping 2" diameter and smaller shall be ball valves, Apollo Series 70-100 or 70-200 or equal.

2. Butterfly Valves: Unless otherwise specified, isolating valves on piping 2-1/2" and larger shall be 150-pound lug type butterfly valves. Valves shall conform to MSS SP-67. If Victaulic valves are used, isolating valves shall be Model 700 butterfly valves. Valves installed higher than 8’ above the floor shall be provided with a chain and sprocket to allow operation from the floor level.

C. Automatic Balancing Valves: Provide Automatic Balancing Valves as manufactured by Bell & Gossett, Danfoss, FDI, Griswold, HCI, Nexus, Pro Hydronic Specialties, Tour & Andersson, or approved equal.

1. Valves shall be factory set and shall automatically limit the rate of flow to required capacity within +/- 5% accuracy over an operating pressure differential of at least fourteen times the minimum required for control. Operating differential is not to exceed 3 psig.

2. The valve body shall be cast iron and shall be provided with inlet and outlet tappings and shall be marked to show direction of flow. Valve bodies shall be rated for use at not less than 150% of system designed operating pressures. Each valve shall be furnished with a kit consisting of nipples, quick disconnect valves (located outside of insulation), and fittings suitable for use with measuring instruments specified.

3. The control mechanism of the valve shall consist of a self-contained, open chamber cartridge assembly with unobstructed flow passages. The cartridge shall be removable in one piece and all internal working parts shall be stainless steel or brass. No plastic components shall be permitted. The unit shall utilize the available differential pressure across the valve to actuate the control mechanism and shall be capable of self-cleaning the variable inlet ports over the full control range.

D. Check Valves: Provide Check Valves as manufactured by Apollo, Crane, Hammond, Jenkins, Mueller, Nibco, or approved equal.

1. Check valves on piping 2" diameter and smaller shall be Class 150 bronze, threaded regrinding swing check valves with bronze disc and screw-in cap. Valves shall conform to MSS SP-80.

2. Check valves 2-1/2” diameter and larger shall be Class 125 flanged, iron body, bronze mounted swing check valves with regrind-renew bronze disc and seat ring and bolted cover. Valves shall conform to MSS SP-71.

E. Drain valves shall be provided on all low points of water piping. Drain valves shall be 3/4" bronze drain valves with solid bronze cap and chain, Jenkins Fig. No. 314, or equal as manufactured by Apollo, Hammond or Crane.

F. Relief valves shall be 1/2" brass valves, Bell & Gossett Model A3 set for 50 psig or equal as manufactured by B&G, Taco, Apollo, or Amtrol.

G. Pressure reducing valves shall be 3/4" brass valves, Bell & Gossett Model 7 set for 25 psig or equal as manufactured by B&G, Taco, Apollo, or Amtrol.

H. Triple Duty Valves: Triple service valves shall be furnished and installed on pump discharge lines as indicated on the plans. The triple service valves shall be TACO Triple Service valves Model MPV or equal.

I. Furnish and install Differential pressure by-pass valve where indicated on the drawings. Valve shall be Model #519700A as manufactured by Caleffi, Taco, and Honeywell or approved equal. Differential pressure by-pass valve shall have threaded connections 1-1/4" FNPT x 1-1/4" MNPT outlet, 1-1/4" FNPT x 1-1/4" sweat outlet, brass body, brass valve plug, EPDM valve plug gasket, EPDM O-Ring seals, asbestos free NBR union seals, ABS control knob, and stainless-steel spring. Valve shall be rated for a temperature range 32–230°F, maximum working pressure 150 psi (10 bar). Setting range shall be 2–10 psi and 1-1/4" flow up to 45 GPM.

J. Control valves shall be two position or modulating pressure-independent type as specified under the Controls Specifications.

K. Gas System Valves

1. Gas shutoff valves shall be furnished and installed at the connection to each piece of equipment, at each riser, and where shown on the Drawings.
2. Gas shutoff valves 2" and smaller shall be brass, of the ball type, with stops and lever handle.
3. Gas shutoff valves used for pressures greater than ½ psig or which are 2½" or larger shall be brass, of the lubricated plug type, with stops and tee handle.
4. Gas shutoff valves shall be UL listed.

2.6 METERS AND GAUGES FOR HVAC PIPING

A. Pressure Gauges:

1. Furnish and install pressure gauges where indicated on the drawings and specified herein. The gauges shall be Bourdon spring type pressure gauges as manufactured by Trerice, Taylor Instruments, Weiss, Weksler, Winters or approved equal.
2. Unless otherwise specified, the gauges shall have 4-1/2" dials.
3. The gauges shall have white faces with black filled engraved figures. The body of the gauge shall be dull black with the bezel or rim chrome plated. The accuracy of the gauges shall be plus or minus 1% of the scale range. The gauges shall be suitable for pressures to which they are subjected.
4. Each gauge shall be provided with a ball valve on the system side of the gauge.
5. Gauges on the suction and discharge of each pump shall be provided with a snubber.
6. Gauges on the suction of pumps shall have a range of 0 to 60 psi.
7. Unless otherwise noted, all other pressure gauges on water lines shall have a range of 0 to 100 psi.

B. Thermometers and Wells:

1. Furnish and install where shown on the drawings and where specified herein, separable well type, industrial stem thermometers as manufactured by Trerice, Taylor Instruments, Weiss, Weksler, Winters, or approved equal.
2. Unless otherwise specified, the thermometers shall have a 9" scale and a white face with black filled engraved letters. They shall be angle or straight stem type as conditions necessitate.
3. All thermometer wells shall be installed in such a manner that a minimum of restriction will be caused to the flow in the pipes and so that the thermometers can be easily read.

4. The scale range for thermometers in hot water piping shall be 35º to 240ºF.
5. The scale range for the thermometer in chilled water piping shall be 0 to 100ºF.

C. Combination Pressure/Temperature Test Plugs:

1. Provide where at the inlet and outlet of coils and where indicated on the drawings, combination pressure temperature test plugs by Peterson Equipment Company "Petes Plug", Sisco, Inc. "P/T Plugs", Trerice, Weiss, Winters, or equal.
2. The plug shall be 1/4" or 1/2" NPT, constructed of solid brass with a Nordel valve core suitable for temperatures up to 350°F. Plug shall be rated zero leakage from vacuum to 1000 psig.
3. Provide extension fitting for each plug suitable for use with specified pipe insulation.

2.7 HYDRONIC SPECIALTIES

A. Furnish and install, where indicated on the drawings and in accordance with the manufacturer's recommendations.

B. Strainers:

1. Furnish and install full size, Y-pattern, self-cleaning strainers where specified and where indicated on the drawings. Strainers shall have stainless steel screens with perforations recommended by the manufacturer for the intended service.
   a. Strainers 2” diameter and smaller shall be semi-steel, iron body or bronze body, screwed strainers rated for 250 psig.
   b. Strainers 2-1/2” diameter and larger shall be semi-steel or cast-iron body flanged strainers rated for 125 psig.
2. A valved dirt blowout connection shall be made to each strainer with a ball valve located 6” to 12” below the strainer. Blow off valves shall be ¾” on strainers 2” and smaller. Blow off valves shall be 1” on strainers 2-1/2” and larger. The blow out connections shall terminate at a point where there will be no risk of danger to personnel or damage.

C. Air Vents: Furnish and install manual and automatic air vents where specified and where indicated on the drawings. Air vents shall be as manufactured by Amtrol, Armstrong, Bell & Gossett, Taco, or approved equal.

1. Manual air vents shall be Taco No. 423 or equal.
2. Automatic air vents shall be provided at each air separator and at each high point in hydronic piping systems.
3. Automatic air vents shall be rated for a maximum operating temperature of 240ºF at 150 psig. Vents shall be Bell & Gossett No. 87, Taco 418 Hy-Vent, or Amtrol 706. A ball valve shall be installed on the system side of each automatic air vent. Furnish and install a copper drain line from each automatic air vent down to 6" above the boiler or mechanical room floor.

D. Combination Dirt and Air Separator:

1. Furnish and install air separators where indicated on the drawings. The Separators shall be Spirotherm model VDT or equal as manufactured by Taco, Bell & Gossett, Amtrol, Thrush, or Wessels.
2. Construction: Steel tested and stamped in accordance with ASME SEC 8 Division 1, rated for a maximum allowable working pressure equal to or greater than the pressure of the heating source equipment, in-line inlet and outlet connections and internal stainless-steel air and dirt removal devices.
3. Performance: The air and dirt removal device shall remove 100% of the free air, 100% of the entrained air and up to 99.6% of the dissolved in the system fluid. The unit shall be 100% efficient at removing debris down to 150 microns in ten passes or less. Also the unit shall be 100% efficient at removing debris down to 90 microns and over 85% efficient at removing debris down to 35 microns in 100 passes or less.

E. Expansion Tank - Bladder Type: Furnish and install an ASME rated pressurized captive air bladder type expansion tank as indicated on the drawings. The expansion tank shall be shall be manufactured by Amtrol, Bell and Gossett, Taco, Thrush, Wessels, approved equal.

1. Construction: ASME rated pre-charged bladder-type pressure vessel. Designed and constructed per ASME Section VIII, Division 1. The vessel shall be steel with tank stand and lifting rings. The bladder shall be replaceable, heavy duty, seamless type made of butyl rubber. Equip the tank with pressure gauge, Schrader valve fitting, tank drain, and shutoff valves on tank drain and connection to hydronic system.
2. Performance: 125 PSI working pressure, 240°F max operating temperature. Pre-charge tank to 30 psig.

F. Bypass Filter & Chemical Shot Feeder: Provide a steel bypass filter and liquid chemical shot feeder of approximately 5-gallon capacity. The bypass feeder shall be rated at 300 psi and to 200^{0}F. Provide units with mounting legs, wide mouthed opening, and 10 micron bag filter supported by stainless steel basket. The feeders shall be provided with the required valves and fittings to be connected to the hydronic systems as indicated on the drawings. The Bypass Filter and Chemical Shot Feeder shall be as manufactured by Axiom, J.L. Wingert, Neptune, Skidmore, Thrush, Wessels, or approved equal.

G. Glycol Feed System (Duplex): Furnish and install duplex glycol feed system serving the chilled water and heating hot water systems as indicated on the drawings. Glycol feed systems shall be as manufactured by Axiom, J.L. Wingert, Neptune, Skidmore, Wessels, or approved equal.

1. Tank: 50 gallons polyethylene tank with hinged cover and steel bottom mounting stand.
2. Pump: The package shall consist of two independent autonomous pumping assemblies. Provide with a ball valve and wye strainer on the pump suction, and a check valve and pressure gauge on the pump discharge. An adjustable pressure switch on the pump discharge shall engage the pump on a loss of pressure in the system. A pre-piped pressure relief valve shall be located near the connection to the hydronic system, with the valve discharge piped to the tank.
3. Controls: NEMA 4X panel with two-position main power switch, hand/off/auto switch, low level indicator, audible alarm and silence switch, and dry contacts for passing of alarms to the building BAS.

H. Pump Suction Diffuser: The suction diffusers shall be TACO Model SD or equal. Suction diffusers shall be furnished and installed on suction lines for all base mounted pumps and floor mounted inline pumps.

I. Flexible Connections: Furnish and install flexible pipe connections in the inlet and outlet of each chiller, the suction and discharge of each base-mounted pump, and elsewhere as shown on the drawings. Connections shall be Type MFTNC as manufactured by Mason Industries or approved equal. The connections shall be installed in strict accordance with the manufacturer's recommendations.

J. Hydronic Coil Valve Kit: At the discretion of the HVAC subcontractor preassembled coil piping kits may be used for coils with pipe sizes 2" or under, Including coils for unit heaters, cabinet unit heaters, and Fan Coil Units.

1. Coil kits shall be manufactured by Bell & Gossett, Danfoss, FDI, Griswold, Nexus, Pro Hydronic Specialties, Taco, Tour & Andersson, or approved equal.
2. Coil kits must contain all components in order as shown in the project drawings, including Isolation ball valves with integral unions, unions at coil piping connections, wye strainer, and Automatic flow control valve.
3. The coil kit shall be pre-assembled, packaged, and tagged with the location and flow rate of the coil on which it is to be installed.

2.8 SHEET METAL DUCTWORK

A. Furnish and install, in an approved manner, all sheet metal work that is indicated on the drawings or that is specified or required for the various systems of heating, ventilation, air conditioning, return air and exhaust air.

B. All sheet metal work shall be manufactured and erected in a first class and workmanlike manner, in accordance with the Duct Manual of the Sheet Metal and Air Conditioning Contractors National Association, Inc. and shall be approved by the Engineer. All ducts, unless otherwise approved, shall be true to the dimensions indicated on the plans and shall be straight and smooth on the inside with neatly finished joints. The ducts shall be securely anchored to the building construction in an approved manner and shall be so installed as to be completely free from vibration under all conditions of operation. All ducts shall be supported in accordance with requirements of Plate Numbers 18, 19 and 20 of the SMACNA Duct Manual.

C. All slip joints for low velocity rectangular ducts shall be made in direction of air flow and, unless otherwise indicated on the plans, all elbows shall have long turns with the inside radius no less than the plan dimension of the duct. Where short radius elbows or square corner elbows are used, they shall be fitted with turning vanes. All notches for connecting sections of duct and all governing seam notches shall not be cut any deeper than necessary to insure tight corners. Any notched corners not meeting with approval shall be removed and reinstalled or sealed with solder.

D. Install and seal ducts in accordance with SMACNA HVAC Duct Construction Standards – Metal and Flexible. The ductwork shall be sealed to provide a SMACNA Seal Class A installation. All transverse seems, longitudinal seems, joints, and duct penetrations shall be sealed with water-based vinyl copolymer mastic formulated to withstand temperature from -20F to +150F. Sealant shall have a temperature UL Classification with a flame spread of 25 or less and smoke developed of 50 when tested in compliance with ASTM-E-84-87. Duct sealants shall be in compliance with LEED VOC off gassing requirements 250 g/l or less permitted.

E. Unless otherwise specified, all rectangular ducts shall be of the best bloom galvanized steel of the U.S. Standard gauges specified below and shall be stiffened by cross breaking and by use of galvanized rolled steel angles as specified below:

Rectangular Sizes	Gauge No.	Galvanized Iron Angle Stiffeners	Center Spacing
Up to 14"	26	Standing Seams	
15" to 30"	24	Standing Seams	Not Greater Than 33"
31" to 60"	22	1" x 1" x 3/16"	Not Greater Than 33"
61" to 84"	20	1-1/2"x1-1/2"x3/16"	Not Greater Than 33"

F. All rectangular sheet metal ductwork, unless otherwise specified, shall be constructed with longitudinal Pittsburgh Lock seams thoroughly flattened down to make a tight joint. Transverse joints shall be made up with slip joints and standing lock seams. Branches to and from the main trunk shall be made at an angle but shall, in no case, exceed 45º to the line of air flow.

G. The exact locations of all ducts to be installed above the ceilings shall be agreed upon among the mechanical trades under the supervision of the General Contractor before work is fabricated or installed. In general, the plumbing piping shall be given the right of way owing to pitch requirements and the HVAC Subcontractor shall raise or lower his ducts to clear the plumbing piping.

H. All openings in building construction surrounding transversing ducts shall be sealed with mineral wool or other non-combustible material to prevent the passage of flame or smoke. Maintain rating of assembly as shown on architectural plans.

I. Duct Sizes: All duct sizes indicated on the drawings are inside dimensions of either the bare metal or the sound insulation where specified. Where sound insulation is specified for installation, the sheet metal ducts shall be increased in size to provide the free area inside the sound insulation called for on the drawings.

J. Flexible Duct:

1. Furnish and install flexible ducts from sheetmetal ducts to supply outlets as indicated on the drawings.
2. Flexible ducts shall be fabri-flex coated fiberglass fabric ducts or approved equal. Flexible supply ducts shall be Fabriflex Type IV insulated ducts or approved equal with 1", 3/4 Lb. density insulation in a seamless polyethylene covered jacket.
3. Flexible ducts shall be installed in strict accordance with the manufacturer's recommendations. Lengths of flexible ducts shall not exceed 5 feet.

K. Exposed ductwork shall be fabricated from paint grip galvanized sheet metal. Painting shall be by the painting subcontractor.

L. Louver Blank-Off Panels: Laminated panels consisting of an insulating core surfaced on back and front with metal sheets and attached to back of louver. The insulated core shall be made of rigid, glass-fiber-board insulation or extruded-polystyrene foam, R value 17.5 or higher. Seal perimeter joints between panel faces and louver frames with gaskets or sealant. The panel finish shall be the same type of finish applied to louvers, but black color:

M. Existing ductwork to remain: Existing ductwork to remain shall be inspected, cleaned, and resealed.

1. Clean existing, to remain, duct systems with high power vacuum machines. Protect equipment that may be harmed by excessive dirt with filters or bypass during cleaning. Provide adequate access into ductwork to completely clean all existing ductwork in system. The company that performs the duct cleaning shall be a current standing member of the National Air Duct Cleaners Association (NADCA) with an Air System Cleaning Specialist (ASCS) certified staff member.

2. Existing ductwork shall be resealed to provide a SMACNA Seal Class A installation for all longitudinal seams, all transverse seams and all duct penetrations.

2.9 DUCTWORK ACESSORIES

A. Furnish and install, in an approved manner, all ductwork accessories indicated on the drawings or that is specified or required for the various systems of heating, ventilation, air conditioning, return air or exhaust air. All work shall be manufactured and erected in a first class and workmanlike manner, in accordance with the Duct Manual of the Sheet Metal and Air Conditioning Contractors National Association, Inc. and shall be approved by the design team.

B. Volume Damper: Furnish and install where indicated on the drawings, where specified or where required. Provide in each branch runout to diffuser, register, or grille. Locate damper so as to be accessible or provide remote actuating mechanism.

1. Manual dampers: Provide with indicating and locking quadrants or push rods and pillow blocks. The dampers shall be two gauges heavier than the ducts in which they are installed. Damper blades shall be riveted to the surrounding rod. Case or malleable brackets riveted to the sides of the ducts shall be used to support the damper rod.

2. Remote Balance Damper: For dampers located in concealed locations, provide with remotely actuated opposed blade damper. The damper shall be actuated by a rack and pinion controller using a flexible casing and wire assembly.

C. Fire Damper: Furnish and install fire dampers, where indicated on the drawings, as required by the Massachusetts building Code and as specified herein. Fire dampers shall be as manufactured by Buckley, Greenheck, NCA, Air Balance Inc, Pottorff, Ruskin, or approved equal.

1. Unless otherwise indicated, fire dampers shall be interlocking blade curtain type fire damper and shall be UL approved and labeled. Type B (damper curtain out of the air stream) shall be used. Fire dampers shall be gravity operated for vertical installation and shall be provided with closure springs and latches for horizontal installation.

2. All fire dampers shall be constructed and installed in accordance with the conditions of their approval, the manufacturer's instructions, NFPA Bulletin #90A and the National Board of Fire Underwriters Pamphlet No. 90. Samples of fire damper shall be submitted to and approved by the local authorities having jurisdiction if requested. Fire dampers shall have the UL time rating as required by the building element/assembly in which the fire damper is to be installed.

3. A full size and tight access door shall be provided at all dampers, regardless of type. Access doors installed in ducts near fire dampers shall be made of same gauge galvanized steel as ducts in which they are installed, hinged to a galvanized mounting frame, and provided with fastening devices to give tight closure on felt gasket. The doors shall have the same thickness of insulation as that specified for the ducts.

4. Provide access panels in walls or ceilings to allow for inspection of fire dampers as required by regulations.

D. Flexible Connections: The inlet and outlet of each of the fans and air handling units shall be connected to the ductwork by an approved flexible connection made of Ventfab as manufactured by Iden Associates, tightly secured to the fan inlet and outlet with metal bands. A minimum 4" space shall be maintained between the duct and fan connection and the flexible connection shall not be stretched tight

E. Automatic Dampers: Install automatic dampers furnished under Automatic Temperature Controls.

F. Install duct smoke detectors furnished by the Electrical Subcontractor in the supply ductwork of the Dedicated Outside Air System Unit.

2.10 DIFFUSERS, REGISTERS AND GRILLES

A. Provide all diffusers, registers and grilles as scheduled on the drawings. The units shall be of the size, type and direction of flow noted on the drawings. Test and rate air outlet and inlet performance in accordance with ADC Equipment Test Code 1062 and ASHRAE 70. All registers and diffusers shall be furnished with individually adjustable volume control dampers. Diffusers, registers and grilles shall be as manufactured by Tuttle & Bailey, Krueger, Metal-Aire, Nailor, Price, Titus or approved equal and shall be complete with the finishes and accessories specified on drawings

B. Coordinate the location of ceiling supply, return and exhaust outlets with architectural ceiling plans.

C. All diffusers, registers and grilles shall have color selected by Architect. Contractor shall coordinate the color with the Architect prior to order. The units shall be factory painted the Architects selected color.

D. Ceiling diffusers shall be of the restricted multi-orifice jet induction and air mixing type consisting of louver sections with built-in diffusing vanes. The vanes shall be arranged to discharge air from adjacent louvers to insure rapid mixing of primary and room air. Diffusing vanes shall be welded and mechanically fastened to the adjacent louver sections to make a rigid unit. The vanes shall extend to the discharge edges of the louvers. Where louver sections join the core frame, the louver ends shall be welded to the core frame. The leaving edge of each louver shall be hemmed and the louver end shall be rounded and hemmed before welding to the core frames. Diffuser shall be provided with a connection. The diffusers shall extend no less than 1" to prevent leakage into the ceiling space. Diffusers shall be of steel construction with extended pan to accommodate 2' x 2' lay-in ceiling or gyp-board ceiling configuration as scheduled. Diffusers shall have baked enamel finish.

E. Exhaust, return, and transfer registers and transfer grilles shall be of steel construction with opposed blade dampers as scheduled on drawings (no damper for transfer grilles), 35-degree horizontal fixed bars maintaining an effective area capacity of greater than 75% and baked enamel finish.

F. Supply air registers shall be double deflection and aluminum construction and integral opposed blade dampers.

G. Heavy Duty Return Grilles shall be steel, 38° deflection, 1/2” spacing, and have blades parallel to long or short dimension as shown on schedule.

H. Linear slot diffusers shall be constructed of extruded aluminum and be of the sizes, performance, and slot numbers as shown on the drawings. Provided diffusers with insulated plenums, pattern controllers, border trim, and mounting hardware. Size and performance shall be as indicated on drawings. Wall mounted diffusers in gypboard walls shall be provided with hidden flanges.

2.11 INSULATION

A. Provide pipe covering and duct insulation of the type hereinafter specified on the following: hot water piping, cold water make-up piping, refrigerant piping and sheet metal ducts. All sealers, solvents, tapes, adhesives and mastics used in conjunction with this section of the specifications shall possess the maximum safety quantities available and Standards #90A and #90B. Insulation shall be fiberglass except as specified hereinafter having a minimum density of four pounds per cubic foot. Insulation shall be as manufactured by Armstrong, CertainTeed, Johns-Manville, Knauf, Owens/Corning, or equal and installed in accordance with the manufacturer's recommendations.

B. Piping: All new piping and fittings throughout the building, as shown on the drawings, shall be insulated with Owens/Corning Fiberglass, or equal, 25 ASJ glass fiber insulation in molded sections. Glass fiber insulation shall have a minimum density of 3-1/4 pounds per cubic foot with a thermal conductivity ("K" value) of 0.23 at 75ºF mean temperature. All piping shall have a factory applied all service vapor barrier jacket. The end joints of the insulation shall be sealed with factory furnished end joint sealing tape. Longitudinal seams shall be sealed with Benjamin Foster 85-75 adhesive. The thickness of insulation to be applied to piping shall be as follows:

1. Hot water supply and return piping less than 1.5” in diameter shall be insulated with 1.5" thick insulation and piping 1.5” and greater in diameter shall be insulated with 2” thick insulation. Staples shall not be used in any part of this installation.
2. Chilled water supply and return piping less than 6” in diameter shall be insulated with 1.0" thick insulation and piping 6” and greater in diameter shall be insulated with 1.5” thick insulation. Staples shall not be used in any part of this installation.
3. All cold-water make-up piping shall be covered with 1" fiberglass pipe covering with factory applied flame resistant vapor barrier adhesive. End joints shall be finished with 4" wide matching vapor barrier strips, sealed with adhesive. Staples shall not be used in any part of this installation.

4. All refrigerant suction lines shall be insulated with 1" wall thickness flexible elastomeric closed cell pipe insulation. All insulation exposed to the weather shall be furnished with two coats of Armstrong Armaflex finish or approved equal. Contractor shall provide on both the suction and liquid lines as recommended by the manufacturer. Flexible elastomeric cellular insulation shall be manufactured by Armstrong Armaflex, Aerocel3: K-Flex, or approved equal.
5. The end joints of insulation shall be tightly butted and covered with factory furnished end joint sealing tapes. The jacket overlap shall be sealed with an approved sealer which shall not mar the jacket finish. Staples shall not be used for fastening insulation.
6. All fittings, valves and flanges shall be insulated with the same thickness of fiberglass as on the piping, with mitered segments of pre-molded F/G fittings wired in place after which a one mil aluminum foil vapor barrier shall be wrapped tightly over the insulation with all laps sealed with the manufacturer's vapor seal mastic. Wet coats of vapor seal mastic with imbedded glass fabric shall be applied to fittings, per the manufacturer's recommendations. Staples or tacks shall not be used.
7. Provide PVC plastic pipe jacket over pipe insulation on locations indicated on drawings. Jacket shall be 10 mil thickness, ASTM C921, sheet material, off-white color, ASTM E96; 0.002 perm-inches. Adhesives and mastic shall be compatible with insulation.

C. Ductwork: Provide duct insulation as specified and shown on the drawings. All insulation shall be Installed per manufacturer's recommendations.
1. All new air conditioning supply air ducts above ceilings shall be insulated with 1-1/2" thick fiberglass insulation wrap with 0.0025" aluminum foil facing that has been tested in accordance with ASTM E-84, having a flame spread rating of 25 maximum and smoke developed rating of 50 maximum. Insulation shall have a rating of R-8 as required by MA Energy Code and the installation shall be in accordance with MA Mechanical Code, i.e. R-value to be rated after taking into account compression of the insulation. (If 1-1/2” of insulation is required then 2” will be installed).
2. All plenums behind intake and exhaust louvers shall be insulated with 1" thick 703 Series Fiberglass board insulation, with 0.0025-inch aluminum foil facing that has been tested in accordance with ASTM E-84, having a flame spread rating of 25 maximum and smoke developed rating of 50 maximum. Install per manufacturer's recommendations. (ADD ALTERNATES 2 and 3).
3. Acoustical Lining: Furnish and install 1" thick Ultralite duct liner of 1-1/2 pound density with coating one side, or equal. Fasten to inside of ducts with Type A stic klips, Type S stic klip adhesive and speed clip washers. For medium pressure ductwork the acoustical lining shall be rated for medium pressure ducts. Duct liners must meet the ASTM standards C 1071 or UL 181 for surface erosion resistance and ASTM standards C 1104 or C 209 (at <0.5% absorption by volume) for water vapor sorption. Acoustical lining shall be used in the first 20 feet of all supply and return air ductwork from the DOAS, in all transfer ductwork, in the supply and return trunks of the fancoil units, and in other locations as shown on the drawings.

2.12 ACCESS PANELS

A. Furnish access panels for access to all concealed parts of the HVAC system which require accessibility. The access panels shall be provided for the same fire integrity as the walls or ceiling in which they are installed. The access panels shall be furnished by this section to the General Contractor. These access panels shall be installed by the SECTION installing the construction into which the panel is located.

B. All access panels shall be located in a workmanlike manner as approved, positioned so that the component can be easily reached and the size shall be sufficient for this purpose (minimum size of 12” and 12”). The project shall be laid out in such a manner that access panels shall be minimized. When it becomes necessary that an access panel be provided, the following shall apply.

C. Access panels shall be prime painted and be provided with cylinder lock and two keys as manufactured by Inland Steel Products Company Milcor, Miami Carey or Walsh-Hannon-Gladwin, Inc. Wayloctor. All access panels shall be keyed alike. They shall be as follows:
1. Acoustical Tile Ceilings: Milcor Type A.
2. Plastered Surfaces: Milcor Type K.
3. Masonry Construction: Milcor Type M.

4. Access panel shop drawings shall be submitted to the Architect for approval.

2.13 EXHAUST FANS (ADD ALTERNATE #2 – INDOOR FIRING RANGE AND ADD ALTERNATE #3 – SALLYPORT EXHAUST.

A. Furnish and install exhaust fans for ADD Alternate #2 and/or ADDD Alternate #3, when approved, where shown on the drawings. Exhaust fans shall have the capacities and characteristics listed in the schedule on the drawings. Fans shall conform to the design and fabrication requirements of the AMCA Standard Test Code for Air Moving Devices and shall be as manufactured by Greenheck, ACME, CaptiveAire, Carnes, Loren Cook, PennBarry, Twin City, or approved equal.

B. Quality Assurance: The fan fabrication shall conform to AMCA 99. The fan performance ratting shall conform to AMCA 210 and bear the AMCA Certified Rating Seal. Sound ratings shall meet AMCA 301, tested to AMCA 300 and bear AMCA Certified Sound Rating seal. Motors shall be UL 705 compliant.

C. **The Following Equipment Will Be Provided Under Add Alternate #2**: Roof Mounted Upblast Fans: Upblast exhaust fans shall be centrifugal direct-driven type. The fan wheel shall be centrifugal backward-inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced. The fan housing shall be constructed of heavy-gauge aluminum with a rigid internal support structure. The windband shall be welded to the one-piece and 100% continuously welded to one-piece aluminum curb cap and on all sizes with UL/cUL 762. Motors and drives shall be mounted on vibration isolators, out of the airstream where no steel-to-steel contact between rotating components and the base shall occur. Fresh air for motor cooling shall be drawn into the motor compartment through a ten-square-inch tube free of discharge contaminants. Motors and drives shall be readily accessible for maintenance. A disconnect switch shall be factory-installed and wired from the fan motor to a junction box within the motor compartment. A conduit chase shall be provided through the curb cap to the motor compartment for ease of electrical wiring. All fans shall bear the AMCA Sound and Air Performance seal. Each fan shall bear a permanently affixed manufacturer's engraved metal nameplate containing the model number and individual serial number for future identification. A leakproof fan housing shall be constructed with a one-piece windband with an integral rolled bead for added strength. Provide following options and accessories.

1. Provide insulated roof curb. The base of the fan shall be sized to match the curb. Provide curb extensions between roof curb and roof mounted fans as required to meet NFPA requirements of 40 inches minimum discharge above the roof.

2. Duct Mounted HEPA Filter Housing: Similar to Camfil Magna/Pack 1x2 HEPA Housing with Prefilter Track. The housing shall be able to house two (2) 24x24x2 30/30 Prefilter and 2 24x24.11.5 99.97% HC HEPA.

   a. Provide a Side-Access Filter Housing that is constructed from 14 gauge stainless steel (304). It shall be reinforced with channel bracing to withstand 8.0" w.g. positive or negative pressure. Standing flanges shall be provided to mate the housing to the ductwork. The housing shall be weatherproof without modification. Housing shall be provided with pin-hinged removable access doors for service from either side the housing. Doors shall include high memory door gasketing to prevent leaks to +/- 8.0" w.g. Filter securing swing bolt assemblies shall be of the same construction as the housing.

   b. A minimum of four assemblies shall make up a filter unit. The units shall be comprised of equi-bearing filter clamps that secure the filters into each of the assemblies.

   c. Housing will also include a filter track to hold a nominal 2" deep prefilter.

   d. There shall be a means to inject filter evaluation challenge, built into the housing

D. **The Following Equipment Will Be Provided Under Add Alternate #3**: Inline Fans: Inline fans shall be belt or direct drive as indicated on schedule. The fan system shall include a duct mounted inline fan, speed controller, and motorized damper. The fan shall have an aluminum housing; resilient mounted motor and non-overloading, backward inclined centrifugal wheel. The motor shall be electronically commutated, permanently lubricated, heavy duty ball bearing type, matched to the fan load, and furnished at the specified voltage, phase and enclosure. The fan enclosure shall be provided with a Class I motorized dampers controlled by the BMS. The damper must provide positive close off, and shall have an air leakage rate not greater than 4cfm/ft2 (20.3 L/s • m2) of damper surface area at 1.0 inch water gauge (249 Pa) and shall be labeled by an approved agency when tested in accordance with AMCA 500D for such purpose.

2.14 MOTOR STARTERS

A. Furnish and install all motor starters required for HVAC equipment under this section if not factory installed by the equipment manufacturer. The starters shall be wired by a licensed Electrician.

B. Motor Controls – Manual and Magnetic:

1. The individually mounted magnetic starters indicated on the plans and as required shall be magnetic across-the-line starters with thermal overload on each phase.
2. Starters shall be of the size and type required for particular motor horsepower and voltage. Minimum size starter to be Size 0.
    a. All starters shall have OL reset button, pilot light to indicate on or off and hand-off-auto switch in cover, unless indicated otherwise.
    b. All starters to have 120-volt control via individual control transformers fused on the secondary, where not fed at 120 volts.
3. Manual motor starters shall be furnished with thermal overloads on each phase. Thermal switches shall be provided with pilot lights.
4. Three (3) auxiliary contacts shall be furnished and installed in all motor starters (1 NC, 2 NO).
5. Motor starters shall be all manufactured by the same company and shall be one of the following: Square D Company, Allen Bradley, General Electric, Cutler Hammer or ITE.

2.15 VARIABLE FREQUENCY DRIVE (VFD)

A. The pump motors for hydronic circulating pumps, and variable speed supply, return, and exhaust air fans shall be controlled by variable frequency drives to insure maximum operating efficiency.

B. Acceptable VFD manufacturers: ABB, Danfoss, Hitachi, Reliance, Sumitomo, Toshiba, Yaskawa or approved equal.

C. Provide VFDs with microprocessor-based inverter logic isolated from power circuits, pulse-width-modulated inverter system, ability to operate controller with motor disconnected from output, integral digital display, Status Indicators, door and safety interlocks, output filter, and 5% AC line reactor.

D. HVAC Contractor shall furnish and install the wall mounted VFDs. Electrical Subcontractor shall wire them.

2.16 BOILER

A. Furnish and install as shown on the drawing, packaged, modulating, sealed combustion, power-vented, high efficiency gas-fired boilers with stainless steel heat exchangers that use outside air for combustion. Boiler shall be Knight, Model FTX as manufactured by Lochinvar, or comparable product as manufactured by Heat Transfer Products, Burnham or approved equal. Manufacturer shall provide field start-up for each boiler.

B. Category IV Sealed Combustion Boiler:

1. Each Boiler shall be factory assembled and fire-tested, requiring only connection to the water circulating system, fuel electric utilities, condensate drain and flue gas vent. Factory fire-test results and complete operating and maintenance instructions are to be furnished with the Boiler.

2. Boiler heat exchanger shall be constructed of 316L stainless steel. Aluminum or Copper tube boilers are not acceptable, but may be considered with additional manufacturers guarantee. Each Boiler shall be capable of full modulation firing down to 20% of rated input with a turndown ratio of not less than 5:1 - Control system shall comply with UL/CSD-1/GE-GAP criteria.

3. The boiler shall bear the ASME "H" stamp for 80 psi working pressure and shall be National Board listed. The boiler shall have a fully welded, stainless steel, fire tube heat exchanger. There shall be no banding material, bolts, gaskets or "O" rings in the pressure vessel construction. The heat exchanger shall be designed for a single-pass water flow to limit the water side pressure drop. The condensate collection basin shall be constructed of welded stainless steel. The complete heat exchanger assembly shall carry a twelve (12) year limited warranty.

4. Each Boiler shall be constructed with a heavy gauge steel jacket assembly, primed and pre-painted on both sides. The combustion chamber shall be sealed and completely enclosed, independent of the outer jacket assembly, so that integrity of

the outer jacket does not affect a proper seal. A burner/flame observation port shall be provided. The burner shall be a premix design and constructed of high temperature stainless steel with a woven metal fiber outer covering to provide modulating firing rates. The Boiler shall be supplied with a gas valve designed with negative pressure regulation gas valve and be equipped with a pulse width modulation blower system, to precisely control the fuel/air mixture to the burner. The Boiler shall be capable of normal operation and shall operate in a safe condition with gas supply pressures as low as 4 inches of water column. The burner flame shall be ignited by direct spark ignition with flame monitoring via a flame sensor. If inlet gas pressure exceeds 13" W.C., a 100% lock-up type gas pressure regulator of adequate size shall be installed in gas supply piping and adjusted to prevent pressure in excess of 13" W.C. The boiler shall be equipped with leveling legs.

5. Each boiler shall utilize a 24 VAC control circuit and components. The control system shall have a factory installed display for boiler set-up, boiler status, and boiler diagnostics. All components shall be easily accessed and serviceable from the front and top of the jacket.

a. Boilers shall be equipped with:

1). A temperature/pressure gauge.

2). A high limit temperature control with manual reset.

3). ASME certified pressure relief valve set for 30 psi (standard).

4). Outlet water temperature sensor with a dual thermistor to verify accuracy.

5). System supply water temperature sensor.

6). Outdoor air sensor, flue temperature sensor with dual thermistor to verify accuracy.

7). Low water cut off with manual reset, blocked drain switch and a condensate trap for the heat exchanger condensate drain.

6. Each boiler shall feature the "SMART SYSTEM™" control which is standard and factory installed with 128 x 128 resolution display, password security, outdoor air reset, pump delay with freeze protection, pump exercise, ramp delay featuring six steps, domestic hot water prioritization with limiting capabilities, USB drive for simple uploading of parameters and a PC port connection for connection to a local computer for programming and trending. A secondary operating control that is field mounted outside or inside the appliance is not acceptable. Boilers shall have alarm contacts for any failure, runtime contacts and data logging of runtime at given modulation rates, ignition attempts and ignition failures. Boilers shall have a built-in "Cascade" with leader redundancy to sequence and rotate while maintaining modulation of up to eight boilers of different Btu inputs without utilization of an external controller. The internal "Cascade" function shall be capable of lead-lag, efficiency optimization, front-end loading, and rotation of lead boiler every 24 hours. Boilers shall be capable of remote communication via CON-X-US™ Remote Connectivity with the capability of historical trending and sending text message or email alerts to notify the caretaker of a boiler alarm and remote programming of onboard boiler control. The control must have capability to communicate via Modbus protocol with a minimum of 46 readable points. Boilers shall have an optional gateway device which will allow integration with LON or BacNet protocols.

7. The "SMART SYSTEM™" control shall increase fan speed to boost flame signal when a weak flame signal is detected during normal operation. A 0-10 VDC output signal shall control a variable speed boiler pump to keep a fixed Delta T across the boiler regardless of the modulation rate. Each boiler shall have the capability to receive a 0-10 VDC input signal from a variable speed system pump to anticipate changes in system heat load in order to prevent flow related issues such as erratic temperature cycling.

8. Each boiler shall be equipped with two terminal strips for electrical connection. A low voltage connection board with 46 connection points for safety and operating controls, i.e., Alarm Contacts, Runtime Contacts, Low Water Cut Off, Louver Proving Switch, Tank Thermostat, Domestic Hot Water Building Recirculation Pump Contacts, Domestic Hot Water Building Recirculation Temperature Sensor Contacts, Remote Enable/Disable, System Supply Temperature Sensor, Outdoor Temperature Sensor, Tank Temperature Sensor, Modbus Building Management System Signal and Cascade Control Circuit. A high voltage terminal strip shall be provided for Supply voltage. Supply voltage shall be 120 volt / 60 hertz / single phase. The high voltage terminal strip plus integral relays shall be provided for independent pump control of the System pump, the Boiler pump and the Domestic Hot Water pump.

9. In addition to previously specified, Control System shall also provide dual level password security, Data logging and boiler diagnostics, outdoor air reset, pump delay with freeze protection, and pump exercise. The control system shall monitor both boiler lockout and limit circuits to automatically skip over those boilers that are powered down for maintenance, tripped or

otherwise will not start. The control shall be compatible with Modbus RTU protocol. The control system shall be fully integrated into the burner control cabinet and incorporate single and multiple boiler control logic, inputs, outputs and communication interfaces. Using parameter menu selections, the control system shall allow the boiler to respond to remote system water temperature and outside air temperatures and warm weather shut down or building automation system remote start/stop commands. All components shall be easily accessed and serviceable from the front of the Boiler.

10. Any Boiler not equipped with a factory wired shut-off switch: Electrical subcontractor shall furnish and install an electrical junction box at the Boiler equipped with a SPST switch marked “ON/OFF” to function as a service switch. Switch box shall be mounted on the Boiler jacket without obstructing cleanout panel accessibility or preventative maintenance routines.

11. Each Boiler shall be installed and vented as shown on the Plans and as specified below:

    a. **(By Plumbing Sub-Contractor)** Direct Vent Vertical system with a vertical roof top termination of the flue exhaust vent and sidewall termination for combustion air. The flue shall be Category IV approved material constructed of CPVC, Polypropylene or Stainless Steel. A separate pipe shall supply combustion air directly to the boiler from the outside in a different pressure zone from that of the exhaust vent. The boiler’s total combined air intake length shall not exceed 100 equivalent feet. The boiler’s total combined exhaust venting length shall not exceed 100 equivalent feet. Foam Core pipe is not an approved material for exhaust piping.

12. This Contractor shall furnish and install a condensate neutralizing box complete with limestone granules shipped loose for field installation. A condensate trap assembly shall be furnished if a condensate collection tray is not provided by the Boiler manufacturer. The trap allows condensate to drain from sump while retaining flue gases in the boiler. The trap has factory installed overflow switch, which shuts down the boiler in the event the drain line becomes obstructed, preventing proper condensate removal.

13. Contractor shall provide the boiler circulator pumps if not provided by the boiler manufacturer. Contractor shall size the pumps per manufacturer’s recommendations.

14. Boiler Trim

    a. All electrical components to be high quality manufacture and bear UL label.

    b. Water boiler(s) controls furnished:

        1). High limit temperature control (190 degrees F maximum allowable boiler water temperature).

        2). Combination pressure-temperature gauge. Gauge dial clearly marked and easy to read.

        3). ASME certified pressure relief valve, set to relieve at 30 PSIG.

        4). Flue gas, outlet water temperature sensor, return water temperature, flue temperature sensor and outdoor air temperature sensor.

        5). Low water protection.

        6). Built-in freeze protection.

        7). Boiler circulator.

15. Boiler Manuals

    a. The boiler(s) shall be provided with complete instruction manuals, including:

        1). Boiler Installation Manual.

        2). User’s Manual.

        3). Gas Conversion Supplement.

        4). Venting Supplements and Instructions.

        5). Wall Mount Instructions.

16. This Contractor shall arrange for the boiler manufacturer’s representative to provide four (4) hours of operating and maintenance instructions for the boilers to the Owner’s maintenance personnel at the site.

17. This Contractor shall provide a flow switch on the discharge side of the boiler piping. The flow switch shall be located on the boiler side of the isolation valve. This flow switch shall be install in accordance with the manufacturer's recommended installation procedure and shall be connected to the boiler control system in accordance with the boiler's manufacturer recommended installation procedure.

2.17 VARABLE REFRIGERANT FLOW (VRF) SYSTEMS

A. General: Furnish and install VRF systems as specified in the bid documents. The systems shall be in accordance with the schedule on the drawings for type, size, capacity, efficiency, model numbers and components. All units shall be listed and rated by ANSI/AHRI Standard 1230-2010, be ANSI/UL STD 1995 listed, and listed by Electrical Testing Labs (ETL) and bear the cETL label. All wiring shall be in accordance with the National Electric Code (NEC). All system designs shall comply with ASHRAE 15 Mechanical Refrigerant Code. The Variable Refrigerant Flow Systems shall be manufactured by Mitsubishi/Trane, Daikin, .

B. System Descriptions: VRF system shall automatically vary the target evaporating and condensing temperatures based on building load and weather conditions to increase part load efficiency (Variable Refrigerant Temperature). VRF system shall automatically vary the target evaporating and condensing temperatures based on building load and weather conditions to increase part load efficiency (Variable Refrigerant Temperature).

C. Outdoor Air-Cooled Condensing Units:

1. General:

   a. The outdoor air-cooled condensing units shall be of a type specifically used in a VRF system. Each outdoor unit module shall be completely factory assembled, piped and wired and run tested at the factory. The outdoor units shall be equipped to interface with the controls of the VRF system and shall perform all functions necessary for operation of the VRF system. VRF system shall meet performance requirements per schedule and be within piping limitations & acceptable ambient temperature ranges as described in manufacturers' published product catalogs. Non-published product capabilities or performance data are not acceptable.

   b. All units requiring a factory supplied twinning kits shall be piped together in the field, without the need for equalizing line(s).

   c. The outdoor unit shall have an accumulator with refrigerant level sensors, an auto-charging feature to ensure proper refrigerant charge, and controls.

   d. The outdoor unit shall have a high efficiency oil separator plus additional logic controls to ensure adequate oil volume in the compressor is maintained.

   e. The system will automatically restart operation after a power failure and will not cause any settings to be lost.

   f. The following safety devices shall be included on the condensing unit: high pressure sensor and switch, low pressure sensor, control circuit fuses, crankcase heaters, fusible plug, overload relay, inverter overload protector, thermal protectors for compressor and fan motors, over current protection for the inverter, and anti-recycling timers.

2. Unit Cabinet:

   a. The casing(s) shall be fabricated of galvanized steel, bonderized and finished. The outdoor unit shall be tested in compliance with ISO9277.

   b. The outdoor unit shall be provided with a manufacturer supplied snow /hail guard. The snow/hail guard protects the outdoor coil surfaces from hail damage and snow build-up.

3. Fan:

   a. Each outdoor unit module shall be furnished with direct drive, variable speed, propeller type fan(s). The fan shall be factory set for operation under 0.12 in. WG external static pressure, but capable of normal operation under a maximum of 0.24 in. WG external static pressure via dipswitch.

b. All fan motors shall have inherent protection, have permanently lubricated bearings, and be completely variable speed. All fan motors shall be mounted for quiet operation.

c. All fans shall be provided with a raised guard to prevent contact with moving parts.

4. Coil: The outdoor coil shall be of nonferrous construction with lanced or corrugated plate fins on copper tubing. The coil fins shall have a factory applied corrosion resistant finish. Uncoated aluminum coils/fins are not acceptable. The coil shall be protected with an integral metal guard.

5. Compressor:

a. Each outdoor unit module shall be equipped with inverter scroll compressors. Compressors shall be high efficiency reluctance DC (digitally commutating), hermetically sealed, variable speed type. Temperatures and pressures shall be read and calculated. With each reading, the compressor capacity (INV frequency) shall be controlled to eliminate deviation from target value. Non inverter-driven compressors shall not be accepted.

b. All compressors shall have an inverter to modulate capacity. The capacity for each module/system shall be variable with a minimum turndown not greater than 20% of the scheduled nominal capacity. Inverter board shall be cooled to prevent inefficient and unstable operation.

c. The compressor will be equipped with an internal thermal overload.

d. The compressor shall be mounted to avoid the transmission of vibration.

e. In the case of multiple condenser modules, operation hours of the compressors shall be balanced by means of the Duty Cycling Function.

6. Electrical:

a. The outdoor unit electrical power shall be 208/230 volts, 3-phase, 60 hertz.

b. Control wiring shall be installed in a daisy chain configuration between all VRF components as per Manufacturer.

c. The control circuit between the indoor units, BC Controller and the outdoor unit shall be completed using a 2-conductor, communication type twisted pair shielded cable to provide total integration of the system.

D. Indoor Air Conditioning Units:

1. Wall Mounted Indoor Units

a. General: The wall mounted indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory. The unit shall be suitable for installation within a conditioned space. The cabinets shall be fastened to the wall with horizontal refrigerant and condensate knockouts

b. Cabinet: galvanized steel cabinet shall be constructed with sound absorbing fiberglass urethane foam insulation. The cabinet shall be affixed to a factory supplied wall mounting template and located in the conditioned space. The front grille shall be removeable for filter access.

c. Fan: The fan type shall be direct-drive cross-flow with statically and dynamically balanced impeller with high and low fan speeds available.

d. Filter: The return air shall be filtered by a washable resin net mold resistant filter.

e. Condensate drain pan: A polystyrene mildew-proof condensate drain pan shall be included as standard equipment.

f. Provide unit with an associated condensate pump.

g. Electrical: The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz.

2. Ceiling-Concealed Ducted Indoor Units

   a. General: The ceiling-concealed ducted indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory. The unit shall be suitable for use in plenums in accordance with UL1995 ed 4.

   b. Unit Cabinet: The cabinet shall be constructed of galvanized steel, ducted with a 2-position, field adjustable return and a fixed horizontal discharge supply. The cabinet panel shall have provisions for a field installed filtered outside air intake. The unit shall ship from the factory in a rear return configuration and shall be field convertible to a bottom return configuration.

   c. Fan: The fan shall have a variable speed direct drive DC motor with statically and dynamically balanced impeller with user-selectable fan speeds plus the Auto-Fan function. The automatic fan speed mode shall allow the fan to vary based on space load. The unit shall have logic for automatically adjusting external static pressure settings of the fan motor (selectable during commissioning).

   d. Filter: Return air shall be filtered by means of a field supplied/field installed 2” filter rack.

   e. Coil: The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing. All tube joints shall be brazed with phos-copper or silver alloy. The coils shall be pressure tested at the factory. Coil shall be provided with a sloped drain pan.

   f. Condensate drain pan: A corrosion proof condensate drain pan and condensate pump shall be included as standard equipment. The condensate pump shall provide up to 25” of lift from the center of the drain outlet and have a built-in safety shutoff and alarm.

   g. Electrical: The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz.

3. Ceiling Cassette Units.

   a. General: 2' x 2' or 3" x 3' ceiling cassettes hung in ceilings. Return air shall be through a concentric panel, which includes a mold resistant filter. Factory assembled and tested. Included in the unit is factory wiring, piping, electronic expansion valve, control circuit board, fan motor thermal protector, condensate drain pump, self-diagnostics, auto-restart function, fused time delay, and test run switch. Indoor unit refrigerant pipes will be charged with dehydrated air prior to shipment from the factory.

   b. Unit Cabinet: A galvanized steel cabinet shall be constructed with sound absorbing fiberglass urethane foam insulation. The cassette face shall be impact resistant with a washable decoration panel.

   c. Fan: The fan type shall be direct-drive with statically and dynamically balanced impeller with high and low fan speeds available.

   d. Coil: The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing. All tube joints shall be brazed. The coils shall be pressure tested at the factory. Coil shall be provided with a sloped drain pan.

   e. Accessories: Units shall be equipped with a condensate pan and condensate pump piped to indirect condensate drain. Cassettes mounted in exposed ceilings shall be provided with manufacturers exposed ceiling cassette cover.

   f. Electrical: The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz

E. Controls:

   1. Local Controls:

      a. The indoor units shall be supplied with individual zone controllers hard wired by installing contractor. The zone controllers shall be capable of the following actions: a thermostat sensor, 7-day weekday plus Saturday Sunday schedular, single and dual setpoints for occupied periods and independent setback setpoints for unoccupied periods, the controller shall have the ability to digitally prohibit

individual buttons and functions, custom mode selection, and a self-diagnosis function that constantly monitors the system for malfunctions.

b. The thermostat thermostats shall have the room temperature setpoint as the primary display with the real time space temperature available for secondary view. The temperature indicator shall be digital display and shall be visible without removing the thermostat cover.

2. Central Control System:

a. Provide a gateway for connection to the Building Automation System for installation. The controller shall be able to display all points required for the diagnostics, and maintenance of the systems, and be able to write to the VRV/VRF controller all global points needed for the proper operations functionality of the system.

b. The central controller shall be capable of the following functionalities:

i. Control of set points, schedules, fan speeds, heat/cool mode, and of setback (override) temperature settings during unoccupied periods.

ii. Remotely adjust temperature limits or disable individual functions of the wall mounted zone controllers.

iii. Visible and audible alarm indication of system malfunctions with error code on the BMS Head-end.

iv. Tiered hierarchy allowing for control of indoor units independently or as a group.

v. Automatic changeover control of indoor units with averaging method, voting method, and changeover, a guard timer control.

vi. Floor plan graphic layout. Floor plan will include capability to control indoor unit, and auxiliary inputs / outputs as follows: Up to 4 status points to be assigned to the control point icon, Status and control points to display on corresponding location of zone served on floor plan, Digital input and output icons will display On/Off status, Analog input icons will display analog value.

c. Provide automatic alert and error emails.

d. Provide automatic start of the systems if there is a loss of power in the building or if the HVAC system should fail.

e. Provide capability for future VRF system expansion.

f. The central controller shall be capable of interfacing with a BACnet BAS system and be able to send/receive communication from the BAS system.

g. System controls and control components shall be installed in accordance with the manufacturer's written installation instructions.

h. Control system start-up shall be a required service to be completed by the manufacturer or a duly authorized, competent representative that has been factory trained in controls system configuration and operation.

F. Refrigerant and Refrigerant Piping

1. Refrigerant: R410A refrigerant shall be required for the VRF systems

2. Piping: All refrigerant piping materials and joining methods shall be approved by the VRV system manufacturer Refrigerant line sizing shall be in accordance with manufacturer specifications. Future changes to indoor unit styles or sizes must be possible without resizing/replacing refrigerant piping to any other branch devices or indoor units.

a. Pre-insulated line sets: Manufacturer approved Pre-insulated line sets may be used. Lines shall be hung to avoid sagging. Do not allow lines to lay on ceiling system. Pre-Insulated line sets shall have an insulation thickness as recommended by the VRF manufacturer.

b. Rigid Copper Refrigerant Pipe: ASTM B819, type #ACR hard drawn or annealed with ASME B16.22 wrought copper fittings.

c. All refrigerant pipe connections shall be brazed.

d. Service shut-off valves shall be field-provided/installed for each branch to allow service to any indoor unit without field interruption to overall system operation.

e. All refrigerant piping must be insulated with 1/2" closed cell, CFC-free foam insulation with flame-spread index of less than 25 and a smoke-development Index of less than 50 as tested by ASTM E 84 and CAN / ULC S-102. R value of insulation shall be at least 3.

2.16 EXISTING FAN COIL UNITS (FCU)

A. The existing Fan Coil Units shall have the following work done under the base bid: Add a mixing box with a modulating control damper sized for the outdoor air ductwork as shown on the plans. Replace the existing three-way control valve, with a two-way control valve. Remove and permanently cap by-pass piping. Damper, damper actuator, and two-way control valve provided by the ATC Contractor.

B. Work to be done under ADD ALTERNATE #2 – update the unit controller and remaining pneumatic control sensors (space thermostat, discharge air temperature) with DDC sensors and actuators for the fan coil units to remain.

2.17 NEW FAN COIL UNITS (FCU)

A. Furnish and install fan coil units as indicated on the drawings. The units shall have the capacities and characteristics listed in the schedule on the drawings. Units shall be manufactured by Airtherm, Carrier, Daikin, Greenheck, JCI, Krueger, Nailor, Price, Trane, Williams, or approved equal:

1. General Description.
   a. Unit shall have a draw-through supply fan configuration and discharge air horizontally. The unit shall include mixing box, filters, supply fans, hot water coil, chilled water coil, and drain pan.
   b. Unit shall be factory assembled and tested including leak testing of the coils, and run testing of the supply fans and factory wired electrical system.
   c. Unit components shall be labeled, including pipe stub outs, electrical and controls components.
   d. Unit nameplate shall be affixed to the exterior of the unit
2. Construction:
   e. Chassis and internal supports shall be 20-gauge galvanized steel. Unit construction shall be G90 galvanized steel.
   f. Unit shall be designed to reduce air leakage and infiltration through the cabinet. Sealing shall be included between panels and between access doors and openings to reduce air leakage. Piping and electrical conduit through cabinet panels shall include sealing to reduce air leakage.
   g. Unit insulation 1/2-inch closed cell insulation.
3. Mixing Box: Unit shall contain a mixing box with return air opening and outside air opening. Refer to design drawings for location of return air and outside air openings. A modulating damper and actuators shall be provided by the ATC Contractor to be installed by this contractor.
4. Supply Fan: Centrifugal forward-curved double-width galvanized wheels, statically and dynamically balanced, direct driven. Motor shall be a high efficiency Electronically Commutated Motor (ECM) direct drive motor with thermal overload protection. Motors shall have capability for on/off and 0-10 vdc control.
5. Hydronic Coils.
   h. Coil shall be certified in accordance with AHRI Standard 410 and be hydrogen or helium leak tested.
   i. Coil shall have Evenly spaced aluminum fins mechanically bonded to copper tubes designed for 200 psi and 220^{o}F with the capacities indicated on the drawings.
   j. Coil shall have right- or left-hand external piping connections as shown on the drawings. Supply and return connections shall be sweat connection. Coil connections shall be labeled, extend beyond the unit casing, and be factory sealed on both the interior and exterior of the unit casing to minimize air leakage.

k. Provide sloped corrosion resistant drain pan under cooling coil.

l. Control valves shall be field supplied by ACT contractor and field installed by HVAC contractor.

6. Filters:

m. Unit shall include pleated panel filters with an ASHRAE efficiency of 85% and a MERV rating of 13, upstream of the cooling coil.

n. Provide filter access such that filters are coordinated and compatible with ducted return and outdoor air supply.

7. Provide each unit with supplemental drain pan.

8. Electrical.

o. Unit shall have built in transformers to allow for a single point power connection.

p. Provide the manufacturer's electrical disconnect.

9. Warranty: The Manufacturer shall provide a "parts only" warranty for a period of not less than one year from the date of substantial completion. Warranty shall cover material and workmanship that prove defective, within the specified warranty period, provided manufacturer's written instructions for installation, operation, and maintenance have been followed. Warranty excludes parts associated with routine maintenance, such as belts and air filters.

10. Controls: The unit shall be constructed so that it can be operated as a heating and cooling system controlled by the Building Management System (BMS). The ATC Sub-subcontractor shall provide all required DDC controls (hardware, software and sensors) to provide a working system as per the ATC specification. The FCU unit controls shall be able to cooperate with BAS to perform sequence of operation as described in specification.

2.19 AIR COOLED CHILLERS

A. Furnish and install air-cooled chillers with the capacities and characteristics listed in the schedule on the drawings. The HVAC contractor shall be responsible for any electrical, mechanical, or structural modifications required when substituting a product other than the basis of design scheduled on the drawings. The chiller shall be manufactured by Trane, AAON, Carrier, Daikin, Johnson Controls, or engineer approved equal.

B. Chiller Description:

1. ACC-1 & 2 shall be a factory assembled, packaged, air-cooled, chiller suitable for outdoor operation. The chiller shall include hermetic scroll compressors, shell and tube evaporator, air-cooled condenser, electronic expansion valves and microprocessor control system. Contained within the unit cabinet shall be all factory wiring, piping, controls, refrigerant charge, and special features required prior to field start-up.

2. The chiller shall be ANSI/UL certified and include the UL label. The unit shall be rated in accordance with AHRI Standard 550/590. Unit construction shall comply with ASHRAE 15 Safety Code, Massachusetts Electrical Code, and ASME applicable codes.

3. Unit shall be pressure tested and full load run tested at the factory. The testing shall include verification of the condenser fans, compressors, and temperature and pressure sensors.

4. The chiller shall, at a minimum, be able to start and operate at ambient conditions between 32ºF (0ºC) and 125ºF (52ºC).

C. Frame and Cabinet:

1. Frame: heavy-gage galvanized steel frame and base.

2. Cabinets & Panels: shall be insulated, double wall, galvanized steel casing with pre-painted finish.

3. Security Guards: Unit shall be supplied with factory (or field) installed, louvers to protect the condenser, evaporator, and compressors.

4. Finish: The structure and panels of the unit shall be protected by a factory provided corrosion resistant paint or powder coat finish. Components shall be capable of withstanding 500-hour salt spray test in accordance with the ASTM B-117 standard. The coating or paint system shall be evaluated and rated in accordance with procedures A and B of ASTM D 1654.

5. Mount starters and Terminal Blocks in a UL 1995 rated weatherproof panel provided with full opening access doors. If a circuit breaker is chosen, it should be a lockable, through-the-door type with an operating handle and clearly visible from outside of unit indicating if power is on or off.
6. Provide unit with lifting lugs along the base of the unit.

D. Compressors:

1. The chiller shall have fully hermetic scroll type compressors with optimized and dedicated scroll profile, direct-drive, internal muffler, and check valve.
2. Provide direct-drive compressor motor that is suction gas cooled with robust construction and system design protection.
3. Provide oil lubrication system with oil charging valve and oil filter to ensure adequate lubrication during starting, stopping, and normal operation.
4. Each compressor will have crankcase heaters installed and properly sized to minimize the amount of liquid refrigerant present in the oil sump during off cycles.

E. Evaporator:

1. The evaporator shall be of shell and tube type construction and designed for use with R-410A refrigerant. The shell shall be fabricated from carbon steel with the inside tubes made of seamless copper.
2. The heat exchanger shall be designed, tested, and stamped in accordance with the current ASME code for a refrigerant side working pressure of 460 psig. Waterside working pressure shall be 150 psig.
3. Insulate the evaporator with a minimum of K=0.28 UV rated insulation
4. Evaporator heaters shall be factory installed and shall protect unit down to -20ºF. Contractor shall wire separate power to energize heat tape and protect cooler while chiller is disconnected from the main power.
5. Provide water drain connection, vent, and fittings for factory installed leaving water temperature control and low temperature cutout sensors.
6. If an alternate manufacturer provides 2 separate evaporators, the chiller shall be provided with the required manifolds, and pressure gauges, and controls, to ensure equal flow is provided to each evaporator.
7. Proof of flow shall be provided by the equipment manufacturer, mechanically installed and electrically wired, at the factory of origin.

F. Condenser & Condenser Fans:

1. Condenser coils shall be of constructed of microchannel design and constructed of aluminum. Designs with aluminum fins mechanically bonded to condenser tubes are also permitted. The condenser coils shall have an integral subcooling circuit and shall be designed for 525 psig or higher working pressure.
2. Condenser fans shall be dynamically and statically balanced, direct-drive, corrosion resistant, low noise fan blade. Air shall be discharged vertically upward.
3. Fans shall be protected by coated steel wire safety guards.
4. Coil Coating: the chiller condensing coils shall be provided with a flexible, epoxy polymer e-coat uniformly applied to all coil surface areas without material bridging between fins. Humidity and water immersion resistance shall be up to a minimum 1,000 and 250 hours respectively (ASTM D2247-92 and ASTM D870-92). [ADD3]

G. Refrigeration System:

1. The unit shall have at a minimum two (2) compressors manifolded together to from a circuit. The circuit shall have a liquid line shutoff valve, suction service valve, filter, liquid line sight glass, electronic expansion valve, charging valve, discharge and oil line check valves, high side pressure relief valve, and full charge of refrigerant.
2. Provide capacity modulation. The chiller shall be capable or operation down to 40% of rated capacity.
3. Size electronic expansion valve for maximum circuit operating pressure.

H. Chillers Controls:

1. The chillers shall be provided with a controls package capable of controlling the units and interfacing with the buildings BAS system. The control system shall be Microprocessor based and capable of performing chilled water temperature control, chiller operation, safeties, and diagnostics.

2. Capabilities: The chiller control system shall be capable of performing the following functions:

   a. Status (on or off).

   b. Seven-day time scheduling of pump(s) and chiller.

   c. Condenser fan sequencing to automatically cycle fans in response to ambient, condensing pressure and expansion valve pressure differential thereby optimizing unit efficiency.

   d. A variable method to control capacity in order to maintain leaving chilled water temperature based on PI algorithms. solid state anti-recycle timer to prevent compressor from short cycling.

   e. Chilled water pump output that activates when the chiller is given a signal to start.

   f. Load limit thermostat to limit compressor loading on high return water temperature.

   g. High ambient unloader pressure controller that unloads compressors to keep head pressure under control and help prevent high pressure nuisance trip outs on days when outside ambient is above design.

   h. Compressor current sensing unloader unit that unloads compressors to help prevent current overload nuisance trip outs.

   i. Auto compressor lead-lag functions that constantly even out run hours and compressor starts automatically. If the manufacturer cannot provide this function then cycle counter and hour meter shall be provided for each compressor so owner can be instructed by the HVAC contractor on how to manually change lead-lag on compressors and even out compressor starts and running hours.

   j. Low ambient lockout control with adjustable setpoint.

   k. User Interface: Provide user interface on the control panel. The interface shall display the following features:

      1) Leaving chilled water setpoint adjustment from LCD input.

      2) Entering and leaving chilled water temperature output.

      3) Percent RLA output for each compressor.

      4) Pressure output of condenser.

      5) Pressure output of evaporator.

      6) Ambient temperature output.

      7) Current limit setpoint adjustment from LCD input.

3. Safeties:

   a) Provide the following safety controls with indicating lights or diagnostic readouts.

      (1) Reverse rotation.

      (2) Low chilled fluid temperature.

      (3) Loss of chilled water flow.

      (4) Low oil pressure (each compressor unit).

      (5) Ground current fault.

      (6) Thermal overload.

      (7) High refrigerant pressure.

      (8) Motor current overload.

      (9) Phase reversal/unbalance/single phasing.

      (10) Current imbalance.

      (11) Failure of water temperature sensor used by controller.

(12) Over/under voltage.

b) Fan motors shall have inherent overcurrent protection.

c) The unit controller shall utilize the following components to automatically take action to prevent unit shutdown due to abnormal operating conditions which will perform as follows: High pressure switch that is set 20 PSIG lower that factory pressure switch, Motor surge protector that is set at 95% of compressor RLA, and a low-pressure switch that is set at 5 PSIG above the factory low pressure switch. If these cases occur, the chiller will continue to run in an unloaded state, and will continue to attempt to meet the cooling load. However, if the chiller reaches the trip-out limits, the chiller controls will take the chiller off line and a manual reset will be required.

4. Control Panel: On the chiller, mount weatherproof control panel, containing starters, power and control wiring, factory wired with terminal block power connection. Provide primary and secondary fused control power transformer and a 115 Volt 60 Hz single phase connection for evaporator freeze protection heaters. A control power transformer shall be factory-installed and factory-wired to provide unit control power from the main unit power connection. Control panel doors shall have door stays.

5. Display Diagnostics:

a) Display module shall be capable of displaying set points, time, system status (including temperatures, pressures, and percent loading), and any alarm or alert conditions.

b) Compressors: Status (on/off), %RLA, anti-short cycle timer, and automatic compressor lead-lag.

6. BAS System communication minimum points list: The chiller BACnet controller shall be capable of interfacing with the building BAS system and communicating at a minimum the following control points between the chiller and BAS system.

a. Chiller Enable.
b. Chiller Runtime.
c. Outdoor air temperature.
d. OA Reset High/Low
e. Chilled water supply setpoint.
f. Chilled water entering temperature.
g. Chilled water leaving temperature.
h. Set point source.
i. Flow Switch Status.
j. Suction Pressure.
k. Discharge Pressure.
l. Discharge Temperature.
m. Compressor Enable.
n. Compressor run time.
o. Compressor Lockout.
p. Pumpdown Command.
q. Lead Lag Staging/Status.
r. Lockout Set Point.
s. Compressors Status.
t. General Alarm.

I. Electrical Characteristics:

1. Unit shall operate on 3-phase power at 208 volts.

2. Control voltage shall be 115-V (60 Hz), single-phase, from factory installed transformer.
3. The unit shall ship with a two plug 115V (60 Hz) service plug rated for 15 amps on one side of the chiller base.
4. Unit shall be shipped with factory control and power wiring installed.
5. Non-fuse Disconnect: Unit shall be supplied with factory-installed, non-fused electrical disconnect for main power supply.

J. Sound Performance: At full load chiller sound pressure shall not exceed 70 (dBA) A-weighted at 30 feet from the side of the unit. At part load chiller sound pressure shall not exceed 60 (dBA) A-weighted at 30 feet from the side of the unit. Submitted sound data shall be in accordance with AHRI 370. Provide manufacturer's sound reduction accessory kit which shall include panels with sound blankets designed to reduce sound levels and protect coils.

K. Warranty: The chiller manufacturer must comprehensively warrant all equipment and material of its manufacturer and all equipment and material of all subassemblies manufactured by others but factory installed onto the chiller (i.e. adjustable speed drive, control components) against defects in workmanship and material for not less than one year from the date of substantial completion.

1. The motor/transmission/compressor warranty shall be 5 years.
2. The comprehensive equipment and material warranty must repair or replace defective components, including labor to do so, at no cost to the customer.
3. Any removal of refrigerant, evacuation of the refrigerant circuit(s), reinstallation of refrigerant and lubricating oil and replacement of lost refrigerant and oil required due to the warranted defect or the consequent warranted repair must be provided as part of the warranted repair and at no cost to the customer.

L. Installation:

1. Align chiller package on the existing roof supports for the existing chiller and 8x8 sleepers and install in accordance with manufacturer's instructions. The chiller shall also be vibrational isolated from the building and positively attached to withstand a sustained 108 mph winds per 780 CMR Chapter 16. (See Seismic, Wind
2. Chiller shall be installed level. Add shims as required so that the chiller is level within 1/2" over the entire length and width.
3. Arrange chiller piping for easy dismantling to permit tube cleaning.
4. Startup shall be performed by a factory trained and authorized servicing technician.
5. During the first 12 months of operation, a factory-trained and authorized servicing technician shall perform quarterly on-site operating inspections to confirm the chiller's operational performance. The manufacturer shall provide the owner with a report describing the condition of the equipment, current operating log, any issues found, with those needing immediate attention listed first. The report should also list any corrective action taken, or to be taken.

2.20 DEDICATED OUTDOOR AIR SYSTEMS (DOAS)

A. Furnish and install, roof mounted dedicated outdoor air unit as specified on the design drawings. The HVAC contractor shall be responsible for any electrical, mechanical, or structural modifications required when substituting a product other than the basis of design scheduled on the drawings. Products shall be provided by the following manufacturers: AAON, Captive Aire, Carrier, Daikin, Greenheck, JCI/York, Trane, or engineer approved equal.

B. Rooftop DOAS Units

1. Outdoor air handling unit shall include casing, filters, supply fans, dampers, heat pump and reheat coils, exhaust fans, energy recovery wheels, accessories and roof curb adaptor.
2. Unit shall be factory assembled and tested including leak testing of the coils, and run testing of the completed unit. Run test report shall be supplied with the unit in the controls compartment's literature pocket.
3. Unit shall have decals and tags to indicate lifting and rigging, service areas and caution areas for safety and to assist service personnel.

4. Unit components shall be labeled, including pipe stub outs, refrigeration system components and electrical and controls components.
5. Estimated sound power levels (dB) shall be shown on the unit ratings sheet.
6. Installation, Operation and Maintenance manual shall be supplied within the unit.
7. Laminated color-coded wiring diagram shall match factory installed wiring and shall be affixed to the interior of the control compartment's access door.
8. Unit nameplate shall be provided in two locations on the unit, affixed to the exterior of the unit and affixed to the interior of the control compartment's access door.

C. Construction
1. All cabinet walls, access doors, and roof shall be fabricated of double wall, impact resistant, rigid polyurethane foam panels.
2. Unit insulation shall have a minimum thermal resistance R-value of 13. Foam insulation shall have a minimum density of 2 pounds/cubic foot and shall be tested in accordance with ASTM D-1929 for a minimum flash ignition temperature of 610°F.
3. Unit construction shall be double wall with G90 galvanized steel on both sides and a thermal break. Double wall construction with a thermal break prevents moisture accumulation on the insulation, provides a cleanable interior, prevents heat transfer through the panel, and prevents exterior condensation on the panel.
4. Unit shall be designed to reduce air leakage and infiltration through the cabinet. Cabinet leakage shall not exceed 1% of total airflow when tested at 3 times the minimum external static pressure provided in AHRI Standard 340/360. Panel deflection shall not exceed L/240 ratio at 125% of design static pressure, at a maximum 8 inches of positive or negative static pressure, to reduce air leakage. Deflection shall be measured at the midpoint of the panel height and width. Continuous sealing shall be included between panels and between access doors and openings to reduce air leakage. Refrigerant piping and electrical conduit through cabinet panels shall include sealing to reduce air leakage.
5. Roof of the unit shall be sloped to provide complete drainage. Cabinet shall have rain break overhangs above access doors.
6. Access to filters, dampers, cooling coils, reheat coil, heaters, exhaust fans, return fans, energy recovery wheels, compressors, water-cooled condensers, and electrical and controls components shall be through hinged access doors with quarter turn, zinc cast, lockable handles. Full-length stainless-steel piano hinges shall be included on the doors.
7. Exterior paint finish shall be capable of withstanding at least 2,500 hours, with no visible corrosive effects, when tested in a salt spray and fog atmosphere in accordance with ASTM B 117-95 test procedure.
8. Units with cooling coils shall include double sloped corrosion proof drain pans.
9. Unit shall be provided with base discharge and return air openings. All openings through the base pan of the unit shall have upturned flanges of at least 1/2 inch in height around the opening.
10. Unit shall include lifting lugs on the top of the unit.
11. Unit base shall be fabricated of 1-inch thick double wall, impact resistant, rigid polyurethane foam panels.
12. Unit shall include factory wired control panel compartment LED service lights.

D. Electrical
1. Unit shall be provided with standard power block for connecting power to the unit.
   a. Unit shall be provided with factory installed and factory wired, non-fused disconnect switch.
   b. Unit shall be provided with factory installed and field wired 115 v. 20-amp GFI outlet in the unit control panel.
   c. Weather proof utility type lights with a switch at unit.
   d. Unit shall be provided with phase and brown out protection which shuts down all motors in the unit if the electrical phases are more than 10% out of balance on voltage, the voltage is more than 10% under design voltage or on phase reversal.

E. Supply Fans
1. Unit shall include direct drive, unhoused, backward curved, plenum supply fan(s). The fans must be selected to deliver the scheduled CFM at the scheduled Total Static Pressure.

2. Blowers and motors shall be dynamically balanced and mounted on rubber isolators. Blower and motor assembly shall utilize neoprene gaskets.
3. Motor shall be variable speed, high efficiency electronically commutated motor. Variable frequency drives are acceptable alternatives. VFDs shall be factory wired and mounted in the unit
4. Provide self-aligning, grease lubricated ball or roller bearings selected for L50 200,000-hour average life per ANSI/AFBMA 9. Extend both grease lubrication fittings to drive side of unit with plastic tubes and Zerk fittings rigidly attached to drive side-bearing support.
5. ECM driven supply fan speed shall be controlled with field provided 0-10 VDC control signal.

F. Exhaust Fans
1. Fans and motors shall be dynamically balanced.
2. Motors shall be premium efficiency ODP with ball bearings rated for 200,000 hours service with external lubrication points.
3. Access to exhaust fans shall be through double wall, hinged access doors with quarter turn lockable handles.
4. Unit shall include belt driven, unhoused, backward curved, plenum exhaust fans.
5. Variable frequency drives shall be factory wired and mounted in the unit. Fan motors shall be premium efficiency.

G. Coil Section with Factory Installed Coils: The coil section shall be provided complete with coil and coil holding frame. Coil section side panels shall be easily removable to allow for removal and replacement of coils without impacting the structural integrity of the unit. The coils shall be installed such that headers and return bends are enclosed by unit casings. If two or more cooling coils are stacked in the unit, an intermediate drain pan shall be installed between each coil.
1. Condensate Drain Pans:
a. Primary Drain Pan: Provide double-sloped corrosion proof drain pan of sufficient size to collect all condensation produced from the coil and sloped to promote positive drainage to eliminate stagnant water conditions. The outlet shall be located at the lowest point of the pan and shall be sufficient diameter to preclude drain pan overflow under any normally expected operating condition
b. Intermediate drain pan: the intermediate drain pan shall be designed being of sufficient size to collect all condensation produced from the coil and sloped to promote positive drainage to eliminate stagnant water conditions. The intermediate pan shall begin at the leading face of the water-producing device and be of sufficient length extending downstream to prevent condensate from passing through the air stream of the lower coil. Intermediate drain pan shall include downspouts to direct condensate to the primary drain.
2. Modulating Electric Heating Section
a. The unit(s) may have fully modulating, SCR controlled, electric heat. The primary heating section will include finned tubular heating elements, automatic and manual cut-outs, low voltage controls, air proving switch, maximum 48 amps per circuit and fusing for heaters over 48 amps.
b. Heater shall be internal to unit cabinet and downstream of the evaporator fan.
c. Heater shall be UL or CSA listed and approved and provide single point power connection.
3. Evaporator Condenser and Reheat Coils
a. Evaporator and hot gas reheat coils shall be constructed of copper tubes mechanically bonded to a configured aluminum plate fin.
b. Coils shall be leak tested at the factory to ensure pressure integrity. The evaporator coil, reheat coil and condenser coil shall be leak tested to 500 psig and pressure tested to 500 psig.
c. The condenser coil shall have a fin designed for ease of cleaning.
d. Evaporator coil shall have four interlaced rows for superior sensible and latent cooling with a maximum of 12 fins per inch.
e. Reheat coil shall be fully integrated into the supply air and fan system and capable of delivering design supply air temperature.
f. To prevent re-hydration of condensate from evaporator coil, the evaporator coil face and the hot gas reheat coil face shall be separated a minimum of six inches.
4. Condenser Section:

a. Outdoor Fans: vertical discharge, direct drive fans constructed of glass reinforced polypropylene blades. Fans shall be low-noise and corrosion resistant. Other fan construction is not acceptable

5. Refrigeration System
   a. Compressor(s): All units shall have direct drive, hermetic, digital scroll type compressors on the first circuit
   b. Motor shall be suction gas-cooled and shall have a voltage utilization range of plus or minus 10 percent of unit nameplate voltage.
   c. Internal overloads shall be provided with the scroll compressors.
   d. Each compressor shall have a crankcase heater to minimize the amount of liquid refrigerant present in the oil sump during off cycles.
   e. Provide each unit with hermetically sealed refrigerant circuit(s) factory-supplied completely piped with liquid line filter-drier, liquid line charging port, discharge, suction and liquid line pressure ports, sight glass, thermal expansion valve, 4-way reversing valve, suction line accumulator, and charge compensator.
   f. Provide each circuit with automatic reset high and low pressure switches for safety control.
   g. Refrigerant Capacity Control: Capacity control for units equipped with digital scroll compressors on the primary circuit shall be accomplished through a 0-10V signal by the MCM to the compressor controls
6. Filters:
   a. Unit shall include 4-inch thick, pleated panel filters with an ASHRAE efficiency of 30% and MERV rating of 13, upstream of the cooling coil.
   b. Unit shall also include 2-inch thick, pleated panel pre-filters with an ASHRAE MERV rating of 8, in the outdoor air stream upstream of the energy recovery wheel(s).
   c. Provide clogged filter switches across the filter bank.
   d. Provide a Magnehelic gauge, measuring the pressure drop across the filter rack, mounted in the controls compartment.
7. Damper Assemblies:
   a. Unit shall include motor operated outside air, exhaust air, and economizer damper assemblies constructed of extruded aluminum, hollow core, airfoil blades with rubber edge seals and aluminum end seals. Damper blades shall be gear driven and designed to have no more than 4 cfm of leakage per sq ft. at 4 in. w.g. air pressure differential across the dampers. Low leakage dampers shall be Class 1 AMCA certified, in accordance with AMCA Standard 511. Damper assembly shall be controlled by spring return fully modulating actuator.
   b. Dampers and actuators shall be provided and installed by the unit manufacturer. Control of the dampers shall be by the ACT contractor.
   c. The dampers shall be sized and constructed to allow for 0-100% economizer operation.
8. Energy Recovery:
   a. Unit shall contain a factory mounted and tested energy recovery wheel(s). The energy recovery wheel(s) shall be mounted in an insulated rigid cassette frame containing the wheel drive motor, drive belt, wheel seals and bearings. Frame shall slide out for service and removal from the cabinet.
   b. Wheels shall be wound continuously with one flat and one structured layer in an ideal parallel plate geometry providing laminar flow. The layers shall be effectively captured in stainless steel wheel frames or aluminum and stainless-steel segment frames that provide a rigid and self-supporting matrix.
   c. Wheels shall be provided with removable energy transfer matrix. Wheel frame construction shall be a welded hub, spoke and rim assembly of stainless, plated and/or coated steel and shall be self-supporting without matrix segments in place. Segments shall be removable without the use of tools to facilitate maintenance and cleaning. Wheel bearings shall be selected to provide an L-10 life in excess of 400,000 hours. Rim shall be continuous rolled stainless steel and the wheel shall be connected to the shaft by means of taper locks.
   d. All diameter and perimeter seals shall be provided as part of the cassette assembly and shall be factory set. Drive belts shall be provided for wheel rim drive without the need for external tensioners or adjustment.

e. The energy recovery cassette shall be an Underwriters Laboratories Recognized Component for electrical and fire safety. The wheel drive motor shall be an Underwriters Laboratory Recognized Component and shall be mounted in the cassette frame and supplied with a service connector or junction box. Thermal performance shall be certified by the manufacturer in accordance with ASHRAE Standard 84, Method of Testing Air-to-Air Heat Exchangers and AHRI Standard 1060, Rating Air-to-Air Energy Recovery Ventilation Equipment. Cassettes shall be listed in the AHRI Certified Products.

f. Unit shall include 2-inch thick, pleated panel outside air filter with an ASHRAE efficiency of 30% and MERV rating of 8, upstream of the wheels.

g. Hinged service access door shall allow access to the wheel(s).

h. Total energy recovery wheels shall be coated with silica gel desiccant permanently bonded by a process without the use of binders or adhesives. The substrate shall be lightweight polymer and shall not degrade nor require additional coatings for application in marine or coastal environments. Coated segments shall be washable with detergent or alkaline coil cleaner and water. Desiccant shall not dissolve nor deliquesce in the presence of water or high humidity.

i. Unit shall include energy recovery wheel defrost control which includes an adjustable temperature sensor and timer wired to periodically stop the wheel rotation, which allows the warm exhaust air to defrost the wheel.

j. Unit shall include energy recovery wheel rotation detection sensors and a set of normally open and normally closed contracts for field indication of wheel rotation.

k. Substitutions: Energy recovery cores may be considered as an equal. Manufacturers unit shall provide all required controls and performance. Manufacturer shall include all costs for required modifications to the design for the substitution including electrical, ductwork, roof curb, and controls requirements. The substitution shall occur at no additional cost to the owner.

9. Controls

a. Control Panel: Unit shall be provided with an internal control cabinet with a hinged service access door with a quarter-turn lockable handle.

b. The unit shall be constructed so that it can be operated as a DOAS controlled by the Building Management System (BMS). The ATC Sub-subcontractor shall provide all required controls (hardware, software and sensors) to provide a working system as per the ATC specification. and sequence of operation.

10. Accessories:

a. Unit shall be provided with a smoke detector sensing the exhaust\ and supply air of the unit, wired to shut off the unit’s control circuit.

b. Unit shall be provided with a safety shutdown terminal block for field installation of a smoke detector which shuts off the unit's control circuit.

c. Unit shall include outside air hood and air opening bird screens.

11. Curb Adaptors:

a. Curb adaptors shall to be fully gasketed for the surfaces between the existing curb and the curb adaptor and the curb adaptor and unit bottom with the curb providing full perimeter support, cross structure support, vibration isolation, wind and seismic restraint while providing the air seal for the unit. Curb gasket shall be furnished within the control compartment of the dedicated outside air unit to be mounted on the curb immediately before mounting of the DOAS.

b. Solid bottom curb shall be factory assembled and fully lined with 1-inch neoprene coated fiberglass insulation and include a wood nailer strip. Curb shall be adjustable up to 3/4 inch per foot to allow for sloped roof. Knockdown curbs (with duct support rails) factory furnished for field assembly are acceptable.

12. Warranty:

a. Manufacturer shall provide a “parts only” warranty for a period of not less than one year from the date of substantial completion. Warranty shall cover material and workmanship that prove defective, within the specified warranty period, provided manufacturer’s written instructions for installation, operation and maintenance have been followed.

b. Energy recovery wheel cassette shall carry a 5-year non-prorated warranty, from the date of original equipment shipment from the factory.

c. Warranty excludes parts associated with routine maintenance, such as belts and air filters.

d. Coil coating shall carry a 5 year warranty, from the date of original equipment shipment from the factory.

2.18 AUTOMATIC TEMPERATURE CONTROL SYSTEM

A. General:

1. Furnish and install, as hereinafter specified and indicated on the drawings. The system shall be an extension of the existing direct digital control (DDC), and electric/pneumatic and electric/electronic control system. The new equipment shall be able to communicate via the existing communications protocols or be native BACnet-based. The Operator Workstation, all building controllers, application controllers and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135, BACnet.
   a. ADD ALTERNATE #1 – Install a complete DDC System including an updated head-end that will communicate with the new DOAS, Chillers factory mounted controllers, and provide and install new unitary controllers for the heating plant, and existing fan coil units.
   b. ADD ALTERNATE #2 – Install a new controller that will allow control of the existing AAON Unit, the new exhaust fans and dampers per the approved sequence of operation. The controller must have the ability to operate the Indoor Firing Range Ventilation System without any input from the BMS based on the scenes selected by the Range Master on the Scene Control Box provided under the Alternative. (See Scope of Work)
   c. ADD ALTERNATIVE #3 – Install a new standalone gas controller similar to INTEC Controls PolyGard 2 SGC6 or approved equal. Unitary controller that will control the new dampers and DDC damper actuators, as well as the speed of the new exhaust fans with EC Motors based on the CO and NOx levels in the Sallyport.
2. The automatic control system shall be Delta Controls.
3. The DDC control panels shall be programmed, monitored and controlled from a Building Management System (BMS) which includes an Operator Workstation (OWS) located per the owner's direction. The OWS shall be equipped with all software, programming and servicing tools, and access credentials to operate and maintain the system. The OWS shall be provided with essential software and network terminals for both remote access and local troubleshooting. All Input/Output points connected to DDC control panels shall be displayed on the BMS & OWS and Network Terminals. The OWS shall be remotely accessible using the building IT network.
4. The control system shall be furnished and installed by competent control engineers and mechanics.
5. The system shall be expandable for future equipment.
6. The control system shall include native BacNet control components with a web based graphical user interface (GUI). Up to five (5) concurrent users shall be able to access the control system using conventional web browser software (Internet Explorer, Google Chrome, Mozilla Firefox).
7. The ATC system shall communicate seamlessly with the specified Energy Efficiency Educational Display system.
8. The ATC system shall communicate seamlessly with Electrical, Photovoltaic, Natural Gas, Domestic Cold Water and Domestic Hot Water control points for trend-logging and energy logging.
9. IT IS THE RESPONSIBILITY OF THE HVAC SUBCONTRACTOR TO VERIFY THE CONTROL COMPONENTS BEING PROVIDED BY THE VARIOUS EQUIPMENT MANUFACTURERS AS PART OF THE EQUIPMENT AND REVIEW THIS INFORMATION WITH THE ATC SUBCONTRACTOR TO ENSURE WHAT EXTRA CONTROL COMPONENTS WOULD BE PROVIDED BY THE ATC SUBCONTRACTOR TO INSTALL A FULLY FUNCTION SYSTEMS AS NOTED IN THIS SECTION. ATC SUBCONTRACTOR IS RESPONSIBLE TO PROVIDE ALL CONTROL COMPONENTS FOR INSTALLATION AND OPERATION OF THE VARIOUS EQUIPMENT AS PER THIS SPECIFICATION.
10. The Automatic Temperature Controls System shall be on standby power provided by the building generator.

B. Scope:

1. Install and/or wire all control devices furnished with equipment which is not factory installed and/or wired. Furnish all control devices required for equipment to operate under these sequences which is not furnished with the equipment.

a. The boilers and associated primary pumps shall be controlled by the boiler's onboard controller. The BAS shall interface with the onboard controller for commands, status, and alarms. The existing boiler's controller shall be updated if it cannot control the new associated boiler pump.

b. The chillers shall be controlled by the chiller's onboard controller. The BAS shall interface with the onboard controller for commands, status, and alarms.

c. The VRF/VRV system indoor and outdoor units shall be controlled by the unit's onboard controller. The BAS shall interface through the gateway controller for commands, status, global points, setpoints, and alarms.

d. All other new and existing equipment controls are by the ACT contractor unless otherwise specified.

2. The control system shall consist of all hardware and software and not limited to, temperature sensors, thermostats, temperature transmitters, controllers, automatic valves, pressure sensors, DDC control panels, operator devices, and other accessory equipment, relays, transformers, automatic dampers and damper operators, along with a complete system of electrical & control wiring to fulfill the intent of the specification and provide for a complete and operable system. All control equipment shall be fully proportioning, except as noted otherwise. A well-defined component naming convention shall be established to clearly identify all the control components. The object naming convention shall be approved by the building Owner before controls installation and programming begins, and all existing and new controls shall conform to this naming system (which can be an extension of the existing system).

3. The Direct Digital Control System shall be capable of integrating multiple building functions including equipment supervision and control, alarm management, energy management, and historical data (trends) collection and archiving for five (5) years or longer, and shall consist of the following:

a. Stand-alone DDC Panels.

b. Stand-alone Application Specific Controllers (ACS's).

c. Personal Computer Operator Workstation.

d. Building architecture displaying the different spaces throughout the building.

e. License for five (5) seats.

The control system shall be capable of archiving the historical data on a local server if needed.

4. The System shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, stand-alone DDC panels, and operator devices.

5. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC panel shall operate independently by performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

6. Stand-alone DDC panels shall be able to access any data from or send control commands and alarm reports directly to any other DDC panel or combination of panels on the network without dependence upon a central processing device. Stand-alone DDC panels shall also be able to send alarm reports to multiple operator workstation without dependence upon a central processing device.

7. Provide capability to monitor and control the DDC system remotely. The BMS shall be capable of remote alarming in the form of text alerts and/or email.

8. System Adjustment: Upon completion of the project, the ATC Subcontractor shall completely adjust, ready for use, all thermostats, controllers, valves, damper operators, relays, and other items., provided under this section. Include a points check-out report.

C. The following incidental work shall be furnished by the designated contractor under the supervision of the control contractor:

1. The HVAC Subcontractor shall:

a. Coordinate the work required for the ATC system with other contractors.

b. Install automatic valves, instruments wells, taps, flow stations and other similar devices specified to be furnished by the ATC Subcontractor.

c. Provide, on magnetic starters furnished, all necessary auxiliary contacts, with buttons and switches in required configurations.

d. Furnish and install access doors or other approved means of access through ceiling and walls for service to control equipment.

2. The Sheet Metal Contractor shall:
   a. Install all automatic dampers and airflow stations that are specified to be supplied by the ATC Subcontractor.
   b. Provide necessary blank-off plates (safing) required to install dampers that are smaller than duct size.
   c. Assemble multiple section dampers with required interconnecting linkages and extend required number of shafts through duct for external mounting of damper motors.
   d. Furnish and install access doors or other approved means of access through ducts for service to control equipment.
3. The General Contractor shall provide all necessary cutting, patching.
4. The Electrical Subcontractor shall,
   a. Provide 120v power sources for use by the ATC Subcontractor as shown on the electrical drawings. All other required power sources shall be provided by the ATC Subcontractor.
   b. Wire all power feeds through all disconnect starters to electric motor.
   c. Wire and remote start/stop switches and manual or automatic motor speed control devices not furnished by the ATC manufacturer.
   d. Wire any electrical sub-metering devices not provided by the ATC manufacturer.
   e. Provide and wire to the fire alarm system all required smoke detectors. Detectors shall be installed by the Sheetmetal Contractor and wired to shut down the unit by the ATC Subcontractor.
   f. The Automatic Temperature Controls System shall be on standby power provided by the building generator.

D. Electric Wiring:
1. All electric wiring and wiring connections, either line voltage or low voltage, required for the installation of the temperature control system, as herein specified, shall be provided by the temperature control contractor unless specifically shown on the electrical drawings or called for in the electrical specifications. The wiring installation shall be in accordance with National and local codes and with the electrical portion of these specifications. All wiring shall be run concealed wherever possible. Exposed wiring in occupied spaces shall be run in raceways. Raceways shall be Wiremold 200 Series with all elbows, raceways, covers, mounting stops, box extensions and wiring for a complete and neat installation. 120-volt power shall be provided by the Electrical Subcontractor. Exposed wiring in the Mechanical spaces shall be run in EMT conduit.
2. All wiring shall comply with the requirements of the state and National Electric Code.
3. All control wiring required for the automatic control system shall be provided from these points by the ATC Subcontractor who shall provide transformers and all control devices required for the control system. The wiring installation shall be in accordance with National and Local Codes. All wiring shall be run concealed wherever possible. Exposed wiring in occupied spaces shall be run in raceways. Raceways shall be Wiremold 200 Series with all elbows, raceways, covers, mounting stops, box extensions and wiring for a complete and neat installation. Exposed wiring in the Mechanical spaces shall be run in EMT conduit. Provide control wiring between HVAC equipment and associated remote-control panels and between control panels and remote sensors. Provide all interfaces between HVAC equipment and the DDC system.
4. All conduits for control system wiring and cabling must match the color required in the electrical specifications.

E. Submittal Brochure: The following shall be submitted for approval:
1. Control drawings with detailed piping and wiring diagrams, including bill of material and description of operation for all systems.
2. Panel layouts and nameplate lists for all local and central panels.
3. Valve and damper schedules showing size, Cv, configuration, capacity and location of all equipment.
4. Calculations for valve coefficients (CVs).
5. Data sheets for all control system components.
6. Control strategies (software flow charts) shall be included within the first ATC shop drawing submittal. The listing of each strategy shall be in English and demonstrate the desired ATC sequence of operation. Submittal shall be complete with proposed schedules, listing of setpoints and end device point listing and address.

7. Sequence of operations. Provide narrative descriptions of sequences of operation, Descriptions shall not merely duplicate specified sequences of operations.
8. Point names and addresses.
9. System riser diagrams.
10. Data sheets for all control system components.

F. Owner Training: The controls contractor shall have the following training responsibilities:

1. Provide designated Owner personnel (5) 4-hour training sessions, (5) 4-hour follow ups during warranty period. The sessions shall cover all areas listed in this section including:
   a. General purpose of the system and equipment
   b. DDC panel equipment locations
   c. Review of control drawings and schematics
   d. Sequence of Operations for HVAC equipment: Occupied mode, start-up, normal operation, heating, ventilating, shutdown, unoccupied operation, night ventilation.
   e. Building Automation System: programming, trending, troubleshooting, alarms, manual operation, interface with equipment packaged controls.
   f. Energy conservation strategies and operations, system and setpoint adjustments.
   g. Preventative Maintenance and replacement part sources.
   h. O&M Manual review
   i. Questions and Answers.
2. Provide the Commissioning Authority and the Design Team with a training plan four weeks before the planned training.
3. The controls contractor shall provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on all the capabilities of the control system.
   a. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals and in all software displays. Manuals will be approved by the CxA and AE. Copies of audiovisuals shall be delivered to the Owner.
   b. The trainings will be tailored to the needs and skill-level of the trainees.
   c. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The Owner shall approve the instructor prior to scheduling the training.
   d. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
   e. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
   f. There shall be three (3) training sessions:
      1) Training I. Control System. The first training shall consist of 8 hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
      2) Training II. Building Systems. The second session shall be held on-site for a period of 8 hours of actual hands-on training after the completion of system commissioning. The session shall include instruction on:

3) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems.
4) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing set points and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
5) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
6) Every screen shall be completely discussed, allowing time for questions.
7) Use of keypad or plug-in laptop computer at the zone level.
8) Use of remote access to the system via phone lines or networks.
    i. Setting up and changing an fancoil unit controller.
    ii. Graphics generation.
    iii. Point database entry and modifications.
    iv. Understanding DDC field panel operating programming.
9) Training III. The third training will be conducted on-site six months after occupancy and consist of 8 hours of training. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

G. Guarantee: The control system designated on drawings and plans and herein specified shall be guaranteed to be free from original defects in both material and workmanship for a period of eighteen (18) months or normal use and service, excepting damages from other causes. This guarantee shall become effective starting the date the owner begins to receive beneficial use of the system. During the eighteen (18) month guarantee period, Contractor shall provide programming changes to the installed system as requested by the Owner for a maximum of forty (40) hours.

H. Programmed Maintenance:
1. Upon completion of the installation, the control contractor shall submit to the owner, an agreement to provide the necessary programmed maintenance to keep the various control systems in proper working condition.
2. This programmed maintenance agreement shall fully describe the maintenance work to be performed and shall advise the cost of this work during the guarantee period, as well as for subsequent years thereafter. For two (2) thru five (5) years, Contractor shall advise the cost breakdown for annual service, discount on parts, miscellaneous programming and telephone support.

I. Local Area Network:
1. Operator workstation and DDC panels shall directly reside on a dedicated local area network such that communication may be executed directly between controllers, directly between workstation, and between controllers and workstation on a peer-to-peer basis.
2. All operator devices, either network resident or connected via modems, shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network. Access to data shall be based upon logical identification of building equipment. Access to system data shall not be restricted by the hardware configuration of the facility management system. The hardware configuration of the EMA network shall be totally transparent to the user when accessing data or developing control programs.

J. Operator's Workstation:
1. Workstation shall be BACnet compliant, comply with BACnet Annex J for IP connections and must support remote connection to server.
2. Uninterruptible power supply shall be installed at the PC, sized for 50% spare capacity with sufficient capacity to allow emergency power for a minimum of 10 minutes backup.

K. Graphical User Interface Software:

1. Provide one (1) minimum graphical display per building system.
2. Operating System: Windows XP Professional and support ActiveX Controls.
3. System Configuration shall include:
    a. Create, delete or modify control strategies.
    b. Add/delete objects to the system.
    c. Tune control loops via the adjustment of control loop parameters.
    d. Enable/disable control strategies.
    e. Select points to be alarmed and define alarm state.
    f. Select points to be trended over a period of time and initiate the recording values automatically.
    g. System shall gather and display Energy Log Information
    h. System shall be capable of interfacing with Electrical, Photovoltaic, Natural Gas, Domestic Cold Water and Domestic Hot Water control points.
4. On-line Help
5. Security: Password protection.
6. System Diagnostics.
7. Built-in Editor: for the development of logic scripts.
8. Logic System shall execute defined logic scripts.
9. Graphical User Interface shall support distributed access through the alarm and historical modules, employ pull-down menus to permit operator to perform tasks with ease and minimum knowledge of HVAC Control System.
10. Graphical User Interface shall be capable of I/O points into .CSV format for input and editing in a spreadsheet such as Excel or Lotus 1-2-3.
11. Graphical User Interface shall include Real-Time Displays.
12. The temperature, airflow, GPM, and CO_2 control point shall be displayed graphically on the BMS pages for their respective units.
13. Alarm Display shall be provided with ability to allow the operator to view details of the alarm and acknowledge the alarm. Standard alarm details shall include: Date, Time, Event, Alarm Type, Operator, Priority, Comment, Tag-name, Group Name, Value of Variable in Alarm, Alarm Limit and Alarm State.

L. Remote Alarming:
1. Alarm Reporting shall be able to do the following:
    a. Listen to and acknowledge alarm details
    b. Max tag limit of 20K
    c. Four contact devices per operator
    d. Compatible with SuiteLink and DDE protocols
    e. Capable of e-mailing alarm log files at scheduled intervals
    f. Broadcast alarms over speakers, intercoms, radios and multimedia systems
    g. Send alphanumeric and numeric messages to pagers and mobile phones
    h. Ability to group alarms and prioritize individually
    i. Human voice recording
    j. Multiple operator clearance levels
    k. Daily schedule and personal calling preferences for each operator

M. Trending:
1. Real-Time Trending:
    a. Real-Time trend displays shall support up to 4 trend pens and unlimited trend windows per display.

b. Real Time time trend displays shall be able to continue to update regardless of whether the operator is currently viewing the trend window. Trend displays shall also support the option to update trends only when displayed in the active window.

c. Real-time trend displays shall support any local tag name or an expression that contains one or more local tag names including add, multiply, divide, or similar. to permit proper scaling of variables.

1. Historical Trending

a. Historical data shall be recorded and archived for all control points listed unless otherwise noted.

b. Historical trend display should allow the user to zoom in and out in time from 1 second up to 6 weeks in one display. It shall be possible to activate the zoom-in and zoom-out features using action scripted command buttons available to the operator.

c. The operator shall have the capability to pan backward and forward in time to view historically logged data.

d. The operator should have the capability to print out historically trended information in the form of a printed record for documentation purposes.

N. Energy Log Information:

1. System server shall be capable of periodically gathering energy log data stored in the field equipment and archive the information. Archive files shall be appended with new data, allowing data to be accumulated. Systems that write over archived data shall not be allowed unless limited file size is specified. Display all energy log information in standard engineering units.
2. All data shall be stored in database file format for direct use by third-party programs. Operation of system shall stay completely online during all graphing operations.
3. Operator shall be able to change the energy log setup information as well. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. All meters monitored by the system may be logged. System shall support using flow and temperature sensors for BTU monitoring.
4. System shall display archived data in tabular format form for both consumption and peak values. Data shall be shown in hourly, daily, weekly, monthly and yearly formats. In each format, the user shall be able to select a specific period of data to view.

O. Reports:

1. System server shall be capable of periodically producing reports of trend-logs, alarm history, device summary, energy logs, and override points. The frequency, content, and delivery are to be user adjustable.
2. All reports shall be capable of being delivered in multiple formats including text- and comma-separated value (CSV) files. The files can be printed, emailed, or saved to a folder, either on the server hard drive or on any network drive location.

P. WEB Interface:

1. BAS supplier shall provide Web-based access to the system as part of standard installation. Web browser shall tie into the network through an owner-supplied Ethernet network connection.
2. Browser Technology shall be Microsoft Internet Explorer v6.0 or later. PDA Browser connection shall be Pocket PC 2003, Windows Mobile 5.0, or Blackberry. All displays shall be viewable and the Web page host shall directly access real-time from the FMCS BACnet network and update automatically without user interaction. User shall be able to change data on displays if logged in with the appropriate user name and password.
3. Communications:

a. Web page host shall include two Ethernet network connections. One network connection shall be dedicated to BAS BACnet network and shall be used to gather real-time data from all the BACnet devices that form the BAS. This network shall communicate using BACnet, allowing the Web page host to gather data directly from units on the local LAN or from other projects connected over a WAN. This network shall also provide the connection to the BAS server for Web page generation.

b. The second Ethernet connection shall provide the physical connection to the Internet or an IP-based WAN. It shall be the port that is used for the browser to receive Web pages and data from the Web page host. The Web page host shall act as a physical barrier between the BAS network and the WAN or Internet connection

that allows the browser to receive Web pages and data. The two separate network connections provide for a physical barrier to prevent raw BACnet traffic being exposed on the IP network.

c. The Web page host shall provide for complete isolation of the IP and BACnet networks by not routing networking packets between the two networks.

d. BAS BACnet Ethernet network shall be provided and installed by the BAS supplier. Owner shall provide and incur any monthly charges of WAN/Internet connection.

Q. Control Units – General:

1. Provide an adequate number of control units to achieve monitoring and control of all data points specified and necessary to satisfy the sequence of operation for all mechanical systems shown on the plans. Multiple DDC controllers may control one system provided that all points associated with individual control loops are assigned to the same DDC controller. Points used for control loop reset such as outside air or space temperature are exempt from this requirement. Each of the following panel types shall meet the following requirements.

2. Controllers shall be suitable for the anticipated ambient conditions.

a. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at -40°F to 140°F and 5 to 95% RH, non-condensing.

3. Serviceability: Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.

4. Memory: The Control Units shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.

5. Diagnostics: The Building Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall assume a predetermined failure mode and generate an alarm notification.

6. Immunity to power and noise: Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 3 ft.

R. Control Panels

1. Local Control Panels: Unitized NEMA 1 cabinet with suitable brackets for wall or floor mounting, located adjacent to each system under automatic control. Provide common keying for all panels.

a. Fabricate panels of furniture-quality steel, or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish.

b. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL Listed for 600 volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.

c. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.

d. Provide ON/OFF power switch with over-current protection for control power sources to each local panel

S. Sensors:

1. Room Type Instruments: Day/night heating/cooling electronic space thermostats shall be provided as indicated on the drawings. Each room temperature thermostat shall include a terminal jack integral to the thermostat assembly. The terminal jack shall be used to connect a portable service tool or similar operator’s terminal to control and monitor all hardware and software points associated with the controller.

a. Each room thermostat shall also include the following auxiliary devices:

1) Setpoint Adjustment: local thermostats shall have ability to change room set-point temperature +/- 3ºF (adj.).

2) Temperature Indicator: Room thermostats shall have the room temperature setpoint as the primary display with the real time space temperature available for secondary view. The temperature indicator shall be digital display and shall be visible without removing the thermostat cover.

3) Occupancy override switch: The occupancy override switch shall have ability to override the room occupancy setting for 1.25 hours (adj.).

b. The setpoint adjustment shall allow for modification of the temperature by the occupant. Setpoint adjustment may be locked out, overridden or limited as to time or temperature through software by an authorized operator at the central DDC system.

c. The override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant. An authorized operator at the central DDC system may lock out, the override function overridden or limited as to the time through software.

d. Any thermostat or sensor located on an exterior wall or an interior wall adjacent to an interior space that is not maintained at a similar temperature during the winter (i.e., a sometimes-heated garage) must have an insulating base.

2. Temperature Sensors and Transmitters:

a. Accuracy:

1) Duct Mounted: Plus or minus 0.75F accuracy over a range of 20F to 120F. These temperature sensors may be thermistor or RTD; thermistors shall have a maximum 5-year drift of no more than .225°F maximum error of no more than .36°F.

2) Liquid: The temperature sensor must have an accuracy no worse than +/- 0.3C.

b. Insertion Elements in Ducts: Single point, 6 inches long; use where not affected by temperature stratification or where ducts are smaller than 4 sq. ft.

c. Averaging Elements in Ducts: 60 inches, long, flexible for use where prone to temperature stratification or where ducts are larger than 4 sq. ft.; 264 inches long, flexible for use where prone to temperature stratification or where ducts are larger than 10 sq. ft; length as required.

d. Insertion Elements for Liquids: Provide a sensor suitable for service with liquids; 1,000 Ohm @ 0C platinum RTD or 10K @ 25C thermistor. The sensor must be inserted into a separable brass or stainless-steel immersion well.

e. Outside-Air Sensors: Provide with NEMA 4 Watertight inlet fitting, shielded from direct sunlight. Locate sensor in a sheltered area on North side of building and monitor by BAS for use in specified control sequences.

3. Low Temperature Safety Thermostat: Snap acting, single-pole, single throw, manual reset switch which trips if temperature sensed across any 12 inch of bulb length is equal to or below setpoint.

a. Electrical low-temperature warning thermostats shall have 20 ft. low point sensitive elements (not averaging type) installed to cover the entire duct area. Where coils are two banks, two freezestats, wired in series, shall be provided.

b. Except as otherwise specified in the sequence or on the drawings, place the bulb(s) on the entering side of the first coil in the air handler unless the air handler has more than a 25% minimum outside setting and the first coil is a heating coil. In that case, place the bulb on the leaving side of the coil, no more than one inch (1") downstream of that coil.

c. Except as otherwise specified in the sequence or on the drawings, serpentine the bulb evenly across the duct area and place one run of the bulb within six inch (6") of the expected cold air stratification. (For example, if the outside air duct connects to the top of the return duct, one run of the bulb must be within six inch (6") of the top of the duct). Orient the lay of the bulb so it is parallel with the expected stratification. For example, if the outside air duct connects to the side of the return duct, run the bulb vertically. If the outside air duct connects to the top or bottom of the return duct, run the bulb horizontally.

4. High Temperature Safety Thermostat: Electric high-temperature thermostats shall have a bimetal type sensing element with at least a 10" insertion length. These thermostats shall be two-position manual reset type.

5. Humidity Sensors: Bulk polymer sensor element.

a. Accuracy: 2 percent at 10-90% RH with linear output.

b. Room Sensors: Range of 0 to 100 percent relative humidity

c. Duct and Outside-Air Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.

6. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
    a. Accuracy: +/- 1 percent of full scale with repeatability of 0.5 percent.
    b. Output: 4 to 20 mA, 0-5 vDC, 0-10 vDC.
    c. Building Static-Pressure Range: -.1 to .1, -0.25 to 0.25, -.5 to .5, -1.0 to 1.0 IN WC., jumper selectable.
    d. Duct Static-Pressure Range: 0 to 1, 0 to 2.5, 0 to 5, 0 to 10 IN WC., jumper adjustable.
    e. Water Differential Pressure Transmitter: Low differential pressure transducer for wet-wet application. 4-20 milliamp output signal. Setra C230 or equal.
7. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; proportional output 4 to 20 mA.
8. Airflow Monitoring Station: Provide an airflow measuring station on the outdoor air intakes of the Indoor Firing Range's RTU, and the DOAS unit. An airflow station will also be provided for the Indoor Firing Range's two exhaust air streams, and in the DOAS's exhaust ductwork after the heat wheel and before the exhaust louver. The station shall consist of electronic sensors using thermal dispersion to measure air flow. (The AFMS for the Indoor Firing Range shall be excluded from the BASE BID and carried as part of ADD ALTERNATE #3)
    a. The accuracy of each sensor must be +/- 2% of full scale reading over the range of 50 FPM to 5,000 FPM and temperature range of -20°F to 120°F.
    b. The probe assembly air flow accuracy must be +/- 5% of full scale reading over the range of 400 FPM to 5,000 FPM and temperature range of -20°F to 120°F when installed with five equivalent duct diameters of straight duct upstream and two equivalent duct diameters of straight duct downstream of the probe assembly.
    c. The transmitter must average the sensors' equally weighted measured velocities and output this result in FPM to the FMS by a linear 4-20 mA or 0-10 Vdc signal. The span of this signal must be field selectable so that the transmitters high output represents a velocity that is no more than 50% higher than the maximum expected velocity.
    d. The probes may be installed in the intake hood of HVAC equipment, insertion mounted through the side or top of duct, internally mounted inside the duct, or factory installed inside a prefabricated duct section. The permanent pressure drop of the probe assembly must not be higher than 0.1-inch WC at the maximum expected flow.
9. Equipment Operation Sensors:
    a. Status Inputs for Fans: Differential-pressure switch with adjustable range of 0 to 5 IN WC
    b. Status Inputs for Electric Motors: Current-sensing relay with current transformers, adjustable and set to 175 percent of rated motor current.
    c. Water-Flow Switches: Pressure-flow switches of bellows actuated mercury or snap-acting type, with appropriate scale range and differential adjustment, with stainless steel or bronze paddle.
10. Electronic Valve/Damper Position Indication: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
11. Carbon-Dioxide Sensor and Transmitter: Return air duct mounted or space (wall/ceiling) carbon dioxide sensors shall be provided for on the following Rooms: 004, 101, 107, 108, 117, 119, 202, 216, 215, 213, 218, 220, 221, and 224, as well as the exhaust and transfer air ductwork that serve the secure area (FCU B-7 and FCU B-8) the sensors shall all be accessible from the non-secure side. Single detectors, hard wired, using solid-state infrared sensors, suitable over a temperature range of 23°F to 130°F, calibrated for 0 to 2 percent, with continuous or averaged reading, 4 to 20 mA output, and wall mounted. Combination temperature and CO_2 sensors are not acceptable.
12. Occupancy Sensor: Passive infrared, with time delay, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment, for flush mounting (all spaces except for the indoor firing range, and the secure area).

T. Equipment
1. Stand-alone DDC Panels: Shall be microprocessor based multi-tasking, multi-user, real time digital control processors. Each stand-alone DDC panel shall consist of modular hardware and plug in enclosed processors,

communication controllers, power supplies, and input/output modules. A sufficient number of controllers shall be supplied to fully meet the requirements of this specification and the attached point list. Each DDC panel shall have sufficient memory to support its own operating system and data bases, including:

a. Control process.
b. Energy management applications.
c. Alarm management.
d. Historical/trend data for all points.
e. Maintenance support applications.
f. Custom processes.
g. Manual override monitoring.

2. Application Specific Controllers (ASC): The air handling units (DOAS, RTU, MAU, AHU, AC, FCU) shall be furnished with control panels by the unit manufacturer. Furnish and install application specific controllers for each cabinet unit heater, wall heater, unit heater and exhaust fans. Application specific controllers shall be 16-bit microcomputer based, providing a multi-tasking, multi-user operating system. The ASC controllers shall permit the simultaneous operation of all control, communication facilities management and operator interface software as programmed by the ACT Contractor or user. Modification of the on-board ASC controller data base shall be performed online using the built in or portable POT. Systems which require the ASC to be removed from service while DDC control sequences are modified shall not be accepted. ASC controllers shall utilize true floating-point arithmetic capabilities.

3. Local Control Panels:

a. All controllers, relays, and switches for equipment located within the mechanical equipment rooms shall be mounted on enclosed control panel with hinge lock type door mounted adjacent to the system controlled. All temperature setting, adjustments and calibrations shall be made at the system control panel. Each panel shall have a canopy light and on/off switch.
b. Details of each panel shall be submitted for approval prior to fabrication. Location of each panel shall be convenient for adjustment and service. Provide engraved nameplates beneath each panel mounted control device and air gauge clearly describing the function of said device and range of operation. All manual switches, dial thermometer and indicating air gauges shall be flush mounted on the hinged door.
c. All electrical devices within the panels shall be factory pre-wired to a number terminal strip. All wiring within the panel shall be in accordance with NEMA and UL standards and shall meet all local codes.
d. The boilers and chillers shall each be provided with manufacturer supplied onboard controller to control the standard operations of the equipment. Provide a DDC controller to allow for remote access and monitoring through the BAS.

4. Boiler Control System (By Boiler Manufacturer): Micro-Processor type electronic microprocessor-based boiler control system to operate the boilers and associated boiler pumps. This system shall be monitored by the BAS and shall interface with the BAS for alarms, status, and enable/disable commands.

a. The boiler control system shall be provided with the boilers and shall be by the boiler manufacturer.
b. Boiler control shall be equipped to monitor Outside Air temperature, Supply Water temperature, and shall directly control the Boiler modulation to maintain target water temperature.
c. Adjustable setpoint(s) for reset water and minimum water supply temperature; Boiler differential; and Warm Weather Shutdown.
d. The operational algorithm shall have a Proportional plus Integral plus Derivative (PID) logic structure and shall include:
    1) Primary pump output, Pump exercising and Pump purging.
    2) Boiler demand for space heating loads, and Setpoint demand for setpoint loads.
    3) Setback (Unoccupied & Occupied).
    4) Boiler pump with soft start and Boost.
e. Provide LED Display to visually indicate control status, display system temperatures, settings and menus.
f. Wiring chamber and terminals; Outdoor Air temperature Sensor; Heat Starter for Warm Weather shutdown, and System supply water temperature sensor.

g. Furnish and install Class II 24 Volt Transformer.

h. Boiler control panel shall be capable of interfacing with the BMS. ATC to provide BACnet Interface Bridge.

5. Automatic Control Valves:

a. Provide control vales as shown on the project drawings and as required to perform the sequence of operation. The valves shall be quiet in operation and fail-safe in normally open position in the event of power failure. All valves shall be capable of operation as required by the sequence of operation. All control valves shall be sized by the control manufacturer and shall be guaranteed to meet the loads as specified.

1) Ball Valves: Ball valves in sizes up to 2 inches shall have a brass or bronze body, NPT female connections. The value trim must include a stainless-steel ball and stem. In sizes over 2 inches the valve must have a brass, bronze or iron body, ANSI Class 125# flanges. The valve trim must include a stainless-steel ball and stem.

2) Globe Valve: Globe valves in sizes up to 2 inches shall have a bronze body and NPT female connections. Sweat or flare connections are allowed for copper piping. The valve must have stainless steel trim. The valve must have a renewable composition disc or metal to metal seating meeting ANSI Class IV leakage requirements. Globe valves over two inches shall have a brass, bronze, cast iron, ductile iron or steel body. ANSI Class 125/150 flanges for fluid temperatures, including steam superheat, up to 300 deg F. ANSI Class 250/300 flanges for fluid temperatures over 300 deg F. The valve must have stainless steel trim. The valve must have a renewable composition disc or metal to metal seating meeting ANSI Class IV leakage requirements.

3) Butterfly Valves: Butterfly pattern valves may be used in sizes over 2 inches. Valve must have a stainless steel, brass, bronze or iron lug body, ANSI Class 125/150 pound flanges and ANSI Class 150 body rating. Valve assembly must provide a bubble right close off that is 10 PSIG higher than the pump close off head plus one PSIG for every two feet (2') in elevation that the valve is located below the pump. The valve must have a stainless steel, aluminum bronze or nylon coated ductile iron disc. The valve must have a resilient replaceable seat or metal to metal seating meeting ANSI Class IV leakage requirements.

4) Pressure Independent Assembly: A pressure independent valve automatically adjusts to maintain the flow rate (GPM) set point established by its actuator's position as the supply to return differential pressure changes. The valve must maintain the GPM set point as the pressure difference across the valve varies from 5 PSID to 30 PSID. The GPM through the valve must not vary more than +/- 10% from the GPM set point as the GPM set point is changed from a value that is 10% of the valve's maximum scheduled GPM for the coil or application to a value that is the valve's maximum scheduled flow rate for the coil or application. Each valve must have test ports that allow the test and balance (TAB) contractor to determine the valve's GPM by using an instrument that measures differential pressure. If the valve does not have the required test ports, the FMS contractor may meet this flow measuring requirement by furnishing a separate venturi principle flow measuring station with test ports that allow the TAB contractor to determine the valve's GPM by using an instrument that measures differential pressure. The mechanical contractor must install this separate flow measuring station as part of the valve assembly, following any requirements for straight pipe lengths before and after the station. The ACT contractor must provide plastic laminated calibration charts to the mechanical contractor for each unique kind and / or size and / or GPM range of pressure independent valve or venturi flow measuring station that allow the TAB contractor to convert differential pressure to GPM. These charts must be given to the owner as part of the operations and maintenance documentation.

b. The valve manufacturer recommended maximum pressure drop for modulation service must be greater than the pump shut off head for modulated valves in water or glycol solution service.

c. All hydronic valve assemblies, including packing, must be capable of continuous service at pressure of 125 psig and medium temperature of 250º F. The valves shall be sized for between 4 and 6 PSIG maximum pressure drop at design flow for modulating service. Size equal to line size and use full port design for two-position service. Two-way valves must have equal percentage characteristic, three-way valves linear characteristics. Two-way valve and actuator must be rated to close off against the pump shut off head. Three-way valve and actuator installed upstream of a pump must be rated to close off either inlet port against the shut off head of the more upstream pump supplying that pump. If the 3-way valve is a mixing valve for a coil, it must be rated to close off a 10 psig pressure difference across a closed port.

d. All valves sequenced with other valves or control devices shall be equipped with pilot positioners and position indicator on the actuator.

6. Automatic Control Valve Actuators: Valve operators shall be electronic using a 0-10 Vdc or 4-20 mA positioning input. They shall be of the molded synthetic rubber diaphragm type. Body pressure rating and connection type (screwed or flanged) shall conform to pipe schedule in this specification. All fail in place valve actuators on standard and pressure independent valves must have a manual means for an operator to position the valve.

7. Motorized Dampers:

   a. Automatic dampers, furnished by the control contractor shall be single or multiple blade as required. Dampers are to be installed by the sheet metal contractor under the supervision of the temperature control contractor. All blank-off plates and conversions necessary to install smaller than duct size dampers are the responsibility of the sheet metal contractor.

   b. All damper frames are to be constructed of #13-gauge galvanized sheet metal and shall have flanges for duct mounting.

   c. Damper blades shall not exceed 6" in width. All blades are to be corrugated type construction, fabricated from two (2) sheets of #22 galvanized sheet steel, spot welded together. Blades are to be suitable for high velocity performance.

   d. All damper bearings are to be made of nylon. Bushings that turn in the bearings are to be oil-impregnated sintered metal.

   e. Replaceable butyl rubber seals are to be provided with the damper. Seals are to be installed along the top, bottom and sides of the frame and along each blade edge. Seals shall provide a tight-closing, low-leakage damper. Leakage and flow characteristic charts must be submitted to the engineer prior to approval of dampers.

8. Damper Actuators:

   a. All damper operators shall be shall be electric On/Off spring return type and shall be fully proportioning, unless otherwise specified. They shall be quiet in operation and shall all have ample power to overcome friction of damper linkage and air pressure acting on louvers to position dampers accurately and smoothly. The damper operator mounting arrangement shall be outside the airstream wherever possible. The actuators must be designed so that they may be used for either clockwise or counterclockwise fail-safe operation. Actuators shall be protected from overload at all angles of rotation.

   b. The operators shall be capable of operating at varying rates of speed to correspond to the dictates of the controllers and variable load requirements. The operators shall be capable of operating in sequence when required by the sequence of the operation. The operators shall have external adjustable stops to limit the stroke in either direction. The operator linkage arrangement shall be such as to permit normally open or normally open or normally closed position of the dampers as required.

   c. All damper operators mounted on modulating dampers are to have pilot positioners of the fully relay type with an interconnecting linkage to provide mechanical feedback as to provide accurate positioning and control. Provide position indicator on the actuator.

9. Smoke Detection System: Duct smoke detectors shall be installed in all air handling equipment exceeding 2000 cfm. Upon detection of smoke, the unit shall be shut down. Unless noted otherwise, the detectors shall be installed in the return air duct or outside air duct as applicable

   a. Smoke Detector: ATC Subcontractor shall wire duct mounted smoke detectors, furnished by the Electrical Subcontractor.

   b. Smoke detectors shall be furnished and wired to building alarm system by the Electrical Subcontractor. Smoke detector shall be installed in air handling unit by the HVAC Subcontractor. All hard-wired interlocking for shutdown of fans shall be by the Electrical Subcontractor. The ATC Sub-subcontractor shall use the auxiliary contacts furnished and monitor these points, with an alarm sent to the central workstation.

   c. Except as otherwise specifically indicated, all supply, return and/or exhaust/ventilation systems 2000 cfm and larger that are interlocked with the air handling unit shall automatically stop when the in-duct smoke detectors are activated.

10. Control Cable: Electronic and Fiber-Optic Cable for Control Wiring: As specified in Division 16 Section "Control/Signal Transmission Media."

11. Lighting Control System shall be monitored through a BACnet connection to the FMCS provided by ATC (ADD ALTERNATE #1 Future Ability).
12. Natural Gas: shall be monitored by ATC providing, wiring and configuring a Mercury Corrector for Volumetric Pulse Outputs from the gas meter(s) serving HVAC and Domestic Hot Water Equipment. The Mercury Corrector shall be configured in Master Link software for pulse outputs.
13. Miscellaneous Devices: Provide all the necessary relays, cumulator, temperature and humidity sensors, carbon dioxide sensors, air flow measuring devices, positioners, transformers, and other devises to make a complete and operable system.
14. System Software:
    a. General:
        1) All necessary software to form a complete operating system as described in this specification shall be provided.
        2) The software programs specified in this section shall be provided as an integral part of the DDC panel and shall not be dependent upon any higher-level computer for execution.
    b. Control Software Description:
        1) Two position control.
        2) Proportional control.
        3) Proportional plus integral control.
        4) Proportional, integral, plus derivative control.
        5) Automatic control loop tuning.
    c. Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
    d. The system shall provide protection against excessive demand situations during start up periods by automatically introducing time delays successive start commands to heavy electrical loads.
    e. Upon the resumption of normal power, the DDC panel shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation.
15. Building Management Application Software:
    a. DDC panels shall have the ability to perform any of all of the following energy management routines.
        1) Time of day scheduling.
        2) Calendar based scheduling.
        3) Holiday scheduling.
        4) Temporary schedule overrides.
        5) Optimal start.
        6) Optimal stop.
        7) Night setback control.
        8) Peak demand limiting.
        9) Temperature compensated load rolling.
        10) Heating/Cooling interlock.
        11) Hot water reset
        12) Chilled water reset
        13) Economizer.
        14) Demand Control Ventilation (DCV).
        15) Supply Air Temperature Reset.
    b. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow user customization. Programs shall be applied to building equipment as described in the Sequence of Operation portion of this specification.

16. Points List: The Building Management System shall have the ability to control, adjust and monitor each system as described in the sequence of operation. Provide all control points as required to provide a fully functional and controllable system, including but not limited to those listed below:
    a. Global Points:
        1) Outdoor air temp. (DB/WB)
        2) Outdoor air humidity. (Rh)
        3) Outdoor Static Pressure
    b. Packaged Rooftop Units (DOAS):
        1) Unit enable/disable.
        2) Supply fan enable/disable.
        3) Supply fan status.
        4) Supply fan speed
        5) Supply airflow cfm.
        6) Discharge air temperature.
        7) Discharge air humidity.
        8) Discharge static pressure.
        9) Return airflow cfm.
        10) Return air temp.
        11) Return air humidity.
        12) Exhaust fan enable/disable.
        13) Exhaust fan status
        14) Exhaust fan speed
        15) Leaving Heat Pump Coil Low Temperature Alarm
        16) Outside air damper position
        17) Outside airflow cfm.
        18) Outside air minimum CFM setpoint.
        19) Outside air entering temperature. (DB/WB).
        20) Economizer On / Off status
        21) Economizer Damper
        22) Filter status.
        23) Indoor static pressure
        24) Occupied setpoint.
        25) Unoccupied setpoint.
        26) Return air CO_2 monitoring.
        27) Alarms
    c. Hot Water Boilers
        1) Boiler enable/disable.
        2) Boiler status.
        3) Boiler primary pump status
        4) Boiler leaving heated water temperature.
        5) Boiler entering heated water temperature.
        6) Outside air temperature.
        7) Boiler alarms.
    d. Hot water circulator pumps & system:
        1) Secondary pumps enable/disable

2) Pump status.
3) Variable frequency drives % command.
4) System differential pressure.
5) System proof of flow.
6) System Flow GPM
7) System (building) hot water supply temperature.
8) System (building) hot water return temperature.
9) Outside air temperature.
10) Alarms.

e. Exhaust Fans - General Exhaust:
1) Exhaust fan enable/disable.
2) Exhaust fan status.
3) Space Temperature
4) Alarm.

f. Fancoil Units (FCU):
1) Unit enable/disable.
2) Discharge air temp.
3) Chilled water valve position
4) Hot water valve position
5) Low Discharge Air Temperature Alarm.
6) Fan status
7) Room temperature.
8) Room humidity.
9) Room setpoint.
10) Room Occupancy
11) Room CO_2 Level
12) Unoccupied override
13) Filter status
14) Secondary drain moisture switch
15) Alarms

g. Unit Heaters/Cabinet Unit Heaters/Wall Heaters:
1) Unit enable/disable.
2) Unit status.
3) Room temperature.
4) Room setpoint.
5) Heating valve command.
6) Alarm.

h. Baseboard Radiation and Convectors:
1) Room temp.
2) Room setpoint.
3) Heating valve command.
4) Alarm.

i. Glycol Fill
1) Status.

2) Alarm.

j. CO_2 Monitoring
   1) CO_2 monitoring.
   2) Alarm.

k. Domestic Hot Water Heaters:
   1) Supply Water Temperature

l. Lighting System: (FUTURE)
   1) Occupancy Sensor.
   2) Day-light Sensor
   3) Momentary Switches for dimming control.

m. Sallyport Gas Monitoring System (ADD ALTERNATE #3)
   1) CO Levels
   2) NOx Levels
   3) CO Alarm
   4) NOx Alarm
   5) Sallyport Fan Speed
   6) Sallyport Fan Status
   7) Sallyport Fan Alarm
   8) Inlet Damper Position
   9) Inlet Damper Alarm
   10) Outlet Damper Position
   11) Outlet Damper Alarm
   12) Boiler Room Temperature
   13) Boiler 2 Status
   14) Boiler Damper Position
   15) Boiler Room High Temperature Alarm

n. Indoor Firing Range (ADD ALTERNATE #2)
   1) AAON Unit Status
   2) AAON Unit Start/Stop
   3) AAON Unit Discharge Air Temperature
   4) AAON Unit Low Temperature Alarm
   5) AAON Unit High Temperature Alarm
   6) AAON Unit Outside Airflow
   7) Space Temperature (existing sensor)
   8) Space Temperature (Average of the temperature at FR-1 and FR-2)
   9) Space Temperature Setpoint
   10) Exhaust Fan FR-1 Status
   11) Exhaust Fan FR-1 Start/stop
   12) Exhaust Fan FR-1 Airflow
   13) Exhaust Fan FR-1 Airflow Setpoint
   14) Exhaust Fan FR-1 Temperature
   15) Exhaust Fan FR-2 Status
   16) Exhaust Fan FR-2 Start/stop
   17) Exhaust Fan FR-2 Airflow

18) Exhaust Fan FR-2 Airflow Setpoint
19) Exhaust Fan FR-2 Temperature

2.19 SEQUENCE OF OPERATION

A. Dedicated Outdoor Air Systems (DOAS-1): The unit shall be a self-contained heat pump that has variable speed supply fans, direct expansion coil for heating and cooling, a direct expansion reheat coil to reheat the air while in dehumidification mode, and an electric heating coil that will be used only when the heat pump is not available to be use in heating mode, energy recovery wheel, and variable speed exhaust fans, with modulating outdoor air and exhaust air dampers. The unit shall be interfaced with the BMS for start/stop status and alarms. Install all control equipment furnished with the unit which are not factory installed, including remote control panels and potentiometer switches with dials. Provide a unit or duct mounted discharge air temperature sensor for the unit. Provide all control wiring. The unit shall be provided with occupied/unoccupied modes and economizer controls. The scheduling of occupied and unoccupied cycles of operation shall be determined from the BMS.

1. Operation: The building is in operation twenty-four a day.
    a. The outside air dampers and exhaust air dampers shall be open. The supply fan shall operate continuously and shall modulate to maintain a constant flow of outdoor air as measured by the air flow sensor. Unit controls shall control the digital scroll and scroll compressors in conjunction with the economizer cycle to maintain an discharge air temperature setpoint of 60°F The supply fan shall operate to maintain a duct static pressure of 0.75 inches water gauge and the exhaust fans shall track with the supply fans to maintain constant exhaust flow.
    b. Economizer: If the outside air temperature is below 69°F (adj.), shut-off the units cooling component and turn off the energy recovery wheel and enable the economizer to operate on demand for cooling. If the outside air temperature is 2°F above the economizer enable temperature, disable the economizer.
2. Alarms: Alarms must appear and buffer at the alarm reporting locations until acknowledged.
    a. If a unit fails to prove operation after commanded on or continues to prove operation after commanded off, annunciate an alarm.
    b. If the outdoor air flow, as measured by the AMS, varies by more than 15% from outdoor airflow setpoint, annunciate an alarm. This notification shall require a manual reset.
    c. If the low limit detection thermostat activates, annunciate an alarm. This is a critical alarm.
    d. If the air filter's pressure drop exceeds set point for more than 15 minutes when the supply fan speed is ½ of maximum or higher, annunciate an alarm. Setpoint must be adjusted for fan speed. The setpoint shall be 0.5 in WC (adj.) at maximum fan speed. The equation shall to determine setpoint at lower fan speeds shall be: $0.5 * (\text{fan speed in HZ} / \text{maximum fan speed in HZ})^2$.
3. Safeties: Safeties must be hard wired and not depend on the operation of the BMS to work.
    a. If the unit smoke detectors activate: stop the supply and exhaust fans, close OA and EA damper.
    b. If the temperature of the Discharge Air drops below 55F when the unit is calling for heat, the unit shall send an alarm to the facilities team to investigate the cause. The unit will continue to operate unit it can no long maintain the temperature in the Supply Air Ductwork above 50F for more than 30 minutes. The unit shall shutdown, and check its internal temperature.

B. MDF, Electrical, IT Rooms, and Combined Dispatch (ACCU):
1. If the DOAS unit or any of the fan coil units serving these spaces should fail or be out for maintenance. The remaining FCUs shall operate a constant speed and close their heating hot and chilled water valves. The outside air dampers shall modulate as required to maintain the Carbon Dioxide Levels and the Variable Refrigerant Volume System shall take over and maintain the space temperatures.

C. (Add Alternated #1) Exhaust Fans (EF): All EFs shall be controlled by a DDC controller and the BMS. The occupied and unoccupied cycles of operation shall be determined from the BMS. The unit shall be interfaced with the BMS for start/stop status and alarms. Provide all control wiring and indicated devices.
1. General exhaust fans (EF-1,2, 12): Exhaust fans shall be controlled by a DDC controller and the BMS.

a. Should the space temperature go above the setpoint (85F(adj.)), then the fan shall cycle on and run until the space temperature drops below the setpoint minus five degrees..
b. Unoccupied Cycle: The units shall be off.
c. Alarms: If the fan does not indicate operation when commanded on or indicates operation after commanded off, annunciate an alarm.

D. Fancoil Units & OA Dampers (FCU): The fancoil unit shall have a supply fan, chilled water-cooling coil, hot water heating coil, and an associated duct-mounted modulating outdoor air damper. The occupied and unoccupied cycles of operation shall be determined by the space occupancy sensor. The unit shall be interfaced with the BMS for status and alarms. Install all control equipment furnished with the unit which are not factory installed, including remote control panels and potentiometer switches with dials (New equipment only). Provide a space mounted CO_2 sensor (for Rooms 004, 107, 110, 101, 202, 224, and 229). Provide all control wiring. The units shall be provided with occupied/unoccupied cycles and morning warm-up modes.
1. Occupied Cycle: The supply fan shall operate continuously. Unit controls shall control the chilled water valve to maintain space cooling setpoint 75°F (adj.), and the hot water valve to maintain space heating setpoint. 70°F (adj.). The hot water coil shall serve as second stage of heat for the space after the FTR serving the space. The minimum OA for each unit shall be controlled by a CO_2 sensor located in the space. The outdoor air damper shall modulate open to maintain the CO_2 levels below setpoint.
2. Unoccupied Cycle: The units shall be off and the chilled water valve and heating water valve closed. The outside air dampers shall be closed. During the heating season, the FTR serving the spaces shall energize to maintain unoccupied/night setback space temperature setpoint. 60°F (adj.). If the FTR is unable to maintain the unoccupied space setpoint the unit shall energize and serve as second stage of heat. During cooling season, the unit shall energize as needed and shall control the chilled water valve to maintain space unoccupied/night setback space cooling setpoint 85°F (adj.).
3. CO_2 Control: The BMS must evaluate the rooms' CO_2 concentrations every 15 minutes (BMS adj.) If the CO_2 concentration is below 800 PPM, set the low value of 5% open (adj.). If the CO_2 concentration is above 1,400 PPM, set the high value of the percentage open required to meet the OA CFM shown on the drawings (adj.). As the CO_2 concentration changes between 800 PPM and 1,400 PPM, the outdoor damper minimum position is linearly reset between the low and high values.
4. Warm-up: When coming off night setback and upon a demand for heat, the outdoor damper shall be closed, the first stage of heat FTR shall be activated, and the hot water valve and supply fan shall modulate to bring the space up to the heating setpoint. Once the heating setpoint is reached, the unit shall resume normal operation.
5. Alarms: Alarms must appear and buffer at the alarm reporting locations until acknowledged.
   a. If the fan does not indicate operation when commanded on or indicates operation after commanded off, annunciate an alarm.
   b. If the outdoor air damper does not open when commanded, annunciate an alarm.
   c. If the outdoor air flow, as measured by the AMS, varies by more than 15% from outdoor airflow setpoint, annunciate an alarm. This notification shall require a manual reset.
   d. If the room CO_2 concentration is above 2,000 PPM for more than 0.5 hr (adj.) annunciate an alarm.
   e. If the room temperature is below 50°F, annunciate a critical alarm.
   f. If the air filter's pressure drop exceeds set point for more than 15 minutes when the supply fan speed is ½ of maximum or higher, annunciate an alarm. Setpoint must be adjusted for fan speed. The setpont shall be 0.5 in WC (adj.) at maximum fan speed. The equation shall to determine setpoint at lower fan speeds shall be: $0.5 * (\text{fan speed in HZ} / \text{maximum fan speed in HZ})^2$.
   g. If the moisture sensor in the supplemental drain pan senses water, annunciate an alarm. This is a critical alarm.
6. Safeties: Safeties must be hard wired and not depend on the operation of the BMS to work.
   a. If the fire alarm activates for the room the fancoil serves, disable the supply fan and close OA damper.
   b. If low temperature freezstat safety activates, close OA damper, disable fan, open the heated coil and chilled water coil valves to 100% and run until reset. The freezstat shall require a manual reset.

E. Glycol Fill Station: The glycol fill station shall consist of a duplex glycol fill assembly serving the heating water and chilled water systems. The unit shall use it's onboard controls to provide makeup solution to the hydronic systems. The BAS shall provide a connection to the unit to monitor status and unit alarms. Alarms must appear and buffer at the alarm reporting locations until acknowledged.

F. Carbon Dioxide Sensors (High Density Rooms): The BAS must monitor the CO_2 level in all densely populated rooms (ASHRAE 62.1-2015 default population density of 25 or more people per 1,000 SF) as shown on drawings. The BMS must evaluate the rooms' CO_2 concentrations every 15 minutes (BMS adj.) If the CO_2 concentration is above 1,800 PPM (BMS adj.) for consecutive measurements the BAS shall annunciate an alarm.

G. Add Alternate #2 (Indoor Firing Range): The existing AAON unit will be started and run continuously along with the two exhaust fans. The Exhaust fans can be arranged to operate at different speeds based on the scenario being run by the Range Master. The controller shall have the ability to alter the exhaust fans by change a switch from off to on. The controller shall have the ability to store five (5) scenes.

H. Add Alternate #3 (Sallyport Carbon Monoxide Control): The exhaust fans shall run continuously on low speed and increase the speed to maintain the levels of CO and NOx. If the levels are below the low-level set point for over an hour and the space is unoccupied then the controller shall stop the exhaust fan and close the dampers. Should the boiler room temperature get above 90F and Boiler Number 2 (the existing boilers) is NOT operating then the controller shall open the damper between the sallyport and boiler room, and open the exhaust air damper in the sally port. Once these two dampers are open then the new fan in the boiler room shall cycle on low and increase speed every five minutes that the temperature remains above 85F and the Boiler 2 does not operate.

PART 3 - EXECUTION

3.1 FIRESTOPPING

A. The Work of this Section shall include, but not be limited to, furnishing and installation of through-penetration firestop systems for penetrations through fire-resistance-rated assemblies.

B. For penetrations through fire-resistance-rated assemblies, provide through-penetration firestop systems that are produced and installed to resist spread of fire, resist passage of smoke and other gases, and maintain original fire-resistance rating of the assembly being penetrated.

1. Fire-resistance-rated assemblies include firewalls, fire partitions, fire barriers, smoke barriers, floors, floor/ceiling assemblies, and ceiling membranes of roof/ceiling assemblies.

C. Provide Shop Drawings for each through-penetration firestop system, indicating each type of assembly penetrated, relationships to adjoining construction, and type of penetrating item. Include UL through penetration firestop system design designation and qualified testing and inspecting agency that evidences compliance with requirements for each condition indicated.

D. Provide a drawing(s) and schedule(s) identifying the locations of penetrations and associated UL through penetration firestop systems, along with the following information:

1. Type of penetrating item including but not limited to material, size, bare or insulated, insulation material, and insulation thickness.
2. Type of assembly penetrated identified by a UL assembly designation.
3. Through-penetration firestop system to be used for each location identified by UL firestop design designation.

E. All through-penetration firestop systems, for each combination of penetration and assembly, shall be obtained from a single manufacturer.

F. Coordinate construction of openings and penetrating items to ensure that through-penetration firestop systems are installed according to the specific UL through penetration system designation requirements. Particular attention shall be paid to the annular space between penetrants and assemblies.

G. Coordinate sizing of sleeves, openings, core-drilled holes, or cut openings to accommodate the UL through-penetration firestop systems. Particular attention shall be paid to the annular space between penetrants and assemblies.

H. Provide through-penetration firestop systems that are compatible with one another; with the substrates forming openings; and with any items penetrating through-penetration firestop systems, under conditions of service and application, as demonstrated by the approved through-penetration firestop system manufacturer based on testing and field experience.

I. Provide accessory components for each through-penetration firestop system as required by the approved manufacturer to install fill materials. Use only components specified by the approved through-penetration firestop system manufacturer and approved by a qualified testing and inspecting agency for firestop systems indicated. Accessories shall include, but not be limited to, the following items:

1. Permanent forming/damming/backing materials, including the following:
    a. Slag or rock wool fiber insulation.
    b. Sealants used in combination with other forming/damming/backing materials to prevent leakage of fill materials in liquid state.
    c. Fire-rated form board.
    d. Fillers for sealants.
2. Temporary forming materials.
3. Substrate primers.
4. Intumescent collars.
5. Sleeves.

J. Drawings, schedules, and shop drawings shall be reviewed and approved by the General Contractor and Architect prior to submission to the Engineer for review, proof of which shall accompany such submission. Failure to provide proof of

the General Contractor's and/or Architect's review and approval will be grounds for immediate rejection of the submission.

3.2 PIPING

A. Provide and erect in a workmanlike manner all piping systems shown on plans or as required to complete the installation as intended. All piping shall be installed so as to provide access to all valves and equipment.

B. The drawings are schematic and do not indicate all offsets and fittings which may be required. The HVAC Subcontractor shall carefully investigate the structural and finish conditions of other trades affecting all his work and arrange his work accordingly.

C. All piping, valves, fittings and appurtenances shall be installed at sufficient distances from other work to permit clearance of not less than 1/2" between the finished covering of such piping and all adjacent work whether under this or any other section of the specifications.

D. All piping within the building shall be so installed that it shall in no way be strained or distorted by expansion and contraction. All mains and risers shall be securely anchored to the building construction. Anchors shall be constructed from heavy, forged wrought iron secured to the piping and the building construction.

E. This Contractor shall be held responsible for the quick and free circulation of water in all piping under actual working conditions. System shall be free from noise due to pipe expansion or contraction or from air.

F. In general, pitch all water piping up in the direction of flow. High points in all hydronic piping shall be vented.

G. Runouts to equipment connections and risers shall be so piped and valved that any one may be shut off without interfering with the system. A plugged drain cock shall be provided at each low point of each supply and each return so that the piping which is shut off may be drained. In making such connections, care shall be taken to provide sufficient pitch to vent the system. Water runouts shall pitch up to equipment above and pitch down to equipment below the main or branch. A 3/4" brass drain cock shall be placed on the return lines at circulators and capped ½" brass hose bibs shall be placed at all low points as necessary for complete drainage of all piping, leaving no pockets. Cocks shall be taken off tees.

H. All openings in pipe and fittings shall be capped or plugged until permanent connections are made. Use care to keep foreign materials out of the system. Where pipe or tubing cutters are used, or where the pipe is threaded, the burr shall be reamed out to the full inside diameter of the pipe

I. All welding shall be performed in accordance with the standard of workmanship set forth in the National Certified Pipe Welding Bureau, "Specification for the Fabrication and Erection of Piping Systems". Assume full responsibility for all deposited welds and repair all defects in welds developing within one year after final acceptance of the building, without additional cost to the Owner.

J. Where piping passes through fire rated walls and floors, the HVAC Subcontractor shall repack the openings with a fire-retardant material so as to maintain the integrity of the fire rated wall assemblies to the satisfaction of the Architect and as per the requirements of the above paragraph 3.1.

K. Valves installed above 8 ft. shall be equipped with chain falls for operation and maintenance.

3.3 DUCTWORK

A. Provide and erect in a workmanlike manner all ductwork systems shown on plans or as required to complete the installation as intended. The drawings are schematic and do not indicate all offsets and fittings which may be required. The HVAC Subcontractor shall carefully investigate the structural and finish conditions of other trades affecting all his work and arrange his work accordingly. All ductwork shall be installed so as to provide access to all dampers or equipment requiring access.

B. Fire dampers and combination fire dampers shall be installed with adequate access, retaining angles, and clearances for expansion in accordance with the Massachusetts Board of Examiners of Sheet Metal Workers *Sheet Metal Board Code Advisory – Fire Dampers and Combination Fire/Smoke Dampers* installation procedures.

C. Kitchen grease exhaust ductwork shall be provided with residue traps and clean outs at all duct elbows and elsewhere in accordance with NFPA 96.

D. Pressure Testing: Provide ductwork pressure testing as required by the applicable codes and in the construction documents.

1. Ductwork shall be pressure tested in accordance with SMACNA HVAC Air Duct Leakage Test Manual, the applicable version of the International Mechanical Code, and other applicable local building codes.

3.4 SYSTEMS IDENTIFICATION

A. Provide Identification for all HVAC ductwork, piping, and equipment included in the scope of the project. The identification shall be in accordance with the owner's identification scheme for the building or with ANSI/ASME Specifications.

1. Brush applied paint and adhesive marking systems shall not be used on this installation.

B. Ductwork: All ductwork shall be identified by pre-printed, color-coded, with lettering indicating system and showing flow direction. Ductwork shall be marked at each junction or branch takeoff, at least once in each room, and at intervals not longer than 20 ft. Stencil shall clearly identify duct service, area served by branch, and arrow indicating direction of flow. On each ductwork label in a mechanical room, prefix the system designation with the associated equipment number (Example: AHU-1 SUPPLY AIR). Provide markings 10 feet on center in mechanical rooms and 20 feet on center throughout the rest of the building.

C. Piping: All piping shall be identified by semi-rigid plastic pipe markings which shall be provided under this contract. Markers shall be applied on supply and return sides of pumps, chillers, and boiler, on supply and return lines throughout the building. Provide markings 10 feet on center in boiler and mechanical rooms and 20 feet on center throughout the rest of the building. Markings shall indicate pipe content and direction of flow. The basic marker shall be in color as called for under the ANSI Specifications A-13.1. Also, an identification of the pipe content and flow arrows shall be shown in black.

D. All valves on the new HVAC piping systems shall have circular brass valve tags of at least 1-1/2" in diameter, attached with brass hooks to each valve stem. Stamp number of the valve and the service, such as "HWS" "CHWS" "HWR" and "CHWR" for hot water supply, chilled water supply, chilled water return, and hot water return respectively. The numbers of each service shall be consecutive and shall correspond with the numbers indicated for valves and controls on the record drawings and on three printed valve lists. These printed lists shall state number and locations of each valve and control and the equipment which it controls and other necessary information, such as sequencing of valves.

1. These printed lists shall be prepared in a form to meet the approval of the Architect and one copy shall be framed under glass mounted in an approved location.

E. All items of mechanical equipment such as DOAS, AC, ACCU, boilers, FCUs, exhaust fans and pumps shall be identified by approved nameplates provided by this Subcontractor.

1. The nameplates to be aluminum 2-1/2" x 3/4" with a black background with etched or engraved natural aluminum lettering. The nameplates shall bear notations corresponding to the same unit notations indicated on the design drawings.
2. All equipment nameplates shall be conspicuously visible externally.
3. Units with unique names i.e. RTU-1 or DOAS-1 shall be tagged with the scheduled names.
4. Units with recurring tags i.e. FCU-A shall be identified with name followed by room number. FCU-A-B200

F. For all mechanical equipment and apparatus including but not limited to control valves, isolation valves, drain-off valves, FCUs, FDs, VAVs, smoke detectors, CO_2 sensors that are concealed above the ceiling this Subcontractor shall provide identification tags at the ceiling above which the above noted equipment is installed for clear identification by the Owner's personnel. The identification tags shall be aluminum 2-1/2" x 3/4" with a black background with etched or engraved natural aluminum lettering that bear notations corresponding to equipment being identified.

3.5 MATERIALS AND WORKMANSHIP

A. All specified materials and equipment shall be furnished new and free of defects.

B. Store all equipment and materials in a clean, dry place to preserve initial quality.

C. Protect installed materials and equipment against damage and corrosion. All equipment shall be left in a first-class condition. The Architect shall determine the adequacy of equipment condition and appearance and it shall be the responsibility of this Contractor to rectify any deficiencies. This shall include, but is not limited to furnishing and applying paint in accordance with the manufacturer's recommendation.

D. All work shall be installed in a first-class manner consistent with the best current trade practices. All devices, materials and equipment shall be securely installed plumb and/or level.

3.6 PROTECTION AND CLEANUP

A. Protection:
   1. Be responsible for the maintenance and protection of all material and equipment furnished during all phases of construction from loss, damage or deterioration until final acceptance by the Owner.
   2. All materials and equipment on the job site shall be suitably stored and protected from the weather.
   3. During the progress of the work all pipes, ducts and equipment openings shall be temporarily closed so as to prevent obstruction and damage.

B. Cleanup:
   1. After installation, equipment with factory finished surfaces shall be cleaned and damaged spots touched up with the same type paint applied at the factory.
   2. Keep the job site free from accumulation of waste material and rubbish, construction equipment and surplus materials from the site and leave the premises in a clean condition.

3.7 SYSTEM START-UP AND OPERATION

A. After completion of the installation and before acceptance by the Owner, this Contractor shall start-up, operate and thoroughly check the entire HVAC system to assure complete adherence to the design intent. It is intended that the start-up/operational endeavor shall conclusively establish that all systems are functioning properly with respect to rotation of equipment, wiring interlocks, control interlocks and sequential control. Should any portion of system performance be found to be contrary to the specified intent, same shall be corrected as required, at no cost to the Owner.

B. After completion of the system check procedure and when the HVAC Contractor is firmly convinced that all systems are performing properly and efficiently, he shall submit in writing to the Architect a certified statement to that effect.

3.8 SUPPLEMENTAL SUPPORTS

A. Furnish and install all supplementary steel, channels and supports required for the proper installation, mounting and support of all equipment. Method of attachment to the building structure shall be in a manner approved by the Architect. Type and size of supports shall be determined by the HVAC Contractor and shall allow only a minimum amount of deflection.

B. All supplementary steel and channels shall be installed in a neat and workmanlike manner parallel to the walls, floor and ceiling construction. All turns shall be made with 90 degree and 45-degree fittings, as required to suit the construction and installation conditions.

C. Coordinate with general contractor to provide concrete housekeeping pads for equipment indicated on the drawings. Provide dimensions of submitted equipment to verify pad sizes. housekeeping pads shall be of concrete, minimum four inch (4") thick and extending six inches (6") beyond supported equipment unless otherwise specified.

3.9 SAFETY PRECAUTIONS

A. Furnish, place and maintain proper guards for the prevention of accidents and any other necessary construction required to secure safety of life and property. Conform to all OSHA requirements.

3.10 TESTING, BALANCING AND CLEANING

A. The Contractor shall engage a Certified Balancing Contractor to balance and adjust the hydronic systems, air handling units, and exhaust systems, using methods and procedures which have been developed and employed to accomplish this service. The HVAC Subcontractor shall coordinate with the Balancing Contractor and provide required information, access and clearances.

1. Piping System Pressure Testing, Balancing and Cleaning:
    e. After completion of the installation of the entire water system and prior to acceptance, the system shall be adjusted and balanced to deliver the water quantities indicated on the drawings.
    f. Water balancing report shall include pumps size, horsepower, RPM, delivered amperage, brake horsepower, delivered system pressure differential and delivered GPM. Submit to the Architect six copies of the complete water balance report.
    g. All equipment and piping shall be thoroughly cleaned of foreign matter as they are installed. Cleaning and flushing of the systems with the main circulators operating and all trapped air removed shall be carried out in accordance with the specifications as indicated in Cleaning and Treatment of Hydronic Systems.
2. Air System Balancing and Cleaning:
    a. Before the systems are tested and balanced, all ducts and equipment shall be thoroughly cleaned so that no dirt, dust or other foreign matter will be deposited in or carried through systems. All filters shall be replaced after air handling systems have been cleaned.
    b. Each air supply, return and exhaust system shall be balanced to deliver within 10% the air quantities specified on the drawings.
    c. Final air quantities shall be achieved by adjusting fan outlet dampers and fan RPM. Final damper settings shall be permanently marked after air balance report.
    d. Set volume controller to airflow setting indicated for variable air volume system powered units. Confirm connections properly made and confirm proper operation for automatic variable air volume temperature control.
    e. Submit to the Architect six copies of the complete air balancing report. Air balancing report shall include for each fan system the fan size, make, model, fan and motor RPM, delivered amperage, CFM, fan static pressures and CFM at each air inlet and outlet.

3.11 COMMISSIONING

A. A Commissioning Agent shall be engaged by the owner to provide commissioning for all systems and equipment installed as part of this project. The HVAC Subcontractor shall coordinate with the Commissioning Agent and provide required information, access and clearances.

B. The commissioning process shall document and verify that the systems are operating as listed in the sequence of operation and shall comply with the requirements of the Owner. The HVAC Subcontractor shall provide all adjustments and modifications to the HVAC systems required for the systems to fulfill commissioning requirements.

C. The HVAC Subcontractor shall coordinate all required owner training of their systems with the Commissioning Agent. Refer to the requirements of these specifications see Paragraph 1.10 OPERATING INSTRUCTIONS AND MAINTENANCE MANUALS.

D. Provide to the Commissioning Agent all required reports documenting the cleaning, passivation, and treatment of the piping systems in the project.

END OF SECTION
THIS PAGE LEFT INTENTIONALLY BLANK