SECTION 23 05 00 - COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Conditions and all Division 01 Sections, apply to this Section and to all of Division 23.

1.2 SUMMARY

A. This Section includes the following:

1. Definitions, references, and abbreviations.
2. General regulatory requirements.
3. General requirements regarding site/field conditions including existing conditions and field measurements.
4. Sequencing and scheduling including coordination.
5. Definition of design equipment and procedures for consideration of specified equivalents, proposed equivalents, or substitutions.
6. HVAC demolition.
7. Equipment installation requirements common to equipment sections.
8. Minimum material requirements and equipment verification.
9. Electrical components for HVAC Work.
10. Concrete bases and grout.
11. Mechanical penetrations, waterproofing, and sealants.
12. Fire-stopping.
13. Access doors.
14. Painting and finishing.
15. General requirements for demonstration of completed systems.

1.3 DEFINITIONS

A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and chases.

E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

F. "Design Equipment," "Design Make," "Basis of Design," and similar terms: Equipment, specified in Technical Specification Section or on Contract Drawings using applicable manufacturer's designation, that forms the basis for performance requirements, physical dimensions, configuration, and similar aspects used in the design of this Project including (but not limited to) physical configuration of surrounding construction and location of connections to other components.

G. Specified Equivalents: Products identified in Technical Specification Section that may provide performance complying with specified requirements but may not have the same arrangement, configuration, size, construction, or other aspects as the specified Design Equipment. Refer to Section 00 21 13 - Instructions to Bidders, and Section 01 25 00 – Substitution Procedures for additional information and requirements regarding equivalents and substitutions.

H. "Equivalents," "Proposed Equivalents," "Proposed Products," and similar terms: These terms may be used interchangeably and mean the same thing: Products NOT identified in Technical Specification Section that the Contractor proposes in accordance with Section 00 21 13 - Instructions to Bidders and Section 01 25 00 – Substitution Procedures.

I. Substitutions: Changes in products, materials, equipment, and methods of construction from those required by the Contract Documents and proposed by Contractor, all in accordance with Section 01 25 00 – Substitution Procedures.

1.4 ABBREVIATIONS

A. Abbreviations: Reference to technical society, organization, body or section made in Division 23 in accordance with the following abbreviations:

1. AIA American Institute of Architects.
2. ADA Americans with Disabilities Act.
3. AMCA Air Movement and Control Association International, Inc.
4. ANSI American National Standards Institute.
5. ASHRAE American Society of Heating, Refrigerating and Air Conditioning Engineers.
6. ASME American Society of Mechanical Engineers International.
7. ASTM American Society for Testing and Materials International.
8. AWS American Welding Society.
9. IEEE Institute of Electrical and Electronics Engineers, Inc.
10. NEC National Electric Code.
11. NEMA National Electrical Manufacturers Association.
12. NFPA National Fire Protection Association.
13. NYBFU New York Board of Fire Underwriters.
14. SMACNA Sheet Metal and Air Conditioning Contractors National Association.
15. UL Underwriters Laboratories Inc.

1.5 SYSTEM DESCRIPTION

A. Provide complete systems, properly connected, tested, balanced, adjusted, and ready for operation, including all necessary and required controls, safeties, details and accessories, including (but not limited to):

1. Demolition and removals required for equipment and system installation.
2. Piping systems and related equipment.
3. Refrigeration systems and related equipment.
4. Ventilation systems and related equipment.
5. Support Systems and related equipment.
6. Insulation Systems and related equipment.
7. Miscellaneous items required for equipment and system installation.
8. Controls and electrical control wiring to equipment furnished in this contract.
9. Electrical power wiring to equipment furnished in this contract, where not covered elsewhere.

B. HEATING WORK DRAWINGS ARE DIAGRAMMATIC. Do not infer that Drawings show level of detail indicating every offset, elbow, union, fitting, elevation or aspect ratio changes, or other details required for complete installation.

1. Provide all required fittings, offsets, elevation changes, dampers, controls, components, and similar items not indicated on Drawings, as required for a complete properly operational system.

1.6 SUBMITTALS

A. General Division 23 submittal requirements:

1. Procedural Requirements: Comply with requirements of Section 01 33 00 - Submittals and as modified below.

   a. Specified Products: If product to be incorporated into Project is specified by name and product designation in Part 2 of product specification, and will be installed as specified in Part 3, and only where allowed as such in submittal portion of product specification, then submit “As-Specified Verification Form” (attached to Section 01 33 00 - Submittals) in lieu of “Product Data” identified.

   b. Do not use “As Specified Verification Form” unless specifically indicated in detailed product specification.

   c. Equivalent Products or Substitutions: If product to be incorporated into Project is <u>not</u> specified by name and product designation in Part 2 below, comply with all Product Data requirements specified.

2. Product Data: Submit Product Data for items listed in individual technical section. Clearly identify manufacturer, pertinent design, function, materials, construction, and performance data specifically addressing specification description and Contract Document requirements of item. Strike out products that are not applicable to item being submitted, where more than one product is indicated on manufacturer product literature.

a. Cover Sheet: Attach cover sheet, identified in Section 01 33 00, to Product Data of each item submitted. Provide cover sheet for only one type of item with related accessories, equipment with related components. Do not combine unrelated items under same cover sheet.

b. Specified Equivalent Product Data: Submit manufacturer's product information including product literature, technical specifications and descriptions, performance data, and similar items to demonstrate compatibility with Basis-of-Design Equipment as specified in "Manufacturers" in Part 2 - Products below.

3. Do not proceed with installation of systems in each area until agreement is reached with all concerned on exact arrangements for each room or area, unless otherwise directed by Architect. If Contractor proceeds prior to resolving conflicts, Contractor shall modify installed Work as required to permit other systems to proceed with a coordinated installation.

4. Specified Equivalent Drawings: Submit detailed drawings of proposed Specified Equivalents, indicating proposed installation of equipment and showing maintenance clearances, required service removal space, and other pertinent revisions to arrangement and configuration shown in Contract Documents.

5. Closeout Information, for inclusion in Operations and Maintenance Manual:

a. Approved submittals.

1) If "As-Specified Verification Form" submittal is approved, also include product data as specified in technical section for all components used.

b. Include all information required in Section 01 78 23 – Operation and Maintenance Data.

c. Include all other closeout information required by the individual technical specification sections.

B. Shop Drawings: Include dimensioned plans, sections, and attachments to other work for concrete bases.

C. Welding Quality Control Submittals

1. When welded or brazed work is required or proposed as a part of this project, submit following for approval before beginning any welding or brazing work:

a. Welding and Brazing Procedure Qualification: Prepare and submit for approval welding and brazing procedure qualification specification qualifying all proposed procedures as specified in Quality Assurance below with copies of all back-up data.

b. Welders' and Brazers' Certification: Submit for approval certification that each proposed welder, welding operator, brazer, or brazing operator has been qualified in all procedures proposed for that worker as specified in Quality Assurance below with copies of all back-up data.

D. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for the following:

1. Sealants.
2. Fire-stopping.
3. Access doors.
4. Painting and finishing.

E. Samples:

1. Submit color chart with paint manufacturer’s color samples for final color selections prior to beginning painting. Comply with additional requirements for color selection samples specified in Division 09.

F. Closeout Information, for inclusion in Operations and Maintenance Manual:

1. Approved submittals.

   a. If “As-Specified Verification Form” submittal is approved, also include product data for all components used.

2. Include all information required in Section 01 78 23 – Operation and Maintenance Data.

3. Letters on manufacturer’s letterhead from equipment manufacturers certifying that their equipment and systems have been installed in strict accordance with manufacturer's recommendations, properly aligned and adjusted, tested, lubricated, wired, balanced, etc.

1.7 QUALITY ASSURANCE

A. Regulatory Requirements

1. Comply with applicable requirements of all Federal, New York State, and Local Building, Health, Mechanical, Plumbing and Electrical Codes, Laws, Ordinances and Regulations, including (but not limited to):

   a. Building Code of New York State.
   b. Mechanical Code of New York State.
   c. Fire Code of New York State.
   d. Energy Conservation Construction Code of New York State.
   e. New York State Education Department Manual of Planning Standards.
   f. In event of a conflict between the Codes identified above and Contract Documents, comply with more stringent requirement.

2. Comply with applicable requirements of NFPA, utility company regulations, and following standards:

   a. Provide Underwriters Laboratories (UL) labels on all electrical materials carrying 50 volts or more.

b. Provide refrigeration equipment complying with Safety Code for Mechanical Carefully consider if a field sample or mockup is required, and include this requirement to establish a standard of care and construction quality that is more readily enforceable in the field by personnel not as familiar with the standard expected. Edit as required for the specific project: four examples only are shown below.

B. Certifications: Obtain and pay for all necessary inspections and certificates from all applicable agencies. Perform all required tests in accordance with regulation of agency having jurisdiction. Submit certificates of approval prior to Final Completion as defined in Section 01 77 00 – Closeout Procedures. Submit certificates of approval prior to request for final acceptance of Contract.

C. Electrical Characteristics for HVAC Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements.

D. Welding Quality Control for General Construction and Support Work:

1. This paragraph refers to qualifications for General Construction and Support Work welding only. Qualify welders, brazers, and any welding or brazing procedure to be used on piping for this Project in accordance with ASME "Boiler and Pressure Vessel Code," Section IX, as specified and detailed in Section 23 21 13 - Hydronic Piping.

2. Welding and Brazing Procedure Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel." Qualification may be made by technically competent group or agency (subject to approval) meeting the following conditions:

a. Group or agency qualifying the procedure meets all procedure qualification requirements of AWS D1.1/D1.1M, "Structural Welding Code - Steel."

b. Contractor accepts full responsibility for procedure qualified.

c. Contractor has qualified at least one welder or welding operator using procedure qualified and provides record of qualification.

d. Contractor accepts full responsibility for qualified procedures by signing related qualification records with procedure and performance qualifications including all dates, results, and associated data.

3. Welders' and Brazers' Qualifications: Ensure that all welders, welding operators, brazers, or brazing operators employed for this project are qualified for all welding and brazing procedures, proposed as part of this Project, in accordance with AWS D1.1/D1.1M, "Structural Welding Code - Steel." Qualification by previous employer or technically competent group or agency (subject to approval) may be acceptable if following information is included:

a. Documentation that the previous qualification was for essentially the same procedures proposed and was in full accordance with AWS D1.1/D1.1M, "Structural Welding Code - Steel."

b. Copy of performance qualification testing record showing who qualified the worker, date of qualification, and work history record showing continuous performance to maintain qualification.

4. Weld and Braze Qualification Records: Maintain and sign certified records of approved procedures used and approved qualified workers employed for welded and brazed joints performed as a part of Prime Contract. Ensure all welding and brazing work can be traced to a specific procedure and welder.

5. Inspection and Examination by Owner, Remedy by Contractor: Owner reserves right to examine, inspect, and test all piping using visual, radiographic, or other recognized testing methods to determine compliance with specified quality control requirements and requirements of applicable regulatory agencies.

a. Cost of Owner's testing of acceptable installation provided at Owner's expense.
b. Repair piping installations not passing Owner's quality inspection testing using approved method or replace at no additional cost.
c. Cost of initial testing of piping not conforming to specified requirements and any retesting of repairs or replacement work shall be deducted from Contract Sum.

E. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Ship materials in manufacturer's containers, fully identified with manufacture's name, trade name, type, class, style, model, grade, size and color.

B. Storage and Protection

1. Store materials, equipment, fixtures, pipe, fittings, attachments, under cover, off ground in original containers as applicable, and protect from physical and weather damage while in storage and during construction.

2. Furnish extra materials identified in technical sections, in original manufacturer's containers and packaging, to Owner at location identified during Preconstruction Conference. Obtain receipt from Owner upon delivery of extra materials and send copy of receipt to Architect.

3. Replace or repair damaged, rusted, corroded or otherwise unusable materials physically damaged or weather damaged equipment as determined by Architect, at no change in Contract Sum.

1.9 PROJECT/SITE CONDITIONS

A. Field Measurements

1. DO NOT SCALE DRAWINGS: Refer to Architectural and Structural drawings for dimensions and details, and verify measurements in field before proceeding.

2. Install all items with proper provision for removal and access to coil bundles, boiler tubes, belts, valves, traps, and similar components.

3. Layout of equipment, piping, and similar components in Drawings is diagrammatic. Review Drawings in the field, identify interference with other construction and verify dimensions at Site prior to beginning installation.

a. Obtain exact size and location of all items and openings and confirm all existing conditions in field. Review Shop Drawings of all Contracts.

b. Coordinate all Heating Work that interferes with other construction with other responsible Contractor.

c. Obtain exact location and roughing requirements for all equipment furnished by others, but installed by this Contractor before roughing. Owner reserves right to make reasonable changes prior to "roughing-in" without increase in Contract Sum.

4. Report any conflicts to Architect in writing before beginning installation.

1.10 SEQUENCING AND SCHEDULING

A. Perform all Heating Work in cooperation with Owner, Architect, Construction Manager, and all Contractors on this Project, and other separate Contractors at the Site.

1. Coordinate all Heating Work with construction schedule requirements in Division 01
2. Coordinate all submittals with the construction schedule and with requirements and schedules contained in Section 01 33 00 – Submittals Procedures.
3. Immediately report any delays in receipt of materials required for Heating Work including circumstances causing delays.

B. Existing Construction: Provide openings, chases, recesses, lintels and bucks required for admission of Heating Work, unless otherwise noted. Do not cut waterproofed floors or walls for admission of equipment or materials without written permission. Do not pierce structural members without written permission.

C. Supports for Heating Work: Provide anchor bolts required supporting or securing Heating Work. Locate settings and check locations as construction progresses. Provide templates or holding fixtures as required to maintain proper accuracy.

D. Cutting and Patching: Bear expense of cutting, patching, repairing or replacing of work of all Contracts required due to fault, error or damage by contractor responsible for Heating Work, unless otherwise specified in Contract Documents. Employ and pay Prime Contractor involved, or if there is no associated Prime Contractor, employ and pay qualified subcontractor as required for corrective work.

E. Refer to Division 01 for cooperation between Contractors. Prior to start of construction:

1. Obtain from Contract Drawings or Architect, exact location of items and openings in construction. Conform to existing conditions in field.

2. Review Shop Drawings of all Contracts.

3. If conflict occurs between Contract Drawings, advise Architect in writing before beginning installation and comply with Architect's directions.

4. Obtain exact location and roughing requirements for equipment furnished by other Contractor or by Owner, but installed by Contractor responsible for Heating Work before beginning roughing.

1.11 COORDINATION

A. Pre-Installation Conference:

1. Attend pre-installation conference. Arrange for all subcontractors to be in attendance.

B. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for HVAC installations.

C. Coordinate installation of required supporting devices and set sleeves in poured-in-place concrete and other structural components as they are constructed.

D. Coordinate requirements for access panels and doors for HVAC items requiring access that are concealed behind finished surfaces. Access panels and doors are specified in Division 08 Section "Access Doors and Frames."

E. Coordinate Heating Work with plumbing systems, lighting fixtures, ceiling mounted devices, ceiling heights, materials, structural work, maintenance clearances, electric code clearance, and building systems. Verify that Work of all Contractors can be installed without interference with Heating Work.

F. Notify Architect in case of unresolved interferences prior to installation of Heating Work.

G. Adjust exact size, location and offsets of exposed HVAC components to achieve reasonable appearance objectives without increase in Contract Sum.

H. Testing and Balancing: Cooperate with contractor responsible for Testing and Balancing work as required ensuring complete and proper testing, balancing and adjustment of air and water systems. Refer to Section 23 05 93 – Testing, Adjusting, and Balancing for HVAC, for details.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis-of-Design Equipment – Provide as specified and scheduled with all options as required for full compliance.

B. Specified Equivalents - If Specified Equivalents (refer to "Definitions" in Part 1 above) are proposed, comply with following requirements:

1. Submit "Specified Equivalent Drawings" as specified in "Submittals" in Part 1 above.

a. Provide required changes in design and adjacent construction or equipment at no increase in Contract Sum.

1) Where required, provide larger motors, equipment, additional control devices, valves, fittings, and other miscellaneous equipment necessary for proper operation and provide proper location of roughing and connections to other Contractors.

2) Provide additional motors, starters, power, wiring, and control wiring required.

3) Provide revisions to equipment, wiring, support structure, controls, valves, fittings, and other miscellaneous equipment.

4) Additional Architectural and Engineering work, coordination, and documentation.

b. If proposed arrangement for Specified Equivalent is rejected, revise to be compliant and resubmit or submit Basis-of-Design Equipment.

2. Submit "Specified Equivalent Product Data" as specified in "Submittals" in Part 1 above to demonstrate that proposed Specified Equivalent is equal to or better than Basis-of-Design Equipment with respect to all performance characteristics, including but not limited to durability, individual equipment operating costs, entire interrelated system operating costs, service access, noise levels, vibration levels, compatibility with Owner's other existing equipment to minimize parts inventory, aesthetics where applicable, and similar characteristics.

3. Do not assume that approval of a specified equivalent submittal implies approval of the installed product. Correct all deviations uncovered during construction and warrantee period that result in or are caused by any lower performance characteristic than the specified Basis of Design equipment.

C. Proposed Equivalents and Substitutions: In addition to requirements described elsewhere in these Contract Documents, all proposed equivalent and substitution products being considered shall be subject to the Specified Equivalent requirements listed above.

2.2 MATERIALS

A. Minimum Material Requirements:

1. Construct potable water systems and equipment according to Plumbing Code of New York State.

2. Provide electrical equipment and systems meeting UL standards and requirements of NEC.

3. Provide UL label on all equipment and material with listing service.

4. Material Flammability:

   a. Flame spread rating of 25 or less.
   b. Smoke developed rating of 50 or less.

5. Equipment Verification: Carefully check manufacturer's drawings and specifications as they affect their particular equipment; follow factory instructions for roughing, installation, connection, filling, lubrication, testing, balancing, adjusting, alignment, wiring, and start-up operation.

2.3 CONCRETE BASES AND SUPPORTS

A. Use 4000-psi f_c air entrained concrete, maximum #1 aggregate, all edges chamfered 1-1/2 inches, trowel finished, and properly consolidated to eliminate voids. Reinforce and secure to floor with #4 rebar dowels 18 inches O.C. 3 to 6 inches from edge around entire perimeter, inserted into structural slab 3 inches minimum and extending to within 1 inch of pad top. Enclose dowels with #4 deformed rebar ring around all dowels overlapped 18 inches minimum and bent in at ends 12 inches minimum, secured to dowels at center of pad height. Roughen structural slab, and coat with cement grout before pour. Ensure all equipment bolt down locations are within reinforcement ring, extended into structural slab as required by seismic considerations.

B. Set adjustable internal threaded concrete inserts at appropriate bolt-down locations before pouring equipment bases. Use expansion anchors extended into structural slab as required by seismic considerations. If reusing existing concrete base, use expansion anchors. After leveling and anchoring equipment, fill equipment bases with grout as required.

C. Equipment Bases: 3-1/2 inches thick minimum, reinforced with 6x6-W1.4xW1.4 welded wire mesh, minimum 1-1/2 inches cover, doubled over 12 inches on long edges, unless otherwise specified.

2.4 GROUT

A. Description: ASTM C 1107, Grade B, non-shrink, non-metallic, high strength grout, suitable for interior and exterior, above and below grade applications.

1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.

2. Design Mix: 5000-psi, 28-day compressive strength.
3. Packaging: Premixed and factory packaged.

2.5 SEALANTS

A. Comply with requirements for sealants in non-fire rated penetrations specified in Section 07 92 00 "Joint Sealants," and also with requirements for Air Duct sealants in Section 23 31 00 – Ductwork.

B. Provide premium products specified for each application as appropriate.

2.6 PENETRATION FIRESTOPPING

A. Comply with requirements for sealants in fire rated penetrations specified in Section 07 84 13 “Penetration Firestopping.”

B. Submit Manufacturers Product Data Sheets for each type of product selected. Certify that Firestop Material is free of asbestos and lead paint, and complies with local regulations.

1. Certification by firestopping manufacturer that products supplied comply with local regulations controlling use of volatile organic compounds (VOCs) and are nontoxic to building occupants.

C. Submit system design listings, including illustrations from qualified testing and inspection agency that is applicable to each firestop configuration.

D. Submit a project specific Penetration Firestopping Schedule indicating where each firestop configuration will be used.

2.7 ACCESS DOORS

A. Comply with requirements for access doors specified in Section 08 31 13 “Access Doors and Frames” for product requirements of access doors in general construction.
B. Comply with requirements for access doors specified in Section 23 33 00 “Air Duct Accessories” for product requirements of access doors in Air Ducts.

2.8 PAINT AND FINISHES

A. Refer to Division 09 for paint and finish product specifications.

PART 3 - EXECUTION

3.1 HVAC DEMOLITION

A. Refer to Division 01 Section "Execution" and Division 02 Section "Selective Demolition" for general demolition requirements and procedures.

B. Disconnect, demolish, and remove HVAC systems, equipment, and components indicated to be removed.

1. Piping to Be Removed: Remove portion of piping indicated to be removed and cap or plug remaining piping with same or compatible piping material at point of continued use or as otherwise specifically indicated.

2. Piping to Be Abandoned in Place: Drain piping and cap or plug piping with same or compatible piping material.

3. Ducts to Be Removed: Remove portion of ducts indicated to be removed and cap remaining ducts with same or compatible ductwork material.

4. Ducts to Be Abandoned in Place: Cap all duct ends with same or compatible ductwork material.

5. Equipment to Be Removed: Disconnect and remove equipment and all associated accessories. Plug, cap, seal, and otherwise patch to match as required.

6. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, protect, and store equipment; when appropriate, reinstall, reconnect, and make equipment operational. Document any existing damage before removals.

7. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to Owner.

C. Disposition of Removed Components:

1. All material and equipment removed during project Work but not being reused in the project is to be offered to the Owner. If accepted by Owner, deliver the removed materials and equipment to a project site location designated by the Owner.

2. For components that become the Contractor's property through this removal process: Confirm transfer of ownership in writing then promptly remove from the site and legally process.

3. For components indicated on the drawings to be turned over to the Owner: deliver to a project site location designated by the Owner.

4. For components indicated on the drawings to be reused: carefully remove, protect, and store until appropriate time for re-installation. Document any pre-existing damage prior to removals.

5. For pipe and tubing indicated to be reused, reuse only those portions of pipe, tubing, and associated fitting assemblies where they are direct replacements of the as specified and as shown new piping assemblies. Valves, strainers, other piping specialties, and insulation shall not be re-used unless specifically indicated on drawings.

3.2 EXISTING CONDITIONS

A. Reuse materials and equipment only as indicated on Drawings. Furnish new equipment and materials in conformance with Contract Documents for all Heating Work, including any material, operation, method or device mentioned, listed or noted within Division 23 Sections, unless reuse is specifically indicated, or unless specified as furnished or installed by Owner, all Contractors, or others.

B. If pipe, insulation, or equipment to remain is damaged in appearance or is otherwise made unserviceable by adjacent or associated work or error, remove damaged or unserviceable portions and replace with new products of equal capacity and quality. Verify, document, and confirm pre-existing damage with Owner and Architect before beginning work.

3.3 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

A. Install equipment to allow maximum possible headroom unless specific mounting heights are indicated.

B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

C. Install HVAC equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

D. Install equipment to allow right of way for piping installed at required slope.

E. Ensure each equipment manufacturer:

1. Carefully checks Contract Drawings and Specifications applicable to manufacturer’s equipment before roughing.

2. Reports to Architect, before or when Shop Drawings are submitted, any discrepancies or conditions applied to manufacturer’s equipment that prevents proper functioning, servicing, and other aspects of equipment operation.

3. Provides manufacturer's printed installation instructions for each piece of equipment.

4. Thoroughly instructs Contractor exactly how equipment should be installed, connected, lubricated, started, operated, and similar aspects to ensure all factory instructions are rigidly followed during installation of equipment.

F. Install, test, start, and operate equipment as instructed by manufacturer.

G. Submit written evidence from equipment manufacturer that manufacturer’s equipment and systems have been:

1. Installed in strict accordance with manufacturer's recommendations.
2. Properly aligned and adjusted, tested, lubricated, wired, balanced, and similar operations.

H. Equipment Connections

1. Provide final make up water, steam, condensate, heating water, drain, vent and refrigerant connections to all equipment as required.

2. Provide isolation valves and flanges or unions on the supply and return piping connections to all equipment arranged as required for reasonable service isolation and access.

3. Provide equipment waste, drip, overflow, bleed water, condensate, and drain connections extended to floor or roof drains or other approved points of discharge. Provide integral condensate pumps and appropriate piping for units where gravity condensate drain is not practical or possible.

4. Provide for Owner-furnished equipment. Refer to manufacturer's drawings and specifications for requirements of Owner-furnished equipment and verify connection requirements.

5. Connect equipment complete and ready-to-use, including all valves, piping, piping accessories, traps, pressure reducing and backflow prevention devices, gauges, relief valves, vents, drains, insulation, sheet metal work, controls, dampers, and similar components required.

I. Precautions Against Freezing: In addition to applicable requirements in Division 01 and individual technical sections, take all necessary precautions with equipment and systems to prevent damage to building, piping, equipment, and other components due to freezing and water leakage until final acceptance. Before freezing weather occurs, make certain all:

1. Safety features are properly functioning.
2. Freeze protection is tested and sensing elements are properly located.
3. Openings around outside grilles, louvers, and similar items are properly sealed; notify Architect in writing if openings are not adequately sealed.
4. Outside air dampers are tight fitting and operational, and damper motors are properly winterized.
5. Air systems are properly balanced.
6. Proper insulation is installed where required.

J. Concealment: Conceal all Work not specifically shown on the Drawings as exposed. Note piping risers may be shown outside of walls due to scale of drawing symbols – the general intent is for these pipes to be concealed within the general construction if possible or if not possible, to be within riser chases. If for any reason concealment is impossible, notify the Architect and obtain written approval before starting that part of the Work.

K. Exposed Items: Install exposed items as shown on Drawings or as approved by Architect. Obtain Architect's approval for final arrangement and appearance before installing items in areas without ceilings.

L. Damaged Components and Replacement: If pipe, duct, insulation, or any HVAC component or equipment is damaged in appearance or is otherwise unserviceable, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.

3.4 ERECTION OF SUPPORTS AND ANCHORAGES

A. Provide a complete system of support and anchorage for all Contract work.

B. Refer to Section 23 05 29 - Hangers and Supports for HVAC Components, Section 23 05 43 – Mechanical Vibration and Movement Control, and Division 05 and Division 06 complete for detailed additional requirements.

3.5 CONCRETE BASES

A. Provide concrete bases for all floor-mounted HVAC systems equipment, unless specifically indicated otherwise in Contract Documents.

1. Shape and size to accommodate equipment, with minimum of 6 inches clear pad all around perimeter unless otherwise required by equipment manufacturer.

2. Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic requirements of Project. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with anchorage.

3.6 GROUTING

A. Mix and install grout for HVAC equipment base bearing surfaces, pump and other equipment base plates, and anchors.
B. Clean surfaces that will come into contact with grout.
C. Provide forms as required for placement of grout.
D. Avoid air entrapment during placement of grout.
E. Place grout, completely filling equipment bases.
F. Place grout on concrete bases and provide smooth bearing surface for equipment.
G. Place grout around anchors.
H. Cure placed grout.

3.7 MECHANICAL PENETRATIONS, WATERPROOFING, AND SEALING

A. Openings Through Roofs: Curbs are required for rooftop air handling equipment, ventilators, fans, piping penetrations, etc. Roofing, flashing, and general waterproofing are the responsibility of the Contractor unless specifically indicated otherwise elsewhere in the Contract Documents. Refer to Architectural Drawings for related work by others.

1. Use factory pre-fabricated units as specified and noted on Drawings.

2. Caulk and waterproof neatly with additional material as required.

3. Employ the services of an approved roofing sub-contractor for all patching and/or new work indicated as part of the Heating Work.

4. Any roofing work performed under this Contract shall be performed in such a way as to not void any existing roofing warrantee. Additionally, whether there is a roofing warrantee currently in force or not for roof in area of new penetrations, all new penetration work shall be warranted leak free for a period not less than one year from final acceptance of project.

5. Provide structural support for roof deck around all roof curbs and roof deck penetrations larger than 12 inch x 12 inch, unless specifically indicated otherwise elsewhere on the Contract Documents.

B. Opening Through Outside Walls:

1. Guarantee all penetrations to be thoroughly air and watertight. Caulk and flash duct penetrations in accordance with specifications, details on Drawings, and as required.

2. Install louvers in accordance with specifications, manufacturer's recommendations, and details, as required to achieve guaranteed air and watertight penetrations. Direct drainage to drip away from building surface.

3. Use special waterproof construction as directed.

4. Provide mechanical sleeve seals for piping penetrations.

5. Provide structural support for wall above all penetrations wider than 12 inches, unless otherwise indicated elsewhere on the Contract Documents.

C. Openings Through Floors and Inside Walls: Provide through penetration systems for all mechanical work floor and wall penetrations which do not compromise the integrity of the floor or wall with regards to fire rating, smoke passage rating, acoustical noise reduction rating, or seismic rating. Insure through penetration system does not transmit mechanical vibrations to building walls or floors. Seal all floor penetrations to effectively block the passage of smoke and fumes.

1. Provide structural support for floor or roof deck around all penetrations larger than 12 inches in any dimension, unless specifically indicated otherwise elsewhere on the contract documents.

3.8 FIRESTOPPING

A. Provide Through-Penetration Firestopping Systems and Devices listed in UL Fire Resistance Directory under categories XHCR and XHEZ and conforming to construction type, penetrant type, annular space requirements and fire rating indicated or required for each application.

B. Provide systems that withstand passage of cold smoke either as inherent property of system or by use of separate product included as part of UL system or device designed to perform this function.

3.9 ACCESS DOORS

A. Provide all access doors shown on Drawings and as required for access to motors, dampers, valves, controls and all other devices requiring periodic inspection, adjustment or maintenance where located above or within inaccessible walls or ceilings except where access doors are indicated to be provided by others.

B. Engage skilled tradesman experienced in installation of access doors in applicable types of adjacent construction to install access doors. Install in accordance with requirements of Division 08 Section on access doors.

C. Existing Walls, Floors, and Ceilings: Cut and patch to install access doors in conformance with Section 01 73 00 - Execution.

D. Ductwork: Provide all access doors as required by section 23 31 00 – Ductwork and 23 33 00 – Air Duct Accessories.

3.10 PAINTING

A. Painting of HVAC systems, equipment, and components is additionally specified in Division 09 Sections on Painting.

B. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

C. Vary initial and final coat colors slightly as required to provide positive identification between coats. Do not proceed with final coat until initial coat is properly cured per manufacturer's instructions, and has been approved as complete by Owner's Project Representative. Final coat shall completely conceal initial coat(s).

3.11 PROTECTION

A. Maintain systems during construction, temporary use, and until acceptance by Owner.

1. Properly lubricate all HVAC systems bearings during use.
2. Maintain limit controls, overload devices, and safety controls in operating condition during use.

3.12 ALTERATIONS

A. Provide protection of existing facilities, demolition and removals, replacement and restoration, including patch-to-match requirements, and hazardous materials procedures to install Heating Work in conformance with Division 01 requirements.

B. Provide cutting and patching required to install Heating Work in accordance with the requirements of Division 01 covering cutting and patching.

3.13 ADJUSTING AND CLEANING

A. Adjust all work as required to insure systems perform as designed and as intended, including but not limited to the following:

1. Adjust all registers and diffusers to insure even air distribution free of objectionable drafts. Include all new and all existing to remain registers and diffusers on systems where HVAC modifications are made.

2. Adjust all hangers and supports to insure proper piping slope, alignment of flexible connections, even loadings, proper venting and draining, proper control over thermal expansion, etc.

3. Adjust all mechanical equipment insuring it runs properly as intended, providing the performance specified and required, and as required to maintain all warrantees.

B. Clean work furnished or provided as part of Heating Work, including but not limited to equipment, control panels and devices.

1. Refer to and comply with Section 01 50 00 - Temporary Facilities and Controls for additional requirements for cleaning during construction and Section 01 77 00 – Closeout Procedures for additional requirements for final cleaning.

2. Remove debris, leftover piping, tubing, metal, insulation, cartons, papers, etc., resulting from Heating Work.

3. Remove all rust, dirt, oil, etc. from Heating Work to be painted and maintain in condition ready for painting.

4. Clean inside and outside of all equipment and distribution systems provided including (but not limited to) following:

   a. All enclosures.

   b. Remove all rust, oils, and similar contamination from all equipment, piping and supports to be painted, and leave components ready for painting.

   c. Remove debris, leftover piping, wiring, tubing, metal, insulation, cartons, papers, and similar items left in building or on Site. Clean building as often as necessary and when directed by Architect.

C. Final Cleaning: In addition to requirements specified in Section 01 77 00 – Closeout Procedures and other sections in Division 23, provide following measures.

1. Where heating units have been used to provide temporary heat, clean all permanent filters, replace all disposable filters, and clean all ducts, blowers, and coils.
2. Clean all piping strainers and replace all "startup" screens with permanent screens.
3. Provide written notification to Architect upon completion of all final cleaning procedures and request inspection of final cleaning.

3.14 DEMONSTRATION OF COMPLETED SYSTEMS:

A. Prior to Final Completion, thoroughly demonstrate and instruct Owner’s designated representatives in care and operation of all heating and ventilating systems and equipment provided in Heating Work. Provide necessary skilled labor to operate all systems for not less than 5 days and provide required instruction.

1. In addition to Contractor’s instruction, arrange for technically qualified factory representatives to train Owner's designated representatives in care, maintenance, and operation of following manufacturer’s equipment and systems.

   a. Temperature controls.
   b. Central station air handling equipment and units.
   c. Air conditioning units and equipment.
   d. Variable speed drives.

2. Coordinate and schedule time and place of all training through Architect at Owner’s convenience.

3. Submit letters verifying satisfactory completion of all instruction including date of instruction, names of persons in attendance and countersigned by authorized representative of Owner.

4. Until final acceptance, Contractor retains full responsibility for systems operations and maintenance, even though operated by Owner's personnel during instruction, unless otherwise agreed to in writing.

5. During instruction, provide list, sealed in clear plastic, outlining operating, maintenance, and starting precautions and procedures to be followed by Owner for operating systems and equipment.

B. Air Filter Chart: Provide an air filter chart for all equipment installed in contract.

1. Chart shall be 8-1/2 inch x 11 inch minimum size, typed in capital letters, mounted under clear laminated plastic; secure to wall where directed.

2. List all equipment that includes filters in Contract. Obtain necessary information containing the following:

   a. Name and location of equipment
   b. Type of filters recommended by the manufacturer.
   c. Size of filters for each piece of equipment.
   d. Recommended replacement schedule from unit manufacturer.

END OF SECTION 23 05 00

SECTION 23 05 13 - COMMON ELECTRICAL REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes:

1. General requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

2. Starters and disconnects for electric motors.

   a. Refer also to Section 23 29 00 for Variable Frequency Motor Controllers.

3. Electrical auxiliary components required for HVAC systems that are not specifically identified in “E” series Drawings or Division 26.

4. Electrical wiring required for HVAC systems that is not specifically identified in “E” series Drawings or Division 26.

1.3 SUBMITTALS

A. General: Submit all action submittals required by this Section concurrently.

B. Action Submittals:

1. Product Data: For each type of product indicated, demonstrating compliance with all specified performance and construction characteristics.

C. Closeout Submittals:

1. Installation, Operation, and Maintenance Data: For motors, drives, electrical power components, and heat trace - include in operation and maintenance manuals.

a. Wiring Diagrams: Employ competent technical aid to prepare composite wiring diagrams for field wiring of power, signal, and control wiring for all equipment and systems installed as part of the HVAC Work. Deliver diagrams to proper parties in time for roughing of conduit and equipment connections. Clearly indicate all items to be mounted or wired as part of Division 26. Include as built wiring diagrams in O&M manual.

1.4 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Manufacturers: Provide products by one of following manufacturers or equal, except where unusual configurations involving frame, hermetic seals, shaft, bearing, or starting characteristics are peculiar to particular item of equipment as specified by Architect:

1. National Resource Management (NRM).
2. Baldor.
3. General Electric.
4. U. S. Motors.

B. Provide all motors required for the work of Division 23 specifications. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or individual technical specification sections.

C. All motors shall be of premium efficiency design where applicable.

1. Provide motors wound specifically for voltages as scheduled and available, with 1.15-service factor at rated voltage and frequency complying with all applicable NEMA standards.

D. Provide all motors suitable for operation at the frequency, voltage, and phasing of the building power.

E. Provide motors 1/2 HP and larger and motors indicated as driven by variable speed drives, designed for operation on 3-phase power, voltage as shown on electrical plans, +/- 10 percent, unless specifically indicated otherwise on drawings.

F. Provide constant speed motors 1/3 HP and smaller designed for operation on single phase, 120 volts +/- 10 percent.

G. Comply with NEMA MG 1 unless otherwise indicated.

H. Comply with IEEE 841 for severe-duty motors.

2.2 MOTOR CHARACTERISTICS AND APPLICATIONS

A. Provide each motor suitable for continuous duty operation at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level, and suitable for speed, enclosure, rating, type and horsepower not less than as scheduled or specified in Contract Documents. Provide motor enclosure and maximum allowable temperature rise in degrees Centigrade over 40 deg. C ambient as follows, unless otherwise specified:

1. General Purpose: Drip-proof 40 deg. C or encapsulated design 60 deg. C.
2. Roof-top unit, damp, high humidity, or condensing applications: Totally enclosed fan-cooled 50 deg. C or drip-proof encapsulated design 60 deg. C.
3. Motors, wiring, and disconnects installed in potentially flammable atmosphere: UL listed, NEC rated explosion proof construction, fan-cooled 50 deg. C rise.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

C. Each equipment manufacturer is responsible for ensuring motors supplied with manufacturer’s equipment are fully compatible with the application and capable of starting and running driven equipment without undue noise, heating, or distress.

2.3 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.
5. Electronically Commutated Motor (ECM).

B. Motors 1/20 HP and Smaller: Shaded-pole type.

C. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

D. Variable Speed Motors: Electronically commutated motor (ECM) shall be of permanent magnet, brushless DC premium efficiency design with variable speed electronic controller capable of maintaining constant speed, torque, and/or cfm as required by service, capable of accepting 0-10vdc or 4-20mA speed control signal from building management system. Adjustable slow start and gradual speed changes, permanently lubricated ball bearings, and extra quiet operation are all included.

E. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

F. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

2.4 POLYPHASE MOTORS

A. Single Speed General Application Motors:

1. NEMA MG 1, Design B, medium induction motor.
2. Efficiency: Premium efficiency, as defined in NEMA MG 1.
3. Service Factor: 1.15.
4. Random-wound, squirrel cage rotor.
5. Re-greasable, shielded, antifriction ball bearings suitable for radial and thrust loading.
6. Insulation: Class F.
7. Temperature Rise: One class below insulation rating.
8. Motors 15 HP and Larger: NEMA starting Code F or Code G.
9. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.
10. Enclosure Material: Manufacturer's standard rolled steel or cast-iron enclosures corresponding to NEMA rating and application requirements.

B. Multi-Speed General Application Motors:

1. Similar to single speed motor requirements above, with separate winding for each speed.

2. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

C. Motors Used with Variable Frequency Controllers:

1. Motors shall meet all other requirements of this document, the driven equipment manufacturer, and the Variable Frequency Controller manufacturer, and be rated for this service with the drive and voltage intended. Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

2. All three phase motors for use with variable frequency controllers shall be special application, inverter duty premium efficiency motors of cast iron construction.

3. Ratings shall be in accordance with NEMA MG-1, Part 31 requirements for the specific application.

4. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.

5. Class B temperature rise; Class F insulation.

6. Thermal protection via one Class F thermostat per phase, NEMA MG 1 compliant with requirements for thermally protected motors.

D. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 STARTERS

A. Manufacturers: Provide all starting equipment and control devices manufactured by same manufacturer and furnished through single responsible supplier unless otherwise specified in Contract Documents. Factory-wired or assembled packaged equipment may be provided with starting equipment of any acceptable manufacturer. Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Cutler-Hammer
2. General Electric
3. Square D

B. Provide starters, contactors, and controllers complying with applicable NEMA standards, minimum size 0, and enclosed in enclosures of type appropriate for environment where installed including general purpose, explosion proof, weather resistant, or weather-tight construction as required.

C. Ensure all parts subject to wear, arcing, and similar use are easily removable.

1. Provide necessary auxiliary contacts for each starter subject to electrical interlock or automatic control.

2. Equip magnetic starters for motors operating 208 volts and over, line-to-line, equipped with self-contained light loads imposed thereon with a control transformer having a 120-volt grounded secondary winding, and having 120-volt starter operating coils.

D. Provide combination-type magnetic starters with non-fused disconnect switches. Protect all starters with manual reset, solid state overload relay equal to (Square “D” motor logic) in one leg of single-phase line to neutral circuits, in two legs of single-phase line-to-line circuits, and in three legs of 3-phase circuits.

E. Provide 6-volt, red pilot light, integral transformer and long-life bulb for all starters and contactors.

F. Manual Starters: Toggle operated, single pole for line to neutral circuits, two pole for line-to-line circuits, with thermal overload devices and neon pilot light; flush mounted unless shown otherwise, ganged with selector switch for multispeed applications. Provide manual starters similar to one of the following:

1. General Electric CR-101
2. Cutler-Hammer 9101
3. Square D Class 2510

G. Combination Magnetic Starters: Single speed, across the line, HAND-OFF-AUTO selector switch in cover. Provide combination magnetic starters similar to one of the following:

1. Cutler-Hammer 9589
2. General Electric CR-107
3. Square D Class 8538

H. Magnetic Contactors: With control coil in series with temperature controls as required.

I. Refer to Section 23 29 00 – Variable Frequency Motor Controllers for requirements of these devices.

2.6 NONFUSIBLE SWITCHES

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
2. General Electric Company; GE Consumer & Industrial - Electrical Distribution.
3. Siemens Energy & Automation, Inc.
4. Square D; a brand of Schneider Electric.

B. Type HD, Heavy Duty, Single Throw, 240 and 600-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.

C. Accessories:

1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
3. Auxiliary Contact Kit: One NO/NC (Form "C") auxiliary contact(s), arranged to activate before switch blades open.
4. Lugs: Mechanical type, suitable for number, size, and conductor material.

2.7 ENCLOSURES

A. Enclosed Switches and Circuit Breakers: NEMA AB 1, NEMA KS 1, NEMA 250, and UL 50, to comply with environmental conditions at installed location.

1. Indoor, Dry and Clean Locations: NEMA 250, Type 1.
2. Outdoor Locations: NEMA 250, Type 3R.
3. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids (All Mechanical/Boiler Rooms): NEMA 250, Type 12.

2.8 COMPONENTS

A. Electrical Wiring: Provide all materials conforming to NEMA Standards and UL approved for intended service. Refer to appropriate sections in Division 26.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which materials and methods are to be installed and notify Architect in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in acceptable manner.

   1. Installation indicates conditions are acceptable to Contractor as required to ensure requirements for applicable warranty or guarantee can be satisfied.

   2. Motors and Starters: Confirm electrical characteristics for all equipment.

   3. Electrical Wiring: Check all electrical wiring associated with equipment for compliance with specifications and correctness of connections. Correct wiring in event equipment or devices fail to function in specified manner, whether due to incorrect connections or improper information and wiring diagrams.

B. Inspect and perform tests on project electrical wiring, including infrared scans (thermography), resistance testing, or other industry standard testing as required to demonstrate acceptable wiring. Owner reserves the right to provide their own additional similar testing:

   1. Cost of Contractor’s testing included in bid price. Cost of Owner’s testing of acceptable installations provided at Owner’s expense.
   2. Repair installations not passing Contractor’s or Owner’s quality inspection testing using approved method or replace at no additional cost.
   3. Cost of initial testing of wiring not conforming to specified requirements and any retesting of repairs or replacement work deducted from Contract Sum.

3.2 INSTALLATION

A. Motors, Starters and Disconnects:

   1. Correct, at no additional cost, any misapplied motor or starter combination and improper thermal overload devices for motor starters provided as part of HVAC systems or components, along with damage to other equipment or construction.

2. Motors: Provide motors furnished by equipment manufacturer, specifically manufactured, or selected for equipment served; mounted, and installed to provide complete installation that is substantially noiseless in performance under intended use. Replace motors unsatisfactory to Architect with new motor.

3. Starters, Disconnects and Accessories

   a. Provide starters and disconnects for all HVAC equipment. Refer to Equipment Schedules.
   b. Provide auxiliary contacts required for temperature controls, interlock with other equipment, alarms, and similar components and applications.

B. Miscellaneous Electrical Wiring included in HVAC systems installations:

1. Provide all control wiring and power wiring for all equipment and associated control devices (including automatic control system) required for HVAC systems and components.

2. Comply with all applicable NEC requirements. Install all electric wiring in accordance with all local and state codes and regulations having jurisdiction.

3. Wiring for Controls: Provide wiring specified in Section 23 09 00 – Instrumentation and Control for HVAC, for all control devices required for temperature control system and other miscellaneous controls not included in "Electrical Equipment and Control Schedule".

4. Allow sufficient headroom under equipment as directed for each location (unit heater, etc.). Verify space available for each equipment item. Refer to Architect for any correction, discrepancy, or suggested change in size of location.

5. Secure all equipment and fixture mountings, wiring devices, and accessories (clips, supports, etc.) to structure with screws, bolts, or similar items, nailing not acceptable.

END OF SECTION 23 05 13

SECTION 23 05 19 - METERS AND GAUGES FOR HVAC SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Liquid-in-glass thermometers.
2. Thermowells.
3. Dial-type pressure gauges.
4. Gauge attachments.
5. Test plugs.

1.3 SUBMITTALS

A. Procedural Requirements: Comply with requirements of Section 01 33 00 - Submittals and as modified below.

1. Specified Products: If product to be incorporated into Project is specified by name and product designation in Part 2 below, submit "**As-Specified Verification Form**" (attached to Section 01 33 00 - Submittals) in lieu of "Product Data" identified below in this Article.

2. Equivalent Products or Substitutions: If product to be incorporated into Project is not specified by name and product designation in Part 2 below, comply with all Action Submittal requirements specified below.

B. Action Submittals:

1. Submit all action submittals required by this Section concurrently.
2. Product Data: For each type of product indicated, demonstrating compliance with specifications. Include schedules of locations and ranges proposed.

C. Closeout Submittals:

1. Approved submittal.

a. If "**As-Specified Verification Form**" submittal is approved, also include product data for all valves used.

2. Include all information required in Section 01 78 23 – Operation and Maintenance Data for all meters and gauges used. Include wiring diagrams for meter power, signal, and control wiring.

1.4 EXTRA MATERIALS

A. Furnish extra materials that match products specified and that are packaged with protective covering for storage and identified with labels describing contents.

1. Provide one complete test plug kit with training as described below. Include receipt signed by Owner’s representative in closeout documentation.

PART 2 - PRODUCTS

2.1 LIQUID-IN-GLASS THERMOMETERS

A. Metal-Case, Industrial-Style, Liquid-in-Glass Thermometers:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   a. Trerice, H. O. Co.
   b. Weiss Instruments, Inc.
   c. WIKA Instrument Corporation - USA.
   d. Winters Instruments - U.S.

2. Standard: ASME B40.200.

3. Case: Cast aluminum; exterior grade powder coated finish, 9-inch nominal size unless otherwise indicated.

4. Case Form: Adjustable angle unless otherwise indicated.

5. Tube: Glass with magnifying lens and non-mercury blue or red organic liquid.

6. Tube Background: Non-reflective with permanently etched scale markings graduated in deg F.

7. Window: Plastic.

8. Stem: Bare aluminum of length to suit installation.

9. Connector: 1-1/4 inches, with ASME B1.1 screw threads.

10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.2 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.
3. Material for Use with Copper Tubing or Steel Piping: solid machined de-zincification resistant brass or stainless steel.
4. Type: Stepped shank unless straight or tapered shank is indicated.
5. External Threads: ASME B1.20.1 pipe threads, size as required for sensors.
6. Internal Threads: ASME B1.1 screw threads, size as required for sensors.
7. Bore: Diameter required to match thermometer bulb or stem.
8. Insertion Length: Length required to match thermometer bulb or stem.
9. Lagging Extension: Include on thermowells for insulated piping and tubing.
10. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

B. Heat-Transfer Medium: Mixture of graphite and glycerin unless otherwise required by sensor manufacturer.

2.3 PRESSURE GAUGES

A. Direct Mounted, Dial Type Pressure Gauges:

1. 4-1/2-inch diameter flat white dials with black characters and graduations, micrometer style or externally adjustable zero point, providing 0.5 percent accuracy at mid scale and 1.0 percent accuracy full scale, certified to ANSI (ASME) B40.100 grade 1A with scales reading in psig.

2. Direct drive helically wound inconel bourdon tube movement with sapphire jeweled bearings or liquid filled stainless steel rotary type movement, rated for pump-mounted service, with bourdon tubes of seamless phosphor bronze alloy with silbrazed tips and forged brass sockets.

3. Impact resistant ABS, drawn steel or cast aluminum case with blow out grommet, snap ring, and “shatterproof” acrylic lens.

4. Provide ranges to read maximum design pressure at between 1/2 and 3/4 of maximum range.

5. Provide combination vacuum pressure gauges where indicated or required.

6. Provide 1/4-inch NPT connections located at bottom, lower back, or center back as required.

7. Provide five-year warranty.

8. Products: Provide one of the following:

   a. “TLG” by 3D Instruments or equal.

b. Ashcroft Duradrive model 1290 or equal.
c. Wika 232.34DD series or equal.

2.4 GAUGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with, ASME B1.20.1 pipe threads and piston or porous-metal-type surge-dampening device. Include extension for use on insulated piping.
B. Valves: Brass or stainless-steel needle type, slow opening, bubble tight shutoff, with ASME B1.20.1 pipe threads.

2.5 TEST PLUGS AND ACCESSORIES

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. 3D instruments Inc.
2. Flow Design, Inc.
3. Peterson Products Co.
4. Trerice, H. O. Co.
5. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
6. Weiss Instruments, Inc.

B. Test Plugs:

1. Description: Test-station fitting made for insertion into piping tee fitting.

2. Brass or stainless steel body, NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe thread with Chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber core inserts and gasketed and threaded cap with retainer. Include extended stem on units to be installed in insulated piping.

3. Minimum Pressure and Temperature Rating: 500 psig at 200 deg F.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
B. Proceed with installation only after unsatisfactory conditions have been corrected.
C. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 INSTALLATION

A. Install meters and gauges adjacent to machines and equipment in easily readable position but protected locations to allow and facilitate service and maintenance of meters, gauges, machines, and equipment.

B. Install thermowells with socket extending one-third of pipe diameter and in vertical position in piping tees. Provide thermometer stems of length to match thermowell insertion length.

C. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes. For pipe sizes 1 inch and smaller, increase pipe size by one size at location of thermowell to minimize obstruction.

D. Install thermowells with extension on insulated piping. Insulate fitting past piping well and neatly terminate insulation at thermometer body minimizing heat loss while allowing for adjustment.

E. Fill thermowells with heat-transfer medium.

F. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.

G. Install direct-mounted pressure gauges in piping tees with pressure gauge located on pipe at the most readable position.

H. Install valve and snubber in piping for each pressure gauge for fluids (except steam).

I. Install test plugs in piping tees in location that allows for ease of insertion of standard test kit probes.

3.3 LOCATIONS

A. Install thermometers in the following locations, and as additionally shown on drawings:

1. Mixed boiler supply water before reset.
2. Building supply heating water after reset.
3. Mixed building heating water return in boiler room.
4. Each main return branch in equipment room.

B. Install pressure gauges in the following locations:

1. One pressure gauge for each pump with 4 isolation ball valves and snubber, piped to read pressure before suction diffuser screen, at pump suction, at pump discharge, and atmospheric. Valve installed open to atmosphere for zero adjustment of each gauge.

2. One pressure gauge for each differential pressure sensor with 3 isolation ball valves and snubber, piped to read pressure in either supply, return, or atmospheric. Valve installed open to atmosphere for zero adjustment of each gauge.

C. Test Plugs:

1. Provide Pressure / Temperature Test Plugs at the supply and return connections to each new air / water heat transfer coil, adjacent to each thermometer and pressure gauge, and as noted on the drawings.

3.4 ADJUSTING

A. After installation, calibrate meters and gauges according to manufacturer's written instructions. Coordinate calibration with Testing and Balancing Agency (TAB) and include results in TAB report.

B. Adjust faces of meters and gauges to proper angle for best visibility.

3.5 THERMOMETER TYPE SCHEDULE

A. Thermometers in exterior locations or interior locations designed to range outside of the normal operation conditions of light activated thermometers shall be the following:

1. Industrial-style, liquid-in-glass type.

3.6 THERMOMETER SCALE-RANGE SCHEDULE

A. Provide thermometers of approximately the scale range indicated:

1. Scale Range for Heating, Hot-Water Piping: 30 to 250 deg F .
2. Scale Range for Steam and Steam-Condensate Piping: 30 to 250 deg F .
3. Scale Range for Outside Air: Minus 20 to plus120 deg F.
4. Scale Range for return and Supply Air: 30 to plus120 deg F.

3.7 PRESSURE-GAUGE TYPE SCHEDULE

A. Pressure gauges shall all be direct drive as specified.

3.8 PRESSURE-GAUGE SCALE-RANGE SCHEDULE

A. Scale Range for Heating, Hot-Water Piping: 0 to 100 psi

END OF SECTION 23 05 19

SECTION 23 05 23 – GENERAL DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Brass and Bronze Ball Valves.
2. Iron, Single-Flange Butterfly Valves.
3. Check Valves.
4. Automatic Flow Control Balancing Valves.
5. Pump Discharge Valves.
6. Bronze Globe Valves.
7. Air Vent Valves.
8. Chainwheels.

1.3 DEFINITIONS

A. CWP: Cold working pressure.
B. EPDM: Ethylene propylene copolymer rubber.
C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.

1.4 SUBMITTALS

A. Procedural Requirements: Comply with requirements of Section 01 33 00 - Submittals and as modified below.

1. Specified Products: If product to be incorporated into Project is specified by name and product designation in Part 2 below, submit "**As-Specified Verification Form**" (attached to Section 01 33 00 - Submittals) in lieu of "Product Data" identified below in this Article.

2. Equivalent Products or Substitutions: If product to be incorporated into Project is <u>not</u> specified by name and product designation in Part 2 below, comply with all Action Submittal requirements specified below.

B. Action Submittals:

1. Product Data: Submit concurrently for each type of valve proposed, demonstrating compliance with requirements.

C. Closeout Information, for inclusion in Operations and Maintenance Manual:

1. Approved submittal.

   a. If "**As-Specified Verification Form**" submittal is approved, also include product data for all valves used.

2. Include all information required in Section 01 78 23 – Operation and Maintenance Data.

3. Receipt: For spare automatic flow control valve cartridges.

4. Valve Chart: Refer to Section 23 05 00 – Common Work Results for HVAC, for details.

1.5 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. ASME Compliance:

1. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
2. ASME B31.9 for building services piping valves.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set angle, gate, and globe valves closed to prevent rattling.
4. Set ball and plug valves open to minimize exposure of functional surfaces.
5. Set butterfly valves closed or slightly open.
6. Block check valves in either closed or open position.

B. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.

1.7 EXTRA MATERIALS

A. Furnish extra materials that match products specified and that are packaged with protective covering for storage and identified with labels describing contents. Include receipt signed by Owner's representative in closeout documentation.

1. Provide additional Automatic Flow Control Valve cartridges as specified below.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

A. Refer to HVAC valve schedule articles for applications of valves.

B. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.

C. Valve Sizes: Same as upstream piping unless otherwise indicated.

D. Valve Actuator Types:

1. Gear Actuator: For quarter-turn valves NPS 6 and larger.

2. Handwheel: For valves other than quarter-turn types.

3. Handlever: For quarter-turn valves NPS 5 and smaller.

4. Chainwheel: Device for attachment to valve handwheel, gear actuator stem, or other actuator; of size and with chain for mounting height, as indicated in the "Valve Installation" Article.

E. Valves in Insulated Piping: With 2-inch stem extensions and the following features:

1. Ball Valves: With extended operating handle of non-thermal-conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation.

2. Butterfly Valves: With extended neck.

F. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1.
2. Grooved: With grooves according to AWWA C606.
3. Solder Joint: With sockets according to ASME B16.18.
4. Threaded: With threads according to ASME B1.20.1.

2.2 BRONZE AND BRASS BALL VALVES

A. Two-Piece Ball Valves with Stainless-Steel Trim:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   a. Conbraco Industries, Inc.; Apollo Valves.
   b. Milwaukee Valve Company.
   c. NIBCO INC.

2. Description:

a. Standard: MSS SP-110.
b. SWP Rating: 150 psig.
c. CWP Rating: 600 psig.
d. Body Design: Two piece.
e. Body Material: Bronze.
f. Ends: Solder or Threaded.
g. Seats: PTFE or TFE.
h. Stem: Stainless steel.
i. Ball: Stainless steel, vented.
j. Port: Full or Regular per application schedule.

2.3 IRON, SINGLE-FLANGE BUTTERFLY VALVES

A. 150 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Aluminum-Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

a. Conbraco Industries, Inc.; Apollo Valves.
b. Milwaukee Valve Company.
c. NIBCO INC.

2. Description:

a. Standard: MSS SP-67, Type I.
b. CWP Rating: 150 psig.
c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
d. Body Material: ASTM A 216 carbon steel, ASTM A 126, cast iron or ASTM A 536, ductile iron.
e. Seat: EPDM/Teflon, reinforced, resilient, for water temperatures up to 250 deg. F at 150 PSI.
f. Stem: 316 or 416 stainless steel shaft mounted within corrosion resistant bearings.
g. Disc: Aluminum bronze, bronze, or nickel coated iron.

2.4 BRONZE GLOBE VALVES

A. Class 125, Bronze Globe Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

a. Milwaukee Valve Company.
b. NIBCO INC.
c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

a. Standard: MSS SP-80, Type 1.
b. CWP Rating: 200 psig.
c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
d. Ends: Threaded.
e. Stem and Disc: Bronze.
f. Packing: Asbestos free.
g. Handwheel: Malleable iron, bronze, or aluminum.

2.5 CHECK VALVES

A. 1/2-inch to 2-inch Lines: Y-pattern swing-type manufactured in accordance with MSS-SP80, Class 125, bronze ASTM B-62 body with TFE seat disc; similar to “T413-Y (threaded) S413-Y (solder)” by Nibco.

B. 2-1/2-Inch Lines and Larger: Swing-type manufactured in accordance with MSS-SP71, Class 125, flanged ASTM A126 Class B cast iron body with bronze trim, non-asbestos gasket; similar to “F918-B” by Nibco.

C. Provide silent type where indicated and when check valves are installed in vertical lines.

1. 1/2-Inch To 2-Inch Lines: Bronze body, ball-cone check, straight through design, 1/2 PSI opening pressure or other opening pressure if so indicated on drawings, bubble tight shut-off with liquid media, 125 PSIG steam rating; similar to “Apollo 61-100” by Conbraco.

2. 2-1/2-Inch Line And Larger: Globe type, semi-steel body with bronze trim and stainless steel spring, 125 lb. ASA. similar to “Fig. #105-MAP or #107-MAP” by Mueller Steam Specialty.

2.6 AUTOMATIC BALANCING VALVES

A. Provide each valve with an identification tag attached by chain, factory marked with the zone identification, valve number and flow rate. Valve to be line size.

B. The GPM for the automatic flow control valves shall be factory set and shall automatically limit the rate of flow to within 5 percent of the specified GPM over at least 95 percent of the control range. Select and submit on automatic flow control valves based on flowrates shown on approved submittals.

C. For 1/2 inch – 2 inch, the flow cartridge shall be removable from the Y- body housing without the use of special tools to provide access for regulator change-out, inspection and cleaning without breaking the main piping.

D. Pump head requirement: The permanent pressure loss added to the pump head shall not exceed seven feet.

E. Each valve shall have two P/T test plugs.

F. Construction:

1. For 1/2” through 2” pipe sizes: Assembly consisting of a de-zincification resistant (DZR) brass, bronze, or A-metal Y-type body, integral full port SS ball and stem ball valve and ‘O’ ring type union. For all insulated pipe services, provide manufacturer’s pre-formed insulation cover to fit each valve, with extended, insulated, non-condensing handle on ball valves.

2. For 2 1/2” and larger flanged connections: Ductile iron body suitable for mounting wafer style between standard 150# or 300# flanges. Provide long flange bolts and nuts with each valve.

3. Stainless steel internal flow cartridge body and wear surfaces, with machined threads for spring free height adjustment, permanently marked with the GPM and spring range.

4. Factory leak tested at 100 psi. air under water.

G. Flow Verification:

1. Differential pressure measured across the valve shall be measured for flow verification and to determine the amount of system over heading or under pumping.

H. Design Make: IMI Flow Design Inc.

2.7 PUMP DISCHARGE VALVES

A. Provide pump discharge valve for each new pump and as otherwise noted on drawings.

1. For constant speed pump applications, provide pump manufacturer’s “triple duty valve” sized to provide maximum 3 feet water gauge pressure drop at the design flow.

2. For variable speed pump applications, provide either pump manufacturer’s “triple duty valve” or a combination of a venturi measuring station, non-slam check valve, and isolation valve, all as specified. Size to larger of full line size or as required to provide maximum 3 feet water gauge pressure drop at the design flow.

B. Pump manufacturer’s “triple-duty valve”:

1. 175-psig pressure rating, cast-iron body of angle or straight pattern.

2. Globe style combination shutoff, calibrated multi-turn flow throttling / measuring, and spring loaded non-slam check valve.

3. Include gage ports with integral check valve, and provision for attaching a portable differential pressure meter, with each meter connection having positive shutoff access valves.

4. Provide with removable insulating cover providing minimum R value of 5.

C. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. "Model 3D Triple Duty Valve" by Bell & Gossett.
2. Armstrong.
3. Paco.
4. Victaulic.

2.8 AIR VENTS

A. Manual Air Vents:

1. For All Pipe Sizes in Accessible Locations Only: Bronze body, quarter turn ball valve with minimum 1/4-inch discharge and inlet connections. Provide collection chamber at inlet and 1/4-inch tube with return bend on outlet, piped to point of collection.

2. For Terminal Units in Accessible Locations: Bronze or brass body and non-ferrous internal parts, 150 PSIG working pressure, 225 deg. F operating temperature. 1/8-inch MNPT inlet connection. Coin or key operated, supply three keys minimum to owner. Similar to "Model 4V" by Bell & Gossett.

B. Automatic Air Vents:

1. High Capacity Type: Cast iron body with internal working parts of stainless steel, brass, bronze, and EPDM and float-operated sealing valve designed to purge free air from the system and provide positive shut off at pressures to 125 PSIG and temperatures to 250 deg. F. Vent prevents air from entering the system if system pressure drops below atmospheric. Vent readily serviceable by disassembly to access the internal working parts. Similar to "Model "107A" by Bell & Gossett or "720" by Amtrol.

2. Standard Capacity Type: Cast bronze body with internal working parts of stainless steel, brass, bronze and EPDM and float operated sealing valve designed to purge free air from the system and provide positive shut off at pressures to 150 PSIG and temperatures to 230 deg. F. Vent prevents air from entering the system if system pressure drops below atmospheric. Vent readily serviceable by disassembly to access the internal working parts. Similar to "No. 700-C" or "701-C" by Amtrol.

2.9 CHAINWHEELS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries.
3. Trumbull Industries.

B. Description: Valve actuation assembly with sprocket rim, brackets, and chain.

1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.

2. Attachment: For connection to butterfly valve stems.
3. Sprocket Rim with Chain Guides: Ductile or cast iron, of type and size required for valve. Include zinc coating.
4. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.

B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.

C. Examine threads on valve and mating pipe for form and cleanliness.

D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage. Verify dielectric bolt kits are provided for flanged connections between dis-similar materials.

E. Do not attempt to repair defective valves; replace with new valves.

3.2 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

A. Install isolation valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Install isolation valves at each new branch connection serving three or more pieces of terminal equipment, and as additionally shown on drawings.

C. Install check valves at each pump discharge and elsewhere as required to control flow direction.

D. If valves with specified CWP ratings are not available, the same types of valves with higher CWP ratings may be substituted.

E. Select valves with the following end connections:

1. For Copper Tubing, NPS 2 inch and Smaller: Threaded or solder joint ends.
2. For Copper Tubing, NPS 2-1/2 inch and larger: Flanged ends.
3. For Steel Piping, NPS 2 and Smaller: Threaded ends.
4. For Steel Piping, NPS 2-1/2 inch and Larger: Flanged or grooved ends.

3.3 GENERAL DUTY VALVE SCHEDULE

A. Unless otherwise specifically indicated elsewhere, use the following:

B. Hydronic Flow Shutoff Service:

1. 2 inch and smaller: Full Port Ball Valves.
2. 2-1/2" and larger: Butterfly Valves.

C. Pressure Gage Shutoff Service: Standard or Full Port Ball Valves.

D. Flow Adjustment and Balancing:

1. Provide line size automatic flow control balancing valves for all individual terminal loads. Size valve flow cartridges based on approved equipment submittal flow rates where different from that scheduled. Include in contract changing cartridges on 10% of automatic flow control valves to some different flow as required during TAB and system commissioning work. Turn over original cartridges which have been changed, or the unused portion of the 10% extra, to the Owner with receipt.

2. Select final flow based on approved submittals, not on flow indicated on contract documents.

E. Pump Service:

1. Suction: Provide full line size isolation valve at pump inlet before reducers, flex connections, and suction diffuser.

2. Discharge:

a. Constant speed pumps: Provide Pump Discharge Valves by pump manufacturer, full line size of system piping (typically larger than pump discharge size), after flex connections.

b. For VSD driven pumps, the pump discharge valve may consist of a manufacturer's triple duty valve or alternately a combination of a venturi measuring station as specified in Section 23 05 19, a non-slam check valve, and an isolation valve.

c. Install with sufficient length of straight pipe before and after valve as recommended by manufacturer to obtain good and stable measurements.

F. Hydronic System Drain Service: Provide drain valves at all system local or global low points as required for complete system drainage.

1. 2-1/2 inch and larger service: Provide ¾ inch full port ball valves with ¾ inch hose thread end and chained cap.
2. 2 inch and smaller service: Provide ¾ inch full port ball or globe valves, with ¾ inch hose thread end and chained cap.

G. Hydronic System Air Venting:

1. Manual vents: provide standard or full port ball valve, minimum 1/4" NPT; ½" NPT on 4" and larger piping.

2. Provide Standard Capacity Type Automatic Air Vent at accessible points in piping system where air may collect, including all local high points and at the end of each horizontal run before a drop in elevation.

   a. If any such point will be inaccessible after construction is complete, provide only Manual Air Vent in lieu of automatic, installed as described below.

3. Equipment Air Vents:

   a. Provide High Capacity Automatic Air Vent above each air and air/solids separator.

   b. Equipment Above Mains: Connect run outs or risers to upper quadrant or top of mains. Install vent assembly at branch high point, concealed within enclosure if possible, consisting of 1 in. diameter by 6 in. long air collection chamber with 1/4 in. soft copper tube to manual valve. Mount securely near bottom of enclosure, but not fastened to enclosure. For individual units, radiators, fan convectors and units with return grilles: Provide coin air vent valve, operated from discharge grille or access door. Positioning of valve shall not interfere with removal of enclosure.

   c. Equipment Below Mains: Connect piping run outs or risers to bottom or lower quadrant of mains. Vent assembly not required in unit. Provide means of purging and draining each unit. Use tees instead of ells at low point of run outs.

3.4 VALVE INSTALLATION

A. When installing solder-joint end valves, protect valve body from soldering heat using water soaked rags or other heat sink method as required to avoid valve damage. Leaking stems or seats on solder-joint end valves shall be subject to immediate replacement with new valve.

B. Locate valves for easy access and provide separate support where necessary.

C. Install valves in horizontal piping with stem at or above center of pipe.

D. Install valves in position to allow full stem and handle movement.

E. Install all Automatic Air Vents above manual vent assembly described below, with discharge piped to point of collection - for glycol venting, pipe discharge to glycol feed station as shown, or if not shown to minimum 1 quart clear plastic container, secured and removable for service.

F. Install all Manual Air Vents with air collection chamber above flow piping (minimum line size diameter x 6 inches long), and minimum ¼” tube extended to accessible location, terminating with ball valve located so liquid discharged during venting may easily be collected in minimum 1 quart container.

   1. Coin vents may be connected directly to equipment served.

G. Install chainwheels on operators for butterfly valves more than 96 inches above floor. Extend chains to no higher than 48 inches above finished floor, or longer as required to hang on adjacent wall hook out of the way.

3.5 ADJUSTING

A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

END OF SECTION 23 05 23

SECTION 23 05 29 - HANGERS AND SUPPORTS FOR HVAC COMPONENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Conditions and Division 01 Specification Sections, apply to this Section.
B. Division 06 Section “Roofing Rough Carpentry” for roof mounted support blocking.

1.2 SUMMARY

A. Section Includes

1. Hangers and supports for (but not limited to) following components:

    a. Piping hangers and supports.
    b. Duct hangers and supports.
    c. Equipment hangers and supports.

2. Roof mounted supports and equipment penetrations including (but not limited to):

    a. Roof curbs.

3. Miscellaneous components and accessories including (but not limited to):

    a. Anchors.
    b. Guides.
    c. Fasteners.
    d. Custom supports.
    e. Insulation protection systems.

1.3 DEFINITIONS

A. MSS: Manufacturers Standardization Society of the Valve and Fittings Industry Inc.

1.4 PERFORMANCE REQUIREMENTS

A. This section does not detail mechanical vibration or movement control requirements. Refer to Section 23 05 43 – Mechanical Vibration and Movement Control for additional hanger and support requirements.

B. Provide corrosion resistant construction as described below for hangers, hanger rods, supports, fittings, hardware, etc, unless otherwise noted or approved. Note that not all products described below are available in corrosion resistance as required for all applications listed – select appropriate corrosion resistant products as required. Multiple conditions may apply, in which case the more corrosion resistant construction is required:

1. General purpose indoor: ASTM B-633 Fe/Zn 25 minimum zinc plated fasteners, ASTM B-653 G90 minimum sheet steel, factory baked enamel paint, or anodized.

2. In contact with copper: Copper plated for size identification and felt lined or plastic coated.

3. In contact with aluminum: Same aluminum alloy as equipment or 300 series stainless steel. 300 series stainless steel fasteners.

4. Outdoors, in crawl spaces, manholes, pits, and below grade: 300 series stainless steel or post-fabrication (after forming, welding, drilling, etc.) ASTM A-153 hot dipped galvanized steel, minimum coating thickness 3 mils.

5. Miscellaneous fabricated custom supports, anchor bases, etc..: painted in accordance with Section 23 05 00 – Common Work Results for HVAC.

6. Other special conditions: where noted on drawings, provide materials of special temperature, corrosion resistance, or other properties, as required for durable and safe performance.

C. Allowable Working Loads:

1. Use only manufacturer’s load rated hangers, supports, and fasteners designed and rated for the intended service.

2. Do not load connectors, hangers, or supports to more than the manufacturers′ recommended working load or the following:

   a. Use a safety factor of 5:1 minimum with respect to manufacturers′ published ultimate shear strength.
   b. Use a safety factor of 10:1 minimum with respect to manufacturers′ published ultimate tension or pull-out strength.

D. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, service loads, and test water.
2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
3. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

1.5 SUBMITTALS

A. Product Data: Submit manufacturer's product literature, technical specifications, and other data required to demonstrate compliance with specified requirements for following components:

1. Hangers and supports.
2. Roof mounted supports.
3. Miscellaneous components.

B. Roofing Work:

1. Submit qualifications of proposed roofing and structural subcontractor(s).

2. Submit copy of any existing roofing warranty and certification by existing warranty holder that proposed roofing subcontractor is certified to provide compliant roofing warranty work and that this project's roofing work will not (before construction) and has not (after construction) voided any warranty.

3. Submit copy of new warranty for roofing performed on existing out-of-warranty roofing.

C. Shop Drawings: Submit intended custom support construction for approval.

D. All supports, etc., shall meet the approval of the Architects / Engineers. Submit shop drawings showing fabrication and installation details including calculations for the following; include Product Data for components:

1. Trapeze pipe hangers.
2. Metal framing systems.
3. Pipe stands.
4. Equipment supports.
5. Include detailed layout and loading drawings for all above roof piping and equipment.

1.6 QUALITY ASSURANCE

A. Comply with applicable requirements of following standards for all hangers and supports:

1. MSS-SP-58 Pipe Hangers and Supports – Materials, Design, and Manufacture.
2. MSS-SP-69 Pipe Hangers and Supports – Selection and Application.
3. ANSI / ASME Code for Pressure Piping B 31.1/
4. ASTM standards for corrosion resistant Zinc coatings.
5. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
6. UL 203 Standard for Pipe Hanger Equipment and Fire Protection Service/
7. Metal Framing Association MFMA-2.
8. ANSI/ NFoPA NDS - National Design Specification for Wood Construction.
9. SMACNA – Sheet Metal and Air Conditioning Contractor's National Association, Inc.

B. All welding shall be approved procedures performed by approved welders. Refer to Division 05 Section for "Structural Steel Framing," and Section 23 05 00 – Common Work Results for HVAC, for details on welder's qualification requirements.

PART 2 - PRODUCTS

2.1 GENERAL

A. For convenience, details and specifications have been based on product types as defined in MSS SP-58 and 69 where applicable, and, where not applicable, catalog numbers shown have been based on products by the listed manufacturers.

2.2 PIPING ATTACHMENTS

A. Individually Suspended Horizontal Rigid Piping or Tube Attachments:

1. Band Type:

   a. 1-1/4 inch diameter pipe size and less only.
   b. Formed steel loop overlapped at top with rod sized hole or insert nut. With or without side insert closure.
   c. MSS SP-58 type 5, 6, or 10.

2. Clevis Type:

   a. Any size pipe or tubing.
   b. Formed steel bands top and bottom connected by sheer bolt.
   c. MSS SP-58 type 1.

3. Roller Type:

   a. Any size pipe or tubing.

   b. Radiused or angled roller and steel axle; yoke for single hanger rod or end sockets for double rod applications. Designed to accommodate longitudinal movement through roller action.

   c. MSS SP-58 type 41 and 43.

4. Provide products by one of the following manufacturers:

   a. B-Line Systems, Inc., Highland Illinois, or equal.
   b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal.
   c. Grinnell Corporation; Pipe Support Division, Cranston, Rhode Island, or equal.

B. Supported from below Horizontal Rigid Piping or Tube Attachments:

1. Split Ring Type:

   a. 1-1/4 inch diameter pipe size and less only.

   b. Cast malleable iron split ring with steel pivot and bolt, cast boss on one side threaded for standard rod or pipe attachment. Designed to accommodate minimal longitudinal movement only.

c. MSS SP-58 type 12.

2. Stanchion Saddle Type:

a. Any size pipe and tubing.

b. Radiused pipe saddle support with U-bolt upper restraint. Threaded adjuster rod or pipe integral / welded to saddle for vertical adjustment. Designed to accommodate minimal longitudinal movement only.

c. MSS SP-58 type 37.

3. Roller Type:

a. Any size pipe or tubing.

b. Radiused or angled roller and steel axle with end sockets for double rod applications. Provide with U-bolt upper restraint. Designed to accommodate longitudinal movement through roller action.

c. Roller MSS SP-58 type 41 and U-bolt MSS SP-58 type 24.

4. Provide products by one of the following manufacturers:

a. B-Line Systems, Inc., Highland Illinois, or equal.
b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal.
c. Grinnell Corporation; Pipe Support Division, Cranston, Rhode Island, or equal.

C. Group Supported or Suspended (Trapeze) Horizontal Rigid Piping or Tube Attachments (Common Support Beam):

1. Support frame or trapeze beam of load rated brackets or channel strut product.

2. U-Bolt Type:

a. Any size pipe or tubing.

b. Insulation support system rests directly on beam or shim, with U-bolt or split strut clamp upper restraint. Designed to accommodate minimal longitudinal movement only.

c. U-bolt MSS SP-58 type 24, Strut clamp similar to B-Line “B-2000” series.

3. Radius Roller Type:

a. Any size pipe or tubing.

b. Radiused roller and steel axle with end sockets for double rod applications. Provide with U-bolt upper restraint. Designed to accommodate longitudinal movement through roller action.

c. Roller MSS SP-58 type 41 and U-bolt MSS SP-58 type 24.

4. Angled Roller Type:

    a. 6 inch diameter pipe size and less only.

    b. Angled rollers with steel axles and formed steel angle clips designed for channel strut mounting. Provide with U-bolt upper restraint. Designed to accommodate longitudinal movement through roller action.

    c. Roller similar to B-Line “B218” or “B219” and Strut clamp similar to B-Line “B-2000.”

5. Provide products by one of the following manufacturers:

    a. B-Line Systems, Inc., Highland Illinois, or equal
    b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal
    c. Grinnell Corporation; Pipe Support Division, Cranston, Rhode Island, or equal.

D. Individual Vertical Rigid Piping and Tube Attachments:

1. Split Ring Type:

    a. 1-1/4 inch diameter pipe size and less only.

    b. Cast malleable iron split ring with steel pivot and bolt, cast boss on one side threaded for standard rod or pipe attachment. Designed to accommodate minimal longitudinal movement only.

    c. MSS SP-58 type 12.

2. Riser Clamp Type:

    a. 1-1/2 inch diameter pipe size and larger.

    b. Twin formed steel bands with formed radius to fit pipe and extension wings drilled for clamping bolts, space between extension wings designed to accept various connections to building structure.

    c. MSS SP-58 type 8.

3. Provide products by one of the following manufacturers:

    a. B-Line Systems, Inc., Highland Illinois, or equal
    b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal
    c. Grinnell Corporation; Pipe Support Division, Cranston, Rhode Island, or equal.

E. Flexible Pipe, Tube, or Hose:

1. Lengths three feet and under to be supported by adjacent piping system.

2. Similar to attachments for rigid piping systems described above, with “V” notch bottom in lieu of radius, and associated continuous rigid trough angle of same material spanning between attachments.

F. Piping Insulation Protection Systems:

1. Pipe Insulation Shields:

a. One Piece:

1) Formed steel, minimum 18 gauge thickness, longer of 2 times diameter or 12-inch long minimum, and 180 degree circumference, sized for insulation thickness.

2) MSS SP-58/69 type 40.

b. Two Piece Sliding:

1) Manufactured two piece sliding shield system designed to accommodate thermal movement.

2) MSS SP-58/69 type 40 inner shield similar to one piece shield above adhered to pipe insulation, with second outer shield of formed steel, minimum 18 gauge thickness, one times diameter length 6-inch long minimum, and 180 degree circumference, sized to fit outside inner shield, with formed ribs to keep shield centered on support clevis or trapeze.

3) Inner and outer shields separated by layer of PTFE (Teflon), minimizing friction between shields and allowing minimum four inches controlled pipe movement relative to hanger without insulation damage or outer shield moving past the end of the inner shield.

2. Type "A" Insulation Protection System:

a. 1" piping and smaller only.
b. Provide one piece or two piece sliding shield as required by distance from piping anchors.

3. Type "B" Insulation Protection System:

a. 1¼" through 8" heating piping only.

b. Provide one piece or two piece sliding shield as required by distance from piping anchors.

c. Pipe Support Insulation: High density (20 pcf). molded fiberglass blocks consisting of fiberglass wool and urea-phenolic resin cured binder. Provide number and size of support blocks as required to limit deflection to 1% and avoid long-term damage to vapor barrier, and as required for pipe size and insulation thickness, in accordance with manufacturer's written guidelines and project details. Seal cut in piping insulation vapor barrier using manufacturer's recommended matching tape. Similar to AHAMFAB H-Block" by ICA

4. Type "C" Insulation Protection System:

a. Acceptable for any size heating or cooling piping.

b. Manufacturer’s assembly consisting of insulation shield, high compressive strength insulation, and vapor barrier covering. May include hanger also.

c. Hanger: As required above, secured to shield and support insulation.

d. Insulation Shield: Provide one piece or two piece sliding shield as required by distance from piping anchors.

e. High Compressive Strength Insulation: 180 or 360-degree circumference insulation insert formed of water resistance treated hydrous calcium silicate (untreated cal-sil not acceptable) or cellular glass insulation, same thickness as adjacent insulation.

f. Vapor Barrier Covering: White kraft outer surface bonded to aluminum foil, sandwiching reinforcing fiberglass skrim yarn, permanently treated for fire and smoke safety and to prevent corrosion of the foil, with a vapor transmission perm rating of 0.02 or less. Seal to piping insulation vapor barrier using manufacturer’s recommended matching tape.

g. Similar to Models “123,” “124," “1031,” and “4031” by ERICO/Michigan Hanger.

5. Provide products by one of the following manufacturers:

a. B-Line Systems, Inc., Highland Illinois, or equal.
b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal.
c. ICA Inc.; Lehighton, Pennsylvania, or equal.
d. Buckaroos, Inc.

2.3 DUCT ATTACHMENTS

A. Per SMACNA Duct Manual standards for size, height, and location of ductwork, and as noted below.

1. Materials and corrosion resistance as listed above.

2. SMACNA load tables allow for no external loads on duct: provide for 200 lb external load on all duct hangers and supports. Increase hanger and support sizes from SMACNA tables accordingly:

a. Minimum band size 20ga. x 1 inch.
b. Duct 48” wide and larger; provide trapeze style support of metal channel framing or angle iron, suspended from threaded rods.

3. Hanger bands to extend down sides and turn under bottom 1 inch minimum for all duct sizes. Minimum (2) #10 sheet metal screws per hanger (one each on side and bottom), (2) screws minimum on sides for duct over 12 inches tall, 12 inches on center max.

4. Round exposed duct: hang from twin half round bands and rods, or as otherwise detailed.

2.4 BUILDING ATTACHMENTS

A. Structural Steel Connectors:

1. C-Clamp Style:

a. FM approved, U.L. listed, steel or malleable iron C-clamp with hardened set screw and lock nut, tapped for rod size, typically eccentrically loads structure.
b. Hanger rod bypasses structure: MSS SP-58 type 19.
c. Hanger rod in line with set screw: MSS SP-58 type 23.

2. Center Loading Beam and Channel Clamp Style:

a. Forged or formed steel or malleable iron construction, beam clamps with connection for concentrically loading structure, of types as required by loading and configuration.

b. MSS SP-58 types 21, 27, 28, 29, and 30.

3. Pivoting or Adjustable Connection Style:

a. Structural welding lug with forged steel clevis, side beam bracket, or other appropriate pivoting beam clamps as required for sloped steel.
b. Use for sloped steel, where thermal movement requires pivot, where seismic controls requires non-moment building connection, and elsewhere as required.
c. MSS SP-58 types, 21 or 22 with 16 or 17, 34, 57 with 14, etc.

4. Provide products by one of the following manufacturers:

a. B-Line Systems, Inc., Highland Illinois, or equal.
b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal.
c. Grinnell Corporation; Pipe Support Division, Cranston, Rhode Island, or equal.

B. Existing Concrete Connectors:

1. Self-energizing tapered expansion bolt/sleeve: GSA specification FF-S-325, Group II, Type 3, Class 3, UL Listed, FM approved, complete with split expansion sleeve, washer, and hex head nut; similar to “Rawl Lok/Bolt” by Rawlplug.

2. Dual-Interlocking Expansion Wedge Stud: GSA specification FF-S-325, Group II, Type 4, Class 1, UL Listed, FM approved, complete with split expansion sleeve, washer, and hex head nut; similar to “Rawl-Stud” by Rawlplug.

3. Dual-Interlocking Expansion Wedge Threaded Rod Anchors: UL Listed, FM approved, complete with split expansion sleeve; similar to “Rod Hanger Wedge Anchor” by Rawlplug.

4. Provide products by one of the following manufacturers:

a. Hilti, Inc.; Tulsa, Oklahoma, or equal.
b. Ramset/Red Head; Michigan City, Indiana, or equal.
c. Rawlplug Co. Inc.; New Rochelle, New York, or equal.

C. Hollow Masonry, Hollow Concrete, Pre-cast Plank Connectors:

1. Toggle Bolt Type: GSA specification FF-B-588C,Type 1, Class A with ultimate load capacities meeting or exceeding load capacities for hollow concrete block in conformance with ASTM C-90; similar to “Rawl Toggle Bolt” by Rawlplug.

2. Epoxy/Screen tube type: Manufacturer’s load rated epoxy resistant to the chemical exposure of the application and capable of developing the ultimate strength of the threaded rod used, with stainless steel screen tube designed specifically for use with epoxy anchors in hollow masonry. Use manufacturer’s recommended mixing/injection device. Similar to the “Foil-Fast,” “Chem-Fast,” and “Chem-Stud” systems by Rawlplug.

3. Through bolt, nuts, square plate steel washer (thickness equal to half bolt diameter, width equal to six diameters minimum).

4. Provide products by one of the following manufacturers:

a. Hilti, Inc.; Tulsa, Oklahoma, or equal.
b. Ramset/Red Head; Michigan City, Indiana, or equal.
c. Rawlplug Co. Inc.; New Rochelle, New York, or equal.

D. Flanged Connectors:

1. Applicable for attachment to building steel, concrete, or wood.

2. Malleable iron flange base, with central threaded hole for connection to threaded rod and symmetrical side hole for securing to structure with appropriate fasteners, typically used with split rings, similar to “Model No. 365M" by ERICO/Michigan Hanger.

3. Pipe Stanchion Flanged Support Plate and Floor Stand: ASTM A-536 ductile iron support plate with 1-inch rolled thread adjustment stud and nut, or 1/4-inch carbon steel base plate welded to schedule 80 threaded steel pipe, designed for use with Stanchion Saddle style supports described above; similar to “PS1236 Redi-Jack Pipe Support” by Red Hed.

4. Provide products by one of the following manufacturers:

a. B-Line Systems, Inc., Highland Illinois, or equal.
b. ERICO/Michigan Hanger Co.; Solon, Ohio, or equal.
c. Red Hed; Lincoln, Rhode Island. or equal.

2.5 ROOF MOUNTED SUPPORTS

A. Roof Curbs: Double shell, galvanized steel, welded and painted, 1-1/2 inch minimum thickness, with pressure treated wood blocking, braced and fully insulated with rigid fiberglass insulation (3 PCF). Includes gasket at top of curb for airtight seal between curb and ventilator or fan. Provide raised cant, recessed, or flanged curb bottom to suit roof construction and insulation.

1. Steel Thickness: 20 gauge up to 36 inches, 18 gauge 38 to 72 inches, and 16 gauge over 72 inches. Provided with reinforcing and heavier gauge as required to adequately support weight load on curb; coordinate exact size with specified equipment.

2. Minimum height of curbs above finished roof:

   a. 12 inches for curbs supporting exhaust and relief air equipment.
   b. 24 inches for curbs supporting outside air intakes.
   c. For sloped roof curbs, curb of height sufficient to maintain bottom edge of supported equipment at above specified height.

3. Provide with pressure treated blocking, through bolted to structure with stainless steel fasteners, as required bringing base of curb into proper plane for installation. Blocking minimum width to be no less than blocking height. Refer to Division 1 Section "Roof Rough Carpentry" for additional details.

4. Provide products by one of the following:

   a. Pate or equal.
   b. Con-Fab or equal.
   c. Thy-Curb or equal.

B. Curb Adapters: Where shown on drawings, provide curb adapters to transition in size from existing curb to equipment provided as a part of this contract. Curb adapters of fully welded aluminum (12ga) or stainless steel (16ga) construction designed for continuous exposure to the elements. Provide with integral curb counter flashing and drip edge with minimum 2 inch downturn and quarter inch clearance to existing curb exterior on all sides and minimum two screws per side, sized for proper wind resistance, #12 ss screws minimum. Upper portion similar to Roof Curb above.

2.6 EQUIPMENT SUPPORTS

A. Provide custom designed hangers and supports to properly and resiliently support all contract equipment as required by special circumstances encountered. Suspend from above or support from below as shown on drawings and as required.

B. Use structural carbon steel plate and shapes, secured by welding or bolts as required.

C. Use load rated fasteners full size of the component attachment points unless specifically requested and approved otherwise.

D. Provide lateral bracing as required minimizing potential for sway.

E. Fabricate as required to transmit loads and reaction forces to structure, in accordance with applicable details and layouts shown on Drawings, and as approved by Architect. Submit load calculations and fabrication details for approval for all such supports including verified coordinated dimensions, weights, etc., of mechanical component, support component, and building structure proposed.

2.7 MISCELLANEOUS COMPONENTS AND ACCESSORIES

A. Piping Anchor and Guide Bases:

1. Provide custom designed piping anchor and guide bases as required to properly transmit the piping reaction forces to the building structure.

2. Triangulate fabrication to transmit reaction forces to deck edge of structure or other approved anchorage. Submit fabrication details for approval for all such supports including verified coordinated dimensions of support components and building structure proposed for attachment.

3. Use structural steel plate and shapes of pipe wall thickness minimum, with pipe diameter leg dimension minimum, secured by welding or multiple bolts of the pipe’s hanger rod size minimum. Increase dimensions as required due to excessive unsupported length (greater than 15 pipe diameters) or moment bearing (bending) design.

4. Secure to at least two structural members, using at least three points of attachment designed to transmit both longitudinal and lateral piping reaction forces.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Nonstaining, noncorrosive, and nongaseous.
2. Design Mix: 5000-psi, 28-day compressive strength.

C. Threaded Rods, Bolts, Nuts, Washers, Metals, Hardware, and Miscellaneous Assembly Components:

1. Provide manufacturer’s load rated fasteners with size, strength and corrosion resistance as required for the application.

2. Rods, bolts, machine screws: rolled forged ANSI B1 Class 2A or better thread, bolts and screws with heads as required by the application, length as required for full thread engagement of but minimal projection past receiving connector including building attachment, (double) nuts, equipment attachment, etc.

3. Nuts: heavy pattern where space permits and where subject to repeated operation, ANSI B1 Class 2B or better thread.

4. Washers: US pattern where space permits, SAE pattern otherwise, with toothed or split lock washer when attached to equipment with moving or vibrating parts.

5. Sheet metal screws: self drilling, thread forming, hardened steel (hardened SS as required), load rated screws with hex heads designed for power driving.

6. Structural Steel: ASTM A 36/A 36M, carbon-steel, black and galvanized, and/or series 300 Stainless Steel plates, bars, angles, channels, and other shapes in thickness and size as required for load.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which hangers and supports are to be installed and notify Architect in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in an acceptable manner.

1. When Contractor confirms conditions as acceptable to ensure proper and timely installation and to ensure requirements for applicable warranty or guarantee can be satisfied, submit to Architect written confirmation. Failure to submit written confirmation and subsequent installation will be assumed to indicate conditions are acceptable to Contractor.

2. Identify any discrepancies between specifications and field conditions or changes required due to specific equipment selection, prior to installation. Corrective work required by discrepancies after installation at Contractor's expense.

3.2 GENERAL INSTALLATION

A. Provide complete hanger and support systems for piping and ductwork systems and equipment, including all necessary attachments, fasteners, threaded rods, bolts, miscellaneous hardware, and associated work as required.

B. Provide specified products, installed in accordance with applicable sections of this specification, in accordance with the manufacturer's recommended installation instructions, and as detailed on the Drawings.

C. Support pipe, duct, and equipment from the building structure.

1. Provide approved miscellaneous support structure as required to attach hangers and supports to building structure in conformance with all applicable standards and related specification sections.

2. Do not use chain, perforated hanger strapping or band, wire hangers, or kinked, bent, or otherwise damaged hangers and supports.

3. Do not support one pipe from another, one duct from another, pipe from duct or equipment, or any similar combination.

4. Install lateral bracing with pipe hangers and supports as required to prevent swaying.

5. Provide special hangers and supports as shown on the drawings, as required to suit existing conditions, and as required for proper installation of equipment.

D. Coordinate the installation with applied fireproofing and where possible install attachments to structure prior to fireproofing. Where prior installation is not possible, repair fireproofing as required.

1. Repair or replace any fireproofing removed or damaged during installation of components.
2. Ensure repaired or replacement fireproofing continuously matches or exceeds rating of adjacent fireproofing and ensure that all warranties are maintained.

E. Load Distribution: Install hangers and supports so that live and dead loads and stresses from movement will not be transmitted to connected equipment.

3.3 PIPE HANGER AND SUPPORT INSTALLATION

A. Comply with MSS SP-58 and MSS SP-89 and as specified below. Install hangers, supports, clamps, and attachments as required properly supporting piping from the building structure.

B. Trapeze Pipe-Hanger Installation: Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.

2. Field fabricate from manufactured slotted channel system or structural shapes selected for loads being supported.

C. Size piping attachments for insulated piping to fit outside insulation. Size piping attachments for un-insulated piping to fit outside diameter of pipe.

D. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping. Provide for slope of trapeze supported piping systems with adjustable individual piping attachments.

E. Accommodate thermal movement of piping systems.

1. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

2. Provide rods of sufficient length for ample swing. Hang rods from high points to allow maximum swing.

3. Hang piping so that rods are vertical at the design temperature.

4. Where length of rod and thermal expansion combine to cause more than 4 degrees angular movement of rod (or 1 inch lateral movement in a 12 inch rod), provide suitable linkage to permit swing and limit rods to tensile loading only, or, provide pipe roll.

5. Where length of rod and thermal expansion would combine to cause more than 10 degrees angular movement of rod (or 2 inch lateral movement in a 12 inch rod), provide pipe roll.

6. More thermal movement is expected as the straight line distance from piping anchor points increases. Unless unusually long hanging rod length allows swing as indicated above, provide pipe roll hangers and supports at or above the following distances from piping anchor points indicated on drawing or installed in field. Deviations from below values subject to pre-approval:

Piping Service	Distance from Anchorage
a. Individual Copper Heating Service.	35 ft.
b. Trapeze Copper Heating Service.	20 ft
c. Individual Steel Heating Service.	60 ft.
d. Trapeze Steel Heating Service.	50 ft

F. Pipe Hangers and Supports Spacing (Maximum):

1. Provide hanger or support as close as possible to and within 24 inches of any elbow.

2. Provide hanger or support on branch pipe within 24 inches of main at takeoff / tee.

3. All Horizontal / Sloped Heating and Cooling Piping Systems:

Piping Material	Maximum Spacing of Hangers
a. Copper ¾ in. and smaller	5 ft.
b. Copper 1 in. and 1-¼ in.	6 ft.
c. Copper 1½ in. and larger	8 ft.
d. Steel 1¼ in. and smaller.	7 ft
e. Steel 1½ in.	9 ft.
f. Steel 2 in. and larger	10 ft.
g. Annealed copper	3 ft.
h. Flexible piping or hose	Continuous

4. Vertical Piping:

a. Steel and Copper 1¼ in and smaller	Two per floor level.
b. Steel and Copper 1½ in and larger	One per floor level.

G. Insulated Piping

1. Center insulation shields at piping attachments and secure shield from lateral movements by wrapping PVC tape around circumference of piping insulation and shield at both ends of shield.

2. At all piping attachments, provide piping insulation protection system of strength and configuration required to guarantee integrity of pipe insulation and associated vapor barrier. Refer also to Section 23 07 00 - Insulation.

3.4 BUILDING ATTACHEMENTS INSTALLATION

A. Threaded Rod for Hangers:

1. Double nut each end of each rod. Threaded clamp, turnbuckle, etc. counts as one nut.

2. Rod size for individual pipe hangers and two rod / two pipe or duct trapeze style supports:

Rod size:	for Pipe size:	for Duct size:
3/8”	2” and smaller	48” wide to 72”
1/2”	2-1/2" and 3"	Over 72” wide
5/8”	4" and 5"	
3/4”	6"	

3. For multiple pipe or duct trapeze style supports with two rods for more than two pipes or two or more ducts, size rods according to manufacturers recommended safe working loads taking into account total hung weight, 200 pound live load, as well as capacity of structure; each rod not smaller than size shown above for largest pipe or the sum of the duct width in the trapeze. Submit details of all such supports and connectors for approval before construction, including schedule of proposed sizes and capacities.

B. Fastener Systems: Provide screws, bolts, approved anchors, etc., to secure piping, duct, equipment, supports, and miscellaneous components and accessories to structure. Nailing not permitted.

1. Install all fastener systems and anchorage in strict accordance with fastener manufacturer’s instructions and as otherwise indicated below.

2. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 3” and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

3. Minimize eccentric loading of structure as follows:

a. For paired point loads eccentrically suspended (C-clamp attached supply and return pipes, etc), suspend from opposite edges of structural member.

b. For point loads over 400 pounds, use center loading beam clamps or other structurally concentric building attachment, and confirm proposed configuration with Engineer by submittal.

4. For connection to existing concrete:

a. Connect only to sound concrete free of evidence of deterioration.

b. Do not install connections or apply loads to recently cast curing concrete until written approval is received from contractor responsible for concrete strength. Use compressive strength certified by ASTM approved test results.

c. For older existing concrete and in the absence of ASTM approved tests certifying otherwise, assume a concrete compressive strength of *f’c* = 3000 psi.

d. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual. Do not use powder-actuated fasteners in precast concrete or in pull-out tension.

3.5 DUCT HANGERS AND SUPPORTS

A. Install per SMACNA duct manual and as modified by the requirements of this section.

B. Provide support spacing per building structural system but not greater than 8 feet. Provide extra support structure as required.

3.6 ELECTRICAL WORK HANGER AND SUPPORT INSTALLATION

A. Refer to Division 26 complete.

3.7 ROOFTOP SUPPORT INSTALLATION

A. Roof Curbs:

1. Maintain existing roof warranties. Contractor is responsible for the installation of all Roof Curbs, Pipe Curbs, and Equipment Support Rails for their equipment complete. Employ the services of a qualified subcontractor specializing in roofing work and certified by the carrier of all new or existing roofing warranties to perform warranty compliant roofing work as required for this project. Employ the services of a qualified subcontractor specializing in structural work to perform structural roof support work as required for this project. Use their services to cut roof openings, provide structural support and installation of Roof Curbs, Pipe Curbs, and Equipment Support Rails, and to patch roofing cuts complete. Refer to Section 01 73 00 - Execution for additional requirements and procedures for cutting openings in existing roofs and roof decks.

   a. If existing roofing is out of warranty, provide minimum two year warranty for roofing work of this contract.

2. Provide larger of curb height scheduled on Drawings or as recommended by equipment manufacturer, but not less than 12 in. above finished roof. Refer to required installation details and provide additional curb height where finished roof surface is above curb mounting flange.

3. Provide all roof curbs required for all rooftop-mounted equipment in Contract.

   a. Provide structural support for roof deck around all roof curbs and roof deck penetrations 12 inch x 12 inch and larger, unless specifically indicated otherwise elsewhere on the Contract Documents. Refer to drawings for additional support details around roof openings.

   b. Refer to Section 06 10 26 – Roofing Rough Carpentry, for additional wood blocking requirements.

c. Verify exact size and location and set and secure unit to roof.

d. Set and secure curb or support level as required by manufacturer of equipment served and as required by the installation details of the seismic restraint system. Provide tapered shims as required up to 3-1/2 inch thick. If structure slopes more than 3-1/2 inch over length of curb, provide sloped curb to match structure so as to minimize shims. Provide corrosion-resistant fasteners as required to secure curbs to deck or structure, coordinate with subsequent roofing requirements.

e. Coordinate roof openings and set and secure curbs in ample time so as to avoid delay in construction schedule.

f. Coordinate in curb access and rooftop equipment sound transmission mitigation:

1) Coordinate roof deck removal within curbs in all cases with Architect, Owner, Construction Manager and all affected trades as required to optimize access and sound transmission prevention.

2) In general, for exhaust fans, provide for below curb service access by complete removal of roof deck internal to curb throat free area.

3) In general, for Roof Top Air Handling Units, provide in curb sound attenuation and acoustically rated roof deck penetrations as specified in Section 23 05 43 – Mechanical Vibration and Movement Control.

4) Coordinate special circumstances requiring exceptions to above with Architect and equipment manufacturers.

g. Prevent water entry into building. Provide roofing work as required to flash curbs. Provide counter flashing and gaskets with curb mounted equipment as required to keep water from entering curb. Provide temporary caps as required until permanent installation is made.

h. Install Curb Adapters in manner similar to how supported equipment is secured to curb. Provide complete with closed cell gaskets, minimum two stainless steel fasteners per side and additionally as required for equipment support.

3.8 METAL FRAMING AND EQUIPMENT SUPPORT INSTALLATION

A. Provide miscellaneous metal, beams, angles pipe bars, structural steel shapes, bases, braces, etc. accessories required to attach hangers and supports to walls, floors, structural members, etc. in conformance with Section 05 12 00 – "Structural Steel Framing."

B. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

C. Custom Hangers and Supports: Install as required by special circumstances encountered, in accordance with applicable details and layouts shown on Drawings, and as approved by Architect.

D. Provide lateral bracing to prevent swaying for equipment supports.

E. Provide vibration isolation and thermal movement capability for hangers and supports. Refer to Sections 23 05 43 - Mechanical Vibration and Movement Control.

F. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

G. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.9 ADJUSTING

A. Adjust all hangers and supports after installation of piping and associated equipment to distribute loads equally on attachments and to achieve proper pitch for the applicable piping system.

B. Trim excess length of continuous-thread hanger and support rods as required - avoid hazardous protrusion.

3.10 PAINTING AND TOUCHUP

A. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 09.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF SECTION 23 05 29

SECTION 23 05 43 – MECHANICAL VIBRATION AND MOVEMENT CONTROL

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes mechanical movement controls for all mechanical equipment and components, piping, and duct work provided or modified as a part of this Project and as noted on the drawings, whether movement is from sound, vibration, thermal, or other sources including (but not limited to):

1. Vibration isolation hangers and mounts for equipment, piping, and ductwork.
2. Flexible piping and flexible piping connections.

1.3 DEFINITIONS

A. IBC: International Building Code.
B. ICC-ES: ICC-Evaluation Service.

1.4 PERFORMANCE REQUIREMENTS

A. Provide mechanical sound, vibration, and movement control for all mechanical equipment, piping, duct work, and other components provided or modified as a part of this Project, and as shown on the Drawings. Mount on or suspend from vibration isolators to reduce transmission of vibration and mechanically transmitted sound to building structure. Select vibration isolators in accordance with weight distribution to produce reasonably uniform deflections.

1. Correct any variance or non-compliance with specified requirements in manner directed by Architect.

1.5 SUBMITTALS

A. General: Submit all action submittals and informational submittals required by this Section concurrently.

B. Action Submittals:

1. Product Data for the following:

a. Catalog cuts and data sheets on vibration isolators, isolation bases, and isolation curbs. Indicate rated load, rated deflection, and overload capacity for each device. Annotate to indicate application of each product submitted and compliance with requirements.

b. Catalog cuts and data sheets on sound attenuation components used. Indicate style, material, and attenuation characteristics for each device or product.

c. Schedule of flexibly mounted equipment, referencing drawings by number. Include number, type, and loading of all isolation components.

2. Shop Drawings

a. Submit details of following items

1) Equipment bases including dimensions, structural member sizes and support point locations. Equipment bases shall include all curbs for rooftop air handling units.

2) Isolation hangers and systems for ceiling hung equipment, piping and ductwork.

3) Mountings for floor supported equipment, piping and ductwork.

4) Complete flexible connector details.

b. Indicate deflections and model numbers on all hanger, mounting or pad drawings including any other specified requirements.

c. Provide in tabular form spring diameters, rated loads and deflections, heights at rated load and closed height for all springs shown in submittals.

C. Informational Submittals:

1. Product Certificates:

a. Contractor Statement of Responsibility: Refer to Division 01 Section, “Quality Requirements.”

2. Welding certificates.

D. Closeout Submittals:

1. Field quality-control test reports.

2. Contract Closeout Submittals: Comply with requirements of Section 01 73 00, including submission of operating and maintenance instructions as item in "General Construction Instructions" manual described in that section.

1.6 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

1.7 COORDINATION

A. Coordinate layout and installation of vibration isolation and movement control devices with other construction that penetrates ceilings or is supported by, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate size and location of concrete housekeeping pads and vibration isolation bases. Cast anchor-bolt inserts into base. Refer to applicable technical sections in Division 03 for concrete, reinforcement, and formwork requirements.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

D. Coordinate design of vibration isolation design with expansion compensation systems.

PART 2 - PRODUCTS

2.1 VIBRATION ISOLATORS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Amber/Booth Company, Inc.
2. Kinetics Noise Control.
3. Mason Industries.

B. Factory Finishes: Provide manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.

1. Powder coating on springs and housings.
2. All hardware shall be galvanized. Hot-dip galvanized metal components for exterior use.
3. Baked enamel or powder coat for metal components on isolators for interior use.
4. Color-code or otherwise mark vibration isolation devices to indicate capacity range.

C. Where neoprene is referred to and used in vibration isolation components, it shall be bridge-bearing grade premium neoprene of the durometer hardness grade and size specifically recommended by the design make manufacturer for both maximum vibration isolation and load rated for the specific application.

D. Hangers

1. Neoprene Hangers: Rigid steel frames containing neoprene element.

    a. Minimum 1-1/4-inch thick neoprene element on bottom with projecting bushing preventing steel-to-steel contact.

b. Minimum static deflection of 0.20-inch.
c. Boxes not articulated, clearance hole in neoprene element to allow non-moment bearing connection at structural support.
d. Configured for threaded rod, eye bolt, or strap connections as required.
e. Basis-of-Design Product: Mason Industries, Inc.; Type HD.

2. Type A Hangers: Rigid steel frames containing minimum 1-1/4-inch thick neoprene elements at top and steel spring with general characteristics as specified for Spring Isolator above seated in steel washer reinforced neoprene cup on bottom.

   a. Neoprene element and cup have neoprene bushings projecting through steel box.

   b. Boxes not articulated as clevis hangers nor neoprene element stacked on top of spring in order to maintain stability.

   c. Spring diameters and hanger box lower hole sizes large enough to permit hanger rod to swing through 30-degree arc from side-to-side before contacting cup bushing and short-circuiting spring.

   d. Include hanger drawing showing 30-degree capability.

   e. Basis-of-Design Product: Mason Industries, Inc.; Type 30N.

3. Type B Hangers: Similar to Type A Hangers specified above with following modifications.

   a. Pre-compressed and locked at rated deflection by means of resilient up-stop to keep piping or equipment at fixed elevation during installation.
   b. Designed with release mechanism to free spring after installation is complete and hanger subjected to full load.
   c. Deflection clearly indicated by means of scale.
   d. Include drawing of hanger showing 30-degree capability in Submittals required in Part 1 above.
   e. Basis-of-Design Product: Mason Industries, Inc.; Type PC30N.

E. Piping Vibration Isolation and Movement Control

1. Flexible Equipment Piping Connectors: Connections rated for a minimum of 1/8-inch compression and elongation, 1/2-inch lateral, and 5-degree angular misalignment. Provide connectors with flanged, grooved, or threaded end connections meeting specified requirements for fittings and sized to match equipment connected with integral, tapered, concentric size reductions where equipment and piping are not the same size.

   a. Provide one of the following flexible connector types:

      1) Flex Hose Type: Stainless steel annular corrugated closed pitch bellows with braided stainless steel wire reinforcing protective jacket, internally and externally continuously TIG welded to end fittings. Minimum 150 psig working pressure at 250 degrees F operating temperature.

a) Design Make: “SECF” by Southeastern Hose or similar product by Flex-Hose.

2) Spherical Reinforced Elastomeric Type: minimum pressure range of 16 in Hg. vacuum to 150 psig over full temperature range of -20 deg. F to +240 deg. F. Connectors have metal flanged ends tapped to mate with standard 150# or 300# companion flanges, elastomer compatible with the working fluid, and high strength low stretch polymeric reinforcement. Provide complete with pipe anchors or control units as required for system pressure control.

a) Design Make: “Safeflex” by Mason or “Flexzorber” by Flex-Hose.

3) Flexible Mechanical Connector Type: three minimum flexible mechanical grooved couplings, as specified in Section 23 21 13 – HYDRONIC PIPING, installed adjacent to equipment and before first hanger. May be arranged between tapered increasers, check valves, flow measuring stations, etc., or separated by short pipe nipples.

a) Design Make: Style 77 flexible couplings by Victaulic.

2. Flexible Hose: Factory assembled lengths sufficient to handle the anticipated flexing required due to either installation or thermal movement and rated for minimum 150 psig working pressure at 210 deg F operating temperature.

a. Provide one of following two styles of flexible hose. Pipe size listed on Drawings are for smooth bore hose; provide corrugated style hose one pipe size larger:

1) Stainless steel or bronze annular or helically corrugated closed pitch bellows with braided stainless steel or bronze wire reinforcing protective jacket, continuously TIG welded or silbrazed to end fittings.

a) Basis-of-Design Product: Flex-Hose Co., Inc.; Corrugated Metal Hose.

2) Smooth bore polymer liner with braided stainless steel or bronze wire reinforcing protective jacket, mechanically swaged to the end fittings.

a) Basis-of-Design Product: Flex-Hose Co., Inc.; Polyflex.

b. Provide connectors with flanged, grooved, or threaded end connections meeting requirements specified for fittings and including external pipe thread one end and internal pipe thread adapter swivel or union other end for sizes through 2-inch, with flanges on both ends for sizes over 2-inch.

c. Rated for static and intermittent flexing radii no greater than that of the design make (approximately 3 diameters static and 8 diameters dynamic).

d. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Flex-Hose Co., Inc.; Corrugated Metal Hose or Polyflex.
2) Mason Industries, Inc.; Type BSS or BFF.
3) Southeastern Hose, Inc.; SECM or SECC.

2.2 ACOUSTICAL ATTENUATION COMPONENTS

A. Submit published sound attenuation data for all sound attenuation components generated by a certified aero-acoustical testing laboratory in full accordance with ASTM E 477, Standard Method of Testing Duct Silencers. Provide all attenuation components complying with NFPA 90-A requirements.

B. Duct / Pipe Lagging: 2mm thick barium sulphate-loaded vinyl sheet bonded to fiber scrim reinforced aluminum coating on outer side and to 1-inch thick mineral wool or fiberglass batting decoupling layer on the other side. Inner face covered with fiber skrim reinforcing. Minimum 1lb. per square foot weight. Acoustical performance at least that of the design make.

1. Basis-of Design Products: Kinetics Noise Control, Inc.; Type KNM-100ALQ and Sound Seal; B-10 LAG.

C. Damping Compound: Non-asphaltic viscoelastic vinyl based latex emulsion designed for application to metal surfaces for the purpose of damping acoustical vibrations and with damping efficiency at least that of the design make.

1. Basis-of Design Products: Kinetics Noise Control, Inc.; Type KDC-E-162 and Sound Seal; VBD-10.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and movement control devices for compliance with requirements for installation tolerances and other conditions affecting performance. Notify affected Prime Contractors and Architect in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in an acceptable manner.

1. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.

2. Identify any discrepancies between specifications and field conditions or changes required due to specific equipment selection, prior to installation. Corrective work required by discrepancies after installation at Contractor's expense.

B. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 VIBRATION, SOUND, AND THERMAL MOVEMENT CONTROL INSTALLATIONS

A. Install all vibration isolators and acoustical attenuators in strict accordance with manufacturers written instructions and all submittal data. Coordinate installation to avoid rigid contact with building.

1. Install without any change of position of equipment, piping or ductwork resulting in stresses or misalignment.

2. Do not make rigid connections between equipment and building structure that degrade noise and vibration control system specified.

3. Do not install any equipment, piping, duct, or conduit with rigid connections to building or other support structure unless no isolation is specifically called for. "Building" includes, but is not limited to, roof deck, floor/ceiling/roof slabs, beams, joists, columns, studs and walls.

    a. For exterior ground or frame mounted equipment

4. Identify any conflicts which will result in rigid contact with equipment or piping due to inadequate space or other unforeseen conditions to Architect / Engineer prior to installation. Corrective work required by conflicts after installation at Contractor's expense.

5. Correct, at no additional cost, all installations deemed defective in workmanship and materials at Contractor's expense.

3.3 PIPED EQUIPMENT INSTALLATIONS

A. Hydronic Equipment

1. Vibration Isolation of Hydronic Equipment:

    a. Isolate all upper floor, suspended, and roof mounted hydronic equipment with vibration producing parts from structure using vibration isolation system specifically designed for the installation and having deflection tuned to the mass and frequency of the rotating or vibrating machinery so as to minimize the propagation of the vibrations.

    b. Where piping connects to mechanical equipment with vibration producing parts, including air-handling equipment with hydronic or refrigerant based heat exchange coils, install elastomeric spherical or mechanical coupling flexible connection joints.

        1) Where elastomeric based flexible connector joint is not suitable for service (example: refrigerant service), provide flexible stainless steel hose. Install hoses:

            a) On equipment side of shut-off valves.
            b) Parallel to rotating equipment shafts, wherever possible.

c) Perpendicular to anticipated thermal movement.
d) Where movement in two axes is anticipated, install hose of sufficient length to form elbow or install two hoses with elbow fitting between.

B. Piping Installations:

1. Vibration and Acoustical Isolation of Piping: Locate isolation hangers as near to overhead support structure as possible.

a. Horizontal Pipe Isolation

1) Provide Type B hangers and/or restrained mountings for first 2 pipe hangers in lines near pumps, and risers.

a) Provide restrained spring mountings for similar floor supported piping.
b) Provide same static deflection as specified for mountings under connected equipment, minimum 1 inch near chillers and pumps.

b. Riser Isolation

1) Suspend risers from Type A hangers or supported with spring isolator mountings, guided with sliding pipe guides.

2) Provide minimum 0.75-inch steel spring deflections, except in those expansion locations where additional deflection is required to limit load changes to +/-25 percent of initial load.

3) Include riser diagrams and calculations in submittals showing anticipated expansion and contraction at each support point, initial and final loads on building structure and spring deflection changes. Include certification that riser system has been examined for excessive stresses and that none will exist in proposed design.

2. Vibration and Acoustical Isolation of Piping Penetrations: Where piping passes through structure, use Split Wall Seals specified in Part 2 above.

3. Thermal Movement Isolation: Where piping with anticipated thermal movement is connected to fixed location equipment (for example, duct coils near main HWS&R, unit ventilators above crawl-space mains just below, etc.), provide flexible hoses perpendicular to motion rated for total expected movement. Anticipate movement and install so flex hose will be nominally straight at normal operating temperature.

3.4 AIRSIDE INSTALLATIONS

A. Vibration Isolation of Air Handling Equipment:

1. Isolate all suspended air handlers using Type B hangers with minimum 2 inches spring deflection for units having 1/2 KW motors and larger and with minimum 1 inch spring deflection for units having less than 1/2 KW motors.

2. For all roof top air handlers above occupied spaces unless otherwise noted or scheduled on drawings, provide acoustical attenuation within curb below rooftop air handlers as follows:

   a. Coat deck within curb with damping compound.

   b. Seal around duct, pipe, conduit, fastener, etc., penetrations air-tight to maintain air and vapor barrier, typically with 60mil EPDM roofing membrane sealed to deck and cut for a tight stretch fit to pipe or duct. Caulk holes. Fill deck corrugation flutes at edges with fire rated expanding urethane foam and set / seal EPDM into wet foam.

   c. For air handlers with total motor power 5KW and above, with a packaged compressor and/or as specifically called for on the drawings:

      1) Overlay sealed deck with 3” flexible fiberglass batt insulation.

      2) Overlay insulation with one layer of ⅝” thick moisture and mold resistant gypsum board (GWB) fitted 1” from curb perimeter and duct/piping penetrations with annulus filled with fiberglass batt, sealed and taped at all joints with damping compound and skrim joint tape.

      3) Overlay GWB with acoustical duct/pipe lagging fitted closely to duct, pipe, and curb perimeter and seal to each in accordance with manufacturer’s directions.

      4) Provide acoustical duct and piping penetrations both through unit bottom and roof deck.

B. Vibration Isolation of Ductwork:

1. Isolate all ducts from mechanical air handling equipment using flexible connectors.

2. Isolate all discharge runs for distance of 50 ft. from connected equipment from building structure using Type A or Type B hangers. Provide minimum of 0.75-inch spring deflection.

3. Isolate all rectangular duct runs having average air velocity of 1200 fpm or more from building structure using Type A or Type B hangers or spring floor supports. Provide minimum of 0.75-inch spring deflection.

4. Unless internally lined, provide damping compound on all rectangular duct hung over occupied spaces and having average air velocity of 1000 fpm or more as required to eliminate duct rumble.

C. Vibration and Acoustical Isolation of Duct Penetrations: Where duct passes through acoustically sensitive structure (walls, floors, roof, and / or ceilings), and where noted on Drawings to provide sound attenuated penetration, provide damping compound for two feet on either side of wall, insulate per Section 23 07 00, then pack gap between insulation and general construction wall materials with mineral wool and seal with damping compound.

1. Coordinate this requirement with any fire rating of the wall and maintain both fire rating and acoustical separation with UL listed assembly.

2. Acoustically sensitive structure penetrations include:

   a. All walls/ floors/ ceilings of mechanical rooms.
   b. Ceiling / roof deck at all roof top air handling units.
   c. Rooms with substantial noise generated within, such as woodworking, technology, music rooms, etc.
   d. Rooms that require acoustical privacy such as auditoriums and administrative offices.

3.5 ADJUSTING

A. Adjust isolators after piping system is at operating weight.

B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Adjust active height of spring isolators.

D. Adjust restraints to permit free movement of equipment within normal mode of operation.

END OF SECTION 23 05 43

SECTION 23 05 53 - IDENTIFICATION FOR HVAC COMPONENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Pipe labels.
3. Duct labels.
4. Stencils.
5. Valve tags.
6. Equipment Location Ceiling Markers.

1.3 SUBMITTALS

A. Procedural Requirements: Comply with requirements of Section 01 33 00 - Submittals and as modified below.

1. Specified Products: If product to be incorporated into Project is specified by name and product designation in Part 2 below, submit "**As-Specified Verification Form**" (attached to Section 01 33 00 - Submittals) in lieu of "Product Data" identified below in this Article.

2. Equivalent Products or Substitutions: If product to be incorporated into Project is not specified by name and product designation in Part 2 below, comply with all Action Submittal requirements specified below.

B. Action Submittals:

1. Submit manufacturer's data sheets for all proposed products demonstrating compliance with specifications.

C. Closeout Information, for inclusion in Operations and Maintenance Manual:

1. Approved Submittal.

a. If "**As-Specified Verification Form**" submittal is approved, also include product data for all identification components used.

2. Include all information required in Section 01 78 23 – Operation and Maintenance Data.

3. Valve Schedule.

1.4 COORDINATION

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
B. Coordinate installation of identifying devices with locations of access panels and doors.
C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Paint: Refer to Division 09.

B. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Brimar Industries, Inc. or equal.
2. Campbell International (Ltd.), or equal.
3. Craftmark Identification Systems, Fort Worth, Texas, or equal.
4. EMED Company, Inc., Buffalo, New York, or equal.
5. Seton Name Plate Company, New Haven, Connecticut, or equal.

2.2 LABELS

A. Equipment Labels:

1. Material and Thickness: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware, or multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

3. Colors:

a. Brass Labels: black in-filled letters on brass background.
b. Plastic Labels: white letters on black plastic background.
c. Warning Signs: yellow letters on black background.

4. Able to withstand temperatures up to 160 deg F. continuously.

5. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

6. Fasteners: Stainless-steel rivets or self-tapping screws.

7. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Equipment Label Content: Include equipment's Drawing designation or unique equipment number and equipment function.

C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Include Equipment Schedule in Operation and Maintenance Manual.

2.3 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to partially cover circumference of pipe and to attach to pipe without fasteners or adhesive. Secure in place with full circumference tape wrap.

C. Pipe Label Contents: Include identification of piping service using abbreviations indicated below, pipe size, and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction (flow direction arrow circumference tape preferred).

2. Lettering Size: In accordance with ANSI 13.1 and as follows:

Outside diameter:		Letter Height:
a.	2” or less	¾”
b.	6” or less	1.25”
c.	10” or less	2.5”
d.	Over 10”	3.5”

3. Pipes too small to be directly labeled: provide hanging equipment tag with ½” lettering. Outside diameter indicated is to outside of pipe insulation on insulated piping.

D. Piping Systems: Identify the following systems as indicated:

1. Condensate (LPC)
2. Refrigerant Liquid (RL)

3. Refrigerant Suction (RS)
4. Heating Hot Water Supply (HWS)
5. Heating Hot Water Return (HWR)
6. Low Pressure Steam Supply (LPS)
7. Condensate Drain (CD)
8. Make up water (MU)

2.4 DUCT LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

B. Colors: Letter color, black; background color, white.

C. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

D. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

E. Minimum Letter Size: One inch for viewing distances up to 60 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

F. Fasteners: Stainless-steel rivets or self-tapping screws.

G. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

H. Duct Label Contents: Include identification of duct service, duct size (inches x inches clear inside dimensions, side labeled first), and an arrow indicating flow direction.

1. Unless specifically indicated otherwise on Drawings, use duct service designations below, where (SYSTEM) is the equipment served:

   a. (SYSTEM) SUPPLY AIR
   b. (SYSTEM) RETURN AIR
   c. (SYSTEM) RELIEF AIR
   d. (SYSTEM) OUTSIDE AIR
   e. (SYSTEM) MIXED AIR
   f. (SYSTEM) MIXED EXHAUST
   g. (SYSTEM) TOILET EXHAUST

2. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.

2.5 STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts (1 inch for each five feet viewing distance).

1. Stencil Material: Durable, thin, as required to make crisp stenciled pattern.

2. Stencil Paint: Exterior, gloss, acrylic enamel black unless otherwise indicated. Paint may be in pressurized spray-can form.
3. Identification Paint: Exterior, acrylic enamel in colors according to ASME A13.1 unless otherwise indicated.
4. Stenciled Label Contents: as described in pipe and duct labels above.

2.6 VALVE TAGS

A. Valve and Hydronic Specialty Identification: Provide 1-1/2 inchinch diameter brass tags, 0.032-inchminimum thickness, with predrilled or stamped holes for attachment with #16 brass jack chain, factory engraved or stamped with 1/2-inch letters for piping system abbreviation and 1/2-inch numbers, with black in fill, legend as described below.

1. Stamp "H" and valve number for each main, riser, zone, and branch heating valve.

B. Provide manufacturer’s tags for all balancing fittings.

C. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses. Include valve-tag schedule in Operation and Maintenance Manual.

2.7 EQUIPMENT LOCATION CEILING MARKERS

A. 5/8-inch diameter celluloid covered or vinyl PSA backed stickers, suitable for ink notation on a colored face; color coded as follows:

1. Yellow: Volume Dampers
2. Blue: Isolation Valves
3. Green: Controls Devices (valves, automatic dampers, controllers)
4. Orange: Equipment (VAV boxes, fan coils, blower coils, fans, pumps, etc.)
5. Red: Fire Dampers

PART 3 - EXECUTION

3.1 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

B. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.
B. Locate equipment labels where accessible and visible.

3.3 PIPE IDENTIFICATION

A. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels with painted, color-coded bands or rectangles and flow direction arrows, complying with ASME A13.1, on each piping system. Stencils shall be crisp and neat with no overspray, drips, runs, or other imperfections visible from normal viewing distance.

1. Identification Paint: Use for contrasting background.
2. Stencil Paint: Use for pipe marking.

B. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 15 feet along each run.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

C. Piping Painting Requirements:

1. Refer to Section 23 05 00 – "Common Work Results for HVAC" and Division 09 sections covering painting for pipe painting requirements and Pipe Color Code Identification Schedule.

3.4 PIPE LABEL INSTALLATION

A. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels on each piping system.

1. Identification Paint: Use for contrasting background.
2. Stencil Paint: Use for pipe marking.

B. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of **15 feet** along each run.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

3.5 DUCT LABEL INSTALLATION

A. Install plastic-laminated duct labels with permanent adhesive on air ducts.

B. Stenciled Duct Label Option: Stenciled labels, showing service, size, and flow direction as indicated above, may be provided instead of plastic-laminated duct labels, at Installer's option, for concealed ductwork or if lettering larger than 1 inch high is needed for proper identification because of distance (over ten feet) from normal location of required identification. Stencils shall be crisp and neat with no overspray, drips, runs, or other imperfections visible from normal viewing distance. Refer to Division 09 sections on painting for more information.

C. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

3.6 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

1. New construction: Provide a neat typewritten valve directory listing valve function, location and identification number. Minimum size to be 8-1/2 by 11 inches, incased within plastic laminate. Mount securely where directed.

2. Valve Numbering System: Extension of and compatible with existing valve numbering system, where valves are installed in existing building or in addition to existing building. Do not duplicate existing numbers; verify existing numbers in the field.

3. Verification: Verify existing valve numbers in field and provide valve numbering avoiding duplication of existing numbers.

3.7 EQUIPMENT LOCATION CEILING MARKERS

A. Provide markers in the metal grid of lay-in tile, in metal panel ceilings, at access doors in hard ceilings, and other locations as appropriate, indicating the location of dampers, valves, controls, equipment, fire dampers, and other devices as required. Write on markers with sharply contrasting permanent ink in neat handwriting clearly identifying equipment located beyond mark with abbreviation used in valve chart, equipment schedule, etc.

END OF SECTION 23 05 53

SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Testing, Adjusting, and Balancing (TAB) Work shall be a joint effort of the Contractor and the TAB Agency, performed with the intention of leaving the systems involved in a properly functioning and balanced flow condition as designed and indicated in the Construction Documents, similar to the “Total System Balance” condition described in the AABC Standard.

1. The division of responsibility for the TAB Work is outlined below. Contractor to perform preparation and ancillary work described below, with the option of subcontracting a portion of their work to the TAB Agency, but the TAB Agency must take sole responsibility for any portion of the preparation or TAB Work defined as the TAB Agency’s Work.

2. TAB Agency Work to be performed by a fully qualified independent TAB Agency as described in quality assurance below and as approved by the Architects and Engineers, to be paid for by the Contractor responsible for HVAC Work as a first-tier subcontract to their work.

B. Section includes preparation for, and Testing, Adjusting, and Balancing (TAB Work) of HVAC components, equipment, and systems:

1. Contractor Preparation and Participation:

   a. Place systems in satisfactory operating condition as detailed below prior to the arrival of the TAB Agency for the specified TAB Work, and notify the TAB agency, Construction Manager, and Engineer in writing when systems are ready for TAB Work.

   b. Attend and actively participate in coordination and TAB meetings.

   c. Keep TAB Agency apprised of construction schedule as required facilitating TAB agency job site visits prior to concealment of work. Provide overall construction schedule to TAB agency at coordination meetings and TAB meetings, update schedule regularly noting milestones and dates affecting TAB review and work schedule, and provide at minimum 7 calendar days notice prior to concealment.

   d. Coordinate and provide mechanical and controls systems operation, revisions, and other ancillary work as required during TAB Work, as detailed below.

e. Make changes as required to create a testable, balanceable system, as recommended by TAB agency but only as approved by the Engineer.

2. TAB Agency Preparation:

a. Review Construction Documents and Coordination Drawings with Engineer, Construction Manager, and Contractor and assist in preparation of submittals, particularly Coordination Drawings, dampers, and balancing valves, by preparing recommendations to Contractor and Engineer on locations of balancing valves, dampers, access doors, test connections, etc., as well as any other special considerations affecting the TAB Work and/or the fabrication or engineering of the systems. Documentation of assistance shall be both by mutually agreed upon notations on the submittals / sheet metal Shop Drawings prior to submittal, and by TAB Agency's letter accompanying submittal, verifying review and TAB Agency approval of the specific submittal.

b. Visit job prior to concealment of work, repeatedly if necessary due to construction scheduling, check work, and advise the Contractor, Construction Manager, and Engineer on correctness of locations of dampers, access doors, test connections, etc., as well as any other special considerations affecting the TAB work. Advise in writing, copied to the Contractor, Construction Manager, and the Engineer within 3 days of the site visit but in any event before concealment.

C. TAB Work includes:

1. *Testing* of all mechanical components for performance, calibration, capacity, and other characteristics as outlined below and as required, demonstrating conformance with contract documents and submittals.

2. *Adjusting and Balancing* of all mechanical components of this project as described in the contract documents, achieving specified air and water flow at all terminal equipment, distribution at lowest noise levels and energy use, and achieving specified thermometer, gauge, and sensor instrument accuracy and calibration, all as outlined below.

3. Documentation, correspondence, data recording, reporting, and demonstration all as outlined below and elsewhere in the contract documents.

4. *Coordination* with other Contractors, subcontractors, Construction Manager, Owner's Representatives, and Architect / Engineer as required achieving specified TAB results.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.
B. ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
C. Contractor: The entity contracted to perform the HVAC Work described in these contract documents.
D. NEBB: National Environmental Balancing Bureau.
E. NRTL: A nationally recognized testing laboratory according to 29 CFR 1910.7.
F. NVLAP: A testing agency accredited according to NIST's National Voluntary Laboratory Accreditation Program.

G. TAB: Testing, adjusting, and balancing.
H. TABB: Testing, Adjusting, and Balancing Bureau.
I. TAB Agency: An entity engaged to perform TAB Work who is qualified and approved to do so as described below.

1.4 SUBMITTALS, GENERAL

A. Contractor:

1. Prior to submittal of any equipment affecting TAB Agency, review with TAB Agency and obtain commentary and approval as described in “Summary” Article. Include TAB Agency review commentary with affected submittals.

2. Immediately upon approval of other submittals, provide the TAB Agency with copies of approved submittals, including Shop Drawings of all hydronic and air systems and equipment requiring balancing.

1.5 ACTION SUBMITTALS

A. Contractor:

1. Perform no work affecting TAB prior to TAB Agency approval.
2. Within 30 days after award of Contract, submit TAB Agency qualifications proposal for approval.

B. TAB Agency:

1. Submit TAB Agency qualifications proposal for approval.

    a. Name and contact information of proposed TAB Agency.
    b. Documentation that they meet the qualifications specified in "Quality Assurance" Article.
    c. Evidence of current TAB Agency and TAB Supervisor Certification.
    d. List of instruments to be used in testing and balancing, with current certification of all instruments’ calibration.
    e. Examples of data forms proposed for each system type showing input cells for this Project’s required data.
    f. 3 regional references for comparable recent jobs.

2. Submit Strategies and Procedures Plan: Within 30 days of Architect’s approval of TAB Agency, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

3. Submit Preliminary Partial TAB Reports.

4. Submit Certified Final TAB Report.

1.6 INFORMATIONAL SUBMITTAL

A. Contractor and TAB Agency:

1. Systems Readiness Report as described more fully below.

B. TAB Agency:

1. Instrument Calibration Reports: Include the following on calibration agency letterhead:

   a. Instrument type and make.
   b. Serial number.
   c. Application.
   d. Dates of use.
   e. Dates of calibration.
   f. Test data points over range qualified – standards and measured values.

2. Contract Documents Examination Report: Within 15 days of Architect's approval of TAB Agency, submit the Contract Document Examination Report as specified in Part 3.

3. Include commentary with all Contractor submittals affecting TAB work as described above.

4. Pre-Construction Inspection and Testing Report: Prior to removal of any affected construction.

1.7 QUALITY ASSURANCE

A. TAB Agency, Employee, and TAB Work Qualifications:

1. TAB Agency: Fully certified current member of "Associated Air Balance Council" (AABC), "National Environmental Balancing Bureau" (NEBB), or "Testing, Adjusting, and Balancing Bureau" (TABB), specializing in the adjusting and balancing as specified in this Section of systems as specified and as shown on the Contract Documents, with minimum three years documented experience as a fully certified member, and three current regional references for projects of comparable scope.

2. TAB Field Supervisor: Employee of the TAB Agency and currently certified by AABC, NEBB, or TABB as a Testing, Balancing and Adjusting Supervisor.

3. TAB Technician: Employee of the TAB Agency and currently certified by AABC, NEBB, or TABB as a TAB technician.

4. All TAB Work: Performed by direct employees of the TAB Agency, who are either TAB Field Supervisors themselves, or who are TAB Technicians working under the direct supervision of a TAB Field Supervisor.

B. Conform to basic procedures and methods outlined by applicable publications in testing and balancing of air and water systems by the following organizations, and as modified by this document:

1. Associated Air Balance Council (AABC).
2. National Environmental Balancing Bureau (NEBB).
3. Testing, Adjusting, and Balancing Bureau (TABB).
4. Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA).
5. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).
6. Individual manufacturer requirements and recommendations.

C. TAB Report Data Forms: Follow AABC, NEBB, TABB, or SMACNA format as modified by the data requirements of this Project, subject to submittal approval.

D. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

E. Instrumentation Type, Quantity, Accuracy, and Calibration: Instruments as described in ASHRAE 111, Section 5, "Instrumentation," all currently certified as calibrated by a NRTL or NVLAP in accordance with Division 01 Section "Quality Requirements."

F. Contractor: maintain qualified personnel at Project for system operation, trouble-shooting, making system changes, and performing mechanical adjustments in conjunction with TAB procedures.

1.8 PROJECT CONDITIONS

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

B. Environmental Requirements: Accomplish TAB work under appropriate outdoor temperature conditions.

C. Concealed Conditions: Before concealment of systems, verify and advise on type and location of balancing devices and test points. Make changes as required to balancing facilities.

1.9 COORDINATION AND SCHEDULING

A. Refer to Division 00 and Division 01 for overall project sequencing and scheduling requirements. All HVAC work required for, and, approvable balancing in accordance with the requirements of this section is required to be complete before Contract Substantial Completion.

1. Contractor: Assure that all HVAC work required to properly and completely test and balance the various systems, occurs in a timely fashion coordinated with the overall project schedule as required, with final readiness reported at minimum two calendar weeks prior to contract scheduled Substantial Completion Date. For HVAC Work required to be performed simultaneous with TAB Work, coordinate schedule with TAB agency and provide qualified staffing as required keeping pace with TAB agency personnel. Coordinate and report partial systems readiness to TAB agency to allow TAB work to proceed in an orderly fashion.

2. TAB Agency: Assure that all TAB Work and all subsequent reporting on same occurs in a timely fashion coordinated with the overall project schedule prior to contract scheduled Substantial Completion Date. For HVAC Work required to be performed simultaneous with TAB Work, coordinate schedule with Contractor and provide qualified staffing as required to complete TAB work and reporting within two calendar weeks of final HVAC systems readiness for TAB.

B. Tab Agency: Coordinate, schedule, and run a TAB Strategies and Procedures meeting, with Contractor, Owner, Architect, Engineer, Controls Subcontractor, and Commissioning Agent all present. Provide TAB Plan and agenda in advance, and produce and distribute meeting minutes.

C. Contractor and TAB Agency: Perform all examination and preparation work required and submit Systems Readiness Report(s) prior to beginning TAB work.

D. Contractor and TAB Agency: After submission of Systems Readiness Report, coordinate and schedule all preparation and TAB work with each other, Architect/Engineer, Construction Manager, Commissioning Agent, and Owner. Notify O/AE/CM/Cx team of all scheduled TAB work test dates and times in writing with at least seven days' advance notice for each visit.

1. Cooperate with other contractors and affected subcontractors as required to provide complete and proper testing, adjusting, and balancing of HVAC systems.

E. Accomplish TAB Work during construction period as soon as the systems are complete enough to perform TAB work. Coordinate with project phases and before Owner takes possession. TAB work and approval of at least partial pencil copy reports is required before Owner takes possession.

F. Multiple visits will be required for phased construction in cooperation with construction schedule, with multiple “pencil copy” submittals of partial TAB reports required promptly as each phase of TAB work is accomplished.

G. Perform balancing for record at final stage when all previously completed sub-systems are checked and re-balanced to design performance.

H. Contractor and TAB Agency are subject to recall to site to verify report information before acceptance of the report by the Architect.

I. Contractor: provide 2 additional copies of Shop Drawings and other submittals for all equipment and systems to be tested and balanced to TAB Agency as soon as possible but no later than 60 days prior to scheduled completion of equipment and systems installation.

J. TAB Agency:

1. Verify that Contractor has placed all systems and equipment in satisfactory operating condition as required allowing TAB Work to be properly performed.

2. Cooperate with Contractor and affected subcontractors as required to provide complete and proper testing, adjusting, and balancing of air and water systems.

3. Visit Project prior to concealment of Work and note location of dampers, test connections, and similar items. Record this information, transmit to Contractor, and incorporate on Record Drawings.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. TAB Agency: Provide tools, ladders, recording meters, gauges, thermometers, velometers, anemometers, Pitot tubes, inclined gauge manometers, magnehelic gauges, amprobes, voltmeters, psychrometers, tachometers, ultrasonic or other non-intrusive flowmeters, and all other instrumentation required to perform specified TAB work. Accurately calibrate all instruments.

1. Make instruments available to Architect to facilitate spot checks during testing and back-checking.
2. Provide additional balancing devices as required.

PART 3 - EXECUTION

3.1 EXAMINATION

A. By TAB Agency:

1. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

2. Visit Site and examine existing systems before construction and new / re-worked systems prior to concealment of construction to check on and advise regarding location of installed balancing devices, such as test ports, gage cocks, thermometer wells, thermometers and gages, flow-control devices, balancing valves and fittings, volume dampers, test connections, etc. Verify that locations of these balancing devices are accessible. TAB Agency shall advise Contractor and Architect of TAB Agency findings by letter.

3. Examine the submittals for HVAC systems and equipment. Verify that proposed equipment can be balanced as specified and as required. Provide commentary on all submittals advising where additional balancing devices are needed or configuration adjustment is desired to facilitate TAB work.

4. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

5. Examine test reports specified in individual system and equipment Sections.

6. Examine manufacturer's equipment performance data including pump and fan curves.

    a. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

B. By Contractor:

1. Examine systems and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections has been performed, and all TAB preparation as described in "Preparation" Article is complete.

3.2 PREPARATION

A. TAB Agency:

1. Prepare a TAB plan that includes site specific strategies and step-by-step procedures with this project's equipment identified.

B. Contractor: Before TAB work commences on any portion of the system, and before new system startup, verify that systems are complete and in proper operating condition. Ensure the following:

1. Equipment is operable, in a safe and normal condition, and is of the size and capacity specified in the Contract Documents, bearings are greased, belts are aligned and properly tight, and equipment with functioning controls is ready for operation. Required modifications to systems shall be made in advance of the TAB Agency's arrival for that portion of the work.

2. Provide proper equipment start-up as specified, complete with manufacturer's filled out standard published start-up forms.

3. Temperature control systems are operable to the extent required for that portion of the TAB Work. Control valves must at least be installed complete and hand operable. Automatic dampers must be operable and under control. Safety interlocks and controls on HVAC equipment must be properly functional.

4. All motors, pumps, and fans have correct rotation.

5. Permanent electrical-power wiring is complete, and proper thermal overload protection is in place for all electrical equipment.

6. All ductwork, air handlers, grilles, registers, and diffusers are installed, complete, and cleaned of dust and debris.

7. All piping, terminal radiation, boilers, chillers, heat exchangers, pumps, valves, required pressure taps, and hydronic specialties are correctly installed, complete, operational, and clean.

8. All ductwork, diffusers and registers have dampers where specified, and all hydronic systems have balancing and isolation valves where specified.

9. Duct system leakage has been tested where required and minimized.

10. Hydronic systems are flushed, vented, cleaned, leak free, and filled with specified heat transfer fluid.

11. Hydronic expansion tank has been pre-charged to the proper pressure and systems filled to proper cold fill pressure.

12. System pump suction piping is properly vented to ensure absence of entrained air.

13. All manually set dampers (fire, fire/smoke, register, grille, diffuser, and manual volume dampers) operate smoothly and are adjusted open. All automatic dampers have actuators and required linkages installed and rough adjusted.

14. All hydronic systems valves are installed with proper direction of flow and operate smoothly, balancing valves are adjusted open, two-way control valves are open, three-way valves are properly installed for their intended function of diverting or mixing fluid flows, and service valves are open or closed as required for normal flow.

15. Make preliminary adjustments to airflow patterns of all registers, grilles, and diffusers to obtain uniform space temperatures and air movement free from objectionable drafts and noise.

16. Clean new final design filters are installed everywhere called for.

17. Hydronic strainers are clean and any temporary screens are replaced with permanent screens. Sidestream filters have clean new filter bag installed and valves are closed.

18. Coil fins are clean and straight.

19. Access doors in ducts are closed and duct end caps are in place.

20. Access doors necessary to reach duct volume dampers, balancing valves, and measuring stations are installed in accessible locations and are operable.

21. As-built conditions are accurately recorded on working as-built drawings, including locations of all access points, manual and automatic dampers, isolation, balancing, and control valves, fittings, and all other items affecting TAB work. Provide copies of these annotated as-built drawings for TAB agency's use during TAB work.

C. Contractor:

1. Prepare and submit Systems Readiness Reports to Engineer, Commissioning Agent, and TAB Agency, with itemized checklists of the above items as appropriate for the equipment to receive TAB Work, with a column for Contractor indicated status and another with room for TAB Agency commentary, itemizing any remaining deficiencies discovered and confirming all systems preparation and examination has been properly performed.

   a. Include itemized list of all examination and preparation procedures outlined above and as otherwise required by TAB Agency's procedures, with initialed dated verification of each item by authorized responsible party.

   b. Promptly report abnormal conditions in mechanical systems or conditions that prevent system balance. If, for design reasons, system cannot be properly balanced, report as soon as observed.

2. Report any defects or deficiencies observed during performance of TAB procedures.

D. TAB Agency:

1. Review, edit, and submit annotated Contractors Systems Readiness Reports to Contractor, Engineer, and Commissioning Agent, with itemized TAB Agency concurrence or commentary, itemizing deficiencies discovered and confirming all systems preparation and examination has been properly performed, with initialed dated verification of each item by authorized responsible party.

   a. Report abnormal conditions in mechanical systems or conditions that prevent system balance within 24 hours of discovery. If, for design reasons, system cannot be properly balanced, report as soon as observed.

2. Report any defects or deficiencies observed during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values. Include updates in partial TAB report submittals. Adjust as-built drawings as required to accurately reflect deviations from draft as-built set.

3. Promptly report abnormal conditions in mechanical systems or conditions that prevent system balance. If, for design reasons, system cannot be properly balanced, report as soon as observed.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. In the following TAB procedures portions of Part 3 Execution of this document, the procedures are deemed to be TAB Agency work unless specifically identified as Contractor work.

B. Contractor required assistance and Ancillary Work during TAB Agency Work includes the following general work categories and notes on Contractor Work requirements in subsequent specific procedure descriptions:

1. Maintain mechanically qualified personnel at Site to perform necessary mechanical modifications and adjustments in conjunction with TAB procedures.

2. Operate systems.

3. Provide trouble-shooting.

4. Cut insulation, pipes, ducts, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures. Properly plug all holes. Provide new insulation that matches removed materials, finished in accordance with Division 23 Section "HVAC Insulation."

5. Change air filters as required.

6. Adjust automatic damper linkages so they all operate smoothly and close tightly.

7. Perform necessary controls operations required for TAB procedures.

8. Re-adjust / make final adjustments to registers, grilles, and diffusers in cooperation with Owner and TAB Agency as required to obtain uniform space temperatures and air movement free from objectionable drafts and noise. As this affects system pressure drops, this must be completed before final airflow balancing.

9. Make any required additions or changes in types, locations, etc., of balancing equipment.

10. Provide other mechanical adjustments as required in conjunction with TAB procedures.

11. Leave system in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes and securing cover plates, restoring thermostats to specified settings, restoring systems to automatic operation as required, replacing ceiling tiles, plugging access ports and repairing insulation, cleaning, etc.

C. Tab Agency: Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance," ASHRAE 111, NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," or SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing," and in this Section.

1. Provide all testing and Balancing as required by the specific procedures outlined below and as required to provide the final test report as described below.

2. Mark equipment and balancing devices, valve position indicators, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

3. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES: AIR SYSTEMS TESTING, ADJUSTING, AND BALANCING

A. Visit Site prior to concealment of construction to check and advise regarding location of dampers, test connections, etc. TAB Agency shall advise Contractor and Architect of TAB Agency findings by letter.

B. Review sheet metal shop drawings and mark locations of all required balancing dampers before duct fabrication.

C. Make air quantity measurements in ducts by Pitot tube traverse of entire cross sectional area of duct in such a manner that local flow dynamics have a negligible effect on the measurements. Use multiple, bidirectional, traverses if flow measurements cannot be made in a section with at least 8 diameters straight duct upstream and 4 diameters of straight duct downstream from the measuring station. Mark all traverse locations on plans in report.

D. After adjustments, take measurements to verify balance has not been disrupted. Verify that disruptions in balance have been corrected.

E. Permanently mark valve, damper, and other adjustment device settings at devices to simplify restoration of settings. Record settings and include in report. Set and lock memory stops.

F. Procedures:

1. Verify that all systems are complete and operable as scheduled.

2. Verify that registers, grilles, and diffusers are adjusted to obtain uniform space temperatures and air movement free from objectionable drafts and noise. Cooperate with Owner and Contractor and reach agreement on air distribution pattern before proceeding.

3. Provide temporary filter media as follows: with the system fully operational, all dampers open, and the fan running at the scheduled RPM, check submittal values for new, midlife, and final/clogged filter pressure drops, check and record air pressure drop across the new clean final design filters, and provide temporary media to approximate midlife pressure drop across the filters for use during balancing. Record and report both pressure drop values at the final design flowrates. Adjust filter differential pressure switches to trip at correct final/clogged filter pressure drop in cooperation with Energy Management and Control System manufacturer's representative.

4. With the system fully operational, all dampers open, and the fan running at the approved submittal RPM, measure the airflow through all terminal units as well as the total system volume, without making any adjustments, and formulate a plan for preliminary adjustments of dampers and fan speed. Terminal units shall be defined to include all diffusers, registers, grilles, duct entries, louvers, hoods, etc.; i.e., wherever air enters or leaves ductwork whether indoors or outdoors. Record and report all initial values.

5. In cooperation with Energy Management and Control System manufacturer's representative, make mechanical adjustments of automatically operated dampers to operate as specified, indicated, and/or noted. Adjust and set the extreme operating conditions of these dampers and check completed damper control operations for proper calibration, reporting to control installers conflicts with those requiring adjustment. Test leakage of closed dampers. Adjust and set intermediate positions of outside air and return air dampers as required to achieve design outside airflow requirements defined in the sequence of operations, and / or calibrate outside air flow meters at this point. Balance variable volume systems at maximum air flow rate with full cooling and at minimum air flow rate with full heating

6. Adjust terminal units to the proportionally correct cfm, not necessarily the design cfm.

   a. If all the dampers in a branch line's terminal units must be adjusted to limit cfm, then use the branch line volume damper to limit the pressure drop across the terminal units in that branch so that at least one terminal unit's damper remains wide open but still has the correct flow. Adjust all branch ducts to proper proportional cfm in this way, leaving the volume dampers in the flow limiting branches wide open.

   b. Provide branch duct volume control by duct internal devices such as dampers and splitters only to the extent that the most open damper or splitter remains wide open and adjustments do not create objectionable air motion or sound levels. Under no circumstances shall total air system volume be throttled back to design flow through the partial closing of all dampers and splitters.

   c. Record and report all initial adjustment positions and proportional flowrates achieved.

7. Vary total air system flowrate by adjustment of fan speeds. Provide drive changes required.

   a. For variable frequency drive fans, perform the following procedure:

   b. Adjust the VSD to the maximum non- overloading frequency for the system, and measure and report the flowrate at this frequency.

   c. If other specific air flow rates are required due to the sequence of operations as reported on the drawings or in Section 23 09 00 – Instrumentation and Control for HVAC, coordinate with these requirements and determine the required frequency - flow relationships.

8. Verify that all terminal units are at the design cfm to within the balancing tolerance, and if not, repeat steps f. and g. above until design conditions are satisfied.

9. Test and record final motor, air moving equipment, exhaust fan, damper, and terminal unit information at this point.

10. Test and record air heating and cooling coil information after this point, as follows:

    a. Perform this step in conjunction with hydronic system balancing and after cooling and heating systems are operational.

    b. Set hydronic control valve to fully open at design flow and temperature as described below. Allow cooling coils to become fully wet with condensation. Test temperatures outside of the line of sight to the coil.

    c. Test and adjust coil performance for all data indicated to be on report test sheets.

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

    a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.

    b. Measure static pressure directly at the fan outlet or through the flexible connection.

    c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.

    d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

    a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.

5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

6. Obtain approval from Architect for adjustment of fan speed higher or lower than indicated speed.

7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.

3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.

2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.6 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.

2. Check liquid level in expansion tank.

3. Check makeup water-station pressure gage for adequate pressure for highest vent.

4. Check flow-control valves for specified sequence of operation, and set at indicated flow.

5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.

6. Set system controls so automatic valves are wide open to heat exchangers.

7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.

8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.7 PROCEDURES FOR HYDRONIC SYSTEMS

A. Measure water flow at pumps:

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump at 60Hz/VSD bypass. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved and mark pump manufacturer's head-capacity curve with this initial balance point. Note and record pump discharge valve position, then return to wide open (or maximum non-overloading position) for proportional balancing procedure.

    a. Monitor motor performance during procedures and do not operate motors in overload conditions.

3. Verify pump-motor brake horsepower at intended flow rate at run-out. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.

4. Report flow rates that are not within plus or minus 10 percent of design.

B. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.

C. With the system fully operational, all branch and terminal isolation, balancing, and control valves open, and the pump running at 60Hz/VSD bypass, measure the flow through all terminal units as well as the total system volume, without making any adjustments, and formulate a plan for preliminary balancing valve adjustment. Record and report all initial flow and pressure drop values.

D. Vary total system flowrate by adjustments at pump.

1. For variable frequency drive pumps, Perform the following procedure for each pump circuit running individually:

a. Ramp the VSD to the minimum frequency required to obtain the design flow, with each pump discharge valve open to the maximum position consistent with accurate reading and VSD bypass/60Hz non-overloading operation.

b. Repeat this VSD adjustment for each pump circuit of lead / lag pumps driven by one VSD, and set the VSD at the higher of these two frequencies.

c. At this frequency (the full design frequency - could be more or less than 60Hz), adjust the higher flow rate circuit to the design flow rate by further throttling the pump balancing valve, so that the flow rate from each pump is identical at the design frequency.

d. Verify that all terminal units are at the design gpm to within the balancing tolerance, and if not, repeat steps above until design conditions are satisfied at all system valves, with no excessive pressure and resultant energy use.

e. Report this value as the design frequency in the balancing report, and in writing to the Contractor responsible for incorporation into controls work of the Division 23.

f. Measure and report the flow-rate at 60Hz, and also at the frequency where the pump motor is running at full load amperage.

g. Measure and report all other pump flow data at this point.

h. Check settings and operation of each safety valve. Record settings.

3.8 PROCEDURES FOR STEAM SYSTEMS

A. Measure and record upstream and downstream pressure of each piece of equipment.
B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.
C. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
D. Check settings and operation of each safety valve. Record settings.
E. Verify the operation of each steam trap.

3.9 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.

5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the automatic and manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.10 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.
B. Measure entering- and leaving-air temperatures.
C. Record compressor data.

3.11 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

B. Measure, adjust, and record the following data for each steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Air pressure drop.
4. Inlet steam pressure.

C. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.12 PROCEDURE FOR MISCELLANEOUS DEVICE TESTING

A. Test and adjust all devices on project as required to correctly report the data listed below under paragraph on final report.

3.13 TOLERANCES

A. Adjust system totals to the sum of the connected load (plus leakage for air systems) rather than the scheduled pump or fan capacity.

B. Adjust air handling systems as follows:

1. Main ducts (ie. each fan system) to within minus 5 percent and plus 10 percent of the design values.
2. Outside air flow tolerance shall be at minimum that scheduled, with a tolerance of minus 0 percent and plus 10 percent.
3. Branch ducts and terminal units to within plus or minus10 percent of the design flow.
4. A total maximum variation of 10 percent between terminal units designated as “typical of (#).”

C. Adjust hydronic systems as follows:

1. Each pump to within 5 percent of the design flow values.
2. Branch lines and radiation to within 10 percent of the design flow values
3. A total maximum variation of 10 percent between terminal units designated as “typical of (#).”

3.14 PRELIMINARY REPORTING

A. Contract Document Examination Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for proper systems' balancing. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Pre-Construction Inspection and Testing Report: Prior to removal of any affected construction, prepare and submit report outlining results of Pre-Construction Inspection and Testing as outlined above and on the contract drawings.

C. Status Reports: Prepare biweekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.15 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:
    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:
    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.

f. Inlet vane settings for variable-air-volume systems.
g. Settings for supply-air, static-pressure controller.
h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air Moving Equipment (FCU, RTU, UV, VUV):

1. Location.

2. Manufacturer.

3. Model.

4. Air flow, specified and actual.

5. Return air flow, specified and actual.

6. Outside air flow, specified and actual.

7. Total static pressure (total external), specified and actual.

8. Labeled diagram showing pressure drop across each internal component including dampers, filters, coils, diffusers, and blowers. Provide multiple readings for complex systems with multiple internal dampers affecting system pressure drops, under all specified modes of operation.

9. Inlet pressure.

10. Discharge pressure.

11. Applicable data as specified elsewhere including coil, motor, damper, and drive data.

12. Fan RPM (for VSD driven fans, under various design conditions including at least full heating, 100% OA economizer, and full cooling loads).

F. Exhaust Fan Data (PRE, EF, F):

1. Location.
2. Manufacturer.
3. Model.
4. Air flow, specified and actual.
5. Total static pressure (total external), specified and actual.

6. Inlet pressure.
7. Discharge pressure.
8. Fan motor and drive data.
9. Fan RPM (for VSD driven fans, under various design conditions including at least full heating, 100% OA economizer, and full cooling loads).

G. Apparatus-Coil Test Reports:

1. Coil Data:

   a. System identification.
   b. Location.
   c. Coil type.
   d. Number of rows.
   e. Fin spacing in fins per inch o.c.
   f. Make and model number.
   g. Face area in sq. ft.
   h. Tube size in NPS.
   i. Tube and fin materials.
   j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

   a. Air flow rate in cfm.
   b. Average face velocity in fpm.
   c. Air pressure drop in inches wg.
   d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
   e. Return-air, wet- and dry-bulb temperatures in deg F.
   f. Entering-air, wet- and dry-bulb temperatures in deg F.
   g. Leaving-air, wet- and dry-bulb temperatures in deg F.
   h. Water flow rate in gpm.
   i. Water pressure differential in feet of head or psig.
   j. Entering-water temperature in deg F.
   k. Leaving-water temperature in deg F.
   l. Refrigerant expansion valve and refrigerant types.
   m. Refrigerant suction pressure in psig.
   n. Refrigerant suction temperature in deg F.
   o. Inlet steam pressure in psig.

H. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

   a. System and air-handling-unit identification.
   b. Location and zone.
   c. Room or riser served.
   d. Coil make and size.
   e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

   a. Air flow rate in cfm.
   b. Entering-water temperature in deg F.
   c. Leaving-water temperature in deg F.
   d. Water pressure drop in feet of head or psig.
   e. Entering-air temperature in deg F.
   f. Leaving-air temperature in deg F.

I. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

   a. System and air-handling-unit number.
   b. Location and zone.
   c. Traverse air temperature in deg F.
   d. Duct static pressure in inches wg.
   e. Duct size in inches.
   f. Duct area in sq. ft.
   g. Indicated air flow rate in cfm.
   h. Indicated velocity in fpm.
   i. Actual air flow rate in cfm.
   j. Actual average velocity in fpm.
   k. Barometric pressure in psig.

J. Air-Terminal-Device Reports:

1. Unit Data:

   a. System and air-handling unit identification.
   b. Location and zone.
   c. Apparatus used for test.
   d. Area served.
   e. Make.
   f. Number from system diagram.
   g. Type and model number.
   h. Size.
   i. Effective area in sq. ft.

2. Test Data (Indicated and Actual Values):

   a. Air flow rate in cfm.
   b. Air velocity in fpm.
   c. Preliminary air flow rate as needed in cfm.
   d. Preliminary velocity as needed in fpm.
   e. Final air flow rate in cfm.
   f. Final velocity in fpm.
   g. Space temperature in deg F.

K. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and size.
e. Model number and serial number.
f. Water flow rate in gpm.
g. Water pressure differential in feet of head or psig.
h. Pump rpm.
i. Design frequency for VSD pumps.
j. Impeller diameter in inches.
k. Motor make and frame size.
l. Motor horsepower and rpm.
m. Voltage at each connection.
n. Starter size, rating, heater data.
o. Amperage for each phase.
p. Rated efficiency, full-load amperage, and service factor.
q. Seal type.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig.
b. Pump shutoff pressure in feet of head or psig.
c. Actual impeller size in inches.
d. Full-open flow rate in gpm.
e. Full-open pressure in feet of head or psig.
f. Final discharge pressure in feet of head or psig.
g. Final suction pressure in feet of head or psig.
h. Final total pressure in feet of head or psig.
i. Final water flow rate in gpm.
j. Voltage at each connection.
k. Amperage for each phase.

L. Electric Motors:

1. Manufacturer.
2. HP/BHP.
3. Phase, voltage, amperage (nameplate, actual, and no load).
4. RPM.
5. Service factor.
6. Starter size, rating, heater elements.

M. Automatic Air Dampers (AAD, or internal to air moving equipment):

1. Location.

2. Manufacturer.

3. Model.

4. Airflow, specified and actual.

5. Check closed position leakage and report.

6. Damper and/or actuator position at all required positions, along with associated controls signal required to achieve position. Coordinate required positions of return air and outside air ventilation control dampers with positions required by required ventilation rates. Refer to Section 23 09 00 – Instrumentation and Controls for HVAC, and coordinate damper position adjustment with temperature controls and Owner's required occupancy schedule.

7. Total static pressure drop at all required positions.

N. Manual Air Volume Dampers (VD, or shown with no text as: ˥):

1. Location.
2. Report final damper position as angular deviation of blades from axial, with 0° being fully open and 90° being closed. Mark this position on duct at damper also.
3. Total static pressure drop across damper in as balanced condition.

O. Air Distribution Test Sheet (registers, grilles, and diffusers):

1. Air terminal number.
2. Room number/location.
3. Space Temperature.
4. Terminal type.
5. Terminal size.
6. Area factor.
7. Design velocity.
8. Design air flow.
9. Test (initial, adjusted, and final) velocities.
10. Test (initial, adjusted, and final) air flows.
11. Percent of design air flow.

P. Louvers:

1. Air terminal number / drawing designation.
2. Room number/location.
3. Terminal type.
4. Terminal size.
5. Free Area.
6. Design velocity.
7. Test (final) velocity.
8. Design air flow.
9. Test (final) air flow.
10. Percent of design air flow.
11. Design Pressure drop.
12. Test (final) pressure drop.

Q. Pump Discharge, and Balancing Valves:

1. Identification/station.
2. Location.
3. Size.
4. Manufacturer.
5. Model.
6. Design flow rate.
7. Design pressure drop.
8. Actual/final pressure drop.
9. Actual/final flow rate.
10. Station calibrated setting.

R. Automatic Balancing Valves Reports:

1. Identification/station.
2. Location.
3. Size.
4. Manufacturer.
5. Model.
6. Design flow rate.
7. Functional pressure drop range.
8. Actual/final pressure drop at system full flow condition.

S. Hydronic Control Valves Reports:

1. Location.
2. Manufacturer.
3. Model.
4. Flowrate, specified and actual.
5. Pressure drop at full flow condition.

T. Gauges and Thermometers Reports:

1. Identification/number.
2. Location.
3. Service.
4. Manufacturer.
5. Test all gauges and thermometers for mid range accuracy. Adjust thermometers where applicable; adjust all gauges for best 0 and/or midrange accuracy.
6. Temperature, test reading and actual.
7. Pressure, test reading and actual.

U. Controls Sensors Reports:

1. Coordinate work with Energy Management and Control System.

2. Test all controls system temperature, pressure, air monitoring (CO_2, CO, combustible gasses, humidity, etc.), and electrical current analog sensors for mid normal operating range accuracy. Adjust where applicable.

3. Test all controls system temperature, pressure, air monitoring (CO_2, CO, combustible gasses, humidity, etc.), and electrical current digital (on/off) sensors/switches for trip point. Adjust where applicable.

4. Verify that locations shown on Operators Work Station are schematically correct.

5. Identification/number

6. Location

7. Service

8. Manufacturer

9. Temperature, test reading and actual

10. Pressure, test reading and actual

11. Air composition, parts per million, test reading and actual. Test and adjust at normal ambient and alarm conditions.

V. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.16 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.

2. Check the following for each system:

a. Measure water flow of each device.
b. Verify that balancing devices are marked with final balance position.
c. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection by TAB Agency is complete and documentation verifies that testing and balancing are complete and accurately documented in the report, request that a final inspection be made, giving at minimum 7 calendar days' notice. Deliver copies of Draft Final Report to Engineer and Commissioning Authority with final inspection request.

   a. Engineer may elect to postpone final inspection upon delivery of written notice to TAB Agency that significant portions of the required TAB results are missing from draft report. If inspection is postponed, TAB Agency shall promptly return to site and provide missing TAB Work, then submit a revised draft and request the Final Inspection again.

2. The TAB Agency and Contractor's qualified technicians are to provide access, tools, and measurements during the inspection in the presence of the TAB Agency Supervisor and the Commissioning Authority.

3. Commissioning Authority will randomly select measurements, documented in the report or as required by contract, to be rechecked. Rechecking will be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED." If recheck calls for a measurement that is required but cannot be found in the draft report, the missing measurement will be noted as "MISSING."

5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the TAB Work will be considered defective and rejected. If the number of "MISSING" measurements is greater than 10 percent of the total measurements checked during the final inspection, the TAB Work will be considered defective and rejected.

C. If TAB Work is considered defective and rejected, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection. Pay all costs associated with second inspection including Commissioning Authority's reasonable additional fees.

2. If the second final inspection also fails, Owner may require additional inspection similar to second inspection or may contract the services of another TAB agency to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB Agency's final payment.

D. Prepare test and inspection reports.

END OF SECTION 23 05 93

SECTION 23 07 00 – HVAC INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes materials and installation requirements for mechanical component insulation and related accessories.

1. Insulation Materials:

   a. Calcium silicate.
   b. Cellular glass.
   c. Flexible elastomeric.
   d. Mineral fiber.
   e. Phenolic.
   f. Polyisocyanurate.
   g. Polyolefin.
   h. Polystyrene.
   i. Fire rated insulation systems

2. Insulation Accessories:

   a. Adhesives.
   b. Mastics.
   c. Lagging adhesives.
   d. Sealants.
   e. Factory-applied jackets.
   f. Field-applied fabric-reinforcing mesh.
   g. Field-applied cloths.
   h. Field-applied jackets.
   i. Tapes.
   j. Securements.
   k. Corner angles.
   l. Insulation protection systems

1.3 DEFINITIONS

A. “Concealed”: Work within or behind various construction elements, or in crawl spaces or trenches, that is not exposed to view when Project has been completed. (Areas above ceilings, including above Auditorium or Large Group Instruction partially open “cloud” ceilings and chases are considered a concealed location).

B. “Exposed”: Anything exposed to view when project has been completed.

1.4 SUBMITTALS

A. Comply with requirements of Section 01 33 00 – Submittal Procedures and as modified below.

B. Provide all submittals required by this Section concurrently.

C. Product Data

1. Submit complete manufacturer’s product information for each type of insulation and accessory specified in this section demonstrating compliance with specified requirements and including:

    a. Thermal and vapor transmission performance.
    b. MSDS information.
    c. Flame spread / smoke developed data.
    d. Manufacturer’s recommended installation methods.

D. Submit insulation schedule indicating each required service with type of insulation, thickness and R value, covering method, finishes, and any applicable notes.

E. Quality Control Submittals

1. Qualifications Certification: Submit written certification of installers signed by applicable certification agency and/or manufacturer (where applicable) indicating compliance with “Installer Qualifications” requirements specified below in “Quality Assurance” article.

2. Installer Experience Listing: Submit list of completed projects using products proposed for this Project, including Owner contact information for each project, demonstrating compliance with applicable “Qualifications” requirements specified below in “Quality Assurance” article.

F. Contract Closeout Submittals: Comply with requirements of Division 1 sections on closeout, including submission of maintenance instructions as item in "Operating and Maintenance Data" manual described there.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Provide insulation system installation by qualified Installers who are trained in installation of each proposed insulation material and product with at least one of the following qualifications:

1. Have successfully completed a mechanical insulation apprenticeship program by the Department of Labor, Bureau of Apprenticeship and Training,
2. Have successfully completed an ASHRAE / NIA 8 hour Mechanical Insulation Training course or equal, or
3. Have five years documented experience as a mechanical insulation specialist with references attesting to successful completion of at least three comparable projects.

B. Condensation Resistance: Provide insulation and vapor barrier systems complete as required to eliminate condensation under any normal operating conditions from surfaces of all cooling equipment and components provided or modified as a part of this contract Work, unless those surfaces are designed to remove moisture by condensation from process air, and to contain and drain the condensate.

C. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic and tapes, with appropriate markings of applicable testing and inspecting agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 COORDINATION

A. Coordinate size and location of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Components."

B. Coordinate clearance requirements with piping Installer for piping insulation application, duct Installer for duct insulation application, and equipment Installer for equipment insulation application. Before preparing piping and ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate with installation and testing of heat tracing.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

1.8 DELIVERY, STORAGE AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. For convenience, details and specifications have been based on products by the following manufacturers:

1. Armstrong; Lancaster, Pennsylvania.
2. Benjamin Foster.
3. CertainTeed; Valley Forge, Pennsylvania.
4. Fit Tight Covers, Inc.
5. Johns Manville; Defiance, Ohio.
6. Kingspan Tarec.
7. Knauf; North Carolina.
8. No Sweat Valve Wraps, Inc.
9. Owens-Corning; Toledo, Ohio.
10. Polyguard Products Inc., Ennis, Texas.
11. Thermaxx, LLC.
12. Or Approved Equal.

2.2 MATERIALS

A. Pipe and Fitting Insulation: Provide pipe insulation in compliance with ASTM C 585 Dimensional Standards.

1. Insulation Thickness:

a. Pipe and fitting insulation thicknesses specified assume an insulation conductivity (k) value of 0.27 btu•in/hr•ft2•ºF. For pipe and fitting insulation with conductivity other than 0.27 btu•in/hr•ft2•ºF, insulation must be thicker for higher conductivity and may be thinner for lower conductivity as required to achieve same or higher R value. Adjust insulation thickness from that specified in accordance with the following formula:

T = r[(1+t/r)K/k-1] where:

1) T = Adjusted insulation thickness, inches.
2) r = Actual pipe outside radius, inches.
3) t = Insulation thickness specified, inches.
4) K = actual insulation conductivity, btu•in/hr•ft2•ºF.
5) k = specified conductivity, 0.27 btu•in/hr•ft2•ºF.

b. Hydronic Piping for Heating:

1) Pipe sizes ½ inch through 1-¼ inches .... 1-1/2 inch
2) Pipe sizes 1-½ inches and larger .... 2 inches

c. Steam Heating Piping:

1) Pipe sizes ½ inch through 3-½ inches .... 2-1/2 inch
2) Pipe sizes 4 inches and larger .... 3 inches

d. Make-Up Water and Condensate Drain Piping

1) All pipe sizes .... ½ inch

e. Refrigerant Suction Piping:

1) All pipe sizes .... 1 inch

f. Flexible Connections:

1) Pipe sizes ½ inch through 1-½ inches .... 1/2 inch
2) Pipe sizes 2 inches and larger .... 1 inch

g. Runout piping in restricted spaces where it is not possible to provide the specified thickness may use reduced thickness insulation as required by space restriction.

2. Interior Above Grade Hydronic and Steam Piping Insulation:

a. ASTM C547, cylindrically molded preformed rigid half pipe shell forms, factory one-piece “hinged” construction.

1) Rigid pipe or tube insulation may be of mineral wool, fiberglass, closed cell glass, formed polyisocyanurate, formed phenolic, or extruded polystyrene (chilled service only).

2) Thermal Conductivity (“k”): Measured in accordance with ASTM C 335. For k values greater than 0.27, include calculations and compliant increased thickness proposed. For k values equal or less than 0.27, provide specified insulation thickness or calculations justifying thinner insulation.

3) Jacket: All Purpose (AP) vapor barrier jacket with:

a) White kraft paper outer surface bonded to aluminum foil, reinforced with fiberglass yarn, permanently treated for fire and smoke safety and to prevent corrosion of foil.
b) Self sealing pressure sensitive lap.
c) Water Vapor Permeance: ASTM E96, Procedure A, 0.02 perm maximum.
d) Puncture resistance: ASTM D781, 85 scale units minimum.
e) Burst resistance: ASTM D774, 100psi minimum.
f) Similar to “150TL facing” as used in “AP T Plus Jacket” and tape by Johns Manville, or equal.

3. Refrigerant Piping, Flexible Connections Insulation: fire-resistant, closed cell flexible (elastomeric) foam plastic, similar to Armacell Armaflex with manufacturer’s white painted mastic protective finish.

4. Make-up water and Condensate Drain Lines: insulation material similar to rigid pipe or refrigerant piping insulation specified above.

5. Fitting and Valve Insulation: Precut fiberglass blanket to match thickness, appearance and insulation value of adjacent pipe insulation; similar to "Hi Lo Temp Fiber Glass Insulation Insert" by Johns Manville, with fitted protective jacket specified for the installation.

B. Pipe and Fitting Protective Jackets:

1. Intended for permanent installation on non-serviceable components only.

2. Interior Pipe and Fitting Insulation Protective Jacket:

a. Plastic: High-impact, UV resistant polyvinyl chloride, white, paintable, covering designed to fit over AP jacketed insulated piping systems, molded to fit various sizes of fittings and piping as required; similar to "Zeston 2000 or Zeston 300 PVC Jacketing" by Johns Manville.

1) 20 mil thickness: Fittings and valves in interior applications eight feet above finished floor and higher.
2) 30 mil thickness: Fittings, valves, and straight pipe in interior applications lower than eight feet above finished floor.

C. Valve Covers, Serviceable Hydronic Component Insulation Jackets:

1. 2" nominal size and smaller Strainers, Triple Duty, Autoflow Control, Manual Balancing, Check, Combination, and Control Valves, and other similar piping components needing periodic service, maintenance or adjustment - provide easily removable insulation jacket requiring no special tools for installation or removal / replacement:

a. Factory fabricated removable and reusable cover similar to products by No Sweat Valve Wraps, Inc., or approved equal.

b. Size so outer jacket overlaps adjoining sections of pipe insulation.

c. Flame and smoke spread 25/50 per ASTM E-84 or less.

d. Maximum k- factor .26 or matching surrounding insulation, using fiberglass blanket.

e. Outer jacket made of material equal to DuPont Tychem® QC (polyethylene coated Tyvek), overlapping and completely covering the insulation with seams joined by integral elastic banding and tabs made from hook and loop fasteners (Velcro).

f. Butt ends and stem penetrations have sewn-in-place elastic. On cooling service, provide PSA backed closed cell foam gasket material adhered to stem penetration or surrounding insulation jacket between substrate and elastic jacket closure, as required insuring a complete vapor seal.

2. Pumps, Suction Diffusers, Triple Duty Valves, Balancing and Control Valves over 2” nominal size, and other HVAC components needing periodic service, maintenance or adjustment - provide easily removable, reusable insulation jacket in one of two types:

   a. Fabric type insulation jacket similar to products by ThermaXX, LLC, Fit Tight Covers, or approved equal:

      1) Silicone impregnated fiberglass composite cloth jacketing, 17 oz/sq. yd. minimum, 5 lb/cf type E needled fiberglass mat insulation, 35 lb test Kevlar thread, fiberglass or nylon webbing, Velcro closures or high temperature FRP buckles.

      2) Constructed in a folded three-dimensional shape designed to minimize the air space and convection current in the space between the hot metal surface and the inner layer of insulation, seamed for removal and replacement inspection ease. Insulation sandwiched and protected between inner and outer layers of jacketing cloth.

      3) All jacket pieces which match mating seams must include an extended 2" flap constructed from the exterior fabric (or equivalent) secured using hook & loop closure (i.e. Velcro®) and SS D-rings parallel to the seam or quick release adjustable buckles. Hog rings, staples, wire, etc., are not acceptable methods of closure.

      4) Insulation sewn to inner and outer jackets to prevent shifting, in two layers minimum with staggered stitch lines between inside and outside jackets, of thickness as required to match R value of surrounding pipe insulation. All seams sewn with lock stitch at a minimum of 5 stitches per inch using specified thread. All seams except closing seam introverted, closing seam on inside: no raw cut jacket edges exposed after install.

      5) For below ambient services, provide vapor barrier coated exterior jacket, with seam sealant at all stitch lines. Seal between jacket and equipment with replaceable closed cell gasket material to form a vapor barrier.

      6) Provide a permanently attached Laser Etched Anodized Aluminum nameplate (2” x 3.5”) on each jacket with the following information (or QR code and scanner app linking to information):

         a) Item Number
         b) Location Information
         c) Application Type
         d) Operating Pressure
         e) Component Type
         f) Component Size
         g) Jacket Min Max Temp
         h) Insulation Thickness
         i) Jacket material Hot Side
         j) Jacket material Cold Side
         k) Pre Photo & Post Photos
         l) Pattern

b. Metal box type field-fabricated insulation jacket:

1) Fabricate two piece removable metal boxes lined with insulation of thickness as specified.

2) Sheet metal box construction in accordance with Section 23 31 00 – Ductwork and as follows.

3) Materials shall be G-90 galvaneal, painted to match surrounding insulation system color.

4) Secure enclosure to equipment with repeatedly re-usable bolts, clips, or bands that do not require tools for service access or additional tape for re-assembly.

5) Fabricate joints with hemmed edges, outward bolted flanges or secure latching mechanism. Bolt flanges on 6-inch centers, starting at corners, using 3/8-inch- diameter fasteners with wing nuts.

D. Duct Insulation

1. Provide insulation thickness on ducts, plenums, and equipment equal to height of flanges, but not less than thickness required to achieve duct insulation R values specified herein:

a. R=6 deg. F-sq. ft.-h/Btu-in:

1) All interior HVAC duct where insulation is required, unless otherwise noted elsewhere.

b. R=12 deg. F-sq. ft.-h/Btu-in

1) Interior outside air intake duct

2. Rigid Board: 3 PCF minimum density glass fiber board (6PCF when exposed in mechanical or utility spaces) or phenolic, with factory-applied AP vapor barrier; similar to "800 series Spin-Glas" and "AP" facing by Johns Manville, or Kingspan KoolDuct.

3. Semi-Flexible: 2.5 PCF minimum density continuous glass fiber oriented strand sheets, with factory-applied AP vapor barrier. Strand orientation such that material has comparable rigidity to board type insulation above in one direction and comparable compressive strength, but is flexible enough in the other direction to wrap curved surfaces at a factory recommended minimum bend radius of 3T where T is the material thickness. Similar to "CrimpWrap" by CertainTeed.

4. Flexible: Glass fiber blanket, 3/4 PCF minimum density, with factory-applied, flame-resistant, FSK jacket; all joints taped; similar to Owens Corning "Fiberglas All Service Duct Wrap".

E. Ductwork Insulation Protective Jackets:

1. All Purpose (AP) Vapor Barrier for Duct Insulation: White kraft paper outer surface bonded to aluminum foil and reinforced with fiberglass yarn, permanently treated for fire and smoke safety and to prevent corrosion of foil.

   a. Water Vapor Permeance: ASTM E96, Procedure A, 0.02 perm maximum.
   b. Puncture resistance: ASTM D781, 85 scale units minimum.
   c. Burst resistance: ASTM D774, 100psi minimum.
   d. Similar to “150TL facing” as used in “AP T Plus Jacket” and tape by Johns Manville, or equal.

2. Foil-Skrim-Kraft (FSK) Vapor Barrier for Duct Insulation: Foil faced outer surface bonded to kraft paper backing and reinforced with fiberglass yarn, permanently treated for fire and smoke safety and to prevent corrosion of foil.

   a. Water Vapor Permeance: ASTM E96, Procedure A, 0.02 perm maximum.
   b. Similar to “FSK Jacket” and tape by Johns Manville, or equal.

F. Mechanical Equipment Insulation:

1. Thickness of insulation:

   a. Air Conditioning Service Diffusers: ½ inch (R=2 minimum).

   b. Heating Equipment:

      1) Pumps, air separators, suction diffusers: 2 inches (R=8 minimum).

2. Air Conditioning Service Diffuser Insulation:

   a. Insulation: fire-resistant, closed cell flexible (elastomeric) foam plastic; similar to Armstrong "AP Armaflex." Provide sheet stock with either PSA backing or manufacturer’s recommended adhesive – seal all joints with same adhesive.

3. Heating Equipment (Pumps, Suction Diffusers, Air Separators, etc.):

   a. Insulation: Same as rigid board and semi-flexible duct insulation described above, in 6pcf density.
   b. Prefabricate assemblies so as to be easily removable in assembled sections for service.

G. Insulation Accessories:

1. Mechanical Pin Fasteners: Provide welded or adhered pins of length based on manufacturer’s recommendations for insulation density and thickness, securely holding insulation with insulation manufacturer’s recommended compression. Mechanical Pin Fastener types include:

a. Stud style welded pins minimum 12 gauge diameter with matching push-on washers. Welded on with capacitor discharge type pin welder with no burn through or undercutting. Welded on prior to insulation application allowing for inspection prior to insulating.

b. Cup head style welded minimum 12 gauge diameter with integral washers. Welded on with capacitor discharge type pin welder with no burn through or undercutting. Welded on after insulation application dis-allowing inspection of pin welds without insulation removal. Not permitted for any Class A or tighter duct, not permitted for any fire rated duct insulation application.

c. Adhered style with perforated metal back plate (minimum 4 square inches surface area) welded to 12 gauge pins with matching push washers, bonded with full coverage of manufacturer's recommended adhesive. Not permitted for any fire rated duct insulation application.

d. Not permitted: PSA backed "peal and stick" pins, sheet metal fastening screws, or any other penetration of duct by fasteners.

2. Insulation Securement Bands: For larger cylindrical surfaces and fire rated duct insulation, tension securement bands may be used to supplement or replace mechanical pin fasteners. Provide bands of material compatible with insulation and system being insulated, minimum ½ inch wide and as required to avoid compressing insulation at required securement tension (3/4 inch minimum for diameters over 36 inches), 24 gage thick or thicker. End buckles of similar material. Wrapping or securing with wires not permitted.

3. Insulation Covering Canvas: 8 oz., 100 percent cotton, with flame spread 10 and smoke developed 0 ratings; similar to "Thermocanvas" by Fattal, Chicago, Illinois.

4. Insulation Tapes: Provide insulation manufacturers' recommended and matching tapes, matching characteristics of exterior jacket of insulation, in widths as required and as specified below to seal all gaps and reinforce vulnerable areas in vapor barrier. Provide tapes with peel off protective coating covering high performance acrylic adhesive unless manufacturer documents superior performance of alternative recommendation.

5. Insulation Adhesives and Mastics: Provide insulation manufacturers' recommended and matching adhesives and mastics, as required and as specified below to seal all gaps and reinforce vulnerable areas in vapor barrier. Provide with water based and low VOC formulations unless manufacturer documents superior performance of alternative recommendation and performance deficiencies of water based low VOC products.

6. Corrosion Inhibition Coating:

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Polyguard Brand, ReactiveGel™ RG-2400 series of coatings and accessories.

b. Materials shall be compatible with insulation materials, jackets, substrates, and conditions of service. Provide product formulation specifically designed for the conditions of service.

c. Product is a field applied gel chemical surface conversion compound utilizing reactive mineralization technology, creating a corrosion resistant mineral barrier 50-200 angstroms deep into the metal surface which increases in thickness as time passes.

d. Viscosity: Brookfield method; 200,000-300,000 cps

e. Specific Gravity: Gravimetric; 0.98-1.08

f. Application: Spray, rag, brush, roll, glove.

g. Corrosion test performance, thickness .025":

1) 1000 hours Accelerated Weathering per ASTM B117 - pass with no corrosion.
2) ASTM G-23 – pass with no corrosion.

h. Service Temperature Range: Minus 40 to plus 350 deg F. depending on formulation.

i. Color: Blue.

j. V.O.C.: EPA Method; NONE.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation and other conditions affecting performance of insulation application.
B. Verify that systems and equipment to be insulated have been tested and are free of defects.
C. Verify that surfaces to be insulated are clean and dry.
D. Proceed with installation only after unsatisfactory conditions have been corrected.
E. Beginning installation constitutes Contractor's acceptance of substrates and conditions.

3.2 PREPARATION

A. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion inhibition coating to surfaces to be insulated as follows:

1. All non-galvanized ferrous components with a service temperature below ambient: Coat with one full coverage coat of specified corrosion inhibition coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

3.3 INSTALLATION

A. General:

1. Provide thermal and acoustical insulation for components shown on the Drawings as specified in this Section for the following:

   a. All heating and air conditioning systems piping including fittings, valves, and accessories.

      1) Include removal of existing insulation and replacement insulation as specified for existing piping where called for on the drawings or where existing insulation is damaged as a result of contract work.

   b. All heating and air conditioning ductwork unless noted otherwise.

      1) All heating and air conditioning ductwork labeled as exposed shall not be insulated unless noted otherwise.
      2) All heating and air conditioning ductwork within a Mechanical Room, Boiler Room, Fan Room, etc., shall be insulated whether exposed or not.
      3) Include re-insulation where insulation is removed as a part of the abatement work. Refer to abatement drawings for quantities.

   c. All outside air ductwork extending from exterior wall or roof to the equipment which it serves.

   d. Exhaust, return, and relief air ductwork extending from exterior wall or roof 15 feet into the building envelope in all directions of duct branch take-offs.

   e. Air separators, exposed boiler supply and/or return ducts, risers, and piping connections, and all other HVAC components that operate below, or more than 15 degrees F above ambient conditions.

   f. All cooling condensate drain lines.

2. Comply with manufacturer's installation instructions and recommendations.

3. Do not begin mechanical insulation until permission is granted to begin mechanical insulation installation, hydronic systems have proved drip free under pressure, duct systems have passed required duct leakage requirements and testing, indoor work areas are weather tight, and outdoor work areas are at appropriate ambient conditions.

4. Below ambient temperature applications:

   a. Provide corrosion inhibition coating as specified above.
   b. Apply vapor barrier mastic and sealant to all open ends, joints, seams, breaks, and punctures in insulation.

5. Do not use any insulation support system which causes compression of insulation, localized or widespread, to less than 75% of the rated nominal thickness. Wires wrapped around rectangular duct insulation are not permitted as insulation support.

6. Provide for durable and repeated service access as part of insulation system.

   a. Do not permanently cover inspection stampings, hand holes, manholes, plugged outlets, or similar features on equipment – provide removable labeled insulated access port with beveled and sealed insulation plug, gasketed if vapor barrier is needed, durably fabricated for repeated access.

   b. Provide removable insulated boxes as specified for Pumps, Suction Diffusers, Heat Exchanger Frames and Heads, Triple Duty, Balancing, and Control valves, and other HVAC components needing periodic maintenance or adjustment.

7. Install thermal mechanical insulation as follows:

   a. Only on clean, dry surfaces and after piping and ductwork has been tested and found to be tight.
   b. Continuously through wall or ceiling openings and sleeves.
   c. On cold surfaces with continuous unbroken vapor seal.
   d. Insulate ducts and pipes individually.

8. Where more than one layer of insulation is required to achieve specified thickness or R value, apply thinner layer first, and stagger joints between insulation layers at least 3 inches.

B. Pipe Insulation

1. Comply with manufacturer's installation instructions and recommendations. Install only when ambient temperatures are within range recommended by manufacturer. STAPLES NOT PERMITTED.

2. Provide high impact plastic wrapper on all exposed, insulated piping from finished floor to 8 ft. above finished floor.

3. Interior Pipe and Fitting Insulation: Install on all heating, cooling, and condensate piping. Seal with factory applied pressure-sealing adhesive strip on the longitudinal lap. Seal butt joints with pressure-sealing adhesive strip at least 2 inches wide. Install valve and fitting covers in all locations.

4. Refrigerant Piping Insulation: Install in full accordance with manufacturers specifications and recommendations on refrigerant and condensate lines, using adhesive specifically intended for flexible foam plastic and provided by insulation supplier. Paint all exposed insulation cut ends with manufacturers (white) finish, similar to “WB Armaflex” or equal. Provide preformed elbows and fittings where available and neatly mitered and fit custom fabrications where manufactured components are not available. Tape and seal all joints vapor tight. For exterior refrigerant piping, install exterior piping protective wrapper water and air tight in accordance with manufacturer’s printed installation directions.

5. Insulation at Pipe Support: Refer to Section 23 05 29 - Hangers and Supports for material specifications of insulated piping support assembly and pipe support insulation. Complete insulation installation for the applicable pipe support insulation type to be used.

a. Type “B” Pipe Support Insulation:

1) Install pipe support insulation at hanger and support locations in conformance with manufacturer’s recommendations and as indicated on Drawings.

2) Remove a section of insulation from pipe insulation and replace this section with heavy density molded fiberglass blocks without breaking vapor barrier wrap.

b. Type “C” Pipe Support Insulation:

1) Provide butt connection to high-density insulation sections at pipe hangers as specified in Section 23 05 29 - Hangers and Supports.

2) Provide insulation with vapor barrier on upper half of insulated piping support assembly.

3) Apply wet coat of vapor barrier lap cement on butt joints and finish coat of vapor barrier mastic.

4) Tape edge of insulation section edge and insulation with white, pressure-sensitive PVC tape with tape extending over adjacent pipe insulation by at least 2 inches.

C. Ductwork Insulation: Provide external thermal insulation on ducts as specified or indicated on Drawings; external thermal insulation not required where ducts are shown or specified with internal acoustical insulation. Insulate and seal around duct dampers, damper motors, thermometers, instruments, access doors, and similar component as required without restricting operation or function. Insulate all ducts in all concealed spaces.

1. Use flexible type insulation on concealed ductwork with widths or diameters of 18 inches or less only. Insulate all other ductwork requiring insulation with rigid board type, semi-flexible type, or other type as required by drawings and specifications.

2. Duct Insulation Mechanical Fasteners: Provide mechanical fasteners for all duct surfaces over 12” wide. For duct surfaces 18’” wide and less, provide single row of fasteners down duct centerline. For duct surfaces over 18” wide, install minimum of 2 rows per side, applied on maximum 18" centers, starting within 3" of any edge.

a. Pins with the point facing out accepting push washers: clip points close to washers and cover with vapor barrier adhesive and tape. Not permitted on mechanical room duct unless covered by puncture resistant protective wrapper.

3. Duct Insulation Tape: Apply only to clean dry dust free surfaces as recommended by tape manufacturer and as required for durable adhesion.

a. Pealing tape, loose insulation, or otherwise broken vapor barrier subject to repeated recall.

4. Rigid Board Type Insulation Installation: Install board with all corners mitered or rabbeted; no butt joints allowed. Secure insulation with mechanical fasteners. Apply corner reinforcement angles (beads) on all corners for exposed ductwork (including in mechanical or storage spaces), with edge tape over beads. Seal all breaks and joints in vapor barrier with 3 to 5 inches wide insulation tape (minimum 1.5" tape past break all around).

5. Semi-flexible Type: Install similar to rigid board type, on round duct, curved elbows, etc. Wrap curved and round surfaces taught, provide circumference tape band maximum two feet on center (butt joints and center of four foot roll stock).

6. Flexible Type Insulation Installation: Make all joints and seams with 2-inch lap of vapor barrier cemented with Benjamin Foster "BF85-20". Apply Benjamin Foster "BF-20" adhesive to ducts in 6-inch brush widths at 1 ft. intervals and at each facing edge. Tape all adhered with Benjamin Foster "BF-20". Tape seal all seams, breaks, and joints in vapor barrier, then continuously coat all tape with manufacturer's recommended vapor barrier adhesive.

D. Equipment, Tank, and Vessel Insulation Installation

1. Insulation Installation for Tanks and Vessels:

a. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.

b. Develop three dimensional curves using cuts and curves, not wrinkles. Miter exterior corners and provide corner reinforcement angles. Do not use mastic or joint sealer as filler for gaps and voids resulting from poor workmanship: re-cut new better fitting pieces with adjacent insulation sections touching.

c. Protect exposed corners with secured corner angles.

d. Secure insulation with adhesive, anchor pins and washers, and securement bands as required.

e. Apply adhesives as follows:

1) Select insulation adhesive compatible with service temperature, substrate, and insulation.
2) Provide 100 percent coverage of tank and vessel surfaces.
3) Follow manufacturers' recommended coverage rates per unit area.

f. Install Mechanical Pin Fasteners on sides of tanks and vessels as follows:

1) Do not weld anchor pins to ASME-labeled pressure vessels.

2) Select insulation hangers and adhesive compatible with service temperature and substrate.

3) Maximum pin spacing is 3 inches from insulation end joints, and 16 inches o.c. in both directions.

4) Impale insulation over anchor pins and attach speed washers.

5) In concealed applications, cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. In exposed mechanical room applications, bend excess portion of pins extending beyond speed washers parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

g. Provide securement Bands as follows:

1) Use where adhesives and mechanical pin fasteners are inappropriate or inadequate as required to secure insulation.

2) Secure each layer of insulation with securement bands separately.

3) Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.

2. Air Conditioning Service Diffusers:

a. Install insulation materials in accordance with manufacturers written instructions. Clean and dry diffuser backs before installation. Use one piece covering entire back of diffusers where possible, adhered durably vapor tight especially at edges, with smooth and even surfaces, and neat hole cut to fit duct collar. Seal to duct insulation.

3. Pumps, Suction Diffusers, Strainers, Triple Duty Valves, Balancing and Control Valves, and other HVAC components needing periodic maintenance or adjustment:

a. Provide removable covers as specified above.

b. Fit covers closely to component being insulated and adjacent system insulation and coincide joints with component and adjacent equipment installations allowing easy removal for service access to all parts requiring service.

c. Valves with insulated non-condensing stem assembly: insulate and seal to stem, leaving insulated adjustable portion of valve\s exposed.

4. Surface Finish of Equipment Insulation:

   a. Heating Equipment with no serviceable parts concealed: Reinforce insulation and cover with metal mesh and insulating cement. Recover with 8 oz. canvas, smoothly applied, adhered and sized with Benjamin Foster “BF-30" adhesive.

   b. Cooling Equipment with no serviceable parts concealed: Glue all joints with 100% adhesive coverage of cut surfaces. Seal assembly vapor tight as required to avoid condensation. Paint all exposed insulation edges with manufacturers (white) finish, similar to “WB Armaflex” or equal, and cover all joints with manufacturer’s matching protective vapor barrier facing tape.

END OF SECTION 23 07 00

SECTION 23 08 00 - COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1. See especially Section 01 08 00 "General Commissioning Requirements" for general commissioning process requirements and Commissioning Coordinator responsibilities.

1.2 SUMMARY

A. Section includes commissioning process requirements for the following Building Mechanical Systems, which are described in more detail in the technical specifications of Division 23.

1. Cooling generation systems, including direct-expansion systems.
2. Distribution systems, including supply and return air distribution systems, hot water distribution systems, exhaust systems and air-handling units.
3. Terminal and packaged units, including unit ventilators, fan-coil units, finned-tube radiation, and packaged units.
4. Energy Management and Control System.
5. Systems testing, adjusting, and balancing verification, including all of the above mentioned systems.

1.3 DEFINITIONS

A. BAS: Building automation system, also known as Energy Management and Control System (EMCS).

B. Building Mechanical Systems: All Systems, Subsystems, Equipment, and Components of the building systems traditionally known as Heating, Ventilating, Air Conditioning, Refrigeration, Plumbing, and Electrical Works.

C. Commissioning Plan: A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.

D. CxA: Commissioning Authority –The Owner or a third-party commissioning agent designated by the Owner.

E. DDC: Direct digital controls, a part of the BAS.

F. HVAC&R: Heating, Ventilating, Air Conditioning, and Refrigeration.

G. "Systems," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.

H. TAB: Testing, adjusting, and balancing.

1.4 SUBMITTALS

A. Qualification Data: For BAS and HVAC&R Testing Technician.

B. Construction Checklists: Provide construction pre-functional test checklists filled out by qualified technician for all equipment to be commissioned on this project, including but not limited to all:

1. Vibration, Sound, and Movement / Seismic controls for HVAC&R.
2. BAS.
3. Heating-water Piping and Accessories.
4. Refrigerant Piping.
5. Metal Ducts and Accessories.
6. Fans.
7. Air-handling Units.
8. Heat Pumps.
9. Hydronic Pumps.

C. Certificates of readiness and completion of installation.

D. Test and inspection reports and certificates.

E. Corrective action documents.

F. Instrumentation Calibration Information

G. Functional Performance Test Procedures

1.5 QUALITY ASSURANCE

A. BAS Testing Technician Qualifications: Technicians to perform BAS construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:

1. Journey-level or equivalent skill level with knowledge of BAS, HVAC&R, electrical concepts, and building operations.
2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.
3. International Society of Automation (ISA) Certified Control Systems Technician (CCST) Level I.

B. HVAC&R Testing Technician Qualifications: Technicians to perform HVAC&R construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:

1. Journey-level or equivalent skill level. Vocational School four-year program graduate or an Associates degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC&R systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC&R equipment, assemblies, and systems.

2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.

3. One of the following:

   a. National Environmental Balancing Bureau (NEBB) Certified Testing, Adjusting, and Balancing Technician.
   b. Associated Air Balance Council (AABC) Certified Test and Balance Technician.
   c. Owner retains the right to waive NEBB or AABC Certification.

C. Testing Equipment and Instrumentation Quality and Calibration: For test equipment and instrumentation required to perform HVAC&R commissioning work, perform the following:

1. Submit test equipment and instrumentation list. For each equipment or instrument, identify the following:

   a. Equipment/instrument identification number.
   b. Planned commissioning application or use.
   c. Manufacturer, make, model, and serial number.
   d. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.

2. Test equipment and instrumentation shall meet the following criteria:

   a. Capable of testing and measuring performance within the specified acceptance criteria.
   b. Be calibrated at the manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
   c. Be maintained in good repair and operating condition throughout the duration of use on this Project.
   d. Be recalibrated/repaired if dropped or damaged in any way since last calibrated.

D. Proprietary Test Instrumentation and Tools:

1. Equipment Manufacturer's Proprietary Instrumentation and Tools: For installed equipment included in the commissioning process, test instrumentation and tools manufactured or prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, perform the following:

a. Submit proprietary instrumentation and tools list. For each instrument or tool, identify the following:

1) Instrument or tool identification number.
2) Equipment schedule designation of equipment for which the instrument or tool is required.
3) Manufacturer, make, model, and serial number.
4) Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

b. Include a separate list of proprietary test instrumentation and tools in the operation and maintenance manuals.

c. HVAC&R proprietary test instrumentation and tools become the property of Owner at the time of Substantial Completion.

1.6 CONTRACTOR'S RESPONSIBILITIES

A. Provide mechanical work in accordance with contract document requirements.

B. Perform commissioning tests including Materials Checks, Installation Checks, Start-up Checks, Startups, and Functional Testing, all at the direction of the CxA.

C. Attend construction phase controls coordination meetings.

D. Attend and participate in TAB review and coordination meetings.

E. Attend and participate in commissioning meetings.

F. Participate in Building Mechanical Systems maintenance orientation and inspection as directed by the CxA.

G. Prepare Construction / Prefunctional Checklists and Functional Performance Test procedures and execute and document results. All Prefunctional Checklists and tests must be documented using specific, procedural forms in Microsoft Word or Excel software developed for that purpose. Prior to testing, Contractor shall submit those forms for review and approval.

H. Submit documentation required for Commissioning work. At minimum, include: Detailed Start-up procedures, Full sequences of operation, Operating and Maintenance data, Performance data, checkout sheet forms used by factory or manufacturer's field technicians, Functional Performance Test Procedures, Control Drawings, and details of Owner-Contracted tests.

I. Review and approve other relative documentation for impact on Functional Performance Tests of the systems:

1. Shop Drawings and product submittal data related to systems or equipment to be commissioned. Review and incorporate comments from the CxA.

2. Incorporate manufacturer's Start-up procedures with Prefunctional checklists.

3. Factory Performance Test Reports: Review and compile all factory performance data to assure that the data is complete prior to executing the Functional Performance Testing.

4. Complete equipment Construction / Prefunctional Checklists, Start-up certification forms, and the manufacturer's field or factory performance and Start-up test documentation: review the documentation prior to commencing with the scheduled Functional Performance Tests.

5. Final Testing Reports: Contractor or Subcontractor performing the test will review the documentation prior to commencing with the scheduled Functional Performance Tests.

6. Operating and Maintenance (O&M) information per requirements of the Technical Specifications and Division 01 requirements: To validate adequacy and completeness of the Functional Performance Tests, the Contractor shall ensure that the O&M manual content, marked-up record Drawings and Specifications, component submittal drawings, and other pertinent documents are available at the Project Site for review.

J. Provide information requested by the CxA for final commissioning documentation.

K. Schedule work so that required installations are completed, and systems verification checks and functional performance tests can be carried out on schedule.

L. Provide measuring instruments and logging devices to record test data, and provide data acquisition equipment to record data for the complete range of testing for the required test period.

M. Inspect, check, and confirm in writing the proper installation and performance of all Work.

N. Provide technicians to assist during system verification and functional performance testing as required by the CxA.

1.7 CxA'S AUTHORITY

A. Directing Commissioning.

B. Assign Commissioning Agent for various commissioning tasks to stand in for the CxA.

C. Edit and approve project-specific construction checklists and commissioning process test procedures for actual Building Mechanical Systems, assemblies, equipment, and components to be provided as part of the construction contract.

D. Verify Testing, Adjusting, and Balancing of Work are complete.

1.8 COMMISSIONING DOCUMENTATION

A. Provide the following information to the CxA for inclusion in the commissioning plan:

1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.
2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
3. Process and schedule for completing construction checklists and manufacturer's prestart and startup checklists for Building Mechanical Systems to be verified and tested.
4. Certificate of completion certifying that installation, prestart checks, and startup procedures have been completed.
5. Certificate of readiness certifying that Building Mechanical Systems and associated controls are ready for testing.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 TESTING PREPARATION

A. Certify that Building Mechanical Systems have been installed, calibrated, and started and are operating according to the Contract Documents.

B. Certify that Building Mechanical Systems instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

C. Certify that Contractor portions of testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing report discrepancies have been corrected, and corrective work approved.

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

E. Inspect and verify the position of each device and interlock.

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

G. Testing Instrumentation: Provide (Furnish and Install) measuring instruments and logging devices to record test data as directed by the CxA.

3.2 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning tests at the direction of the CxA.

B. Scope of Building Mechanical Systems testing includes entire HVAC&R installation. Testing includes measuring capacities and effectiveness of operational and control functions, accuracy and precision of sensing equipment, and other functional parameters as required, demonstrating that systems are performing as specified and intended. Commissioning testing includes verification of up to 30 percent of the control points, Testing and Balancing data, and other system requirements indicated in the individual technical sections, and on the drawings and schedules of these contract documents. Parameters not otherwise specified to be tested, as required to adequately demonstrate system performance, may constitute up to 10 percent of the 30 percent (3 percent of total).

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

D. The CxA along with the Building Mechanical Systems Contractors and their Subcontractors, especially the Testing, Adjusting, and Balancing Subcontractor, and HVAC&R Instrumentation and Control Subcontractor, shall prepare detailed testing plans, procedures, and checklists for Building Mechanical Systems based on the actual installed equipment and the contract documents.

E. Perform tests using design conditions whenever possible.

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

2. The CxA may direct that set points be altered when simulating conditions is not practical.

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

F. If tests cannot be completed because of a deficiency outside the scope of the Building Mechanical System, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests. If deficiencies cannot be resolved, refine tests as required to adequately test Building Mechanical Systems within the constraints of the deficiency.

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

3.3 TESTING, ADJUSTING, AND BALANCING (TAB) VERIFICATION

A. Prior to performance of TAB Work, provide copies of approved sample report forms, checklists, and certificates to the CxA.

B. Notify the CxA at least 10 days in advance of TAB Work, and provide access for the CxA to witness Testing, Adjusting, and Balancing Work.

C. Subsequent to approval of formal TAB report, TAB Work will be subject to field verification. Provide technicians, instrumentation, and tools to verify testing and balancing of Building Mechanical Systems at the direction of the CxA. Roughly 10% of required TAB data points identified in TAB specification will be selected for subsequent field verification.

1. The CxA will notify TAB Subcontractor 10 days in advance of the date of field verification. Notice will not include data points to be verified.

2. The TAB Subcontractor shall use the same instruments (by model and serial number) that were used when original data were collected.

3. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.

4. Remedy the deficiency and notify the CxA so verification of failed portions can be performed.

3.4 SPECIFIC COMPONENT AND SYSTEM COMMISSIONING TESTS

A. Cooling Generation Systems

1. Refrigeration System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of refrigerant compressors and condensers, and other refrigeration systems. The CxA shall determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested, as required demonstrating that any selected operating performance criteria are met or exceeded.

B. Air Distribution Systems

1. TAB Air Flow Verification:

a. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."

b. Completion of "Preparation" Article requirements for preparation of a TAB plan that includes strategies and step-by-step procedures, and system-readiness checks and reports, as specified in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."

c. Scope: HVAC&R air systems and hydronic piping systems.

d. Purpose: Differential flow relationships intended to maintain air pressurization differentials between the various areas of Project.

e. Conditions of the Test:

1) Commissioning Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."

2) Systems operating in full heating mode with minimum outside-air volume.

3) Systems operating in full cooling mode with minimum outside-air volume.

4) For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.

f. Acceptance Criteria:

1) Under all conditions, rechecked measurements comply with "Inspections" Article in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."

2) Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than two times the tolerances allowed.

3) Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

C. General Hydronic System Testing

1. Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment requirements are specified in Division 23 piping Sections. HVAC&R Contractor shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the CxA. Plan shall include the following:

a. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.

b. Description of equipment for flushing operations.

c. Minimum flushing water velocity.

d. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

D. Hot Water Distribution Systems

1. Heating-Water Supply Temperature Control:

a. Prerequisites: Installation verification of the following:

1) Startup of boiler.

2) Startup of heating-water pump(s).

3) TAB of heating-water flow and pressure.

4) Input Device: Heating-water supply temperature sensors, thermometers, and thermostatic devices.

5) Output Device: Control valve.

6) Display the following at the operator's workstation:

a) Heating-water supply temperature.
b) Heating-water supply temperature set point.
c) Control-valve position.

b. Scope: Heating-water system.

c. Purpose: Control of heating-water supply temperature at input device.

d. Conditions of the Test:

1) Minimum heating-water flow.
2) Midrange Heating-Water Flow: 50 to 60 percent of maximum.
3) Maximum heating-water flow.

e. Acceptance Criteria: Under all conditions, heating-water supply temperature is within plus or minus 2.0 deg F of set point.

2. Heating-Water Supply Temperature Reset:

a. Prerequisites: Installation verification of the following:

1) Startup of boiler.

2) Startup of heating-water pump(s).

3) TAB of heating-water flow and pressure.

4) Input Device: Heating-water supply temperature sensors, thermometers, and thermostatic devices.

5) Input Device: Outdoor-air temperature sensor.

6) Output Device: Control valve.

7) Display the following at the operator's workstation:

a) Outdoor-air temperature.
b) Heating-water supply temperature.
c) Heating-water supply temperature set point.
d) Control-valve position.

b. Scope: Heating-water system.

c. Purpose: Control of heating-water supply temperature at heating-water supply temperature input device in response to variable outdoor-air temperature input; outdoor-air sensor.

d. Conditions of the Test: Outdoor-air temperature input value may be overridden for this test.

1) Low Temperature: Outdoor-air temperature between minus 30 and 0 deg F.
2) Midrange Temperature: Outdoor-air temperature between 30 and 45 deg F.
3) High Temperature: Outdoor-air temperature above 65 deg F.

e. Acceptance Criteria: Heating-water supply temperature resets in straight-line relationship with outdoor-air temperature for the following reset schedule. Under all conditions, heating-water supply temperature is within 2.0 deg F of set point.

1) 160 deg F heating water when outdoor-air temperature is minus 10 deg F.
2) 110 deg F heating water when outdoor-air temperature is 45 deg F.
3) Under all conditions, heating-water supply temperature is within plus or minus 2.0 deg F of set point.

3. Pump Testing and Acceptance Procedures: Testing requirements are specified in Division 23 Section “Testing, Adjusting, and Balancing for HVAC.” Provide submittals, test data, inspector record, VSD setup reports, and pump alignment certification to the CxA. Pumps shall deliver the design flow rate and pressure using no more energy than as scheduled. Pump alignment shall be as specified. VSD setup and adjustment shall be as specified.

4. Control Primary Circulating Pump(s):

a. Prerequisites: Installation verification of the following:

1) Startup of heating-water pump(s).

2) Input Device: Outdoor-air temperature; outdoor-air sensor.

3) Output Device: Heating-water pump; DDC system command to starter relay.

4) Display the following at the operator's workstation:

a) Outdoor-air temperature.
b) Operating status of primary circulating pump(s).

b. Scope: Heating-water pump(s) and associated controls.

c. Purpose: On-off control of heating-water pump(s) in response to variable outdoor-air temperature input; outdoor-air sensor.

d. Conditions of the Test:

1) High Temperature: Outdoor-air temperature above 65 deg F.
2) Low Temperature: Outdoor-air temperature below 65 deg F.

e. Acceptance Criteria:

1) High Temperature: Pump(s) are off when outside-air temperature is above 65 deg F.
2) Low Temperature: Pump(s) are on when outside-air temperature is below 65 deg F.

E. Exhaust Systems

1. Exhaust Fan Testing and Acceptance Procedures: Testing requirements are specified in Division 23 Section “Testing, Adjusting, and Balancing for HVAC.” Provide submittals, test data, inspector record, and exhaust fan performance certification to the CxA. Exhaust fans shall be equipped with all accessories as specified and scheduled and shall be demonstrated to operate on the approved fan curve with no greater than the approved power requirements.

F. Air-Handling Units

1. Air-Handler Mixed-Air Control:

a. Prerequisites: Installation verification of the following:

1) Minimum Position Input Device: DDC system time schedule.

2) Output Device: DDC system analog output to modulating damper actuator(s).

3) Heating Reset Input Device: DDC system software.

4) Supply-Air Temperature Input Device: Electronic temperature sensor.

5) Display the following at the operator's workstation:

a) Mixed-air-temperature indication.
b) Mixed-air-temperature set point.
c) Mixed-air damper position.

b. Scope: Air handler with mixed-air control and associated controls.

c. Purpose:

1) Occupied time control.
2) Minimum damper position control.
3) Heating reset control.
4) Supply-air temperature control.
5) Cooling reset control.
6) Unoccupied time control.

d. Conditions of the Test:

1) Occupied Time Control: Start in unoccupied schedule. Advance to occupied schedule time.

2) Minimum Damper Position Control: Command system to mode in which minimum damper position is required.

3) Heating Reset Control: Create a call for heating.

4) Supply-Air Temperature Control: Override supply-air temperature set point to a value 2.0 deg F above current supply-air temperature.

5) Unoccupied Time Control: Advance to unoccupied schedule time.

6) Control Data Trend Log: Set up a data trend log of the following input device values and output device commands. Record data at hourly intervals. Submit trend data for 24-hour periods in which natural conditions require heating reset control, supply-air temperature control, and economizer cooling control.

   a) Minimum position input device.
   b) Heating reset input device.
   c) Supply-air temperature input device.
   d) Cooling reset input device.

e. Acceptance Criteria:

1) Occupied Time Control: Mixed-air control is active in occupied mode.

2) Minimum Damper Position Control: Controller positions outdoor-air dampers to minimum position.

3) Heating Reset Control: Controller sets outdoor-air dampers to minimum position.

4) Supply-Air Temperature Control: Controller modulates outdoor-, return-, and relief-air dampers to maintain temporary supply-air temperature set point plus or minus 1.0 deg F.

5) Economizer Cooling Control: Controller sets outdoor-air dampers to maximum position when outdoor-air enthalpy is less than return-air enthalpy.

6) Unoccupied Time Control: Controller positions outdoor- and relief-air dampers closed and return-air dampers open.

7) Control Data Trend Log: Data verifies control according to sequence of control.

G. Unit Ventilators / Fan-Coil Units

1. Unit Ventilator / Fan-Coil Unit Testing and Acceptance Procedures: Testing requirements are specified in Division 23 Section "Testing, Adjusting, and Balancing for HVAC." Provide submittals, test data, inspector record, and Unit Ventilator / Fan-Coil Unit performance certification to the CxA. Unit Ventilator / Fan-Coil Unit shall be equipped with all accessories as specified and scheduled and shall be demonstrated to deliver the scheduled airflow and heat capacity at no greater noise or power use levels than specified.

H. Finned-Tube Radiation

1. Finned Tube Radiation (FTR) Testing and Acceptance Procedures: Testing requirements are specified in Division 23 Section "Testing, Adjusting, and Balancing for HVAC." Provide submittals, and test data certification to the CxA. FTR shall be installed level and plumb, neat and secure, with ready access to hydronic specialties as required for service, equipped with all accessories as specified and scheduled and shall be demonstrated to provide the specified and approved heating capacity while operating with no greater than the specified water flow.

I. Energy Management And Control System

1. Testing requirements are specified in Division 23 Section "Instrumentation and Control for HVAC," Section 3.11 SYSTEM TESTING AND COMMISSIONING. Provide submittals, test data, inspector record, and EMCS performance certification to the CxA.

2. Provide password and any other hardware and software as required to enable CxA to communicate directly, with full graphics and control capability, with the EMCS from the CxA's office over an internet browser interface. Install complete early in project.

J. ELECTRICAL POWER DISTRIBUTION SYSTEMS SERVING THE ABOVE LISTED MECHANICAL (PLUMBING AND HVAC&R) SYSTEMS

1. Be prepared for CxA to take thermal images of field connections for any line voltage power connections.

END OF SECTION 23 08 00

SECTION 23 09 00 - INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Review and study all drawings and this entire project specification to become familiar with the equipment and system operation as designed and to verify the quantities and types of controllers, valves, dampers, operators, alarms, points, etc., required.

1.2 SUMMARY

A. The Board of Education of the Beacon City School District has decided to purchase controls components (including installation and wiring), engineering, programming and project management labor from Day Automation Systems, Incorporated, using NYS OGS contract pricing, through NYS OGS Group # 77201, Award # 23150, Contract # PT68783. Products and all other controls system components will in general conform to this specification. Please contact Scott Sullivan for additional information:

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Account Executive, Day Automation Systems, Inc.
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Albany, NY 12205
+1 (518) 729-6919
scott.sullivan@dayautomation.com

1. Provide installation of the Energy Management and Control System (EMCS) in full accordance with this specification, by the owner's Temperature Controls Contractor (TCC) as described in quality assurance below and as approved by the Architects and Engineers, to be paid as a direct consultant to the district. Include both removals of existing controls as specified below and installation of new controls as follows:

    a. Control Valves and their actuators,

    b. Automatic Dampers and their actuators,

    c. All control devices: input, output, and logical, including their interface with and mounting in or on piping, sheet metal and general building systems.

    d. All actuation devices for existing valves and dampers should they be involved,

    e. All wiring between all EMCS components and all power source wiring for them,

    f. Removal of all discontinued controls, including but not limited to all pneumatic control air components (piping, compressors, specialties, etc., as shown and as coordinated with continued use).

2. Any incidental installations and work not covered above including but not limited to inspecting, testing, and SV acceptance of controls components installation, and controls programming, testing, adjusting, and commissioning labor shall be included in the product portion of this work and shall be provided complete by the Standardized Vendor, resulting in a complete functional control system per specifications.

B. This section describes the requirements for a complete Energy Management and Control System (EMCS) for building mechanical systems and components, based upon Direct Digital Control (DDC) logic including WEB served operator interface via the existing computer Operator Work Stations, distributed microprocessor controls, and integrated electronic components, interfaces, and actuation, all installed complete as specified.

C. Perform all work in cooperation with the Owner, Architect, Construction Manager, and other Prime Contractors. Coordinate all work with the construction schedule established by the Owner, Architect, and Construction Manager, and immediately report any delays including circumstances causing the delays.

D. The mechanical contractor is responsible to maintain pressure tight HVAC systems. Turn over all control components that are installed in the pressure tight HVAC systems over to the mechanical contractor (for installation), to include:

1. All piping mounted controls components, including control valve, valve and control manifolds, pressure and temperature sensor taps, flow switches, thermal wells, and similar devices.

2. All airside mounted controls components, including dampers, pressure and temperature sensor probe taps, flow sensors, and similar devices.

E. It is the Owner's intent to extend and establish a fully compatible and interoperable Energy Management and Control System (EMCS) network as an extension of the Beacon City School District's distributed **Schneider Electric** EMCS. This shall be accomplished through the general removal of all existing controls components serving the systems affected by this project, and providing new controls complete as specified herein. Provide new graphic displays for all new controls, and custom configure graphic displays to meet Owner and Engineer requirements. Provide each of the following portions of the complete EMCS as a standalone system that can communicate with any other Direct Digital Control (DDC) system which is following the same protocol:

1. Operator Work Stations (OWS): Provide software and hardware updates as required for existing OWS, installed at a location of the Owner's choosing; and integrate this project's controls complete with the EMCS at the District's facilities offices and other buildings. Provide software and programming for OWS and update software at existing EMCS complete to incorporate this addition. Provide guaranteed seamless two way communications from each, including full control, with the EMCS provided as a part of this project and the existing campus EMCS.

a. The OWS shall monitor, display, and control information from the EMCS through one software package. Rebooting of the OWS, or opening a separate program to access the existing building's multiple systems is not acceptable.

b. The OWS shall allow customization of the system as described in this specification.

c. The OWS shall:

1) Provide new color graphic control panels for all equipment provided or modified as part of this project, as outlined below and on the drawings,
2) Allow operators to view and work with all DDC points associated with all DDC equipment provided or modified as part of this project,
3) Allow operators to create custom graphics and/or control programming generation for any and all new equipment.

2. Network Control Unit (NCU): Provide central processor WEB server capability for and fully integrated two way communications with all energy use and management equipment provided or modified by this project, along with any third party stand-alone controls provided by the manufacturers of the Air Handlers, Refrigeration Machinery, Boilers, and Variable Speed Drives. NCU shall be capable of supporting a minimum of 127 field devices, providing reserve capacity for addition of future points and expansion of DDC system into building. The DDC system's NCU shall communicate with the OWS entirely using the BACnet protocol, with a conformance class of 5, as defined in the latest officially amended version of ANSI/ASHRAE 135-2004.

3. Distributed Controls: System controls shall include but not be limited to all controllers, sensors, devices, wiring, and all other hardware and software required to perform all of the functions and controls described later in this specification and on the drawings, including fully integrated two-way control of boilers, chiller, condensing units, pumps, VSDs, heat exchanger, and all associated temperatures, pressures, and other controllable parameters of mechanical equipment and systems provided or modified as part of this project. Provide control through the EMCS as outlined in the general controls sequences of operations below, as shown on the project drawings, and with controls similar to as shown where the exact configuration is not explicitly covered by the drawing and specification sequence of operations.

4. Engineer's Office: Provide password and any other hardware and software as required to enable Engineer to communicate directly, with full graphics and control capability, with the EMCS from the Engineer's office over an internet browser interface. Install complete early in project. Engineer will utilize to check progress of installation, to check operation of system during the punch list period, and to monitor system operation after completion of the work.

1.3 DEFINITIONS

A. DDC: Direct Digital Control.

B. PC: Personal computer.

C. EMCS: Energy Management and Control System, includes the complete automatic temperature control and energy use management system specified herein, based upon DDC technology, incorporating all necessary input and output devices, connecting hardware, software, and accessories.

D. OWS: Operator Workstation which is the main operator interface with the EMCS, comprised of a PC with graphical two way interface with, and data base and control capabilities for, the entire EMCS.

E. UC: Unitary Controller, a version of the SCU which is a smaller microprocessor-based controller, possibly pre-programmed to function specifically for the operation of a particular piece of equipment, such as a standard configuration air handler, unit ventilator, variable air volume box, lighting circuit, etc.

F. SCU: Standalone Control Unit, a microprocessor-based controller panel, which contains all necessary control logic to carry out its own, local functions, and can function independently of other SCU panels and all remaining portions of the EMCS. The SCU may serve one or many types of HVAC equipment and is not factory programmed for only one purpose.

G. NCU: Network Control Unit, a secure central processing unit microprocessor based WEB server residing directly on the Owner's Ethernet TCP/IP LAN/WAN; providing direct communications to SCUs, UCs, and other field devices; integrating and processing their data and presenting it as custom HTML WEB pages in accordance with custom programmed graphical interface edited at an OWS.

H. LAN: Local Area Network - the Owner's existing Ethernet communications backbone which connects all of the owners buildings (and various rooms) on their campus. To be used by the Contractor where possible to connect OWSs, NCUs, SCUs, and UCs. Coordinate with Owner to determine extent of interconnection possible.

I. BACnet: A Data Communication Protocol for Building Automation and Control networks as defined in American National Standard ANSI/ASHRAE 135-1995, including any updates or revisions to this document.

J. LonWorks: A control network technology platform for designing and implementing interoperable control devices and networks.

K. MS/TP: Master slave/token passing.

L. I/O: Input/output.

M. Modbus: a serial communications protocol originally published by Modicon (now Schneider Electric) in 1979 for use with its programmable logic controllers (PLCs).

N. PID: Proportional plus integral plus derivative.

O. RTD: Resistance temperature detector.

P. System Modem: a modem which is installed on the EMCS so that a remote SCU, UC, or OWS can connect up to the LAN and can function the same as if it were locally-installed.

Q. System Printer: a printing device which is installed on the LAN so that all EMCS components can utilize it as an output device.

R. SV: Standardized Vendor of controls components.

S. TCC: Temperature Controls Contractor - The entity responsible for the work described by this section of specifications.

1.4 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.

2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.

3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.

4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.

5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.

6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.

7. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.

8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:

   a. Water Temperature: Plus or minus 1 deg F.
   b. Water Flow: Plus or minus 5 percent of full scale.
   c. Water Pressure: Plus or minus 2 percent of full scale.
   d. Space Temperature: Plus or minus 1 deg F.
   e. Ducted Air Temperature: Plus or minus 1 deg F.
   f. Outside Air Temperature: Plus or minus 2 deg F.
   g. Dew Point Temperature: Plus or minus 3 deg F.
   h. Temperature Differential: Plus or minus 0.25 deg F.
   i. Relative Humidity: Plus or minus 5 percent.
   j. Airflow (Pressurized Spaces): Plus or minus 3 percent of reading.
   k. Airflow (Measuring Stations): Plus or minus 5 percent of reading.
   l. Airflow (Terminal): Plus or minus 10 percent of full scale.
   m. Air Pressure (Space): Plus or minus 0.01-inch wg.
   n. Air Pressure (Ducts): Plus or minus 0.05-inch wg.
   o. Carbon Monoxide: Plus or minus 5 percent of reading.
   p. Carbon Dioxide: Plus or minus 50 ppm.
   q. Electrical: Plus or minus 5 percent of reading.

1.5 QUALITY ASSURANCE

A. Provide all labor, material, equipment, software, and programming necessary to meet the functional intent of the EMCS, and the rigid requirements as specified herein and as shown on the drawings. Provide, without additional cost to the Owner, all equipment and labor not specifically referred to herein or on the plans, which are required to meet the functional intent expressed in the sequences of operations herein or on the drawings. The contractor is responsible for all costs of changes in the work required by substitute equipment.

B. The TCC must have been in business for at least ten years, providing DDC systems as their primary business with documented success. They shall have a minimum of five years as a manufacturer's authorized distributor or branch office representative for one or more of the manufacturers specified. They must have a trained staff of application engineers, project managers, software engineers, commissioning staff, training staff, and service staff experienced in the configuration, programming and service of the EMCS. They must have a local service department and stock the manufacturer's standard replacement parts.

C. The EMCS shall be installed only by skilled mechanics employed directly by the TCC except wiring may be installed by their first tier subcontractor under the TCC project manager’s direct supervision. Any subcontractor shall have documented success installing controls with the TCC for a minimum of five years prior to this project. Sub-contractual relations shall in no way relieve the contractor of any of their obligations under their contract.

D. The TCC shall have a training facility with regularly scheduled training as outlined below so as to provide ongoing regularly scheduled application training.

E. Manufacturer must be a firm regularly engaged in manufacture of microprocessor temperature control equipment, of configuration and capabilities similar to or better than specified equipment, for at least ten years, and must have similar earlier vintage models that have been in continuous satisfactory use for not less than ten years in similar service.

F. All work shall conform to the following Codes and Standards, as applicable to the Contracted Work at the Project job site and to the relevant Authorities Having Jurisdiction at the Project site. All products shall be labeled with the appropriate approval markings. In the case of conflict or discrepancy, the latest and most stringent regulation or code shall apply.

1. National Electrical Code (NEC) and applicable local Electrical Codes.
2. Underwriters Laboratories (UL) listing and labels.
3. Underwriters Laboratories of Canada (ULC) listing and labels.
4. UL 864 UUKL Smoke Control.
5. UL 864 UOJZ Fire Protection Signaling Systems.
6. UL-873; Temperature Indication and Regulating Equipment.
7. UL-916; Energy Management Systems for BAS components and ancillary equipment.
8. NFPA 70 – National Electrical Code.
9. NFPA 92A and 92B Smoke Purge/Control Equipment.
10. Factory Mutual (FM).
11. American National Standards Institute (ANSI).
12. National Electric Manufacturer’s Association (NEMA).
13. American Society of Mechanical Engineers (ASME).
14. Institute of Electrical and Electronic Engineers (IEEE).
15. American Standard Code for Information Interchange (ASCII).

16. Electronics Industries Association (EIA).
17. Occupational Safety and Health Administration (OSHA).
18. American Society for Testing and Materials (ASTM).
19. Federal Communications Commission (FCC) including Part 15, R.F. Devices.
20. Americans Disability Act (ADA).
21. Uniform Building Code (UBC).
22. NEMA 250 – Enclosures For Electrical Equipment (1,000 V Maximum).
23. NFPA 101 – Life Safety Code.
24. IESNA – Illumination Engineering Society of North America.
25. UL 50 – Cabinets and Boxes.

1.6 GUARANTEES

A. Guarantee the EMCS complete to be free from defects in durability, materials, and workmanship, except for damages from other causes, for a period of one year after final acceptance.

B. Guarantee System to:

1. Maintain temperatures within +/- 1ºFof setting, within capacity of HVAC equipment.

C. Provide a one (1) year maintenance agreement to run concurrently with the Guarantee period. The maintenance agreement shall consist of 24 hour emergency and scheduled service (once per month minimum) as required addressing reported issues, for inspection and adjustment of operating controls, and replacement of parts or instruments found deficient or defective during this period.

D. Provide system backup and restore, software, programming, and sequence of operations enhancements, revisions, and adjustments at no charge to the Owner both during construction and commissioning and during this warrantee period.

1.7 SEQUENCE OF OPERATION

A. Refer to controls schematic drawings including written sequence of operations for specific pieces of equipment. Provide controls as specified and as required to achieve sequence of operations shown on drawings as well as specified below in general programming, and with controls similar to as shown where the exact configuration is not explicitly covered by the drawing and specification sequence of operations.

1.8 SUBMITTALS

A. The majority of the required submittals are for the State Contract Controls Vendor Day Automation Systems, Inc. Installation related submittals are required of the Mechanical Contractor.

B. Submit on controls in multiple portions as job progresses. Include in each submittal a summary just inside the cover sheet of previously approved portions of submittal, currently submitted portions, and those portions not submitted yet. During closeout documentation, assemble all approved controls submittals into one package designed for use as both an installation and a maintenance manual.

C. Technical Submittals:

1. Submit a complete Technical Proposal within 30 days of contract award, complete with the diagrams, product information, and supporting documentation outlined below. Arrange the Technical Proposal in order of the specification article numbers, with tabs (bookmarked .pdf files for electronic submittals) at each division. Design Technical Proposal for use as both a clear demonstration of qualifications and as an installation and maintenance manual.

2. Include the following in a complete Technical Proposal:

a. Description of service capabilities including resumes for service technicians and designers that will be responsible for this project.

b. A list of local jobs (three minimum) of similar type and size the bidder has installed, utilizing the products proposed for this project, with Owner's representatives and engineer of record's names and telephone numbers for reference. This list should directly reflect:

1) Projects that include direct integration to third party microprocessor controllers of the type specified within this scope.

c. EMCS network wiring diagram showing interconnection of all panels, workstations, system printer(s) etc. A diagram describing system architecture for this project with product code numbers for workstation, network controllers, application specific controllers, transducers, sensors, communication networks, etc.. Diagram shall include all components intended to be used to meet or exceed specification requirements, shown in their functional relation to one another.

d. Provide information on owner training provided as part of the bid package as well as additional opportunities and factory schools available with associated costs. Include details of Operator HVAC Training System as specified herein.

e. Hardware Product Data Bulletins for all specified products. Each bulletin shall describe product features, model numbers and manufacturer's name.

f. Software Product Data Bulletins for all specified software features. Each bulletin shall describe product features, model numbers, and manufacturer's name.

3. As job progresses and in ample time for review and iteration as required for complete approval, submit the following:

a. Complete written description of all proposed control sequences and control strategy, with any deviations from the specified sequence of operations highlighted and explained.

b. Detailed wiring and piping control diagrams and system description for each system.

c. Detailed layout and nameplate list for all control panels, including pneumatic, unit-specific controllers, data-gathering panels, microprocessor-based panels, third party microprocessor controllers, etc.

d. Damper schedule giving size, type, velocity, pressure drop, configuration, location, and number, type, and size of motorized actuators. Include apparatus bulletins and data sheets. Include all existing to remain dampers proposed for reuse along with comments on condition.

e. Valve schedule giving valve identification tag abbreviation, location, service, failsafe position, pipe size, valve size, make/model, type, configuration, design flow, capacity index (cv), and pressure drop. Include apparatus bulletins and data sheets.

f. Schedule showing direct integration to all third party microprocessor controllers included in this project, including all points available in a point listing describing point type (analog input, binary input, analog output and binary output), point address, units, applicable software interlocks (alarm, interlock, sequence, etc.), and a verbal description of the function and intended control of the point.

g. Termination schedule and point listing describing point type, (analog input, binary input, analog output and binary output), physical point location (eg. AHU #1 mixed air) and software interlocks (alarm, interlock, sequence, etc.).

h. A complete listing of inputs and outputs, control loops and/or routines, timing functions, and facilities management system functions for each controlled system. This listing shall include point logical names and identifiers.

i. For all equipment, submit copy of written installation, maintenance, and operating directions and details, along with manufacturer's printed installation instructions for all equipment furnished, showing required installation and location of the above items.

j. Provide a sample of program language and description of how programming is accomplished.

k. Color printout sheets of representative samples of all proposed graphics and text based OWS pages.

D. Installation Submittals:

1. Submit professional qualifications resumes for installation technicians who will be responsible for this project.

2. Submit name of any proposed installation subcontractors, along with their statement of qualifications, resumes for installation and service technicians who will be responsible for this project, and 3 local references for comparable recent jobs.

3. Software and Firmware Operational Documentation: Include the following:

   a. Software operating and upgrade manuals.
   b. Program Software Backup: On a magnetic media or compact disc, complete with data files.
   c. Device address list.
   d. Printout of software application and graphic screens.
   e. Software license required by and installed for DDC workstations and control systems.

4. Software Upgrade Kit: For Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.

5. Field quality-control test reports.

6. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

   a. Maintenance instructions and lists of spare parts for each type of control device and compressed-air station.
   b. Interconnection wiring diagrams with identified and numbered system components and devices.
   c. Keyboard illustrations and step-by-step procedures indexed for each operator function.
   d. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
   e. Calibration records and list of set points.

1.9 RELATED AND ANCILLARY WORK

A. Electrical control wiring associated with building fire alarm system and duct smoke detectors: Installation is specified under Division 26.

B. Power source wiring for general (non-controls) HVAC motorized equipment: Installation specified under Division 26.

C. Provide power source wiring for all EMCS equipment, complete back to breakers designated as temperature control power breakers on electrical drawings or other approved electrical power panel space. Includes all controls power source wiring, communication wiring, and actuated device power and control wiring. Installation specified both herein and in applicable sections of Division 26.

D. Provide network connectivity and communications wiring for all EMCS equipment, complete back to Owner’s network connection designated as temperature control connection on electrical drawings or otherwise indicated by Owner. Coordinate with District IT personnel. Includes all controls communication wiring, as specified both herein and in applicable sections of Division 26, 27, and 28.

E. Piping work as required to maintain pressure tight integrity of all hydronic, potable water, and refrigerant based systems for the installation of all piping mounted controls components, including control valve installation, valve and control manifolds, pressure and temperature sensor taps, flow switches, thermal wells, and similar devices: Installation specified both herein and under applicable piping section.

F. Sheet metal work as required to maintain pressure tight integrity of all airside systems for the installation of all airside mounted controls components, including dampers, pressure and temperature sensor probe taps, flow sensors, and similar devices: Installation specified both herein and under applicable sheet metal and ductwork sections.

G. Insulation work as required to maintain the thermal integrity of the various systems associated with and subsequent to controls component installations: Installation specified in Division 23 section on Insulation.

H. For all equipment: Provide and follow written installation directions and details, with manufacturer's printed installation instructions for all equipment furnished, showing required installation and location of the above items.

1.10 DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for submittal, approval, fabrication, and shipping of control devices to equipment manufacturer in ample time for factory installation without impacting project schedule.

B. System Software: Update to latest version of software at Project completion.

1.11 INSTRUCTION AND TRAINING

A. Interactive Operator HVAC Training System

1. General:

a. Provide necessary software and learner workbooks to form a complete HVAC training system as described in this specification. Provide two (2) copies of the software and three (3) copies of the learner workbooks for the Owner's use.

b. Provide a quick reference guide for users to trouble shoot operational challenges during standard use.

2. Operation:

a. Usable by multiple students while maintaining records and bookmarks for each learner.

b. Operates from CD-ROM without the necessity of installing the program on a hard disk, or installed on hard drive. Students records stored on the computer's hard drive.

3. Features:

   a. Integrates text and graphics to explain the concepts of building environments, the systems that deliver these environments, and the controls that manage these systems.

   b. Modular in design to allow the student to select and view whichever sections are appropriate in any order desired.

   c. Menu driven with complete sections identified on the menu.

   d. Includes a glossary of terms readily accessible from within the lessons allowing the review of a definition without losing the current lesson location.

   e. Incorporates navigational aids including a learning map that allows the student to move directly to a desired section from the map.

   f. Includes a password protected registration system to record student responses and bookmark progress. The registration system shall allow students to return to their previous lesson location or start the lesson again when logging on after the first session.

   g. Includes a password protected mentor mode which can be used to monitor progress throughout the training program.

   h. Includes mastery exam for each of the three sections of the training program; environments, systems, and controls.

   i. Includes a final test, enabled by the mentor, to assure satisfactory completion of the learning program.

   j. Includes a completion form upon successful completion of the training experience.

B. Factory Authorized Control System Training:

1. Provide factory trained and authorized instructors and control technicians to instruct the Owner's operating personnel.

2. Factory authorized onsite training - Provide two (2) onsite training sessions each two (2) hours in duration covering network layout, controllers, and software functions. Both generic and product specific training shall be provided. Sessions shall be scheduled by the Contractor at the Owner’s convenience, at any time up to two years after system installation.

3. Provide videotaping and audio taping of all training sessions, both off and on site. Turn over two copies of tapes and three copies of maintenance manual to Owner’s representative.

C. Include in closeout documentation signed letter of acknowledgment of receipt of factory authorized training, videotapes, and maintenance manuals.

1.12 COORDINATION

A. Coordinate all controls work required for a complete operable controls system as specified. Carefully review project summary and scoping documentation and coordinate with contractors responsible for various ancillary portions of controls work. Where supportive or ancillary work is not specifically assigned to another contractor, provide complete as required for a complete operable system.

B. Coordinate equipment with Division 28 Sections on Fire Detection and Alarm Systems to achieve compatibility with equipment that interfaces with that system.

C. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

D. Coordinate equipment with Division 26 Sections on Electrical Power Monitoring and Control to achieve compatibility of communication interfaces.

E. Coordinate equipment with Division 26 Sections on Panelboards to achieve compatibility with starter coils and annunciation devices.

F. Coordinate equipment with Division 26 Sections on Motor Controls to achieve compatibility with motor starters and annunciation devices.

G. Coordinate size and location of concrete bases. Refer to Section 23 05 00 – Common Work Results for HVAC Systems for additional information.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Basis of Design Standardized Vendor (SV):

1. Schneider Electric Controls as installed by Day Automation System, Incorporated.

B. In other Part 2 articles where specific components are described, the basis of design and named equivalent TCCs integrate multiple manufacturers' components into a coherent system. Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified:

1. Armstrong.
2. Automated Logic Corporation.
3. Functional Devices Inc.
4. Honeywell International Inc.; Home & Building Control.
5. Invensys Building Systems.
6. Johnson Controls, Inc.; Controls Group.
7. KMC Controls/Kreuter Manufacturing Company.
8. Siemens Building Technologies, Inc.
9. Schneider Electric.
10. Solidyne Corp.

11. Staefa Control System Inc.; Siemens Building Technologies, Inc.
12. TAC Americas, INC.
13. TCS/Basys Controls.
14. Tekmar Control Systems, Inc.
15. Teletrol Systems Incorporated.
16. Tour & Andersson Control, Inc.
17. Trane; Worldwide Applied Systems Group.
18. Triangle MicroSystems, Inc.
19. Victaulic, Inc.
20. Voltec, Inc.

2.2 GENERAL SYSTEM ARCHITECTURE

A. The EMCS shall consist of the following:

1. Operators' Workstations (OWS).

2. File Server (FS).

3. Network Control Units (NCU).

4. Standalone Control Units (SCU).

5. Application Specific Unitary Controllers (UC).

6. All controls power wiring 120 volts or less, all network and communication wiring, fiber optic cable, and other controls communication media.

7. All EMCS communications devices.

8. All related field devices including remote I/O cabinets, transformers and power supplies, relays, contactors, transducers, switches, cabling, and related electronic control equipment.

9. All necessary software and custom programming, including graphics and reports.

10. All necessary inputs, outputs, and devices required to meet the features and intent described herein including but not limited to:

    a. Transducers.
    b. Water flow switches and sensors.
    c. Differential Pressure sensors.
    d. Hydronic control valves.
    e. Opposed blade (control) or parallel blade (shutoff), low leakage dampers.
    f. Temperature, pressure, and humidity sensors and safety devices.
    g. Electronic valve and damper actuators.

11. All other equipment necessary for a complete, operational, EMCS.

B. The design of the EMCS shall network OWSs, FCs, NCUs, SCUs, UCs, and all sensors, safeties, actuators, and other devices. Inherent in the system's design shall be the ability to expand or modify the network via the Internet, the Level 1 LAN, the Level 2 bus, or via auto e-mail or auto-dial telephone line modem connections, or via a combination of all four networking schemes. LAN communications between buildings shall be standard ETHERNET TCP/IP and shall be compatible with the district's existing ETHERNET LAN.

C. The EMCS shall:

1. Be modular in nature, with distributed controllers operating in multi-user, multi-tasking environment on token-passing network.

2. Be re-programmable and programmed to control mechanical, electrical, and plumbing systems.

3. Be capable of integrating multiple building functions, equipment supervision and control, alarm management, energy management, historical data collection, and archiving.

4. Permit expansion of both capacity and functionally through the addition of components and programming.

5. Include an operator workstation which permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.

6. Not be dependent 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.

D. The system architecture shall consist of no more than two communication levels as follows:

1. Level 1 shall be on the Owner's ETHERNET LAN as possible within the constraints of this specification. Contractor shall field verify extent and capacity of existing LAN with Owner prior to creation of network layout drawings, and shall include any and all extensions of the LAN required for complete and robust functioning of the EMCS:

a. Level 1 communications shall use the BACnet protocol.

b. This LAN operates under ETHERNET protocol at 10 Mbps or other speed as determined by the Owner. The Level 1 LAN will provide transfer of point data, alarms and file activity among OWSs, NCUs, and SCUs.

c. Any data from a Level 2 controller can also be transmitted onto this bus through a Level 1 controller. The high speed LAN shall support multi-user communications and multi-session activity. That is, all global data sharing shall occur simultaneously with the transmission of alarm data or user activity.

d. OWSs and NCUs shall reside directly on the LAN such that communications may be executed directly between controllers, directly between workstations, and between controllers and workstations, on a peer-to-peer basis.

e. SCUs and UCs may reside directly on the Level 1 Lan at the TCCs option.

2. Level 2 shall be on a EIA-485 bus or other comparable technology, designed to support a family of dedicated local controllers for control of HVAC equipment and lighting. The Level 2 bus shall communicate bi-directionally with the Level 1 LAN through NCU controllers for transmission of global data:

a. The Level 2 bus, or field bus, shall support local control units (SCUs and UCs) of modular size for operation of the building's HVAC and lighting systems. This bus shall operate at a minimum speed of 200 kbps with a length of 4000 feet and 10Mbps with a length of 150 feet, with 32 nodes before requiring a network repeater. A minimum of 127 controllers shall be configurable on the field bus.

b. The field bus shall permit peer-to-peer communications among all Level 2 controllers and allow simultaneous communications with portable computer service tools that are connected to a Level 2 controller. Failure of any Level 1 NCU controller shall not impair the operation of its associated field bus.

c. All Level 2 field wiring that connects non native BACnet unitary controllers shall have an additional wiring set run in parallel dedicated for future use by native BACnet replacement controllers.

E. NCUs shall be able to access any data from, or send control commands and alarm reports directly to any other NCU or combination of NCUs on the network without dependence upon a central processing device. NCUs shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

F. Dynamic Data Access:

1. All operator devices, network resident, internet connected, or connected via dial-up 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 LAN. Access to data shall be based upon logical identification of building equipment.

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

3. All points contained on Level 1 and Level 2 controllers shall be considered global points. Any program in any controller on the network shall be able to reference any point in any controller regardless of its location on the network.

G. General Network Design:

1. Network design shall include the following provisions:

a. Data transfer rate for alarm reporting, report generation from multiple controllers, and upload/download between SCUs and OWSs shall be a minimum of 2.5 Megabaud.

b. Support of any combination of controllers and operator workstations directly connected to the local area network. A minimum of 50 devices shall be supported on a single local area network.

c. Detection and accommodation of single or multiple failures of either OWSs, SCUs, or the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures.

d. Message and alarm buffering to prevent information from being lost.

e. Error detection, correction, and re-transmission to guarantee data integrity.

f. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.

g. Commonly available, multiple sourced, networking components and Ethernet protocols shall be used to allow the EMCS to coexist with other networking applications on the Owner's existing LAN/WAN. Ethernet and BACnet are acceptable technologies. BACnet system shall conform to the latest ASHRAE Standards and recommendations.

h. Use of an industry standard IEEE 802.x protocol.

i. Provide synchronization of the real-time clocks in all EMCS panels.

2.3 OPERATOR WORK STATION (OWS)

A. Desktop Workstation Computer:

1. Existing to remain – upgrade software and hardware as required.

B. Operator Workstation Software

1. Operating System: Microsoft Windows XP Professional, 7 Business / Enterprise Professional, or comparable OS (verify with Owner and provide system compatible with Owner's IT system), with high-speed Internet access.

2. EMCS Application Software General Requirements:

a. The software shall communicate with the existing EMCS over the Owner's LAN using ASHRAE 135 and ISO 8802-3 (Ethernet) datalink/physical layer protocols.

b. The software shall be a standard application for the off the shelf MS Windows OS selected above, and shall not require a dedicated OWS, nor a different operating system from the Owner's other office management software.

c. Standard utility software packages shall be available through local retail outlets.

d. The OWS shall output advisories and unacknowledged change-of-state or out-of-limits occurrences in a dedicated and protected area of the viewing screen.

e. Graphical and Text Based Displays: At the option of the user, Operator workstation shall provide consistent graphical or text based displays of all system points and application data described in this specification. Point identification, engineering units, status indication and application naming conventions shall be the same at all workstations.

f. Individual point information shall be coded via eight different colors. These colors shall be defined with respect to system type and condition.

g. Multiple, Concurrent Displays: provide the ability to simultaneously view several different types of system displays in overlapping windows to speed building analysis. For example, provide the ability to simultaneously display a graphic depicting an air handling unit, while displaying the trend graph of several associated space temperatures to allow the user to analyze system performance. If the interface is unable to display several different types of displays at the same time, the TCC shall provide at least two networked operator stations.

h. Employ browser-like functionality for ease of navigation, with a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. Provide menu-pull downs and toolbars, "hot-button" commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC Control System or basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.

i. Provide for modifying common application objects, such as schedules, calendars, and set points in a graphical manner, for example using a graphical slider, without requiring operator keyboard entry.

3. Application Software Features:

a. Security:

1) The software shall be designed so that up to 256 users of the software can each have a unique username and password. Each username/password combination shall be linked to a set of capabilities within the software, set and editable only by a system administrator. The sets of capabilities shall range from View only, Acknowledge alarms, Enable/disable and change values, Program, and Administer. The system shall allow the above capabilities to be applied independently to each and every class of object in the system. Passwords shall be changeable through on-line keyboard entry by either the individual user or the administrator.

2) There shall be an adjustable inactivity timer that automatically logs off the current operator after the timer has expired.

3) Record all operator inputs executed under a valid password in a data log, including operator name.

4) At no time shall the actual password numbers be printed on the screen, except for operators with the strictest level of password, who shall be able to generate a password summary listing.

a) The password summary shall include at least a 24-character name, login ID, password, time out value, and security level.

5) Passwords shall be exactly the same for all operator devices, including stationary or portable OWS, or panel mounted network terminals. Any additions or changes made to password definition shall automatically cause passwords at all EMCS panels on a network to be updated and downloaded to minimize the task of maintaining system security. Users shall not be required to update passwords for EMCS panels individually.

6) Operators will be able to perform only those commands available for their respective passwords. Menu selection displayed at any operator device, including portable or panel mounted devices, shall be limited to only those defined for the access level of the password used to log on.

7) Provide user definable, adjustable, automatic log off timer to activate after from 1 to 60 minutes of inactivity (adj.), to prevent operators from inadvertently leaving devices online.

b. I/O capability from each OWS

c. Automatic system diagnostics; monitor system and report failures.

d. Database creation and support.

e. Automatic and manual database save and restore.

f. Object and property status and control.

g. Automatic restart of field equipment on restoration of power.

h. Custom report development.

i. Utility and weather reports.

j. Workstation application editors for controllers and schedules.

k. Maintenance management.

l. Trend logs: Support customized trend log reports with variables assignable at the OWS, automatic archive of trended values, with data retrievable in spreadsheets and database programs.

m. Data collection, reports, and logs. Include standard reports for the following:

    1) Current values of all objects.
    2) Current alarm summary, sorted by priority.
    3) Alarm history.
    4) Disabled objects.
    5) Alarm lockout objects.
    6) Logs.

n. Summaries:

    1) System log shall log the status of points within system.
    2) Alarm summary shall log specified alarm points which are actually in alarm.
    3) Off-normal summary shall log points specified by the operator to be in the off-normal mode.
    4) Lockout summary shall log points specified to be in the lockout condition.

o. Messages:

    1) The system shall support a minimum of 500 different automatic messages defined by the authorized operator on-line via word processing editor with minimum available length of 256 alpha-numeric characters. Messages shall also indicate whether acknowledgment is necessary.

    2) Messages may be assignable as pop-up reactions to operator inputs, system alarms, event processes, and other system messages as required and deemed useful by the programmer, Engineer, and Owner.

p. Totalization:

    1) The energy management system shall allow for analog or digital point totalization with respect to time.

    2) Run time totalization shall be provided to track the run time of point assigned. A summary shall be generatable listing run time points and their present values.

3) Analog totalization shall be provided to measure analog data over real time span. A summary shall be generatable which lists analog totalization points and their current period values, current dry values, previous period and previous day totalized values.

4) Provide customized totalization reports for each major HVAC system.

q. Scheduling:

1) The system shall be capable of initiating equipment based on a preselected time-of-day schedule. This program shall provide scheduling for seven days of the week with 500 unique schedules. The user shall not be required to enter control programs to alter time-of-day schedules.

2) Provisions shall be made to program in holidays up to one year in advance; up to 366 consecutive holidays shall be enterable.

3) On-Line Graphic Generation:

4) This program shall allow the operator to generate color graphics on-line using symbols selected from a standard library of symbols.

4. Energy Management Features: The following energy management programs shall reside in the OWS for global control purposes:

a. Duty cycling program shall periodically turn selected loads off to reduce energy consumption.

b. Optimal run time program shall control the start-up and shutdown of HVAC equipment based on the most energy efficient schedule. Startup shall be staggered to minimize inrush currents.

c. The energy management program shall not allow the energy management features listed above to shut down air systems (air handling units, unit ventilators, cabinet heaters, etc.) which are providing ventilation air to the occupied spaces during the occupied cycle.

d. Programs shall be supervised by an energy management program, which shall oversee the execution of global energy management functions. These programs may also reside in individual field panels on systems of this architecture. If the host computer is to act only in a supervisory mode, specific panels shall be assigned to global function duty.

5. Custom Application Software:

a. English language oriented.
b. Full-screen character editor/programming environment.
c. Allow development of independently executing program modules with debugging/simulation capability.
d. Support conditional statements.

e. Support floating-point arithmetic with mathematic functions.
f. Contains predefined time variables.

6. Control Programming: Definition of operator device characteristics, EMCS panels, individual points, application, and control sequences shall be performed through fill-in-the-blank templates and a graphical programming approach. Allow the user to define the software configuration of EMCS panel logic for HVAC system control sequences, fan interlocks, pump interlocks, PID control loops, and other control relationships through the creation of graphical logic flow diagrams.

   a. Graphical Programming: Control sequences are created by using a mouse input device to draw interconnecting lines between symbols and depicting inputs, operators (comparisons and mathematical calculations), and outputs of a control sequence. As a minimum, graphic symbols shall be used to represent:

      1) Process inputs, such as temperature, humidity, or pressure values, status, time, date, or any other measured or calculated system data.
      2) Mathematical process operators, such as addition, subtraction, multiplication, or greater than, equal to, or less than, etc.
      3) Logical process operators such as IF, AND, OR, ELSE, GO TO, Exclusive OR, NOT, etc.
      4) Time delays.
      5) Process control outputs such as start/stop control points, analog adjust points, etc.
      6) Process calculation outputs.
      7) Text file outputs and advisories.

   b. Network-wide Strategy Development: Inputs and outputs for any process shall not be restricted to a single EMCS panel, but shall be able to include data from any and all other EMCS panels to allow the development of network wide control strategies. Processes shall also allow the operator to use the results of one process as the input to any number of other processes (cascading).

   c. Sequence testing and simulations: Provide a software tool which allows a user to simulate control sequence execution to test strategies before they are actually applied to mechanical systems. Users shall be able to enter hypothetical input data and verify desired control response and calculation results via graphical displays and hard copy printouts.

7. Dynamic Color Graphic Displays:

   a. Provide graphics generation software to allow the user to add, modify, or delete system graphic displays that include any manipulated point data from any networked EMCS panels, including SCUs or Ucs. Develop graphic screens using any drawing package capable of generating a GIF, BMP, or JPG file format, including AutoCadd and Visio. Use of proprietary graphic file formats shall not be acceptable. In addition to a graphic background, support the use of scanned pictures.

   b. Provide for simultaneous viewing of several graphics at the same time (windowing) to analyze total building operation, or to allow display of a graphic associated with an alarm to be viewed without interrupting work in progress.

c. Provide libraries of pre engineered screens and symbols depicting standard air handling unit components (e.g. fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g. constant volume terminal reheat, VAV, etc.) and electrical symbols.

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

1) Define symbols.
2) Position and size symbols.
3) Define background screens.
4) Define connecting lines and curves.
5) Locate, orient, and size descriptive text.
6) Define and display colors for all elements.
7) Establish correlation between symbols or text and associates system points or other displays.

e. Each graphic display shall consist of a static section and a dynamic section. The static section shall consist of elements which usually do not change with time or point condition. The dynamic section shall consist of elements which usually do change with point conditions, and shall be integrated with the respective static section, appearing in appropriate locations in it.

1) A minimum capability of 256 different static sections shall be provided. Each static section shall be capable of being associated with any number of dynamic sections. The elements of a static section shall be capable of outputting in any one of eight different colors. A static section does not have to be associated with a dynamic section to be used as chromatic output. The elements of static sections shall include, but not be limited to: lines, line drawings, symbols, and character strings (single/double sized).

2) The dynamic section shall accommodate a minimum of 40 elements. The elements of a dynamic section shall be capable of outputting in any one of the eight colors. Symbols shall be a pictorial illustration of the point condition. This illustration shall not be dependent on the type of sensor/device being represented. The elements of a dynamic section shall include, but not be limited to: point identifier, point expanded identifier (if abbreviated), analog value, engineering units, mode units, symbols, lines, text strings. Dynamic temperature values, humidity values, flow values, and status indication shall be shown in their actual respective locations, and shall automatically update to represent current conditions without operator intervention.

3) System graphic display shall update the dynamic elements to the current point condition, at least every 30 seconds. System shall include a list of standard symbols. Lines shall include, but not be limited to: vertical, horizontal, diagonal, curved. Character strings shall include alpha/numeric characters and shall be capable of 60 characters minimum length.

4) Dynamic element shall be capable of being used a multitude of times on a single chromatic display and shall be stored in a symbols library program.

f. When a point is in alarm on the screen, the OWS shall be able to display an alarm graphic with a minimum number of keystrokes. Alarm graphic individual point information shall include, but not be limited to: point identification, point location, alarm point value, alarm limit value, engineering units (°F, KWH, etc.), mode units (on/off, alarm).

8. Web Browser Features:

a. On-Line Help: Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext. All system documentation and help files shall be in HTML format.

b. Security: Each operator shall be required to log on to that system with a user name and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system administrator shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the operators' access for viewing and/or changing each system application, full screen editor, and object. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected. This auto log-off time shall be set per operator password. All system security data shall be stored in an encrypted format.

c. System Diagnostics: The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

d. Alarm Console:

1) The system will be provided with a dedicated alarm window or console. This window will notify the operator of an alarm condition, and allow the operator to view details of the alarm and acknowledge the alarm. The use of the Alarm Console can be enabled or disabled by the system administrator.

2) When the Alarm Console is enabled, a separate alarm notification window will supercede all other windows on the desktop and shall not be capable of being minimized or closed by the operator. This window will notify the operator of new alarms and un-acknowledged alarms. Alarm notification windows or banners that can be minimized or closed by the operator shall not be acceptable.

9. Web Browser Clients

a. The system shall be capable of supporting at least 64 clients using a standard Web browser such as Internet Explorer or Netscape Navigator. Systems requiring additional software (to enable a standard Web browser) to be resident on the client machine, are only acceptable if 64 licensed copies of the client machine software are provided, installed, and tested. The system shall support a minimum of ten (10) simultaneous clients.

b. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function with the EMCS, shall only be acceptable if 64 workstation or workstation hardware upgrades are provided.

c. The Web browser shall provide the same view of the system, in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology as is provided by the Graphical User Interface. Systems that require different views or that require different means of interacting with objects such as schedules, or logs, shall not be permitted.

d. The Web browser client shall support at a minimum, the following functions:

   1) User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.

   2) Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the GUI shall be supported by the Web browser interface.

   3) HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.

   4) Storage of the graphical screens shall be in the Building Control Units (BC), without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.

   5) Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.

   6) Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:

      a) Modify common application objects, such as schedules, calendars, and set points in a graphical manner.

      b) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.

      c) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.

      d) Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.

e) View logs and charts

f) View and acknowledge alarms

7) The system shall provide the capability to specify a user's (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.

8) Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

2.4 NETWORK CONTROL UNITS (NCUs)

A. General: Network Control Units shall be microprocessor based, multi-tasking, multi-user, and employ a real time operating system. Each NCU control panel shall consist of modular hardware including power supply, CPU board, and input/output modules. A sufficient number of NCUs shall be supplied to fully meet the requirements of this specification and the controls requirements shown on the drawings.

1. Basis of design NCUs: Schneider Electric Continuum bCX1-CR-xxx with InfbCX1 controller.

B. Webserver Functionality: All NCUs shall reside directly on the Owner's Ethernet TCP/IP LAN/WAN and shall be capable, out-of-the box, to be set up as a Web Server. The NCU shall have the ability to store HTML code and "serve" pages to a web browser. Provides the ability for any computing device utilizing a TCP/IP Ethernet connection and capable of running a standard Internet browser (Microsoft Internet Explorer™, Netscape Navigator™, etc.) to access real-time data from the entire BAS via any NCU.

1. Graphics and text-based web pages shall be constructed using standard HTML code. The interface shall allow the user to choose any of the standard text or graphics-based HTML editors for page creation. It shall also allow the operator to generate custom graphical pages and forms.

2. The WEB server interface shall be capable of password security, including validation of the requesting PC's IP address. The WEB server interface shall allow the sharing of data or information between any controller, process, or network interface (BACnet, LonTalk and TCP/IP) that the BMS has knowledge of, regardless of where the point is connected on the BAS network or where it is acquired from.

3. The BAS network controller must act directly as the WEB server. It must directly generate HTML code to the requesting user (i.e. WEB browser), eliminating the need for and reliance on any PC-based WEB server hardware or software. To simplify graphic image space allocation, HTML graphic images, if desired, shall be stored in any shared network device. The BAS Web server shall have the ability to acquire any necessary graphics using standard pathing syntax within the HTML code mounted within the BAS WEB server. External WEB server hardware and software are not acceptable.

C. Hardware Specifications

1. Memory: A minimum of 4MB of RAM shall be provided for NCUs with expansion up to 8MB. The 8MB versions shall include a floating-point math co-processor.

2. Communication Ports: Each NCU shall provide communication to both the Workstation(s) and the field buses. In addition, each NCU shall have at least three other communications ports that support a telephone modem, portable service tool, serial printer and connection to third party controllers such as a chiller control panel. On a LAN/WAN system, the NCU shall be provided with a 10Mbps plug-in Ethernet TCP/IP network interface card (NIC).

3. Input/Output (I/O): Each NCU shall support the addition of the following types of inputs and outputs:

   a. Digital Inputs for status/alarm contacts.
   b. Counter Inputs for summing pulses from meters.
   c. Thermistor inputs for measuring temperatures in space, ducts and thermowells.
   d. Analog inputs for pressure, humidity, flow and position measurements.
   e. Digital Outputs for on/off equipment control.
   f. Analog Outputs for valve and damper position control, and capacity control of primary equipment.

4. Modular Expandability: The system shall employ a modular I/O design to allow easy expansion. Input and output capacity is to be provided through plug-in modules of various types or DIN-mountable IOU modules. It shall be possible to combine I/O modules as desired to meet the I/O requirements for individual control applications.

5. Real Time Clock (RTC): Each NCU shall include a battery-backed, real time clock, accurate to 10 seconds per day. The RTC shall provide the following: time of day, day, month, year, and day of week. In normal operation, the system clock shall be based on the frequency of the AC power. The system shall automatically correct for daylight savings time and leap years and be Year 2000 compliant.

6. Power Supply: The power supply for the NCUs shall be auto sensing, 120-220VAC, 60/50 Hz power, with a tolerance of +/- 20%. Line voltage below the operating range of the system shall be considered outages. The controller shall contain over voltage surge protection, and require no additional AC power signal conditioning. Optionally, if indicated on the drawings, the power supply shall accept an input voltage of (–48 VDC).

7. Automatic Restart After Power Failure: Upon restoration of power after an outage, the NCU shall automatically and without human intervention: update all monitored functions; resume operation based on current, synchronized time and status, and implement special start-up strategies as required.

8. Battery backup: Each NCU with the standard 120-220VAC power supply shall include a programmable DC power backup system rated for a minimum of 72 hours of battery backup to maintain all volatile memory or, a minimum of 2 hours of full UPS including modem power. This power backup system shall be configurable such that at the end of a settable timeframe (such as 1 hour) of running on full UPS, the unit shall shut off full UPS and switch to memory retention-only mode for the remainder of the battery power. The system shall allow the simple addition of more batteries to extend the above minimum battery backup times.

D. Software Specifications

1. General: The NCU shall contain flash ROM as the resident operating system. Application software shall be RAM resident. Application software shall only be limited by the amount of RAM memory. There shall be no restrictions placed on the type of application programs in the system. Each NCU shall be capable of parallel processing, executing all control programs simultaneously. Any program may affect the operation of any other program. Each program shall have the full access of all I/O facilities of the processor. This execution of control function shall not be interrupted due to normal user communications including interrogation, program entry, printout of the program for storage, etc.

2. User Programming Language: The application software shall be user programmable. This includes all strategies, sequences of operation, control algorithms, parameters, and setpoints. The source program shall be English language-based and programmable by the user. The language shall be structured to allow for the easy configuration of control programs, schedules, alarms, reports, telecommunications, local displays, mathematical calculations, passwords, and histories. The language shall be self-documenting. Users shall be able to place comments anywhere in the body of a program. Program listings shall be configurable by the user in logical groupings.

E. Control Software:

1. The NCU shall have the ability to perform the following pre-tested control algorithms:

   a. Proportional, Integral plus Derivative Control (PID)
   b. Two Position Control
   c. Digital Filter
   d. Ratio Calculator
   e. Equipment Cycling Protection

2. Mathematical Functions: Each controller shall be capable of performing basic mathematical functions (+, -, *, /), squares, square roots, exponential, logarithms, Boolean logic statements, or combinations of both. The controllers shall be capable of performing complex logical statements including operators such as >, <, =, and, or, exclusive or, etc. These shall be able to be used in the same equations with the mathematical operators and nested up to five parentheses deep.

3. Energy Management Applications: NCUs shall have the ability to perform any or all of the following energy management routines:

   a. Time of Day Scheduling
   b. Calendar Based Scheduling

c. Holiday Scheduling
d. Temporary Schedule Overrides
e. Optimal Start
f. Optimal Stop
g. Night Setback Control
h. Enthalpy Switchover (Economizer)
i. Temperature Compensated Duty Cycling
j. CFM Tracking
k. Heating/Cooling Interlock
l. Hot/Cold Deck Reset
m. Free Cooling
n. Hot Water Reset
o. Chilled Water Reset
p. Condenser Water Reset
q. Chiller Sequencing

4. History Logging: Each controller shall be capable of logging any system variable over user defined time intervals ranging from 1 second to 1440 minutes. Any system variables (inputs, outputs, math calculations, flags, etc.) can be logged in history. A maximum of 32,767 values can be stored in each log. Each log can record either the instantaneous, average, minimum or maximum value of the point. Logs can be automatic or manual. Logged data shall be downloadable to the Operator Workstation for long term archiving based upon user-defined time intervals, or manual command.

5. Alarm Management: For each system point, alarms can be created based on high/low limits or conditional expressions. All alarms shall be tested each scan of the NCU and can result in the display of one or more alarm messages or reports.

6. Up to 8 alarms can be configured for each point in the controller.

   a. Messages and reports can be sent to a local terminal, to the front-end workstation(s), or via modem to a remote-computing device.

   b. Alarms shall be generated based on their priority. A minimum of 255 priority levels shall be provided.

   c. If communication with the Operator Workstation is temporarily interrupted, the alarm shall be buffered in the NCU. When communications return, the alarm shall be transmitted to the Operator Workstation if the point is still in the alarm condition.

7. Reporting: The NCU shall be able to generate user-definable reports to a locally connected printer or terminal. The reports shall contain any combination of text and system variables. Report templates shall be able to be created by users in a word processing environment. Reports can be displayed based on any logical condition or through a user command.

2.5 STANDALONE CONTROL UNIT (SCU) PANEL

A. SCUs shall be microprocessor based, multi-tasking, multi-user, real-time digital control processors designed to integrate multiple Unitary Controllers, provide central processing capacity and integration of distributed processing, and interface directly with the system OWS and LAN.

B. Each SCU panel shall consist of modular hardware with 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.

C. The basic elements of the direct digital control system structure shall consist of standard components kept in inventory by the equipment supplier. The components shall not require customizing other than setting jumpers and switches, adding firmware modules or software programming to perform required functions.

D. The system shall be capable of being expanded to its full capacity by adding sensors and entering programs in available random access memory (RAM). Future expansion shall not require hardware modifications to the controller.

E. SCU shall be listed in accordance with UL 864 as required to provide direct control of all smoke dampers.

F. Memory: Provide with sufficient memory to meet system performance requirements and support its own operating system, database system, and database including:

1. Control processes
2. Energy management applications
3. Alarm management
4. Historical/trend data for all points
5. Maintenance support applications
6. Custom processors
7. Operator I/O
8. Dial-up communications
9. Manual override monitoring

G. Point Types: Support the following types of point inputs and outputs:

1. Digital inputs for status/alarm contacts
2. Digital output for on/off requirement control
3. Analog inputs for temperature, pressure, humidity, flow and position measurements.
4. Analog outputs for valve and damper position control, and capacity control of primary equipment.
5. Pulse inputs of pulsed contact monitoring.

H. Expandability:

1. The system shall be modular in nature, and shall permit easy expansion through the addition of software applications, workstation hardware, field controllers, sensors, and actuators.

2. The system architecture shall support expansion capacity of all type of SCU panels, and all point types included in the initial installation.

I. Serial Communication Ports: Provide at least two RS-232C serial data communication ports for simultaneous operation of multiple operator I/O devices such a industry standard printers, laptop workstations, PC workstations, and panel mounted or portable Operator's Terminals. SCU panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or network terminals.

J. Hardware Override Switches:

1. Provide the ability to manually override automatically executed commands at the SCUs via local, point discrete, onboard hand/off/auto operator override control via local keypad function for binary control points and with modulating control for analog control type points.

K. Hardware Override Monitoring:

1. SCU panel shall monitor the status or position of all override, and include this information in logs and summaries to inform the operator that automatic control has been inhibited. EMCS panel shall also collect override activity information for daily and monthly reports.

L. Local Status Indicator Lamps:

1. The SCU panel shall provide local status indication for each binary input and output for content, up-to-date verification of all point conditions without the need for an operator I/O device.

M. Integrated On-Line Diagnostics:

1. Each SCU panel shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all subsidiary equipment. The SCU panel shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each SCU panel, and shall not require the connection of an operator I/O device.

N. Sure and Transient Protection:

1. Isolation shall be provided at all network terminations, as well as all field point terminations to suppress induces voltage transient consistent with IEEE Standard 587-1980. Isolation levels shall be sufficiently high as to allow all single wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.

O. Power failure:

1. In the event of the loss of normal power, there shall be an orderly shutdown of all SCU panels to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.

2. Upon restoration of normal power, the SCU panel shall automatically resume full operation without manual intervention.

P. No digital control panel shall be loaded to more than 80% of its total available point capacity of the digital/analog/input/output sections.

Q. The SCU shall perform its assigned control and energy management functions as a stand-alone unit. Stand-alone control shall include, but not be limited to:

1. Supply and/or water reset.
2. Adaptive optimal start.
3. Time of day start/stop.
4. Zero energy band.
5. Night purge/warm-up.
6. Duty cycle.
7. Control valve, damper, motor and alarm capabilities.

R. EMCS Shall Operate Within The Following Limits:

1. Temperature 32°F to 120°F.
2. Humidity 0 to 95% RH.
3. Voltage +/- 10%.

S. Control algorithms shall be available and resident in the EMCS to permit proportional, integral, derivative, incremental, floating and two position control modes in combination to meet the need of the application and to adapt to job conditions.

T. Control shall be performed in a digital manner using the digital signal from the microprocessor based controller converted through electronic circuitry for modulation of electric or pneumatic actuators. This may take the form of a pulse width modulated signal or a true analog signal generated through a D/A convertor. Electro-pneumatic transducers used for pneumatic outputs shall be cabinet mounted either within the controller or in separate cabinet located immediately next to the digital control panel.

U. Adjustments of control variables shall be available at the controller with the modem through a non-intelligent terminal. Hand held or mounted in cabinet face. If hand held devices are provided two shall be furnished. These adjustments shall include, but not be limited to, setpoints, proportional gain, integral rates, the velocity and acceleration constants associated with incremental control and on/off values of two-position control.

V. The controller shall contain necessary mathematic, logic, utility functions, all standard energy calculations and control functions in ROM. These should be available in combination for programming the unit. These routines shall include, but not be limited to:

1. Math routines:

   a. Basic arithmetic.
   b. Binary logic.
   c. Relational logic.
   d. Fixed formulas for psychrometry.
   e. Calculations.

2. Utility routines for:

   a. Process entry and exit.
   b. Keyboard functions.
   c. Variable adjustments and output.
   d. Alarm indication.
   e. Restart.

3. Control routines for:

   a. Signal compensation.
   b. Loop control.
   c. Energy conservation.
   d. Timed programming.

W. Final field programs shall be stored in battery backed up RAM. The EMCS (SCUs, UCs, etc.) shall be supplied with a minimum of eight hours of battery backup for the RAM with an automatic battery charger.

X. The EMCS shall be expandable by adding additional SCUs, UCs, etc., that operate through the processor of the EMCS.

Y. Provide digital sensors, differential air and/or water flow switches, space temperature sensors (30^{o}F to 90^{o}F), outside and air temperature sensors (-30^{o}F to 120^{o}F), hot water temperature sensor (0^{o}F to 300^{o}F), chilled water sensors (30^{o}F to 90^{o}F), humidity sensors, static pressure sensors, and other sensors and switches required to perform functions as specified.

Z. Provide transducers, EP switches, devices, required by the EMCS to position the control elements.

AA. Provide electric and pneumatic interface devices.

BB. The EMCS software shall contain a self-test procedure for checking the annunciator lights on the digital display, and the computer.

CC. Variable shall be identified as being reliable or unreliable. When a calculation is required to use a value (sensed or calculated), which is identified as being unreliable, the unreliable data value will flash. The calculation will use a default value programmed into the unit.

DD. Alarms (e.g. a pump that did not start) and deviation alarms (e.g. temperature out of limits) will be annunciated.

EE. The SCUs, UCs, shall be enclosed in a metal cabinet. The cabinet shall be constructed such that it can be mounted and electrical terminations made during the construction phase of the project.

FF. The EMCS cabinet shall be a hinged metal type with a baked enamel finish and provided with a key lock. Cabinets on each installation shall utilize one master key. Control wiring and system communications shall be electrically terminated inside the EMCS on a suitable termination board.

2.6 CONTROL UNITS

A. Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.

B. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.

C. Stand-alone mode control functions operate regardless of network status. Functions include the following:

1. Global communications.
2. Discrete/digital, analog, and pulse I/O.
3. Monitoring, controlling, or addressing data points.
4. Software applications, scheduling, and alarm processing.
5. Testing and developing control algorithms without disrupting field hardware and controlled environment.

D. Standard Application Programs:

1. Electric Control Programs: Duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, on-off control with differential sequencing, staggered start, antishort cycling, PID control, DDC with fine tuning, and trend logging.

2. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.

3. Chiller Control Programs: Control function of condenser-water reset, chilled-water reset, and equipment sequencing.

4. Programming Application Features: Include trend point; alarm processing and messaging; weekly, monthly, and annual scheduling; energy calculations; run-time totalization; and security access.

5. Remote communications.

6. Maintenance management.

7. Units of Measure: Inch-pound and SI (metric).

E. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.

F. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.

2.7 LOCAL CONTROL UNITS

A. Modular, comprising processor board with electronically programmable, nonvolatile, read-only memory; and backup power source.

B. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.

C. Stand-alone mode control functions operate regardless of network status. Functions include the following

1. Global communications.
2. Discrete/digital, analog, and pulse I/O.
3. Monitoring, controlling, or addressing data points.

D. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.

E. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.

2.8 I/O INTERFACE

A. Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
B. Binary Inputs: Allow monitoring of on-off signals without external power.
C. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
D. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
E. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation.
F. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA).
G. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
H. Universal I/Os: Provide software selectable binary or analog outputs.

2.9 POWER SUPPLIES

A. Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:

1. Output ripple of 5.0 mV maximum peak to peak.
2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.
3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.

B. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:

1. Minimum dielectric strength of 1000 V.
2. Maximum response time of 10 nanoseconds.

3. Minimum transverse-mode noise attenuation of 65 dB.
4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.10 UNITARY CONTROLLERS

A. Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.

1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or card connected with ribbon cable; memory with bios; and 72-hour battery backup.

2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. Perform scheduling with real-time clock. Perform automatic system diagnostics; monitor system and report failures.

3. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.

4. Enclosure: Dustproof rated for operation at 32 to 120 deg F.

2.11 ANALOG CONTROLLERS

A. Step Controllers: 6- or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.

B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 10 to plus 70 deg F, and single- or double-pole contacts.

C. Electronic Controllers: Wheatstone-bridge-amplifier type, in steel enclosure with provision for remote-resistance readjustment. Identify adjustments on controllers, including proportional band and authority.

1. Single controllers can be integral with control motor if provided with accessible control readjustment potentiometer.

2.12 ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Current Transducer:

1. Solid or split core self powered analog current transducer slips over power wiring to provide combination load status and power use trending data.

a. Linear output from 0 to full scale.
b. 0-5Vdc output.
c. Operating conditions: -15-60 deg C, 0-95%rh.
d. 2 second response time.
e. Use solid core for new applications, split core for retrofits away from terminals.
f. Split core +/- 2% of full scale accuracy from 10% to 100%.
g. Solid core +/- 2% of reading accuracy from 10% to 100%.
h. Similar to Hawkeye 722, 922/932, size and range as required for load.

C. Status Sensors:

1. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.

D. Static Pressure Transmitter / Transducer:

1. Senses differential gauge (static) pressures and converts this pressure difference to a proportional analog output signal.

a. Variable capacitance type, with stainless steel diaphragm and insulated positioning electrode.
b. Voltage Requirement (input): +/- 12 V DC.
c. Output: linear, 4 to 20 mA or 0 - 5 V DC.
d. Pressure ranges 0 to 0.1 in w.g. through 0 to 25.0 in. w.g.
e. Over Pressure Protection: Minimum 10 x full scale.
f. Pressure Part Volumes: Positive part - 0.020 $in.^3$; reference part - 2.0 $in.^3$
g. Accuracy: +/- 1% full scale (includes non-linearity hysteresis and non-repeatability).
h. Factory calibrated with zero span adjustment capability.
i. Temperature compensated output over the entire operating temperature range.
j. Operating Environments: 40 deg. F to 100 deg. F.

E. Electronic Humidity Transmitter.

1. The electronic duct humidity transmitter shall sense duct humidity and shall transmit an electrical signal to the EMCS. A direct acting, proportional relationship shall be developed between the measured relative humidity and the transmitter output voltage,

2. Relative humidity shall be sensed by a cellulose acetate butyrate element and conveyed to a linear variable differential transformer. Changes in percent RH shall reposition the transformer core and create an imbalance in the secondary windings proportional to the magnitude of the RH sensed by the transmitter. The transmitter requires a +12 or +15 volt DC power supply. For a 10 to 100% RH input, the output shall be 0.5 to 5 volts with a +12 volt supply and 20 to 200 mV with a +15 volt supply. Change from one output range to the other shall be possible with a jumper.

3. The transmitter shall be provided with all electrical steel enclosure and cover; the element shall be protected with an aluminum guard.

    a. Action: Direct Acting, Proportional.
    b. Element: Cellulose Acetate; Butyrate-CAB.
    c. Operating Range: 10 to 100% RH.
    d. Supply Voltage: +12 volts DC, 60 mW (max.) or +15 volts supply -20 to 20 mV DC with a 15 volt supply.
    e. Output Signal: 0.5 to 5.0 volts DC with a 12 volt supply -20 to 20 Mv DC with a 15 volt supply.
    f. Load Resistance: 10k ohms with 0.5 to 5 volt output; 100k ohms with 20 to 200 Mv output.
    g. Accuracy: $\pm$ 2% of full scale (or RH) between 20 and 75% RH (includes non-linearity, hysteresis, and repeatability).
    h. Operating Environment: 40 to 125E F, 10 to 90% RH, non-condensing.

F. Temperature Sensors:

1. Temperature sensors shall be:

    a. Platinum wound RTD Type $\pm$ 1°F. Factory calibration point - 70°F at 1000 OHMS or 0°C at 1000 OHMS. Adjustments for zero and span. Output 4-20 mA.

Or (for non averaging sensors)

    b. Contractor may use thermistors which are compatible with system as follows:

        1) Accurate to 0.35°F over a range of -40° to 240°F,
        2) Noncalibrated devices, accuracy traceable to NBS testing,
        3) Guaranteed stability of 0.2°F over a 15 year period,
        4) Interchangable with any other in the new system, and
        5) Shielded cable not require for the guaranteed performance.

2. Room element assemblies shall be located in conditions representative of the zone, on an interior wall where air is free to circulate around the element but away from non-representative air conditions such as drafts or heat radiation. Mount the assembly 5 feet above the floor on a standard electrical wallbox, or as otherwise directed or required to obtain satisfactory results. A mounting bracket, wallplate, decorative cover and tamper resistant screens shall be furnished with the assembly. May be S.S. wall plate type where applicable.

3. Outside air temperature sensing: The outside air sensor shall be mounted where the effects of sunlight and radiant heat are at a minimum (north wall) for true "dry-bulb" reading. Provide in enclosure to fit 1/2" threaded rigid conduit, designed for exterior dry-bulb sensing. Seal off fittings shall be used to prevent condensation on the element in the housing. Monitoring range to suit controls.

4. Duct temperature sensors: Duct insertion sensors for fan discharge and other thoroughly mixed applications designed for control and/or indication shall have a single sensor with an accuracy of 0.25% of scale range. Provide averaging type sensing elements for transmitters and capillary thermostats in mixed air and coil discharge applications to counteract effects of stratification. Length as required to provide at least four full passes across the duct – two long dimension and two diagonal. Capillary systems to be fully compensated. The element shall consist of nickel wire encased in a copper tube. Monitoring range to suit controls.

5. Liquid temperature sensors shall be mounted in separable brass immersion wells with 1/2" - 14 NPT threads, filled with "Insulgrease" or other approved heat transfer compound. Monitoring range to suit conditions. Well and spring loading device to assure RTD contact with end of sensing well. Whenever a sensing element and well are installed in a chilled water line, plumber's putty or some other suitable sealant shall be applied around the adapter as well as the point where the two sensors leads pass through the adapter. This is to prevent condensation of moisture in the well and failure of the element. Minimum well length to be equal to 1/2 of the pipe diameter; match bulb length to well length.

6. Battery powered “wireless communicating” sensors which use batteries as the source of power for transmission and communication of data are <u>not</u> acceptable.

2.13 HVAC PROCESS FLOW CONTROL COMPONENTS

A. Automatic Air Dampers (AAD on drawings):

1. Provide all automatic dampers except those specified as being furnished by equipment manufacturer. Automatic dampers are required at all exterior wall and roof openings serving a HVAC purpose which are provided or modified as a part of this project, whether or not called for on the drawings. Control dampers to operate with sequence described later or as directed.

2. Size dampers at full duct or damper size indicated on the drawings, arranged for flanged to duct rather than inserted in duct installation (clear damper opening, <u>not</u> outside of frame, equal to duct size indicated). If neither duct or damper size is indicated; size for maximum velocity of 1500 fpm and maximum pressure drop including transitions to and from duct 0.05 in w.g.

3. Materials:

   a. General-service dampers not covered by the below restrictions, in galvanized steel ductwork, may be of galvanized steel construction.
   b. Dampers in aluminum ductwork: aluminum or stainless steel.
   c. Dampers subject to corrosive fumes: stainless steel of a type resistant to the fumes.

4. Overall Construction:

   a. Damper frames fabricated of extruded aluminum sections or formed steel, with reinforced corner bracing, suitable for flange mounting to duct. Seal any and all gaps at frame joints to maintain airtight integrity of ductwork.

1) Where flanged to duct mounting is not possible due to space restrictions or where Owner prefers access from inside duct, propose slip in style dampers on a case by case basis in damper submittal along with individual rationale for frame style selection.

b. Provide extruded aluminum airfoil construction for dampers modulating outside and return airflow, isolating lead/lag blowers, those operating on systems with over 2" water column potential close off pressure, and those operating over 1500 fpm.

c. Fasten aluminum frames with approved stainless steel fasteners, separated from dissimilar metal casing by dielectric gasketing.

d. Damper blades not more than 8" in width.

e. Mount blades on electroplated square or hexagonal steel shafting operating in stainless steel, bronze, or approved polymer sleeve bearings.

f. Provide corrosion resistant linkage and actuator mounting compatible with the damper materials and service, concealed in the frame outside of the airstream for flanged to duct applications and mounted in the airstream for slip in construction.

g. Provide parallel blade operation for all two position dampers, and opposed blade operation for modulating dampers, with exception of face and bypass dampers which shall be made up of two sections of parallel blade dampers with the blades of one damper opposed to the blades of the other for proper mixing.

h. Dampers over 48 in. in length and height shall be made into multiple sections.

i. Dampers shall be capable of sequencing as required.

j. Provide AMCA Standard 511 certified class 1A leakage dampers, with maximum leakage not exceeding 3 cfm per square foot at 1 inch water gage pressure differential, or 8 cfm per square foot at 4 inches water gage pressure differential when held in the closed position with a torque of no more than 6 inch pounds per sq. ft.

k. Temperature range shall be suitable for the intended service.

5. Galvanized Formed Blade Construction Dampers:

a. Frame of 16 gauge galvanized hat shaped channel.
b. Blades of single thickness 16 gauge interlocking formed galvanized steel.
c. Neoprene blade seals, and neoprene or compressible spring steel jamb seals.
d. Design make: Arrow Series 395.

6. Extruded Aluminum Airfoil Construction Dampers:

a. Frames and airfoil blades of extruded aluminum construction.
b. Extruded polymer dampers seals with airstream inflatable double edges, mechanically locked in extruded blade slots, and easily field replaceable.

c. Blades jamb seals compressible spring stainless steel.
d. Design make: Ruskin Model CD-50 or equal.

B. Valves:

1. Valve Types:

a. Ball valves – full port for two position on/off service, with characterizing disc for modulating service.
b. Butterfly valves - two-position on/off service or for use in modulating service where specifically called out as such on drawings.
c. Globe valves - modulating service.

2. Valve Bodies:

a. Screwed bronze bodies (2" size and smaller).

b. Flanged iron bodies (larger than 2" size).

c. Ball valves shall be of two piece full port stainless steel ball and stem design similar to those described in Section 23 05 23 but with reinforced actuator duty stems, adapters, and electronic actuators.

d. Butterfly valves shall be similar to those described in Section 23 05 23 with reinforced actuator duty stems, adapters, and actuators.

e. Globe valves shall have characteristic type throttling plug, #316 stainless steel or Monel stem, and removable composition seats, tight closing to class 4 standard minimum. Provided with necessary features to operate in sequence with other valves or damper operators and adjustable throttling range.

f. Two or three way as required.

g. Designed for 125 psi operating pressure.

h. Arrange to spring return to fail-safe position as called for, quiet operating.

3. Two position valves to be full line size unless otherwise indicated. Modulating water control valves shall be sized on the basis of the smaller of 15% of the total system pressure drop or 8 ft. of water column pressure drop, based on the system design flowrates. Include valve pressure drops in submittal for review. Tag each valve before delivery to project site with scheduled valve identification for location and service.

4. Provide valves and actuation so valves fail safe in normally open or closed positions as required to provide freeze, humidity, force, temperature, etc. protection. Fail position choice shall be submitted for review.

5. Select two-way modulating valves to have equal percentage characteristics.

6. Select three-way valves to have linear characteristics.

C. Actuators:

1. Electronic Actuators:

a. Electronic actuators shall be motor driven with cast aluminum enclosure, with completely oil-immersed metal gear trains, sealed integral spiral spring return mechanism, force sensor safety stop, and shall have torque as needed to insure positive movement against system stall pressure. Furnish entire mechanism in housings designed for easy removal for service or adjustment.

b. Size each actuator motor to operate with sufficient reserve power to provide smooth modulating or 2-position action as specified.

c. Provide permanent split-capacitor, shaded pole, or synchronous motors with gear trains completely oil-immersed and sealed.

d. Equip motors for outdoor locations and for outside air intakes with "0 ring" gaskets designed to make motors completely weatherproof, and equip with internal heaters to permit normal operation at -40 deg F (-40 deg C).

e. All actuators for exterior use shall be electronic style and shall have NEMA 4 enclosures with a rain shield covering the valve stem and entire actuator housing.

f. Damper actuators shall be direct-coupled over the damper shaft, and shall be installed without connecting linkage where possible.

1) Where linkages are required, for example with multiple section dampers or dampers where actuator must be installed in the air-stream, provide with linkage furnished by the damper manufacturer and designed for the actuator being used.

g. Ball and Butterfly valve actuators shall be direct-coupled over the valve shaft, installed without connecting linkage.

1) Globe valve actuators shall have a rack and pinion linkage provided by the valve manufacturer and designed for the actuator being used.

h. The actuator shall have electronic overload and digital rotation sensing to prevent damage to the actuator through the entire rotation range of the actuator.

i. Actuators shall be capable of both clockwise and counter clockwise motion by changing mounting orientation.

j. Provide proportional actuators for modulating services that accept a 0 to 10 VDC or 4 to 20mA control input and provide a 2 to 10 VDC or a 4 to 20mA operating range. An actuator capable of accepting a pulse width modulated / floating point control signal and providing full proportional operation is only acceptable for hydronic valve services where there is no connection to outside air.

k. All 24 VAC/DC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 watts for DC applications. Actuators operating on 120VAC power shall not require more than 10VA. Actuators operating on 230VAC power shall not require more than 11VA.

l. All actuators shall have an external manual gear release and actuators with more than 60 in-lb torque capacity shall have a manual crank to allow manual positioning when the actuator is not powered.

m. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.

n. Actuators shall be provided with a conduit fitting and minimum three foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.

o. Actuators shall be UL Standard 873 listed and CSA Class 4813 02 certified as meeting correct safety requirements.

p. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuators rated torque and shall have a minimum 2-year manufacturer's warranty, starting from the date of installation.

q. Design make: TAC-I/A *DuraDrive* series and Belimo models as required by torque.

2.14 SAFETY DEVICES

A. Low Limit: Electric type with 20' long serpentine element, coldest foot sensitivity, with <u>automatic</u> reset and auxiliary contacts to the EMCS. Set for 37 deg. F for "freeze" protection and 55°F for fan discharge application.

B. High Limit: Electric type, with manual reset; and auxiliary contacts to the EMCS, UL listed for fire, set for 125 deg. F.

C. Filter switches: Differential pressure type with adjustable set point, visual and audible trip indication, and auxiliary contacts to the EMCS.

2.15 MISCELLANEOUS DEVICES

A. Provide all necessary relays, controllers, accumulators, positioners, switches, solenoids, transformers, temperature sensors, and transducers for a complete system.

B. Locate these devices on local panel unless specified otherwise.

C. Wiring:

1. Controls power wiring: Provide wiring in accordance with requirements of Section 23 05 13 , Division 26, and the National Electrical Code.

2. Controls communications and data cabling:

   a. Provide plenum rated cables, in full accordance with the requirements of Divisions 26 (Electrical) and 27 (Communication).

   b. Provide cabling as recommended in writing by the controls manufacturer for optimized communications, similar to:

      1) 22AWG single twisted pair, low capacitance (12.5pF/ft), shielded or unshielded plenum rated cable for low voltage communications.
      2) 18AWG single twisted pair, low resistance (6mW/ft), shielded plenum rated cable.

3. Controls communications and data fiber optic cabling: Provide in accordance with the stricter of the requirements of Divisions 26, 27, and the written recommendations of the manufacturer of the equipment served.

4. Where additional wire to wire terminations are required beyond end device and controller termination strips, make connections using NEMA rated termination blocks with barrier isolated strip/screw or tube/screw connections, all labeled for current function. Flying splices not permitted.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which materials and methods are to be installed and notify Architect in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in acceptable manner.

   1. Installation indicates conditions are acceptable to Contractor as required to ensure requirements for applicable warranty or guarantee can be satisfied.

   2. Electrical Wiring: Check all electrical wiring associated with equipment for compliance with specifications and correctness of connections. Correct wiring in event equipment or devices fail to function in specified manner, whether due to incorrect connections or improper information and wiring diagrams.

   3. Verify that conditioned power supply is available to control units and operator workstation as required.

3.2 WORK INCLUDED

A. Provide all labor, materials, equipment, and services required for the complete removal of all existing controls components being replaced or upgraded as a part of this project or which serve equipment being removed as a part of this contract.

1. Insure that controls for areas outside of this contract's work remain intact and functional. Report any existing problems with functionality before demolition. New problem areas not otherwise a part of this scope that result from this demolition work: rebuild original functionality or upgrade to be included in the new controls.

B. Provide all labor, materials, equipment, and services required for the complete EMCS installation, including Related Work, as required in the Contract Documents. Provide all programming labor required for creating the specified sequences of operation and associated graphics. Include labor required for integrating any software and programming enhancements made both during construction and commissioning and during the warrantee period. Include labor for any programming modifications required due to special circumstances not adequately described in the written sequences of operations, as required to control systems operation as intended.

C. Provide all controls wiring required to connect devices furnished as part of or adjunctive to this EMCS regardless of the source of supply. Provide connections to Owner's LAN, WAN, telephone, and internet as required to perform controls work. Coordinate all fiber optic, telecommunications, and other electrical connections with Owner.

D. Provide power wiring for controls requiring connection to AC power. Control circuits to be 120 vac maximum. Install wiring in accordance with requirements of Section 23 05 13 - Common Electrical Requirements for HVAC Equipment, Division 26, and the National Electrical Code. Provide actuator power wiring to all automatic dampers including fire/smoke dampers. Coordinate required relays, etc.. with fire alarm system control wiring by Division 28.

E. Provide all necessary devices required for proper system operation, including special electrical switches, conditioned power supplies, transformers, disconnect switches, relays, circuit breaker protection, as required.

F. Provide all controllers, actuators, sensors, etc. as specified later herein, and as required to meet the specified sequence of operation.

G. Furnish all valves, control wells, and dampers to Contractor responsible for their installation, as specified and as required to meet the sequence of operation.

H. Provide interface connections from EMCS hardware to equipment starting circuits, alarms, etc.

I. The system shall include all accessory equipment and electrical wiring to fulfill the intent of this specification, including all control and communications components required to interface with the Owner's Ethernet LAN, forming a complete and interoperable system.

J. Each portion of the District EMCS system as described above shall include all gateways, translators, interpreters, software, programming, or other accessory devices as required to achieve BACnet communications over the LAN.

3.3 INSTALLATION

A. System shall be installed and adjusted by trained mechanics and technicians, with a demonstrated experience of not less than (5) years, in the installation, adjustment, and repair of temperature control systems.

B. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

C. Connect and configure equipment and software to achieve sequence of operation specified.

D. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC Components."

E. Install hydronic instrument wells, valves, and other accessories according to Division 23 Section "Hydronic Piping."

3.4 SYSTEM COMPONENTS

A. Current Transducer: As required; install per manufacturer’s written instructions.

B. Static Pressure Transmitter: As required; install per manufacturer’s written instructions.

C. Electronic Duct Humidity Transmitter: As required; install per manufacturer’s written instructions.

D. Temperature Sensors: Install per manufacturer’s written instructions, in locations representative of the controlled spaces’ temperature as required for proper control. Include proposed sensor locations in wiring diagram submittal.

1. Provide room temperature sensors for all spaces where thermostats are not specifically called for, as required to properly and individually control all building mechanical HVAC and domestic hot water equipment in accordance with the sequence of operation. For large spaces, provide at least one room sensor per 2000 square feet, in locations representative of the room’s various exposures and internal loads.

2. Temperature Sensor with Guard: Provide sensor with guard (preferably S.S. wall plate sensor) wherever temperature sensor is called for in publicly accessed spaces similar to corridors, vestibules, lobbies, stairwells, cafeteria, gymnasium, auditorium, etc.

3. Duct and pipe temperature sensors: Provide as shown on the controls schematics and as required to properly control per the written sequence of operations.

4. Outdoor air sensors: Provide as required to accurately sense outdoor air conditions for proper economizer control, at least five separate locations facing each of East, West, North, and South, as well as a representative rooftop location.

E. Automatic Dampers: Furnish dampers, tagged for proper location, (with multiple section damper linkages). Install per manufacturer's printed instructions. Adjust to close tightly. Allow for conduit sleeve or blank space for roof fan dampers.

F. Valves: Install with union or flanged connection. Locate close to apparatus controlled with pipe reducers and increasers located adjacent to valve. Locate, arrange, and pipe per installation diagram in an upright position (stem vertical).

G. Actuators: Install per manufacturer's printed instructions as to motor size and quantity, linkage arrangement, drive connection point. Where ducts or valves are insulated, set damper operators at least 2 in. away from equipment to allow for insulation.

H. Safety Devices:

1. Low Limit: Install on all equipment handling both water and any percentage of unheated outside air, including equipment in boiler rooms handling combustion air, serpentined on the discharge face of heating and/or cooling coils, or elsewhere as required for proper freeze protection, set at 37 deg F. Low limit trip shall report an alarm to the EMCS, which shall prevent the unit's fans from operating (not applicable to boiler burner fans), cause full flow of water in elements being protected, and fully close the outside air intake and exhaust air dampers until automatically reset (combustion air dampers shall not be closed when combustion is required for building heating). If some other sequence is required for proper freeze protection of special equipment or circumstances, provide this and detail in submittal.

2. High Limit: Install in the supply medium at the discharge of each fuel fired appliance. High limit trip shall report an alarm to the EMCS, which shall prevent the units burner from operating until manually reset.

3. Filter switches: Install across each bank of air filters in each air handling system.

I. Miscellaneous Devices: As required; install per manufacturer's written instructions.

3.5 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems."

B. Install building wire and cable according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

C. Install signal and communication cable according to Division 27 Section "Communications Horizontal Cabling."

1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
2. Install exposed cable in raceway.
3. Install concealed cable in raceway.
4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.6 SYSTEM SOFTWARE

A. Provide completely installed and ready for use.

B. System Configuration and Definition:

1. All temperature and equipment control strategies and energy management routines shall be definable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

2. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently add, delete, or modify the following:

   a. SCUs.
   b. OWSs.
   c. UCs.
   d. Points of any type, and all associated point parameters and using constants.
   e. Alarm reporting definition for each point.
   f. Control loops.
   g. Energy management applications.
   h. Time and calendar based programming.
   i. Totalization for every point.
   j. Historical data trending for every point.
   k. Custom control processes.
   l. All graphic displays, symbols, and cross references to point data.
   m. Dial-up telecommunication definition.
   n. All operator passwords.
   o. Alarm messages.

3. System Definition/control Sequence Documentation: All portions of system definition shall be self documenting to provide hard copy printouts of all configuration and application data. Control process and EMCS control loop documentation shall be provided in logical, graphical flow diagram format to allow control sequence to be easily interpreted and modified at any time in the future.

4. Database Save/Restore/Back-Up: Back-up copies of all standalone EMCS panel databases shall be stored in at least one personal computer operator workstation, and a secure electronic copy of the original complete database setup shall be stored at the offices of the TCS, available for the Owner's use.

5. Continuous supervision of the integrity of all EMCS panel databases shall be provided. In the event that any EMCS panel on the network experiences a loss of its databases for any reason, the system shall automatically download a new copy of the respective database to restore proper operations. Database back-up/download shall occur over the local area network without operator intervention. Users shall also have the ability to manually execute downloads of any or all portions of an EMCS panel database.

3.7 SCU PANEL LOCAL OR PORTABLE OPERATOR'S TERMINALS

A. Each EMCS panel shall be capable of supporting an operator's terminal for local command entry, instantaneous and historical data display, and program additions and modifications.

1. There shall be a provision for both permanently mounting the standalone EMCS panel operator terminal, or using it as a portable hand held unit.

2. The EMCS panel operator terminal shall simultaneously display a minimum of 6 points with full English identification to allow an operator to view single screen dynamic displays depicting entire mechanical systems.

3. The operator functions provided by the EMCS panel operator terminal shall include, but not be limited to, the following:

   a. Start and stop points
   b. Modify setpoints
   c. Modify PID loop setpoints
   d. Override PID control
   e. Change time/date
   f. Add/modify start/stop weekly scheduling
   g. Add/modify setpoint weekly scheduling
   h. Enter temporary override schedules
   i. Define holiday schedules
   j. View analog limits
   k. Enter/modify analog warning limits
   l. Enter/modify analog alarm limits
   m. Enter/modify analog differentials
   n. Viewpoint history files

4. The EMCS panel operator terminal shall provide access to all real or calculated points in the controller to which it is connected, or any other controller in the network. This capability shall not be restricted to a subset of predefined "global points", but shall provide totally open exchange of data between the operator terminal and any EMCS panel in the network.

5. Operator access at all EMCS panel operator terminals shall be identical to each other, as well as identical to the PC or Laptop operator workstations. Any password changes shall automatically be downloaded to all controllers on the network.

6. The EMCS operator terminal shall provide English language prompting to eliminate the need for the user to remember command formats of point named. Prompting shall be provided consistent with a user's password clearance and the types of points being displayed, to eliminate the possibility of operator error.

7. A multifunction touch pad shall be provided for point and command selection, as well as parameter entry. To minimize the possibility of operator error, the EMCS panel operator terminal shall change the limit touch pad functions based upon an operator's password clearance, the function being performed, and types of points being displayed. Screen displays shall clearly indicate only valid touch pad functions.

8. Context Sensitive Help: On-line, interactive user's "Help" manuals and tutorials shall be provided. Based upon operator request, the "Help" function shall provide general system operating instructions and specific descriptions of commands available in the currently displayed menus.

9. Identification for all real or calculated points shall be consistent for all network devices. The same English language names used at PC workstations shall be used to access points at the EMCS panel operator's terminal to eliminate cross reference or look up tables.

10. In addition to instantaneous summaries, the EMCS panel operator's terminal shall allow a user to view a point history file for system points. Point history files shall provide a record of value of analog points over the last 24 hours, at 30 minute intervals, or a record of the last ten status changes for binary type points.

3.8 GENERAL CONTROLS SYSTEM PROGRAMMING DESCRIPTION

A. Provide color graphic floor plan displays and system schematics detailing all mechanical and electrical systems as indicated in the sequence of operations, at least one for each system and piece of mechanical equipment, including air handling systems, chilled water systems, and heating systems. Create displays to represent logical grouping of system points or calculated data based upon building function, and mechanical system points which aid the operator in the analysis of the facility. The operator shall be able to view and control these systems via graphical and text-based displays and controls.

1. Provide access to the various system schematic and floor plan graphics via any and all of mouse driven graphical penetration scheme, menu selection, “file tree” organization, or text based commands.

a. Graphical menu penetration: locate and display systems graphics via a mouse driven procedure, designed and implemented to optimize performance analysis and speed alarm recognition. Five clicks maximum from whole district map to details of critical alarm via this route.

1) Whole District Map: Include each building shown as an active link; point and click to go to building. Display any building with (Owner defined, TCS implemented) alarms present as highlighted for rapid system review and diagnosis. Include at least three levels of alarm to facilitate prioritizing; each level shall be obvious and visually distinct. The most critical alarm in any building shall define the alarm level of that entire building in this graphic.

2) Main Building Display: Include a full floor key plan of each floor, broken into areas of detailed floor plans, with similar active point/click penetration scheme and highlighted alarm areas.

3) Detailed Floor Plans: Indicate the location of mechanical equipment (boilers, chiller, air handlers, duct and reheat / VAV systems, pumps and pumping systems, metering equip. etc.) and electrical equipment (switch gear, lighting, etc.) on the detailed floor plans. Highlight any systems when in alarm. Outline limits of each control zone (typically along walls, etc..) and provide active multicolored background for each zone. Zone background color shall change with space temperature deviation from setpoint, with a minimum of 8 background colors, colors to be distinct from alarm highlight colors.

4) System Specific Graphics: Provide pictorial schematically correct representations of each and every mechanical system controlled and/or monitored. Include all associated points, digital status, analog values, appropriate and/or significant calculated values, alarms, active adjustment of all user adjustable setpoints, links to all scheduling, trend logs, sequence of operations description, associated systems schematics in appropriate locations, etc. Include plain English descriptions of each active point / link shown. Include appropriate plain English warnings for alarms. Modify as required by Owner and Engineer during system review, start-up, and commissioning.

b. Menu and text based penetration: An operator request for information about a specific system shall cause the associated graphic display to be automatically selected and output on the viewing screen. The operator request may be entered via either the graphical menu penetration procedure or via a pull down directory tree style menu system with “specific building”, “specific mechanical room”, and “specific system” levels of identification. The pull down menu system shall cause the graphical menu system to be updated.

B. Graphic Representations

1. General: The program shall allow the operator to generate color graphics on-line using standard symbols selected from a standard library of symbols.

2. Provide customized graphics with dynamic point values and set points. Graphics shall include but not be limited to:

a. Each third party microprocessor controlled system with all points available.

b. Heating Hot Water System with heat injection systems, primary hot water system, secondary hot water systems, 3-ways, 2-ways, etc.

c. Air Handling Units, air and water sides, with coil pumps, zones, etc.

d. Floor Plans - The operator interface shall allow the user to access the various graphical schematics via a graphical penetration scheme of the floor plans. Minimum breakdown shall include:

1) Whole District map, showing all buildings.
2) Key plan of each building.
3) Floor plans of each building with zoom in capability.

C. Time Schedule Programs

1. The programs for the EMS shall schedule each system's operation on an hourly basis controlled through daily, weekly and/or monthly schedules. Schedules for each individual system, room or area shall be programmed and modified by the user on a calendar-like display at the OWS.

2. The programs shall store 60 months of schedules.

3. An internal time clock shall automatically compensate for daylight savings time and calendars generated by software shall automatically compensate for leap years.

D. Trend Logs

1. Provide customized trend log reports with up to twenty variables per report for each HVAC system. Points shall be assignable at the OWS; coordinate desired points on each log with Owner during training and commissioning. Archive trended values on the system hard disk for future inquiry, with back up copies automatically prompted for and generated on removable media.

E. Alarm Points

1. All temperature inputs to the DDC system (space, return air, mixed air, discharge air, supply and return water, boiler and cooling systems) shall be alarmed at the host computer if the temperature is out of range 10 deg. F (adj.) above or below setpoint.

2. Fan status shall be monitored by analog current sensing devices or differential pressure switch. If the fan is scheduled to run and the status is not proven, an alarm condition shall be shown at the host computer.

3. Pump status shall be monitored by analog current sensing devices. If the pump is scheduled to run and the status is not proven, an alarm condition shall be shown at the host computer.

4. All alarm points of any stand alone controllers such as boiler burner controls, chiller or condensing unit controls, etc., shall be monitored.

5. For all alarms, provide appropriate text and graphical annunciation to facilitate ease of understanding of source and location of problem. Coordinate annunciation with Engineer, equipment manufacturers, and Owner’s representatives.

F. Optimum Start Program

1. The building shall initially be brought to occupied temperature through an optimal start program. This program shall gradually increase space temperature requirements over a predetermined time to not only bring the building to required temperature but also soft start building mechanical equipment.

2. Each system shall have an independent modular program.

3. The program shall minimize the total energy consumption during daily start-up of each heating/cooling system.

4. A control algorithm shall compare the outside air temperature to space temperature and historical startup data to calculate a start time for each air handling system.

5. The start time for each system shall bring its respective zone to occupied setpoint at the time of occupied mode start.

6. The optimum start program shall be adjustable to the rate structure of the local energy company.

G. Optimum Stop Program

1. Each system shall have independent modular program.
2. The program shall minimize the total energy consumption during daily shut-down of each heating/cooling system.
3. A control algorithm shall compare the outside air temperature to space temperature to calculate a stop time for each air handling system.
4. The stop time for each system shall shut-down its respective zone as early as possible without letting the temperature drift out of the specified comfort range.
5. Minimum outside air ventilation shall be maintained where required by occupied status requirements of space served.

H. Smoke Dampers And Fire/Fan Shut Down

1. When fire alarm condition is initiated, the fire alarm system shall directly cause all fans 1000 cfm and larger to shut down and shall provide a signal to the EMCS to note fire alarm condition.

2. When fire alarm condition signal is received from the fire alarm system, initiate the following sequence:

   a. Cause all building fans 1000 cfm and larger to shut down. This is in addition to the direct shutdown caused by the fire alarm system.

      1) Allow variable speed drives to ramp down and ramp up on restart.

   b. Cause all smoke dampers and fire-smoke dampers to close and remain closed for the duration of the alarm condition. Delay closing smoke dampers until associated fan system has completely stopped (10 sec. Maximum).

c. Do not permit unrelated HVAC equipment (heating valves, pumps, etc..) in building to lose control.

d. Provide separate control wiring, connections to fire alarm system, all required smoke dampers, etc.., as required to accomplish the required sequence.

e. Upon termination of the fire alarm condition as indicated by a signal from the fire alarm system, cause all automatic fire/smoke dampers to open and prove open, then return all affected fans to their normally scheduled operation using the staggered start algorithm.

I. Day/Night Setback

1. The day/night setback will consist of lowering the space heating setpoint and raising the space cooling setpoint during the unoccupied mode, thereby reducing the heating and cooling energy requirements. The occupied and unoccupied areas will be specified by the owner and will be coordinated with the control system.

J. Economizer Cooling Cycle

1. The controls shall incorporate an enthalpy logic center with outdoor and return air temperature and humidity sensors that shall maximize the use of outdoor air for cooling before the mechanical cooling is energized and during operation through comparison of outdoor and return air enthalpy as follows. Note that multiple outdoor temperature conditions will be present at different outside air intake locations, and as such a comparable number of outside air sensors are required. Some mechanical systems may share a single outdoor air enthalpy center, for example adjacent UVs each facing east, providing the outdoor air conditions can be demonstrated to be virtually identical from an energy management perspective. Provide at minimum East, West, South, North, and Rooftop outdoor air sensors.

2. When the outdoor air enthalpy is less than the return air enthalpy during cooling mode, the logic circuitry shall cause the outdoor and return air dampers to modulate to the balanced outdoor air position that satisfies the critical space temperature transmitter set point before opening the system chilled water cooling valve.

3. If the outdoor air enthalpy is less than the return air enthalpy and the critical space temperature transmitter set point cannot be satisfied with 100% outside air, then the system shall circulate 100% outside air and the cooling water valve shall modulate open to satisfy the zone temperature requirements.

4. If the enthalpy sensors indicate that the return air has lower enthalpy than the outdoor air, then the system shall revert to normal cooling mode.

5. Upon a call for cooling to maintain the night setback temperature, only the economizer mode shall be operational. The chilled water control valve shall not be opened, and upon satisfying the space temperature transmitter night setback set point, the system shall revert to the normal unoccupied mode.

K. Maintenance Management: Continuously totalize run hours for equipment controlled and/or monitored for use by the maintenance management program.

L. Equipment Scheduling

1. Equipment shall be capable of 7 days, 24 hours schedules with separate holiday hours.
2. There shall be capability for five different holiday schedules which can be selected from the occupancy schedule graphic.
3. Holidays shall be programmed so that they shall need a minimum of manual adjustment year to year and can easily be modified at front end if necessary.
4. All schedule programming shall reside in local controllers, but shall be configurable from the front end.

M. Coil Freeze Protection.

1. Heating and cooling coils and any other equipment provided as a part of this project which are circulating water (not required for glycol coils) or are otherwise subject to water freeze damage, subject to the following, that have any percentage of unheated outside air entering them, shall have coil freeze protection.

2. Mixed outside and return air and the preconditioned discharge air from air to air energy recovery units shall be considered unheated for this purpose.

3. The first stage of coil freeze protection shall incorporate analog input temperature sensing at the expected freeze location. Sensing devices may be immersion style return water temperature sensor piped as close as practical to the outlet of the coil (within the rooftop unit if applicable), surface temperature sensors on the coil surface at the expected freeze location, or other comparable devices approved as applicable to the circumstances. Include details of freeze protection scheme for all such equipment in submittal. When the sensed temperature is above 60ºF (adj.), the coil control valve shall be under space temperature control. If at any time the expected freeze location sensed temperature drops below 60ºF (adj.), the control valve shall temporarily open to raise that coil's return water temperature to above 80ºF (adj.), and the EMCS shall report an alarm to the OWS

4. The second stage of coil freeze protection shall be the low limit freeze stat air temperature sensors with the sequence defined under safeties, above.

3.9 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
2. Test and adjust controls and safeties.
3. Test each point through its full operating range to verify that safety and operating control set points are as required.
4. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
5. Test each system for compliance with sequence of operation.

6. Test software and hardware interlocks.

C. DDC Verification:

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.

2. Check instruments for proper location and accessibility.

3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.

4. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.

5. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.

6. Check temperature instruments and material and length of sensing elements.

7. Check control valves. Verify that they are in correct direction.

8. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.

9. Check DDC system as follows:

a. Verify that DDC controller power supply is from emergency power supply, if applicable.
b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
c. Verify that spare I/O capacity has been provided.
d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.10 ADJUSTING

A. Calibrating and Adjusting:

1. Calibrate instruments.

2. Make three-point calibration test for both linearity and accuracy for each analog instrument.

3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.

4. Control System Inputs and Outputs:

a. Check analog inputs at 0, 50, and 100 percent of span.

b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
c. Check digital inputs using jumper wire.
d. Check digital outputs using ohmmeter to test for contact making or breaking.
e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.

5. Flow:

a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
b. Manually operate flow switches to verify that they make or break contact.

6. Pressure:

a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

7. Temperature:

a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
b. Calibrate temperature switches to make or break contacts.

8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.

9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.

10. Provide diagnostic and test instruments for calibration and adjustment of system.

11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

3.11 SYSTEM TESTING AND COMMISSIONING

A. Test complete control system for control device operation prior to the systems acceptance. Demonstrate complete sequence of operations to Architect’s and Owner’s representatives.

1. Verify operation of system inputs and outputs, control loops and/or software programming, timing functions, operator entered constants, facilities management functions, etc., and observe that they perform their intended functions. Generate check out data sheets for each system so verified.

2. Field verify analog input calibration, analog output operation, digital input function, digital output operation, and coordination of system inputs and outputs between system graphics and field devices for schematic accuracy. Coordinate device testing with Testing and

Balancing Agency – refer to section 23 05 93 – Testing, Adjusting, and Balancing for HVAC for additional information. Generate check list of all devices, keyed with descriptive locations and functions, along with complete calibration, testing, and coordination data, certified by Contractor and TAB agency.

3. Provide complete values and points logs, printed with hourly values for one week, demonstrating correct control functions and programming.

B. When above procedure has been completed and control systems are operating satisfactorily, produce and submit a report of entire systems performance for review, including all data described above. Submit three copies to the Architect's Representative advising them that the control system is 100% complete and operates in accordance with the Contract Documents.

3.12 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 09 00

SECTION 23 21 13 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes pipe and fitting materials, special-duty hydronic systems fittings, equipment, valves, and specialties, and joining methods for the following:

1. Hydronic Systems piping.
2. Make-up water piping
3. Blowdown and system drain piping.
4. Air-vent piping.

B. Related Sections include the following:

1. Section 23 05 19 - Meters and Gauges for HVAC Systems.
2. Section 23 05 23 - General Duty Valves for Hydronic Piping.
3. Section 23 05 29 - Hangers and Supports for HVAC components.
4. Section 23 05 43 - Mechanical Vibration, and Movement Control.
5. Section 23 09 00 - Instrumentation and Control for HVAC.

1.3 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Steel and Copper Hydronic Piping: 125psig at 250 deg F.
2. Makeup-Water Piping: 100 psig at 150 deg F.
3. Safety-Valve-Inlet and -Outlet Piping, Vent and Drain Piping: Equal to the pressure and temperature of the piping system to which it is attached.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Above Grade Piping.
2. Pipe Fittings.
3. Dielectric Fittings.
4. Specialty Valves.
5. Air and Pressure Control.

6. Pressure Control.
7. Special Duty Hydronic Components.

B. Quality Control Submittals

1. When welded or brazed pipe work is required or proposed as a part of this project, submit Welding and Brazing Procedure Qualification and Welders' and Brazers' Certification under Section 23 05 00.

C. Qualification Data: For Mechanical Grooved and Pressure Sealed Joint Installers.

1.5 CLOSEOUT SUBMITTALS

A. Field quality-control test reports.
B. Operation and Maintenance Data: For air control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

1.6 QUALITY ASSURANCE

A. Regulatory Requirements: Comply with all applicable sections of the following:

1. ANSI / ASME B 31.9: "Building Services Piping."
2. ASME "Boiler and Pressure Vessel Code," Section IX, "Welding and Brazing Qualifications."
3. New York State Labor Department Industrial Code Rule No. 4 (cited as 12 NYCRR4).
4. New York State Labor Department Industrial Code Rule No. 14 (cited as 12 NYCRR14).
5. Building Code of New York State.
6. ANSI / ASHRAE 15 "Standard Safety Code for Mechanical Refrigeration."
7. ASME label on all pressure vessels and safety valves.
8. ANSI / ASME B31 – "Code for Pressure Piping."

B. Installer Qualifications:

1. Grooved Mechanical and Pressure Seal Joint Quality Control:

a. Installer Certification: Provide installers trained in and familiar with the installation of the mechanical joint systems, certified by the approved joint manufacturer as having been trained and qualified to join piping with manufacturer's system.

b. Single Source: Obtain mechanically joined piping system components from single approved manufacturer for each system type, grooved or pressed.

c. Proper Tools: Fabricate and install joints using the proper tools, actuators, rolls, cutters, jaws, rings, etc., as manufactured and instructed by the approved manufacturer.

d. Manufacturer's Inspection: Certify grooved system installation for compliance with manufacturer's recommendations.

C. Welded Support Work Quality Control:

1. Qualify processes and operators according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

D. Welded Piping Work Quality Control:

1. Welding and Brazing Procedure Qualifications: Qualify any welding or brazing procedure to be used on this Project in accordance with ASME "Boiler and Pressure Vessel Code", Section IX. Qualification may be made by technically competent group or agency (subject to approval) meeting the following conditions:

a. Group or agency qualifying the procedure meets all procedure qualification requirements of ASME "Boiler and Pressure Vessel Code", Section IX.

b. Contractor accepts full responsibility for procedure qualified.

c. Contractor has qualified at least one welder or welding operator using procedure qualified and provides record of qualification.

d. Contractor accepts full responsibility for qualified procedures by signing related qualification records with procedure and performance qualifications including all dates, results, and associated data.

2. Welders' and Brazers' Qualifications: Ensure that all welders, welding operators, brazers, or brazing operators employed for this project are qualified for all welding and brazing procedures, proposed as part of this Project, in accordance with ASME "Boiler and Pressure Vessel Code", Section IX. Qualification by previous employer or technically competent group or agency (subject to approval) may be acceptable if following information is included:

a. Documentation that the previous qualification was for essentially the same procedures proposed and was in full accordance with ASME "Boiler and Pressure Vessel Code", Section IX.

b. Copy of performance qualification testing record showing who qualified the worker, date of qualification, and work history record showing continuous performance to maintain qualification.

3. Weld and Braze Qualification Records: Maintain and sign certified records of approved procedures used and approved qualified workers employed for welded and brazed joints performed as a part of Contract Work. Ensure all building services piping welding and brazing work can be traced to a specific procedure and welder.

4. Inspection and Examination by Owner, Remedy by Contractor: Owner reserves right to examine, inspect, and test all piping using visual, radiographic, or other recognized testing methods to determine compliance with specified quality control requirements and requirements of applicable regulatory agencies.

a. Cost of Owner's testing of acceptable installation provided at Owner's expense.

b. Repair piping installations not passing Owner's quality inspection testing using approved method or replace at no additional cost.
c. Cost of initial testing of piping not conforming to specified requirements and any retesting of repairs or replacement work shall be deducted from Contract Sum.

E. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Refer to Part 3 for Piping Applications Article.

B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Anvil International, Inc.
2. Cerro Flow Products, Inc.
3. Mueller Industries, Inc.
4. S. P. Fittings; a division of Star Pipe Products.
5. Viega LLC.
6. Victaulic Company of America.

C. Copper Tubing: ASTM B 88, Annealed or Drawn Temper, Types M, L, and K.

D. Copper Tube Fittings:

1. Solder Fittings

a. Tees, Elbows, Reducers, Adapters: ANSI B16.22 streamlined pattern wrought copper or ANSI B16.18 cast bronze; solder end connections; ASTM B62.
b. Unions: Solder type, cast bronze, ground joint, Class 150.
c. Cast Bronze Flanges: ANSI B16.24 Class 150 solder connection flanges, raised ground face, ANSI pattern drilled and spot faced bolt holes.

2.2 STEEL PIPE AND FITTINGS

A. Refer to Part 3 for Piping Applications Article.

B. Steel Pipe: ASTM A53-S, A53-E, or A106 Schedule 40 or 80, seamless (type S) or electric-resistance welded (type ERW), Grade B, black or ASTM A123 and A153 galvanized steel pipe, plain or threaded ends.

C. Threaded Fittings:

1. Pipe threads in accordance with ANSI/ASME B1.20.1 National Pipe Thread taper (NPT) standards.
2. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.
3. Unions: ASME B16.39 malleable iron, threaded, Class 150 or higher, ground joint bronze to iron seat.
4. Cast-Iron Fittings: ASME B16.4; Class 125 or higher.
5. Malleable-Iron Fittings: ASME B16.3, Class 150 or higher.
6. Flanges: Cast Iron ASME B16.1 Class 125 or higher, raised ground face, ANSI pattern drilled and spot faced bolt holes.

D. Welded Steel Fittings: ASTM A 234/A 234M or A106 seamless forged steel.

1. ASME/ANSI B16.9 pattern with ASME/ANSI B16.25 beveled butt weld ends, wall thickness to match adjoining pipe.

   a. Long radius pattern unless space restrictions prohibit, then short radius allowed.

2. ASME B16.11 socket weld class 2000.

3. Flanges: ANSI B16.5 Class 150 or higher, butt weld neck type, raised ground face, ANSI pattern drilled and spot faced bolt holes.

4. Where branch connections are two or more sizes smaller than main size, "weldolets" or "threadolets" are acceptable.

5. Fabricate custom bend angle fittings by removing material from standard butt weld type fittings at the appropriate angle and recreating the original ASME B16.25 weld configuration chamfer.

   a. Shop or site-weld weld/groove adapter nipples to custom angle fitting where applicable to create custom angle grooved mechanical fittings.

E. Grooved Mechanical-Joint Fittings and Couplings:

1. All products – fittings, couplings, gaskets, and grooving tools - shall be manufactured by a single ISO 9001 or higher certified manufacturer.

2. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   a. Anvil International, Inc.
   b. Central Sprinkler Company; a division of Tyco Fire & Building Products.
   c. Victaulic Company of America.

3. Mechanical Joint Fittings: ASTM A 536, Grade 65-45-12 Ductile Iron; ASTM A 47 Grade 32510 Malleable Iron; ASTM A 53, Types E or S, Grade B fabricated steel; or ASTM A 106, Grade B steel fittings with grooves or shoulders designed to accept grooved end couplings. Subject to applicable fitting requirements described elsewhere in this document. Basis of Design: Victaulic.

4. Mechanical Couplings: ASTM A 536, Grade 65-45-12 ductile iron or ASTM A 47 Grade 32510 malleable iron split housing, designed for bolted assembly with full circumferential engagement of coupling into pipe end or fitting groove or alternatively to grip exterior of plain steel pipe where grooving is not possible. Coupling houses pressure responsive gasket by coupling manufacturer that forms durable pressure seal. Provide rigid type couplings for all straight runs and flexible type couplings for all branch takeoff (side of tee) and elbow fittings, unless otherwise specified or directed. Provide couplings with bolt size and strength and pressure rating not less than the listed product.

    a. Grooved End Mechanical Flexible couplings: pad to pad coupling fit with clearance to groove. Basis of Design: Victaulic Style 77.

    b. Rigid Grooved End Mechanical Couplings: full circumference coupling to groove compression contact for rigid style groove couplings. Basis of Design: Victaulic Style 07 and Style 107.

    c. Rigid Plain End Mechanical Couplings: Extra heavy housing with hardened toothed jaws set into housing that engage and grip pipe exterior as bolts are tightened. Basis of Design: Victaulic Style 99 Roustabout.

5. Pipe End Grooves: Pipes may be delivered to site full length with factory grooved ends fabricated to coupling manufacturer’s specifications or shop or site fabricated to length required using coupling manufacturer’s groove cutting or rolling tool, fabricated to coupling manufacturer’s specifications.

6. Coupling Gaskets: Synthetic rubber gasket of central cavity pressure-responsive design manufacturer rated for fluid and temperature of service, minimum 300 psig working pressure at 250 degrees F.

2.3 JOINING MATERIALS

A. Flanges:

1. Gasket Materials:

    a. ASME B16.21, nonmetallic, flat, asbestos free, suitable for chemical, pressure, and thermal conditions of system.
    b. 1/8-inch maximum thickness unless thickness or specific material is indicated.
    c. Full or narrow face pattern to fit flanges.

2. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, electroplated, unless otherwise indicated.

3. Provide dielectric kit for flanges joining dis-similar piping materials.

B. Solder Filler Metals: Use solder conforming to ASTM B 32-95; alloy grades Sn96, Sn95, Sn94, E, AM, WS; lead free alloys with maximum lead content of 0.1percent by weight, minimum solidus temperature of 430 deg. F, and approved for use with potable water. Higher lead content solder not acceptable. Include water-flushable flux according to ASTM B 813.

C. Brazing Filler Metals: Select brazing filler metals compatible with piping to be joined:

1. AWS A5.8 BCuP Series, copper-phosphorus alloys for joining copper with copper only.

2. AWS A5.8 BAg series, cadmium free silver bearing alloys for joining dis-similar metals including copper with any brass, bronze, steel, or stainless steels, or other dis-similar brazeable materials.

2.4 DIELECTRIC FITTINGS

A. Description: Combination fitting of copper-alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials, designed to join dis-similar metallic piping materials with dis-similar metals separated by dielectric material in a configuration to minimize galvanic corrosion of the less noble piping material.

B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Advance Products & Systems, Inc.
2. Capitol Manufacturing Company.
3. Central Plastics Company.
4. Elster-Perfection Corporation.
5. Hart Industries International, Inc.
6. Lochinvar Corporation.
7. Pipeline Seal and Insulator, Inc.
8. Precision Plumbing Products, Inc.
9. Sioux Chief Manufacturing Company, Inc.
10. Victaulic Company of America.
11. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
12. Zurn Plumbing Products Group; AquaSpec Commercial Products Division.

C. All Materials: Suitable for system fluid, pressure, and temperature.

D. Dielectric Nipples:

1. Galvanized steel nipple with insert of noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 deg F.

E. Dielectric Couplings:

1. Galvanized-steel coupling with insert of noncorrosive thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 deg F.

F. Dielectric Unions:

1. Factory-fabricated union assembly, for 250-psig minimum working pressure at 180 deg F.

G. Dielectric-Flange Kits:

1. Flange assembly kit for field assembly. Include full-face or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, steel backing washers, and appropriately sized bolts and heavy pattern nuts. Provide bolts of length as required for full engagement in nuts, of higher strength if undersized for bolt sleeves as required to maintain system working pressure.

2.5 VALVES

A. Isolation, Check, Balancing, Vent, and Drain Valves: Comply with requirements specified in Section 23 05 23 – General Duty Valves for HVAC Piping.

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 23 09 00 - Instrumentation and Control for HVAC.

2.6 THERMAL EXPANSION AND AIR CONTROL DEVICES

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Amtrol, Inc.
2. Armstrong Pumps, Inc.
3. Bell & Gossett Domestic Pump; a division of ITT Industries.
4. Wessels.

B. Air Separator Assemblies

1. Tangential Air Separator: Designed, constructed, and ASME stamped for 125 PSIG working pressure, 225 deg. F operating temperature minimum, and sized as noted on Drawings or, if not noted, for minimum air separation efficiency of 90 percent first pass.

   a. Shell: Centrifugal flow air separation design with minimum three times nominal pipe connection diameter and welded steel construction with tangential flanged, grooved, or threaded connections, perforated air collector tube with threaded air separation fitting, blow down fitting, and hanger fittings.

   b. Design Make: "Rolairtrol RL" by Bell & Gossett.

2.7 HYDRONIC PIPING ACCESSORIES

A. Pipe Sleeves:

1. Sleeve 6-Inches Diameter and Smaller: Schedule 40 galvanized, welded steel pipe, ASTM A53, Grade A.

2. Sleeves Larger than 6-inches: Galvanized sheet metal, 10 gauge, round tube with welded longitudinal joint.

3. Sleeves Installed In Masonry Or Cold Formed Metal Framing/Gypsum Board Construction: Galvanized sheet metal, 20 gauge, round tube with welded longitudinal joint.

B. Escutcheons: Chrome plated, stamped steel, hinged, split-ring escutcheons, with setscrew. Inside diameter closely fits pipe outside diameter or outside diameter of pipe insulation where piping is insulated. Outside diameter completely covers opening in floor, wall, or ceiling.

1. Manufacturer: Manufacturers offering acceptable products include Grinnell.

C. Mechanical Sleeve Seals: Modular mechanical type, consisting of interlocking synthetic rubber links shaped to fill annular space continuously between pipe and sleeve. Connected with bolts and pressure plates causing rubber sealing elements to expand when tightened, providing watertight seal and electrical insulation.

1. Manufacturer: Manufacturers offering acceptable products include Thunderline Corp.

2.8 HYDRONIC PIPING SPECIALTIES SPECIFIED ELSEWHERE

A. Meters and Gauges: as specified in Section 23 05 19.
B. General Duty Valves: as specified in Section 23 05 23.
C. Hangers and Supports: as specified in Section 23 05 29.
D. Flexible Equipment Connectors: as specified in Section 23 05 43.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Closed Loop Hydronic Piping (heating or dual temperature), aboveground, NPS 2 and smaller:

1. Type L drawn-temper copper tubing with wrought-copper fittings, and soldered or brazed joints.

B. Closed Loop Hydronic Piping (heating or dual temperature), aboveground, NPS 2-1/2 and larger:

1. Schedule 40 steel pipe with welded or mechanical grooved fittings and joints.

C. Makeup-water piping installed aboveground: Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.

D. Air-Conditioning Condensate Gravity Drain Piping:

1. Type M or L, drawn-temper copper tubing, wrought-copper drain fittings, and soldered or brazed joints.

E. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to the piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

F. Safety-Valve-Inlet and -Outlet Piping for Hot-Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed with metal-to-plastic transition fittings for plastic piping systems according to the piping manufacturer's written instructions.

3.2 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated piping locations and arrangements were used to size piping, calculate friction loss, expansion compensation, pump sizing, fill volume, and other design considerations. Install piping generally as indicated unless deviations to layout are approved on Coordination Drawings.

B. Select system components with pressure rating equal to or greater than system operating pressure.

C. Install piping in concealed locations except in equipment rooms and service areas, unless otherwise indicated on drawings: install in walls, pipe chases, utility spaces, above ceilings, etc.

D. Install piping orthogonal to building walls as possible within constraints required for sloped drainage, non-orthogonal building construction, etc. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install fittings for changes in direction and branch connections, unless otherwise specified.

1. Branches two or more sizes smaller than main may be weld-o-let welded to steel pipe and brazed to copper using listed mechanically formed outlets similar to “T-drill.”

2. Minor offsets in copper fin-tube piping required to segment enclosures along curved exterior walls may be created by smooth bends in annealed type L or K copper tube. Do not bend fin element.

3. Mitered elbows, "shaped" nipples, and job fabricated reductions are not acceptable.

4. Where corridors or other general construction meets at angles other than standard pipe fitting angles, provide custom bend angle elbows to match general construction and maintain piping orthogonal to building.

F. Install piping so as to provide for positive drainage and air elimination.

1. Install straight piping free of sags and bends. Do not install bent piping – remove from site.

2. Install gravity drain lines at uniform slope down in direction of flow. Maintain maximum slope feasible up to one quarter inch rise per foot of run, but not less than 1% (approximately one eight inch per foot). Where height restrictions do not allow for minimum required slope, provide for pumped condensate removal as shown.

3. Install pressurized pumped flow piping at a uniform grade of 0.2 percent upward in direction of flow or at otherwise indicated slopes.

4. Avoid local high and low points where possible.

5. Install branch connections out the top of mains to serve equipment above mains, and out the bottom of mains to serve equipment below, or otherwise as required to provide drainage and venting with a minimum of drain and vent fittings.

6. Provide eccentric pipe size reducers and increasers, installed so as to allow for both positive drainage and air elimination. In general, where piping is sloped up in direction of flow, reduce pipe sizes with level side up and increase pipe sizes with level side down.

G. Install piping allowing for proper servicing of hydronic systems.

1. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

2. Install piping and specialties with sufficient clearance to allow application of specified insulation.

3. Install valves with sufficient clearance and orientation to permit both ease of operation and servicing.

4. Install dis-assemble able unions, flanges, or mechanical joints on equipment side of isolation valve, as required to remove and service all serviceable components without system drain-down or cutting piping. Install unions and flanges in piping.

   a. Provide unions for NPS 2 and smaller, flanges for NPS 2-1/2” and larger.

   b. Install adjacent to control valves, at final connections of equipment, as required to adjust threaded pipe joints after fixed (non-rotatable) joints are made, and elsewhere as indicated.

   c. Install out of the line of coil pull, tube bundle removal access space, etc.

   d. Install so sensor wires, thermometers, gauges, etc., need not be rotated, removed, or disconnected to service equipment.

   e. Install within two feet of control valves with no elbows between valve and union as required for ease of replacement.

f. One dis-assemble able fitting may be used for two components (ex., both control valve and equipment service) if they are separated by no soldered, brazed, or welded elbows and no more than three feet of pipe.

H. Identify piping as specified in Section 23 05 53 - Identification for HVAC Components.

I. Install sleeves for piping penetrations of walls, ceilings, and floors.

J. Install escutcheons for exposed piping penetrations of walls, ceilings, and floors.

3.3 PIPE JOINT CONSTRUCTION

A. General Pipe Joint Construction:

1. Cut all pipe ends square.
2. Ream ends of pipes and tubes removing burrs past original pipe wall to restore full pipe ID.
3. Remove scale, slag, dirt, and debris from both inside and outside of piping and fittings before assembly.
4. Remake leaking joints using new materials.

B. Threaded Joints:

1. Provide threaded pipe ends in conformance with ANSI B1.20.1, tapered pipe thread standards.

2. Cut threads full and clean using sharp cutting oil flooded dies.

3. Note internal length of threads in fittings or valve ends and proximity of internal seat or wall to determine pipe threading and align threads at point of assembly.

4. Apply appropriate tape or thread compound to the external pipe threads (except where dry seal threading is specified) and assemble joint “wrench-tight” with paired wrenches, one wrench on adjacent pipe and one wrench on valve end where pipe is threaded.

5. Damaged Threads: Do not use pipe or fittings with torn, corroded or damaged threads.

6. Do not use portions of pipe where weld opens during cutting or threading operations.

C. Soldered Joints:

1. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook."

2. Square cut tubing to correct length required to fill sockets.

3. Ream ends and clean surfaces of oils, grease, and oxidation to bright finish with fine sand cloth, cleaning pads, or special wire brush.

4. Apply thin film of solder flux to both surfaces to be joined. Do not clean, flux and assemble joint more than 3 hours before soldering, and do not use acid core, paste type solder, or solder flux combinations.

5. Remove heat-sensitive portions of components prior to soldering. Provide wet rag strip heat sink wrapped around stem and seat of valves and protect all components for soldering heat damage. Replace any components with any evidence of heat damage.

6. Heat joint uniformly and rapidly and fill completely with solder while minimizing external and internal over-soldered dripping.

7. Disassemble joints for inspection of solder penetration as directed. Remake faulty joints at no additional cost.

D. Brazed Joints:

1. Comply with the procedures contained in AWS "Brazing Manual," using qualified processes and brazing operators according to Part 1 "Quality Assurance" Article.
2. Remove stems, seats, and packing of valves and accessible internal parts at piping specialties before brazing.
3. Fill the pipe and fittings with an inert gas (i.e. nitrogen or carbon dioxide) during brazing to prevent formation of scale.
4. Heat joints using oxyacetylene torch. Heat to proper and uniform temperature.
5. Completely fill sockets with braze materials, and make neat fillets on butt joints.

E. Welded Joints:

1. Comply with the requirements of ASME Code B31.9 - "Building Services Piping," ASME B16.25, and AWS D10.12/D10.12M, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

2. Machine-chamfer all pipe ends for butt welded joints.

3. Remove cutting beads and do not allow welding beads to form.

F. Flanged Joints:

1. Select appropriate gasket material, size, type, and thickness for service application.

2. Install gasket concentrically positioned, and dielectric kits if flanges join dis-similar piping materials.

3. Align flanged surfaces parallel.

4. Use suitable lubricants on bolt threads.

5. Make initial contact of flanges and gaskets flat and parallel with bolts only finger tight, then tighten bolts using alternating sequential pattern, gradually and uniformly to full torque using torque wrench.

3.4 HYDRONIC SPECIALTIES INSTALLATION

A. At each system local or global low point, both in piping and heat transfer elements, and as required for complete system drainage, install drain consisting of a tee fitting and drain valve as described in Section 23 05 23 – General Duty Valves for HVAC Piping.

B. At each system local or global high point, both in piping and heat transfer elements, at the end of each horizontal run before a drop in elevation, and elsewhere as required for complete and serviceable venting of system air, install vent consisting of a tee fitting and air vent as described in Section 23 05 23 – General Duty Valves for HVAC Piping.

C. Install all components of Energy Management and Control System (EMCS) into hydronic systems as required for complete EMCS installation and as required by this section maintaining integrity if hydronic systems. Coordinate all locations and quantities with contractor responsible for the EMCS – refer to Section 23 09 00 – Instrumentation and Control for HVAC.

1. Install control valves in accessible locations close to connected equipment or as otherwise shown, with dis-assemble able connections.
2. Install wells for pressure, temperature, and other sensors as shown on details and as called for by the sequence of operations.

D. Install ports and wells for pressure gages and thermometers at coil inlet and outlet connections according to Division 23 Section "Meters and Gages for HVAC Piping."

E. Install pressure / temperature test ports (P/T plugs) at the supply and return of every heat transfer element, and as otherwise called for on drawings.

F. Install piping to pumps. Details of near pump piping are specified in Section 23 21 23 – Hydronic Pumps

G. Install air separator where shown, in general in high temperature low pressure location similar to between boiler outlet and pump suction. Install blowdown piping full size of air separator drain connection, with full-port ball valve; extend full size to point of collection.

3.5 VALVE APPLICATIONS

A. Install General Duty Valves (isolation valves, check valves, balancing valves, air vent valves, and drain valves) as specified in Section 23 05 23 – General Duty Valves for HVAC Piping.

3.6 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Section 23 05 29 "Hangers and Supports for HVAC Components". Comply with the following requirements for maximum spacing of supports.

B. Sound, vibration, and movement control is specified in Section 23 05 43 – Mechanical Vibration and Movement Control.

3.7 TERMINAL EQUIPMENT CONNECTIONS

A. Size supply and return piping run-outs to equipment connections same as shown on the drawings. Where connecting to existing piping run-outs, use same size as existing unless shown otherwise. Transition to equipment connection size close to equipment. If equipment connection size is smaller than piping shown, transition to piping size shown immediately with no elbows (except reducer elbows) or other fittings closer to the equipment than the required transition fitting.

B. Provide for thermal movement of piping adjacent to terminal equipment, using flexible hose connections, swing joints, etc. Refer to Section 23 05 43 – Mechanical Vibration and Movement Control for details.

3.8 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.

2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.

3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.

4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.

5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.

2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.

3. Isolate expansion tanks and determine that hydronic system is full of water.

4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."

5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.

6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 23 21 13

SECTION 23 22 13 – STEAM AND CONDENSATE HEATING PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes

1. Steam heating piping systems including, but not limited to:

a. Steam supply and condensate return piping.
b. Steam and condensate piping specialties.

1.3 DEFINITIONS

A. Pipe Sizes: Where pipe sizes are specified in this Section, provide Nominal Pipe Sizes (NPS) unless otherwise specified.

1.4 SUBMITTALS

A. Comply with requirements of Section 01 33 00 - Submittals and as modified below.

B. Product Data: Submit schedule of piping materials, service, fittings, specialties, and connections, along with full manufacturers' specification data.

C. Quality Control Submittals

1. When welded or brazed pipe work is required or proposed as a part of this project, submit Welding and Brazing Procedure Qualification and Welders' and Brazers' Certification under Section 23 05 00.

D. Contract Closeout Submittals: Comply with requirements of SECTION 017700, including submission of operating and maintenance instructions as item in "Operating and Maintenance Data " manual described in that section.

1.5 QUALITY ASSURANCE

A. Regulatory Requirements: Comply with all applicable sections of the following:

1. ANSI / ASME B 31.9: "Building Services Piping."

2. ASME "Boiler and Pressure Vessel Code", Section IX, "Welding and Brazing Qualifications."
3. Building Code of New York State.
4. ASME label on all pressure vessels and safety valves.
5. ANSI / ASME B31 – “Code for Pressure Piping.”

B. Inspection and Examination by Owner, Remedy by Contractor: Owner reserves right to examine, inspect, and test all piping using visual, radiographic, or other recognized testing methods to determine compliance with specified quality control requirements and requirements of applicable regulatory agency.

1. Cost of Owner’s testing of acceptable installation provided at Owner’s expense.
2. Repair piping installations not passing Owner’s quality inspection testing using approved method or replace at no additional cost.
3. Cost of initial testing of piping not conforming to specified requirements and any retesting of repairs or replacement work deducted from Contract Sum.

C. Single Source: Obtain grooved end piping and system components from same manufacturer.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Provide factory-applied plastic end caps on each length of pipe and tube. Maintain end caps through shipping, storage, and handling to prevent pipe-end damage and prevent entrance of dirt, debris, and moisture.

2. Provide new pipe and fittings marked with manufacturer's name and complying with applicable ASTM and ANSI Standards.

B. Storage and Protection

1. Protect storage pipes and tubes. Elevate above grade and enclose with durable, waterproof wrapping. When stored inside, do not exceed structural capacity of floor.
2. Protect flanges, fittings, and specialties from moisture and dirt by inside storage and enclosure, or by packaging with durable, waterproof wrapping.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Piping and Tubing: Provide following types of pipe and tubing where indicated in the “Schedule Of Applications” specified in Part 3 below:

1. Hard Temper Copper Tubing: ASTM B 88, Type L.

2. Steel Pipe:

a. ASTM A53-S or A53-E, Schedule 40 or 80 (extra strong – XS) weight, seamless or electric-resistance welded (ERW), Grades A and B, black steel pipe, plain or threaded ends.

b. ASTM A53-S or A106; Schedule 40, seamless ASTM A153 galvanized steel pipe, plain or threaded ends.

B. Steel Pipe Fittings: Same pressure class as adjoining pipe minimum. Black or ASTM A153 galvanized; same as adjoining pipe.

1. Cast-Iron Threaded Fittings: ANSI B16.4, Class 125 and 250, standard pattern, for threaded joints. Threads shall conform to ANSI B1.20.1.

2. Malleable-Iron Threaded Fittings: ANSI B16.3, Class 150 and 300, standard pattern, for threaded joints. Threads shall conform to ANSI B.1.20.1.

3. Forged Steel Threaded Fittings: ANSI B16.11 forged steel; Class 2000 (Schedule 40).

4. Welded Steel Fittings:

a. Materials

1) ANSI B16.9 factory forged, seamless construction, butt weld type, chamfered ends; Schedule 40.
2) ANSI B16.11 socket weld type, Class 2000 (Schedule 40).
3) ASTM A 234, seamless or welded, for welded joints.

C. Where branch connections are two or more sizes smaller than main size, "weldolets," "threadolets," or "sockolets" are acceptable. Mitered elbows, "shaped" nipples, and job fabricated reductions not acceptable.

D. Fabricate custom bend angle fittings by removing material from standard butt weld type fittings at the appropriate angle and recreating the original weld configuration chamfer. Shop or site-weld weld/groove adapter nipples to custom angle fitting where applicable to create custom angle grooved mechanical fittings.

E. Unions: ANSI B16.39 malleable iron, Class 150, ground joint bronze to iron seat, for sizes 2 inch and smaller.

F. Flanges:

a. Cast Iron Threaded Flanges: ANSI B16.1 Class 125, raised face, boltholes spot faced.
b. Ductile Iron: ANSI B16.42; Class 150 and 300.
c. Steel Flanges: ANSI B16.5 Class 150, butt weld neck type, raised face, spot faced.

G. Gauge And Instrument Connections, Nipples and Plugs (for adapting gauges and instruments to piping system): IPS brass.

H. Copper Pipe Solder Fittings

1. Tees, Elbows, Reducers, Adapters: ANSI B16.22 streamlined pattern wrought copper or ANSI B16.18 cast bronze; solder end connections; ASTM B62.
2. Unions: 2 in. and smaller use unions, solder type, cast bronze, ground joint, Class 150.
3. Cast Bronze Flanges: 2-1/2 inch and over use ANSI B16.24 flanges, raised ground face, ASME drilled bolt holes spot faced, solder connection, Class 150.

I. Joining Materials

1. Solder For All Soldered Joints: Use solder conforming to ASTM B 32-95; alloy grades Sn96, Sn95, Sn94, E, AM, WS with maximum lead content of 0.1percent by weight, minimum solidus temperature of 430 deg. F, and approved for use with potable water. Higher lead content solder not acceptable.

2. Brazing Filler Metals: Select brazing filler metals compatible with piping to be joined:

   a. AWS A5.8 BCuP Series, copper-phosphorus alloys for joining copper with copper only.

   b. AWS A5.8 BAg series, cadmium free silver bearing alloys for joining dis-similar metals including copper with any brass, bronze, steel, or stainless steels, or other dis-similar brazeable materials.

3. Welding Filler Materials: Comply, with Section II, Part C. ASME Boiler and Pressure Vessel Code and AWS D10.12/D10.12M for welding materials appropriate for the wall thickness and chemical analysis of the pipe being welded.

4. Flanges:

   a. Gasket Materials:

      1) ASME/ANSI Standard (A21.11, B16.20, or B16.21), nonmetallic, flat, asbestos free, suitable for chemical, pressure, and thermal conditions of system.
      2) 1/8-inch maximum thickness unless thickness or specific material is indicated.
      3) Full or raised face pattern to fit flanges.

   b. Provide dielectric kit for flanges joining dis-similar piping materials.

   c. Manufacturer: "DURLON" as manufactured by Durabla Manufacturing Company, or equivalent.

2.2 STEAM PIPING SPECIALITIES

A. Flange Bolting Material

1. ASME B18.2.1, ASTM Specification A-107, carbon steel, electroplated, square bolt heads finished on the underside, semi- finished heavy pattern hexagonal nuts, US or SAE pattern grade 5 minimum washers.

B. Pipe Thread Compound

1. Crane, Dixon, Rutland or approved equal.
2. Use on metal threads only.
3. Do not use oil.

C. Dielectric Unions

1. Threaded or soldered end connections for the pipe materials in which installed.

2. Constructed to isolate dissimilar metals, prevent galvanic action, and prevent corrosion.

3. Manufacturer:

   a. Watts Regulator Co., or approved equal.

D. Dielectric Fittings

1. Electroplated steel or brass nipple, with an inert and non-corrosive, thermoplastic lining.

2. Manufacturer:

   a. Epco Sales, Inc., or approved equal.

E. Pipe sleeves

1. Schedule 40 galvanized, welded steel pipe, ASTM A53m Grade A, for sleeve 6" diameter and smaller.
2. Galvanized sheet metal, 10 gauge, round tube with welded longitudinal joint for sleeves larger than 6".

F. Traps

1. Capacities:

   a. Plans give normal operating condensing rate for each piece of equipment (MBH or EDR).
   b. Maximum pressure drop across trap not to exceed 1/2 psig at operating load.
   c. Determine maximum condensing rate by multiplying operating condensing rate by the following multiplier: 3.0.

2. Float and Thermostatic Traps:

   a. Body to be ASTM A 278, Class 30 cast iron body and bolted cap.
   b. Stainless steel float mechanism, with removable, hardened stainless steel head and seat.
   c. Balanced pressure thermostatic air vent made of stainless steel or monel bellows with stainless steel head and seat.
   d. Straight through pattern traps where necessary to gain extra headroom.
   e. Selected for low pressure service (0 to 15 psig).
   f. Manufacturer: Spirax Sarco or approved equal.

3. Thermostatic Traps:

   a. Body to be cast brass, angle pattern with integral union tailpiece and screw in cap.
   b. Balanced pressure stainless steel or monel diaphragm or bellows element, with removable hardened stainless steel valve head and seat.
   c. Selected for low pressure service (0 to 15 psig).
   d. Manufacturer: Spirax Sarco or approved equal.

G. Vacuum Breakers

1. Brass body, seat, stem, and cap. Maximum operating pressure rating to be 150 psig.
2. Stainless steel spring with adjustable settings (1/4 to 20 inches).
3. Manufacturer: Hoffman No. 62 or approved equal.

H. Air Vents

1. Quick Vents: Cast iron or brass body, with balanced pressure, stainless steel or monel thermostatic bellows and hardened stainless steel heads and seats. Use quick vents to eliminate air from steam mains if only steam and air are present.

   a. Design make: Spirax Sarco model T202, Hoffman #4, or approved equal.

2. Float Vents: Cast iron or brass body, seamless brass float, balanced pressure thermostatic bellows, and replaceable stainless steel seat, float, and head.

   a. Design make: Hoffman model 4-A or approved equal.

3. High Capacity Float Vents: Cast iron or brass body, seamless brass float, balanced pressure thermostatic bellows, and replaceable stainless steel seat, float, and head.

   a. Design make: Hoffman model 75 or approved equal.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which heating piping is to be installed and notify affected Contractors and Engineer in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in an acceptable manner.

1. When conditions are confirmed to be acceptable to ensure proper and timely installation and to ensure requirements for applicable warranty or guarantee can be satisfied, submit to Engineer written confirmation. Failure to submit written confirmation and subsequent installation will be assumed to indicate conditions are acceptable.

3.2 INSTALLATION

A. Steam Piping Installation: Drawings (plans, schematics, details, and diagrams) indicate the general location and arrangement of piping systems. However, they are not intended to show every required offset, fitting, or component required either to fit the intended space or to meet all requirements of this specification. Locations and arrangements of piping take into consideration piping sizing and friction loss, air and pressure control, thermal expansion, pump sizing, and other design considerations. Install piping as indicated as far as practical.

1. Use fittings for all changes in direction and all branch connections, unless otherwise specified.

2. Install piping close to slabs, beams, joints, columns, walls, and other permanent elements of the building. Provide space to permit insulation applications with 1-inch clearance outside the insulation. Allow sufficient space above removable ceiling panels to allow for panel removal.

3. Steam and condensate piping slopes:

a. Provide consistently sloped straight runs with no dips and partial traps.
b. 2-pipe system steam supply piping: ¼” in ten feet down in the direction of flow.
c. 2-pipe system condensate return piping: ¼” in ten feet down in the direction of flow.
d. 1-pipe system steam / condensate piping: ¼” per foot up away from boiler.

4. Make reduction in pipe size using eccentric reducer fittings installed with the level side at bottom of pipe.

5. Do Not:

a. Run within 6 inches of finished floors.
b. Run across windows without Engineer’s approval.
c. Run with less than head clearance without written approval of Engineer.
d. Use bent pipe, unnecessary joints, and short length.
e. Use reducing bushings, close nipples.
f. Use unnecessary unions or joints in concealed piping or allow air pockets to be left in line.
g. Spring or force pipe into position.
h. Use bull headed tees.
i. Use mitered bends or notched pipes.

B. Pipe Joint Construction: Cut all pipe ends square, ream ends of pipes and tubes, and remove burrs. Bevel plain ends of steel pipe. Remove scale, slag, dirt, and debris from both inside and outside of piping and fittings before assembly. Remake leaking joints using new materials.

1. Soldered Joints:

a. Cut tubing to exact lengths with a square cut. Properly ream end of tubing to remove all burrs. Clean surfaces of oils, grease, and oxidation and clean with fine sand cloth, cleaning pads, or special wire brush.

b. Apply thin film of solder flux to surfaces to be joined. Do not clean, flux and assemble joint more than 3 hours before soldering, and do not use acid core, paste type solder, or solder flux combinations.

c. Disassemble joints for inspection of solder penetration as directed.

d. Follow manufacturer's instructions for joining copper tubes and solder cup valves.

2. Brazed Joints: Comply with the procedures contained in AWS "Brazing Manual."

a. Remove stems, seats, and packing of valves and accessible internal parts at piping specialties before brazing.
b. Fill the pipe and fittings during brazing, with an inert gas (i.e. nitrogen or carbon dioxide) to prevent formation of scale.
c. Heat joints using oxyacetylene torch. Heat to proper and uniform temperature.

3. Threaded Joints: Conform to ANSI B1.20.1, tapered pipe threads for field cut threads. Join pipe fittings and valves as follows:

a. Note internal length of threads in fittings or valve ends and proximity of internal seat or wall to determine pipe threading and align threads at point of assembly. .

b. Apply appropriate tape or thread compound to the external pipe threads (except where dry seal threading is specified) and assemble joint “wrench-tight” with wrench on valve on the valve end where pipe is threaded.

c. Damaged Threads: Do not use pipe with corroded or damaged threads. Do not use portions of pipe where weld opens during cutting or threading operations.

4. Welded Joints: Comply with the requirements of ASME Code B31.9 - "Building Services Piping."

a. Use welded fittings, flanges, and V-butt welded joints and machine-chamfer all pipe ends.

b. Remove cutting beads and do not allow welding beads to form.

c. Do not use mitered bends. Make all changes in direction with long radius fittings, unless space restrictions prohibit long radius fittings.

d. Make all branch connection with tees, unless otherwise specified. Branches two or more pipe sizes smaller than main may be welded directly to mains using approved qualified procedure with either Weldolets or shaped nipples.

5. Flanged Joints: Aligned flanged surfaces parallel. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets flat and parallel. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly using torque wrench.

3.3 PIPING SPECIALTIES INSTALLATION

A. Install in accordance with manufacturer's recommendations and instructions.

B. Dielectric Unions:

1. Install at all connections of dissimilar metals, except where bronze or brass body fittings separate dissimilar piping. (Contractors option of using dielectric unions or fittings).

C. Dielectric Fittings:

1. Install at all connections of dissimilar metals, except where bronze or brass body fittings separate dissimilar piping. (Contractors option of using dielectric unions of fittings).

D. Pipe Sleeves:

1. Provide pipe sleeves for all piping penetrations of masonry walls and floors.

a. Provide light gauge sheet metal sleeves for all penetrations of masonry block partitions.

b. For existing construction, bore round holes 1/2" larger than pipe outside diameter for uninsulated piping, and 1/2" larger than insulation outside diameter for insulated piping. Sleeves are not required for bored holes except where required for waterproofing as specified above.

2. Caulk annular space between pipe and sleeve with Silicone Elastomer Compound (Dow Corning Fire Stop Sealant Catalog #2000) at all penetrations of fire rated walls and floors.

3. Do not cut reinforcing rods.

E. Mechanical Sleeve Seals:

1. Provide seals at all penetrations of exterior walls and at sleeves installed in wet areas (kitchens, toilet rooms, equipment rooms, etc).

F. Escutcheons:

1. Provide escutcheons for all piping penetrations of walls, floors and ceilings exposed to view.

G. Steam Traps:

1. Install steam traps in accessible locations as close as possible to connected equipment. Maximum allowable distance from equipment is 4 feet.
2. Install float and thermostatic traps for all coils tempering outdoor air, unit heaters, heat exchangers, and drip traps.
3. Install thermostatic traps for radiation and convectors.

H. Vacuum Breakers:

1. Install in piping between automatic control valve and steam trap where noted on Drawings.

I. Air Vents:

1. Install air vents in accessible but concealed locations as close as possible to connected equipment. Install where shown on drawings and as required to insure rapid and consistent venting of air from steam lines on start-up.

2. Provide high capacity venting at end of mains, and normal capacity vents for runnouts unless otherwise shown.

J. Drip Pan Elbows:

1. Provide piping from safety relief valves full size to drip pan elbow, as short as practical.

2. Provide steel condensate piping from drip pan elbow drain to 6 inches above nearest floor drain, full size of drip pan elbow drain outlet.

3. Provide steel steam piping from drip pan elbow main outlet, sized to fit over drip pan elbow outlet, up as straight as possible to approximately 12 inches below support structure. Terminate in horizontal bull headed tee with straight run pipe size one size larger than riser and side outlet down connected to riser. Support weight of discharge and drain piping separately from valve and rigidly restrain free end of drain near floor.

K. Self-Contained Thermostatic Control Valves:

1. Install self-contained thermostatic control valves at each convector or section of fin tube radiation in spaces with no thermostat or temperature sensor called for or indicated on the Drawings.

3.4 FIELD QUALITY CONTROL

A. Testing Preparation

1. Steam and Condensate Piping: Comply with ASME B31.9 and as follows:

   a. Leave all joints un-insulated and exposed for examination during test.

   b. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restrainers are not practical, isolate expansion joints from testing.

   c. Flush system with clean water. Clean strainer.

   d. Isolate equipment not subjected to test pressure from piping. If valve is used to isolate equipment, provide closure capable of sealing against test pressure without damage to valve. Testing not required on flanged joints where blinds are inserted to isolate equipment.

   e. Install relief valve set at pressure no more than 1/3 higher than test pressure to protect against damage by expansion of liquid or other source of overpressure during test.

B. Testing: Test piping and accessories before insulation, connection to existing piping, or concealment. Repeat as many times as necessary to prove tight system. Notify Owner's Representative and Engineer at least seven days in advance of each test. Isolate valves and equipment not capable of withstanding test pressures. Make systems leak free; no caulking permitted. Remove and replace defective fittings, pipe or connections. Furnish necessary pumps, gauges, equipment, piping, valving, power, and labor for testing. Certify that tests have been successfully completed.

C. Schedule of Test Requirements:

1. Steam and Condensate Systems: Perform hydrostatic test at 100 psig at high point of system; two hours duration with no change in pressure under stable temperature conditions. Verify that entire system(s) are leak free without drips or weeps.

2. Equipment: Test at working pressures.

3.5 SCHEDULE OF APPLICATIONS

A. Piping types and joint styles may be mixed within a system within the scope of the requirements of this Section.

B. Steel steam supply pipe shall be schedule 40 or schedule 80. Condensate return pipe, including low wet condensate return, shall be schedule 80.

C. Steel pipe with threaded joints and fittings: Above ground, within building, for sizes 2" and smaller. Steel steam and condensate pipe with threaded joints shall be schedule 80.

D. Steel pipe with welded joints and fittings: Above or below ground, within building or exterior, any size. Welded steam pipe may be schedule 40.

E. Steel pipe with cut or rolled grooved ends and mechanical couplings and fittings are not approved for use on steam or steam condensate piping systems.

F. Type L hard temper drawn copper tubing with wrought copper fittings and brazed joints: for 2” and smaller steam and steam condensate, above ground, within building.

G. Type L hard temper drawn copper tubing with wrought copper fittings and soldered joints: for 2” and smaller pressurized pumped condensate services, above ground, within building.

END OF SECTION 23 22 13

SECTION 23 29 00 – VARIABLE FREQUENCY MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes separately enclosed, pre-assembled, combination VFCs (variously referred to as VFC, ASD, VSD, or VFD), rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

1. "General Purpose" VFC for use with motors > 1HP (unless scheduled otherwise).

1.3 DEFINITIONS

A. ASD: Adjustable Speed Drive, same as VFC.
B. BAS: Building automation system.
C. CPT: Control power transformer.
D. EMI: Electromagnetic interference.
E. EMC: Electromagnetic Compliance.
F. IGBT: Insulated-gate bipolar transistor.
G. LAN: Local area network.
H. LED: Light-emitting diode.
I. MCP: Motor-circuit protector.
J. NC: Normally closed.
K. NO: Normally open.
L. OCPD: Overcurrent protective device.
M. Output: Variable frequency output power and wiring between the VFC and the load (motor).
N. PCC: Point of common coupling.
O. PID: Control action, proportional plus integral plus derivative.
P. Power: source electrical power input wiring to the VFC.
Q. PWM: Pulse-width modulated.
R. RFI: Radio-frequency interference.
S. Signal: Remote generated electrical signal causing controlled variation in VFC output.
T. TDD: Total demand (harmonic current) distortion.
U. THD(V): Total harmonic voltage demand.
V. VFC: Variable-frequency motor controller.
W. VFD: Variable Frequency Drive, same as VFC.
X. VSD: Variable Speed Drive, same as VFC.

1.4 PERFORMANCE REQUIREMENTS

A. Design and Performance Requirements

1. Designed to convert 60 Hz input power to adjustable frequency output power with constant and/or variable volts/Hz ratio output power. Output frequency and drive voltage adjustable determined by design parameters of driven motor.

2. Capable of operating any standard squirrel cage induction motor with load rating within capacity of adjustable speed drive. Allows substitution of standard motor in field without requiring modification of adjustable speed drive.

3. Designed and manufactured in accordance with applicable current NEMA and IEEE recommendations and designed for installation per NEC. Includes equipment with UL and CSA approval as applicable.

4. Suitable for installation in altitudes up to 3300 ft with ambient temperature range from 32 deg F to 104 deg F.

5. Designed with dedicated variable torque design for specified use with centrifugal loads.

6. “General Purpose” Drive includes all of above features plus:

a. Suitable to serve as starter and disconnect.

b. Designed with surface-mount construction regulator circuits.

c. Provided with UL-listed electrical components in basic ASD, including but not limited to contactors, overload relays, pushbuttons, pilot devices, and other control devices.

1.5 SUBMITTALS

A. Procedural Requirements: Comply with requirements of Section 01 33 00 - Submittals and as modified below.

B. Product Data: For each type and rating of VFC indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories. Include output cabling.

C. Shop Drawings: For each VFC indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.

1. Show tabulations of installed devices, equipment features, and ratings. Include the following:

a. Each installed unit's type and details.
b. Factory-installed devices.
c. Enclosure types and details.
d. Nameplate legends.

e. Short-circuit current (withstand) rating of enclosed unit.
f. Features, characteristics, ratings, and factory settings of each VFC and installed devices.
g. Specified modifications.

2. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

A. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification and IEEE519 Guidelines for both Current and Voltage Distortion in a distribution system; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC to specified levels. Include measurements taken on the line side of the main distribution transformer coordinated with local electrical utility, or if not possible from the load or low voltage side of that same transformer.

B. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

C. Qualification Data: For qualified testing agency.

D. Product Certificates: For each VFC, from manufacturer.

E. Source quality-control reports.

1.7 CLOSEOUT SUBMITTALS

A. Field quality-control reports.

B. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Manufacturer's written instructions for setting field-adjustable overload relays.
3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

C. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.

D. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NFPA 70.

1.9 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Furnish all equipment in cartons and within shrink-wrapped plastic to Project in ample time for installation. Properly tag and identify equipment furnished.

B. Storage and Protection: Store all equipment between delivery and installation in secure location that is dry, permanently enclosed, heated, and air conditioned as required to eliminate any condensation, moisture, heat or cold related damage.

1.10 PROJECT CONDITIONS

A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions unless otherwise indicated:

1. Ambient Temperature: Not less than 14 deg Fand not exceeding 104 deg F.
2. Ambient Storage Temperature: Not less than minus 4 deg Fand not exceeding 140 deg F
3. Humidity: Less than 95 percent (noncondensing).
4. Altitude: Not exceeding 3300 feet.

B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Construction Manager and Owner no fewer than seven days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary electrical service.
3. Do not proceed with interruption of electrical systems without Construction Manager's and Owner's written permission.
4. Comply with NFPA 70E.

C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.

1.11 COORDINATION

A. Coordinate features of motors, load characteristics, installed units, and accessory devices to be compatible with the following:

1. Torque, speed, horsepower, overall power, and other electrical requirements of the load.
2. Ratings and characteristics of supply circuit and required control sequence.
3. Distance of VFC from load and conditions of signal cable installation.
4. Ambient and environmental conditions of installation location.

1.12 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Two years from date of Substantial Completion.

1.13 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. ABB.
2. AC Technology International Ltd (AC Tech); part of the Lenze Group.
3. Square D; a brand of Schneider Electric.
4. Yaskawa America, Inc; Drives Division.

B. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.

C. Application: Variable torque.

D. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."

2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."

3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

E. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

F. Output Rating: Three-phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage.

G. Unit Operating Requirements:

1. Input AC Voltage Tolerance: Plus 10 and minus 15 percent of VFC input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding 3 percent.
3. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
4. Minimum Efficiency: 97 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 96 percent under any load or speed condition.
6. Minimum Short-Circuit Current (Withstand) Rating: 42 kA.
7. Ambient Temperature Rating: Not less than 14 deg Fand not exceeding 104 deg F.
8. Ambient Storage Temperature Rating: Not less than minus 4 deg Fand not exceeding 140 deg F.
9. Humidity Rating: Less than 95 percent (noncondensing).
10. Altitude Rating: Not exceeding 3300 feet.
11. Vibration Withstand: Comply with IEC 60068-2-6.
12. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
13. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
14. Speed Regulation: Plus or minus 5 percent.
15. Output Carrier Frequency: Selectable; 0.5 to 12 minimum kHz.
16. Minimum 0.14µs Dt rise time or other improved technology which limits transient voltage spikes; such as soft switching.
17. Stop Modes: Programmable; includes fast, free-wheel, high slip and dc injection braking.

H. Inverter Logic: Microprocessor based, 32 bit, isolated from all power circuits.

I. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

J. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to 999.9 seconds.
4. Deceleration: 0.1 to 999.9 seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.

K. Self-Protection and Reliability Features:

1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.

2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.

3. Under- and overvoltage trips.

4. Inverter overcurrent trips.

5. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.

6. Critical frequency rejection, with three selectable, adjustable deadbands.

7. Instantaneous line-to-line and line-to-ground overcurrent trips.

8. Loss-of-phase protection.

9. Reverse-phase protection.

10. Short-circuit protection.

11. Motor overtemperature fault.

L. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

M. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

N. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

O. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

P. Integral Input Disconnecting Means and OCPD: NEMA AB 1, instantaneous-trip circuit breaker with pad-lockable, door-mounted handle mechanism.

1. Disconnect Rating: Not less than 115 percent of VFC input current rating.
2. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.
3. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
4. NC alarm contact that operates only when circuit breaker has tripped.

2.2 CONTROLS AND INDICATION

A. All “General Purpose” drives:

1. Adjustments accessible from a keypad integral to VSD.

2. Auto/Manual, Start/Stop, and speed selection accessible on the front of the controller.

3. Power-on, run and trip monitor indications displayed by backlit LCD on the front of the controller.

4. Linear timed acceleration and deceleration, individually adjustable with 0.1 - 600 seconds range.

5. Minimum 40:1 controlled speed range.

6. Minimum 0.1-120 Hz output frequency range.

7. Adjustable Volts/Hz ratio with both factory preset and custom tunable options. Voltage boost adjustable in addition to V/Hz ratio.

8. Controller capable of restarting with the motor coasting in either forward or reverse direction without tripping.

9. Minimum Hertz (0-50 percent), maximum Hertz (50-100 percent).

10. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status, alarms, and energy usage. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.

    a. Network Communications Ports: Ethernet and RS-422/485.
    b. Embedded BAS Protocols for Network Communications: ASHRAE 135 BACnet and/or Echelon LonWorks; protocols accessible via the communications ports.

11. Status Lights: Door-mounted LED indicators displaying the following conditions:

    a. Power on.
    b. Run.
    c. Overvoltage.
    d. Line fault.
    e. Overcurrent.
    f. External fault.

12. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

    a. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.

    b. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

        1) Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.

13. Historical Logging Information and Displays:

    a. Real-time clock with current time and date.
    b. Running log of total power versus time.
    c. Total run time.
    d. Fault log, maintaining last four faults with time and date stamp for each.

14. Indicating Devices: Digital display mounted flush in VFC door and connected to display VFC parameters including, but not limited to:

    a. Output frequency (Hz).
    b. Motor speed (rpm).
    c. Motor status (running, stop, fault).
    d. Motor current (amperes).
    e. Motor torque (percent).
    f. Fault or alarming status (code).
    g. PID feedback signal (percent).
    h. DC-link voltage (V dc).
    i. Set point frequency (Hz).
    j. Motor output voltage (V ac).

15. Control Signal Interfaces:

    a. Electric Input Signal Interface:

        1) A minimum of 2 programmable analog inputs: 0- to 10-V dc and 4- to 20-mA dc.
        2) A minimum of six multifunction programmable digital inputs.

    b. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:

        1) 0- to 10-V dc.
        2) 4- to 20-mA dc.
        3) Potentiometer using up/down digital inputs.
        4) Fixed frequencies using digital inputs.

c. Output Signal Interface: A minimum of 2 programmable analog output signal(s) (0- to 10-V dc or 4- to 20-mA dc), which can be configured for any of the following:

1) Output frequency (Hz).
2) Output current (load).
3) DC-link voltage (V dc).
4) Motor torque (percent).
5) Motor speed (rpm).
6) Set point frequency (Hz).

d. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

1) Motor running.
2) Set point speed reached.
3) Fault and warning indication (overtemperature or overcurrent).
4) PID high- or low-speed limits reached.

16. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms and energy usage. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.

a. Network Communications Ports: Ethernet and RS-422/485.
b. Embedded BAS Protocols for Network Communications: ASHRAE 135 BACnet and/or Echelon LonWorks; protocols accessible via the communications ports.

2.3 LINE CONDITIONING AND FILTERING

A. Input Line Conditioning: Provide 5% input impedance between the line and the drive. Impedance can be either through dual DC bus reactors, AC line reactor, or a combination of the two.

B. Output Filtering: For lead lengths over 50 feet, provide 5 percent AC load reactor between the drive and the load.

C. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

2.4 PROTECTION

A. All "General Purpose" drives:

1. Lockable enclosure containing drive, line reactor, and fused exterior disconnect protecting all components. Enclosure large enough to facilitate ease of service, and configured to fit in available mounting location.

2. Includes capability of riding though power dips up to 2 seconds without a controller trip depending on load and operating condition. During ride through, drive uses energy generated by the rotating load as a power source for all electronic circuits.

3. Instantaneous electronic trip when the current demands of the invertor exceed its intermittent rating, 300 percent maximum.

4. Electronic overload circuit to protect AC motors operated by the VSD output from extended overload operation on an inverse time basis UL and NEC recognized as motor protection.

5. Enclosure, fuses, circuit breakers, and contactors as required allowing use as motor protection per strictest of regulatory requirements having jurisdiction.

6. Minimum 75 percent input line under voltage trip; average 120 percent over voltage.

7. Line-to-line and line-to-ground short circuit protection.

8. Lockable exterior disconnect.

9. Internal disconnect to isolate the drive for service when in bypass operation.

10. Includes capability of riding though power dips up to 10 seconds without a controller trip depending on load and operating condition. During ride through, drive uses energy generated by the rotating load as a power source for all electronic circuits.

11. Minimum 42,000 RMS AISC fault withstand capability.

12. Electronic trip when the current demands of the inverter exceed its intermittent rating for 3 seconds, 150 percent maximum.

13. Electronic overload circuit to protect AC motors operated by the VSD output from extended overload operation on an inverse time basis UL and NEC recognized as motor protection.

14. Fuses, circuit breakers, and contactors as required allowing use as motor protection per strictest of regulatory requirements having jurisdiction.

15. Minimum 80 percent input line under voltage trip; average 110 percent over voltage.

16. Line-to-line and line-to-ground short circuit protection.

17. Input 3-phase AC line reactor (DC link not acceptable).

2.5 ADDITIONAL FEATURES

A. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
B. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
C. Remote digital operator kit.

D. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

2.6 ENCLOSURES

A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Indoor Locations: Type 12.
2. Exterior Locations: Type 3r.

2.7 ACCESSORIES

A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VSD enclosure cover unless otherwise indicated. Pilot Lights: LED types; colors as required; push to test.

B. Reversible NC/NO bypass contactor auxiliary contact(s).

C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.

D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

E. Supplemental Digital Meters:

1. Elapsed-time meter.
2. Kilowatt meter.
3. Kilowatt-hour meter.

F. Cooling Fan and Exhaust System: As required for NEMA 250, Type 12; UL 508 component recognized: Supply fan, with composite or stainless steel intake and exhaust grills and filters; 120 -V ac; obtained from integral CPT.

G. Output Cable: Provide sufficient special purpose VFC output cable for all power wiring between all VFCs and their respective loads, sized per the stricter of NEC, drive and motor manufacturer's recommendations, or as shown on drawings.

1. Comply with NEMA WC 70/ICEA S-95-658 for metal-clad cable, Type MC with ground wire.

2. VFC Cable: Type TC-ER low-capacitance shielded VFC cabling with oversized crosslinked polyethylene insulation over tin-coated high strand count conductors, spiral-wrapped foil plus full coverage braided shields in direct contact with symmetrical ground conductors (one per power conductor), and sunlight- and oil-resistant outer PVC jacket.

3. Capacitance value core to core less than 75pF/m, core to shield less than 150pF/m.

4. Basis of design: Amercable TC-ER VFD cable, or equal by Beldon or Carol.

2.8 SOURCE QUALITY CONTROL

A. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.

   1. Test each VFC while connected to a motor that is comparable to that for which the VFC is rated.
   2. Verification of Performance: Rate VFCs according to operation of functions and features specified.

B. VFCs will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance.
B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
D. Proceed with installation only after unsatisfactory conditions have been corrected.
E. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 INSTALLATION

A. Coordinate layout and installation of VFCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required access, workspace clearances, and required clearances for equipment access doors and panels. Install VFCs in an upright position.

B. Install VFCs including all transformers, line reactors, bypass enclosures and other accessories, on walls or equipment racks level, upright, with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall or floor. For controllers not on walls, provide freestanding racks complying with Division 26 Section "Hangers and Supports for Electrical Systems."

C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

D. Comply with NECA 1.

3.3 CONTROL AND POWER WIRING INSTALLATION

A. Install wiring between VFCs and remote devices and facility's central-control system. Comply with requirements in Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

B. Bundle, train, and support line, load, and control wiring in separate enclosures.

C. Install output cabling in strict accordance with manufacturers' recommendations. Provide for strain relief and cabling protection from damage. Verify cable length prior to installation and provide output line reactor if length exceeds that specified.

D. Connect selector switches and other automatic control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic control devices that have no safety functions when switches are in manual-control position.

2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.4 IDENTIFICATION

A. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Division 23 Section "Identification for HVAC Systems."

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFC with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.5 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

C. Perform Tests and Inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Acceptance Testing Preparation:

1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

E. Tests and Inspections:

1. Inspect VFC, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.

2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.

3. Test continuity of each circuit.

4. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Construction Manager before starting the motor(s).

5. Test each motor for proper phase rotation.

6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:

   a. Initial Infrared Scanning: After Substantial Completion, but before Final Completion and Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.

   b. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

   c. Re-tighten all connections as required.

   d. Generate report for inclusion in close-out documentation including color thermography printouts showing acceptable results.

   e. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Substantial Completion.

9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

F. VFCs will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

A. Provide services of a manufacturer's factory –authorized service representative to inspect complete installation, start and adjust each drive, and train the Owner in drive operation, maintenance, and adjustment.

B. Coordinate services of adjustable speed drive factory –authorized service representative, TAB Agency, and Controls Technicians to insure proper coordinated operation and system control.

C. Complete additional installation and startup checks according to manufacturer's written instructions.

D. Submit letter from manufacturer's factory –authorized service representative attesting to the satisfactory completion of installation and startup, with attached start-up / calibration forms for each drive with all appropriate adjustment settings itemized.

3.7 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Fully adjust each adjustable speed drive including maximum and minimum speeds, rates of speed change, calibration, testing, and as otherwise required to meet the operational intent and all control sequences.

D. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify Architect and Construction Manager before increasing settings.

E. Set the taps on reduced-voltage autotransformer controllers.

F. Set field-adjustable circuit-breaker trip ranges as specified in Division 26.

3.8 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.9 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

1. Submit letter from factory-authorized service representative attesting to the satisfactory completion of Owner’s training, signed by Owner’s representatives.

END OF SECTION 23 29 00

SECTION 23 31 00 - DUCTWORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Sheet metal duct materials and construction.
2. Sheet metal duct fittings materials and construction.
3. Flexible duct and connectors.
4. Ductwork ancillary components materials and construction.

B. Related Sections

1. Section 23 05 29 – Hangers and Supports for HVAC Components.
2. Section 23 05 43 – Mechanical Vibration and Movement Control.
3. Section 23 07 00 – HVAC Insulation.
4. Section 23 33 00 – Air Duct Accessories.
5. Section 23 37 00 – Air Outlets and Inlets.
6. Division 23 Sections covering fans and air handling equipment.

1.3 DEFINITIONS

A. Aspect Ratio: The ratio of duct width to height.

B. Hydraulic Radius: The ratio of duct cross section area to perimeter, or practically, a term used to define flow resistance of duct with differing aspect ratios, with resistance to flow being approximately proportional to hydraulic radius.

C. NRC: Noise Reduction Criteria.

D. Offset: A change in the duct centerline location but not direction occurring within one piece of duct.

E. RGD: Registers, Grilles, and/or Diffusers.

F. STC: Sound Transmission Class.

1.4 PERFORMANCE REQUIREMENTS

A. Provide duct system able to withstand the loads and stresses described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and these contract documents.

B. Fabricate outdoor duct and casings to withstand wind load and snow load indicated on Structural series drawings and specifications. Calculate the snow load as a negative pressure on the top duct surface.

C. Fabricate ductwork able to withstand the forces imposed by the support and restraint system.

1.5 SUBMITTALS

A. Comply with requirements of Section 01 33 00 - Submittals and as modified below.

B. Identify in writing, any proposed deviations from contract Drawings and Specifications.

1. Highlight all changes from plans required by obstructions and job conditions.

2. Bring any proposed deviations from contract plans and specifications to Architect's attention in writing, by separate letter attached to submittal with proposed deviations, along with samples for clarification, demonstrating benefit to Owner.

C. Product Data: Submit for approval annotated Shop Construction Standards showing upgrades as required for conformance in detail to specifications for all factory and shop fabricated air ducts, components, and accessories.

1.6 CLOSEOUT SUBMITTALS

A. Contract Closeout Submittals: Comply with requirements of Section 01 77 00 – Closeout Procedures, including submission of operating and maintenance instructions as item in "Operating and Maintenance Data" manual described in that section.

B. Field quality-control reports – duct leakage, duct cleanliness.

1.7 QUALITY ASSURANCE

A. Provide ductwork by experienced and approved workers specializing in sheet metal fabrication and installation in accordance with the stricter of the below referenced standards and the requirements outlined in these contract documents.

B. Referenced Standards

1. The latest editions of the publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

2. American Society of Civil Engineers (ASCE):

a. ASCE7 Minimum Design Loads for Buildings and Other Structures.

3. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

   a. ASHRAE / ANSI 62.1 – Ventilation for Acceptable Indoor Air Quality.
   b. ASHRAE / ANSI 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings.

4. American Welding Society (AWS)

   a. AWS D1.1, "Structural Welding Code - Steel," for hangers and supports.
   b. AWS D1.2, "Structural Welding Code - Aluminum," for aluminum supports.
   c. AWS D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

5. American Society for Testing and Materials (ASTM)

   a. A167 99 Standard Specification for Stainless and Heat Resisting Chromium Nickel Steel Plate, Sheet, and Strip.

   b. A653-09 Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy coated (Galvannealed) by the Hot-Dip process.

   c. A1011-09a Standard Specification for Steel, Sheet and Strip, Hot rolled, Carbon, structural, High-Strength Low-Alloy, High Strength Low-Alloy with Improved Formability, and Ultra-High Strength.

   d. B209 07 Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate.

   e. C1071-05e1 Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).

   f. D6386 Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting.

   g. D7803 Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Powder Coating.

   h. E84-09a Standard Test Method for Surface Burning Characteristics of Building Materials.

6. National Air Duct Cleaners Association (NADCA)

   a. ACR "Assessment, Cleaning and Restoration of HVAC Systems," for duct cleanliness standards.

7. National Fire Protection Association (NFPA)

   a. 90A Standard for the Installation of Air Conditioning and Ventilating Systems.

8. Sheet Metal and Air Conditioning Contractors National Association (SMACNA)

   a. HVAC Duct Construction Standards, Metal and Flexible.

b. HVAC Air Duct Leakage Test Manual.

9. Underwriters Laboratories, Inc. (UL)

a. 181 Factory Made Air Ducts and Air Connectors.
b. 555 Standard for Fire Dampers.
c. 555S Standard for Smoke Dampers.

PART 2 - PRODUCTS

2.1 DUCT MATERIALS

A. General Material Requirements:

1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated.

2. Provide sheet metals per mill specs and free of pits, voids, seam or roller marks, stains, discolorations, inadvertent bends and kinks, and other imperfections.

B. Standard Supply, Return and Exhaust: Galvanized steel, ASTM A-653/653M G90, lock forming quality, unless otherwise specified.

C. Standard Supply, Return and Exhaust duct which will be exposed to view in the finished project and will not be externally insulated or painted: Galvannealed steel, ASTM A-653/653M G90, lock forming quality, unless otherwise noted.

D. Standard Supply, Return and Exhaust duct which will be exposed to view in the finished project and will be painted: Galvannealed steel, ASTM A-653/653M G90, lock forming quality, prepared for painting via mill phosphatizing and subsequent heat treatment in accordance with ASTM D6386 and ASTM D7803 as applicable, unless otherwise noted.

E. Coatings:

1. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

a. Galvanized Coating Designation: G90.

b. Minimum Thickness for Factory-Applied PVC Coating: 4 mils thick on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil thick on opposite surface.

c. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

F. Flexible Ducts:

1. Flexible Duct (standard ventilation air register, grille, and diffuser connections where noted on Drawings. Maximum installed length to be 5’-0”): Medium pressure CPE or polymeric coated woven fiberglass cloth liner, enclosed spring steel wire, R-6 fiberglass insulation covered by metalized polyester film bi-directionally reinforced vapor barrier. Similar to types S-TL (uninsulated for field insulation), M-KE, or M-KC, with FlexFlow elbow supports, all by Thermaflex (design make).

G. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials, and use stainless steel fasteners.

2.2 RECTANGULAR DUCTS AND FITTINGS

A. Conform to appropriate SMACNA rectangular duct reinforcement tables and figures for the velocity-pressure classification duct construction required as defined in part three of this document, and additionally as follows.

1. Seal all joints and seams in accordance with SMACNA seal classification required for duct in question.

a. Additionally, seal field assembled longitudinal seams for seal class B duct.

2. Transverse Joints: in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure for "Rectangular Duct/Transverse Joints."

a. For all duct requiring reinforcement, provide SMACNA T-24 or T-25 type flanged duct connection system at traverse joints.

1) Joints may be factory manufactured slip on type or integrally shop fabricated onto the duct sheet metal on machinery designed for that purpose. Corner closure pieces are required at each corner.

2) Manufacturers: Subject to compliance with requirements, available manufacturers offering pre-manufactured slip on reinforcement products that may be incorporated into the Work include, but are not limited to, the following:

a) Ductmate Industries, Inc, or equal.
b) Lockformer TDC or equal.
c) Nexus PDQ type G or J or equal.

3. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

4. Tie rods are not permitted on duct or plenums narrower than 72". Where an option for tie rod or heavier gauge sheet metal / shorter joint length / higher category reinforcement is presented in table, the heavier, shorter, more reinforced duct with no tie rods is required.

B. Offsets:

1. Where offset dimension is equal to or less than 0.2 times duct dimension in plane of offset, offset may be angled at maximum 15 degrees (SMACNA type 1).

2. Where offset dimension is greater than 0.2 times duct dimension in plane of offset (example: 10 x 20 duct offset in plane of 10" dimension greater than 2 inches), offset to consist of paired curved elbows, each of the required angle, combined into one fitting (SMACNA type 3).

   a. Conform to elbow requirements as indicated below.
   b. Offset may be replaced with paired curved elbows if required for installation, otherwise provide combined fitting.

C. Transitions of Shape or Cross Section:

1. Reductions in cross section shall have a maximum included cone angle of 60 deg., with a maximum single side angle of 45 deg. from axial, unless otherwise specified in writing.

2. Transformations of section without a net reduction of cross section shall have no section of reduced hydraulic radius nor any local expansion of more than 15 deg. net included cone angle, as defined by ASHRAE and SMACNA.

3. Expansion sections, unless specifically drawn and noted otherwise, shall have:

   a. No section of reduced hydraulic radius
   b. No section of local expansion of more than 15 deg. net included cone angle.
   c. No single side expansion angle of more than 15 deg. from axial unless otherwise specified in writing.

D. Elbows:

1. Make all changes in direction (as opposed to offsets above where direction remains the same) regardless of angle with elbow fittings unless specifically drawn and noted otherwise.

2. Curved Rectangular Elbows:

   a. Along critical pressure drop paths, provide curved rectangular elbows.

1) Critical pressure drop paths shall be as indicated on drawings or if not indicated shall be considered to be entire duct run from air handling unit along mains to or from furthest terminal. Systems with more than one main branch shall be considered to have more than one critical pressure drop path.

2) Provide critical path elbows with throat radius not less than dimension of duct in plane of radius or use smaller inner radius elbows with splitter vanes such that the ratio of inner to outer radius of curvature of any section of the elbow shall not be less than 1/2.

b. Along non-critical pressure drop paths, curved rectangular elbow radius requirements may be relaxed to a throat radius not less than one half the dimension of the duct in plane of radius or use smaller inner radius with splitter vanes such that the ratio of inner to outer radius of curvature of any section of the elbow shall not be less than 1/3.

c. Construct all curved elbows of increasing or decreasing cross section in accordance with critical pressure drop path criteria.

d. Fabricate splitter vanes per SMACNA Duct Manual construction standards.

3. Mitered Rectangular Elbows

a. Only elbows not along critical pressure drop path may be of curved or mitered construction.
b. Mitered rectangular elbows with angle of bend under 15 deg. may have miter at duct end similar to SMACNA type 1 offset.
c. Provide turning vanes in mitered rectangular elbows with angle of bend over 15 degrees.
d. Mitered elbows with angle of bend over 100 deg. or less than 80 deg. shall not use commercially available 90 deg. turning vanes.

4. Double Wall Turning Vanes

a. Provide for mitered rectangular elbows of equal inlet and outlet or increasing cross section.

b. Blades of hollow double wall construction, with smaller radius sheet metal form nested outside larger radius form, tapering down gradually to and welded at double thickness edge, designed for specific spacing and alignment to minimize separation of flow and pressure drop through air duct elbows.

c. Properly spaced to result in constant cross-section area between blades: smaller radius blades to have closer spacing.

d. Maximum spacing 3 inch, unless otherwise approved.

e. Acoustical type where called for or where installed in acoustically lined ductwork.

f. Provide products by one of the following:

1) Titus or equal.
2) Elgen or equal.
3) Hardcast or equal.

5. Single Wall Turning Vanes

a. Provide in mitered rectangular elbows of increasing or decreasing cross section and those with a turning angle greater than 100 degrees or less than 80 degrees.

b. Blades of single wall 16 gauge construction with leading and trailing edges aligned to the direction of flow, installed per SMACNA Duct Manual standards so as to provide smooth area transition. Maximum spacing 3 inch, unless otherwise approved.

E. Duct Branches:

1. Install branches, inlets, and outlets so that air turbulence is reduced to a minimum and air volume properly apportioned. Install airflow adjustment devices at all junctions to permit adjustment of the amount of air entering or leaving the branch.

2. Where a duct branch is to handle more than 25 percent of the air handled by the duct main, use a complete elbow as specified, assembled into a single fitting with the main duct. Size the separate branch and remaining main as shown on the drawings, and partition the division of the combined duct such that each of the branch and main have the same velocity, with cross sectional area proportional to the respective airflow. Join the leading / trailing edge where the branch and main meet airtight via welding or brazing.

3. Where a duct branch is to handle less than 25 percent of the air handled by the duct main, construct the branch connection with a 45 degree side take-off with volume damper in branch line close to takeoff. Round branches off of rectangular main, use 45 deg. entry takeoff with integral transition to round.

a. Supply: increase duct dimension on upstream side of branch by 25 percent, minimum 4 inch.
b. Return: increase duct dimension on downstream side of branch by 25 percent, minimum 4 inch.
c. Multiple flow direction takeoffs: provide twin entries or bell mouths.

4. Where an air-diffusion device is shown as being installed in close proximity to (less than one main duct width) the side, top, or bottom of a duct, provide a commercially manufactured vaned volume extractor fitting to allow adjustment of the air quantity and to provide an even flow of air across the device it services.

F. Duct Entries:

1. Wherever air does not enter the duct system from grilles, registers, or louvers, but instead enters directly from an enclosed or exposed plenum space, provide a duct entry transition with a minimum area ratio of inlet to nominal duct size of 2:1 unless otherwise specifically shown and noted.

2. Duct entry may be angled (pyramidal or conical) or with bell-mouth radius.

   a. Provide angled duct entries with a maximum single side angle to axial of 30 deg. Any combination of sides, top, and bottom may be angled (or conical for round duct) to suit space restrictions, but maintain the specified area ratio.

   b. Provide bell-mouthed entries with radius as required maintaining the specified area ratio.

3. Provide entry grille or if not shown, provide at minimum 1/2 inch welded wire mesh (WWM) secured over the large side of the opening of all duct entries.

2.3 ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   a. Spiral lock-seam duct, joints, and fittings:

      1) Lindab Inc.
      2) McGill AirFlow LLC.
      3) SEMCO Incorporated.
      4) Sheet Metal Connectors, Inc.
      5) Spiral Manufacturing Co., Inc.

   b. Longitudinal fusion-welded duct, joints, and fittings as described in appropriate SMACNA manuals and herein – shop fabricated.

   c. 26 ga. G-60 longitudinal snap-lock construction duct, joints, and fittings.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," and as follows:

1. Spiral lock seam duct:

   a. Machine locked spiral seams with or without formed standing reinforcement ribs.
   b. Leakage through the duct wall and joints certified no greater than design make.
   c. Provide minimum 12 ft. long un-joined lengths, except where interrupted by fittings.

2. Longitudinal seam duct shall have fusion-welded butt seams.

   a. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
   b. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

3. Snap-lock Seam Duct:

   a. Limit snap-lock construction components and systems to concealed round duct run-outs to individual diffusers, registers, and grilles, in sizes 12 inch and under, with all transverse and longitudinal seams sealed.

   b. Longitudinal seams field assembled by interlocking machine formed sprung tabs, with sealant brushed on before and after assembly.

   c. Provide minimum 10 ft. long un-joined lengths, except where interrupted by fittings or shorter lengths are required to work through existing structure.

D. Transverse Joints - Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," and as follows:

1. 24 in. diameter and less: slip fit collars or sleeve couplings, reinforced by rolled beads, insertion length 2 inch. Secure with hexagon head drill point screws or other approved mechanical fasteners 6 inch o.c. max and duct sealant.

2. Over 24 inch to 42 inch diameter, general, concealed joints: Provide roll formed, welded angle ring flanges similar to SMACNA T-24 or T-25 configuration. Attach flange to duct with internal stitch or button welds 6 inch o.c. max and duct sealant. Size angle ring gauges per SMACNA recommendations. Secure with #10 “Tec” screws 6 inch o.c. maximum, seal with closed cell gasket.

3. Exposed over 24 inch diameter, all over 42 inch diameter: two piece angle ring flanges, loose fit outer ring in a "Van Stone" configuration. Provide a 5/8 inch flange inner ring as a gasketing surface for sealing, integrally rolled or attached to the pipe with internal button or stitch welds 6 inch o.c. max and duct sealant. Provide outer rolled, welded angle ring sized per SMACNA recommendations. Secure with bolts 8 inch o.c. maximum, seal with closed cell gasket.

E. Elbows:

1. Fabricated to a centerline radius of minimum 1.5 times the cross-section diameter.

   a. Where space constrictions do not allow specified centerline radius or where shown as such on drawings only, provide mitered elbow of fully welded construction with single thickness turning vanes spaced 3 inch o.c. max.

2. For use with snap-lock round duct, where allowed as described above: Gored adjustable elbows, seal adjustable joints after installation.

3. For standard bends (ex. 45 deg. and 90 deg.), diameters through 9 inch: Two-section stamped and welded 22 ga. elbows.

4. Diameters 10 inch through 30 inch, any angle: Gored standing seam construction similar to United McGill “UNI-SEAM”. Less than 36 deg. - two gores, 36 deg. to 72 deg. - three gores, over 72 deg. - five gores.

5. Diameters over 30 inch and odd angles under 10 inch: Gored construction with gores stitch welded 6 inch o.c. max and sealed with duct sealant. Less than 35 deg. - two gores, 36 deg. to 71 deg. -three gores, over 71 deg. - five gores.

F. Tees and Lateral Branches: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," and as follows:

1. Bull-Headed Tees:

a. Provide wye fitting with subsequent partial bend elbows for critical run bull-headed tees.
b. Provide capped main and twin lateral branches as described below for general purpose bull-headed tees.
c. Provide “bird-mouthed” fitting with turning vanes only where space restrictions require and where specifically shown as such on the drawings.

2. Fabricate lateral tees and all branches with fittings as described herein:

a. Fabricate to longitudinal welded duct standards. Where possible, provide gored standing seam construction similar to United McGill “UNI-SEAM”, otherwise stitch or button welded or riveted. Seal all joints.

b. Fitting entrance free of weld build-up or spatter, burrs, or irregularities, not projecting into either the main or branch runs.

c. Provide manual volume damper at all branch connections.

d. Typical round branch connections to round main duct, provide 45 deg. reducing lateral takeoff fitting, with subsequent elbow resulting in required branch angle to main.

1) Where space restrictions do not permit this combination, provide 90 deg. angled rectangular to round takeoff fitting “birdmouthed” to main, or conical takeoff with similar loss coefficient.

2) For critical run (ie. maximum pressure drop) round branch connections to round main ductwork, provide high performance 45 deg. reducing conical lateral takeoff fitting, with subsequent elbow resulting in required branch angle to main.

3) Exposed, duct side mounted register connections may be tapped into side wall of length of duct. Where an air-diffusion device is shown as being installed in close proximity to (less than one main duct width) the side, top, or bottom of a duct, provide a commercially manufactured vaned volume extractor fitting to allow adjustment of the air quantity and to provide an even flow of air across the device it services.

G. Turning Vanes:

1. As described for mitered rectangular elbows of unequal inlet and outlet cross section above.

H. Offsets:

1. All offsets to consist of paired curved elbows, each of the required angle, combined into one fitting.

I. Transitions of shape or cross section and duct entries:

1. As described for rectangular duct above.

2.4 EXPOSED DUCT SPECIAL CONSIDERATIONS

A. Provide aluminum (as required above) or paintable galvanized steel for all exposed supply, return and exhaust duct which will not be externally insulated. Mill phosphatizing in accordance with ASTM A2092 is acceptable material. Use forming lubricants which are compatible with specified painting systems and provide painters with factory recommendations for appropriate and compatible solvents, primers, etc.

B. Welds: exposed welds ground smooth and all weld spatter scraped or ground off.

C. Sealants: use only paintable sealants, applied neatly, avoiding exposed sealant on surface. Where sealant must be exposed for function apply in neat fillets.

D. Avoid all shipping and handling damage to surfaces. Replace pieces that are damaged and not repaired so that repair is not visible.

E. Joints: rotate all spiral seams of round duct so as to form continuous helical spiral. Carefully coordinate installation of exposed duct side mounted register connections as required.

F. Provide tapered “ramp” couplings for joints where allowed by size.

2.5 DUCTWORK ANCILLARY COMPONENTS

A. In general, duct accessories associated with specialized requirements which are called out and / or scheduled on the drawings are specified in Section 23 33 00 – Air Duct Accessories. The ancillary components included in this section are generally required in all air duct systems, need not be specifically called for on the drawings other than by specification or standard symbols and abbreviations, and are required to be detailed in the shop standards submittal.

B. Duct Connectors

1. Flange Connectors

a. Refer to flange reinforced transverse joint system described under duct construction above. Flanged connections to system components other than adjacent duct sections may be fabricated similar to a transverse joint. If required to connect to equipment or components of different configuration provide flanged connector custom fabricated of reinforcement shapes as specified.

b. Material: Match adjacent duct.

2. Flexible Connectors - Duct to Equipment:

a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1) Ductmate Industries, Inc.
2) Duro Dyne Inc.
3) Ventfabrics, Inc.
4) Ward Industries, Inc.; a division of Hart & Cooley, Inc.

b. Provide factory fabricated flexible connectors with heavy gauge metal edge bands double roll crimped each side onto water, flame-retardant, mildew resistant, NFPA approved flexible fabric connector strip.

c. Metal Edge Bands: 2 strips of 2-3/4 inches wide, 0.028-inch- thick G90 galvanized sheet or stainless steel, or 0.032-inch- thick aluminum sheets. Provide same metal and corrosion resistance as connected ducts.

d. Fabric Connector Strip: minimum 3-1/2 inches wide, 20 oz. per square yard fiberglass fabric strip double coated with neoprene (general service), hypalon (outdoors), nitrile (chemical resistant service similar to fume hoods), or silicone (high temperature service similar to kiln or engine exhaust).

e. Coatings and Adhesives: Comply with UL 181, Class 1.

C. Airflow Adjusters:

1. Single Blade Volume and Splitter Dampers:

a. Construction per SMACNA Duct Manual and as noted below.

b. Materials: Match associated duct corrosion resistance requirements.

c. Provide double wall airfoil blade dampers where duct velocity is over 1000 fpm nominal.

d. Maximum blade width 12 inches.

e. Multiple dampers or manufactured multi-blade damper above 600 square inches duct cross section.

f. Bearings and Adjusters:

1) Heavy duty quadrant adjusters with 12 gauge offset handle, captive bolt/wing nut lock in 2” minimum radius slot, split clamp with bolt on 3/8” shaft up to 300 square inch duct, ½” shaft for duct up to 600 square inch cross section.

2) Closed end bearings for duct rated for 2" WG and above.

3) Standoff under quadrant placing quadrant outside of specified duct insulation. Insulate between duct and quadrant.

4) When occurring in acoustically lined ducts, install with insulated "build-outs" per Duct Manual.

2. Multi-blade Manual Volume Dampers:

a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1) Air Balance Inc.; a division of Mestek, Inc.
2) American Warming and Ventilating; a division of Mestek, Inc.
3) Flexmaster U.S.A., Inc.
4) McGill AirFlow LLC.
5) Nailor Industries Inc.
6) Ruskin Company.
7) Trox USA Inc.
8) Vent Products Company, Inc.

b. Materials: Match associated duct corrosion resistance requirements.

c. Standard leakage rating.

d. Suitable for horizontal or vertical applications.

e. Frames:

1) Hat-shaped channels 0.064-inch minimum thickness.
2) Mitered and welded corners.
3) Flanges for attaching to walls and flangeless frames for installing in ducts.

f. Blades:

1) Opposed-blade design standard unless otherwise noted.
2) Stiffen damper blades for stability.
3) Formed single thickness blades allowed up to 1000 feet per minute (fpm) design duct velocity; provide airfoil blades above 1000 fpm.
4) Galvanized-steel, 0.064 inch thick.

g. Blade Axles: Full length of damper blades, bearings at both ends of operating shaft.

h. Bearings: Oil-impregnated bronze, molded synthetic, or stainless-steel sleeve bearing as applicable.

i. Tie Bars and Brackets: Galvanized steel.

j. Damper Hardware:

1) Zinc-plated, die-cast core with dial and handle made of 3/32-inch- thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
2) Include center hole to suit damper operating-rod size.
3) Include elevated platform for insulated duct mounting.

k. Jackshaft:

1) Provide as required for adjusting multi section multi-blade dampers simultaneously.

2) Size: 1-inch diameter.

3) Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.

4) Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

3. Vaned Volume Extractors

a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1) Variturn RXVA by Carnes, Inc.
2) Model AG-45 / AG-225 by Titus Inc.

b. Factory assembled gang-operated parallelogram mounted single wall turning vanes, designed to be mounted between main and branch ducts at branch duct connections and vary the flow rate extracted to branch air while minimizing turbulence and associated pressure drop.

c. Galvanized steel construction installed with sheet metal screws provides stable operation up to 2500 feet per minute main or branch duct velocity.

d. Single wall radius formed turning vanes with flat trailing and leading edges provide uniform air distribution across the branch duct and overlap in closed position for tight close-off. Vanes spaced no greater than one inch on center up to 18 inch length (measured in direction of main duct airflow) or no greater than two inches on center up to 36 inch length.

e. Fully adjustable from closed (zero protrusion into main duct, zero branch duct flow rate), to fully open (30 degree protrusion into main duct).

f. Where extractor vane length is less than dimension of main duct, provide branch duct with side extensions fully enclosing sides of extractor up to the full open position.

1) Where installed in horizontal duct and the bottom of the main and branch ducts are not in the same plane, provide extension support foot at end of bottom side extension.

g. Provide with adjusting mechanism that securely locks in adjusted position and unlocks allowing for smooth infinite adjustment from closed to open.

1) For extractors up to 18 inches long serving branch ducts provide with internal crank linkage operated by heavy duty manual quadrant and 3/8 inch square shaft.

2) For extractors over 18 inches long serving branch ducts, provide with double wire rod push-pull mechanism secured with welded stud, formed steel captive washer and wing nut.

3) For extractors serving immediately adjacent registers, provide with screw gear operated internal crank linkage operated by key through register face.

D. Duct Access Control

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following. Note not all manufacturers offer all products:

a. American Warming and Ventilating; a division of Mestek, Inc.
b. Carnes.
c. Cesco Products; a division of Mestek, Inc.
d. Ductmate Industries, Inc.
e. Flame Gard, Inc.
f. Flexmaster U.S.A., Inc.
g. Greenheck Fan Corporation.
h. KEES, Inc.
i. Lloyd Industries, Inc.
j. Metal Form Manufacturing, Inc.
k. McGill AirFlow LLC.
l. 3M
m. Nailor Industries Inc.
n. Price Industries.

o. Ventfabrics, Inc.
p. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

2. General Purpose Duct-Mounted Service Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."

a. Door:

1) Double wall, rectangular.
2) Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
3) Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
4) Fabricate doors airtight and suitable for duct pressure class.

b. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.

c. Number of Hinges and Locks:

1) Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
2) Access Doors up to 18 Inches Square: Two hinges and two sash locks.
3) Access Doors up to 24 by 48 Inches: Three hinges and two compression latches.
4) Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

3. Instrument Test Access Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

2.6 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.

2. Tape Width: 4 inches.

3. Sealant: Modified styrene acrylic.

4. Water resistant.

5. Mold and mildew resistant.

6. Maximum Static-Pressure Class: 10-inch wg, positive and negative.

7. Service: Indoor and outdoor.

8. Service Temperature: Minus 40 to plus 200 deg F.

9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.

10. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

11. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.

2. Type: S.

3. Grade: NS.

4. Class: 25.

5. Use: O.

6. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.

2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.7 HANGERS AND SUPPORTS

A. Provide complete system of Air Duct Hangers and Supports as required by the Air Duct systems included. Refer to Section 23 05 29 – "Hangers and Supports for HVAC Components" for details of Hanger and Support requirements for Air Ducts and associated components.

B. Provide complete system of Air Duct Vibration and Movement Control as required by the Air Duct systems included. Refer to Section 23 05 43 – "Mechanical Vibration and Movement Control" for details of vibration isolation and movement control requirements for Air Ducts and associated components.

C. Flexible Duct Supports and Accessories:

1. Elbow Supports: UL listed for plenum installation molded fiber reinforced plastic elbow support at connections to ceiling mounted devices designed to maintain tension in flex duct and eliminate collapsed elbows. Basis of design: Thermaflex FlexFlow elbows.

2. Flexible Duct Supports: UL listed for plenum installation molded fiber reinforced plastic 1-1/2" wide straps adjustable for 4" to 16" diameter flex duct, supports duct without damaging vapor barrier or collapsing soft insulation or duct. Basis of design: Thermaflex FlexTie straps.

3. Clamps: Re-usable stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action in sizes 3 through 18 inches, to suit duct size, or single use "zip-tie" strap of plenum rated plastic, sizes 3 through 10 inches diameter maximum.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine conditions under which duct work is to be installed for compliance with requirements for proper installation.

1. Check all drawings for detailed information and locations and field verify all conditions affecting installation.
2. Notify Architect in writing of any conditions detrimental to proper and timely installation.
3. Obtain Architect's approval before fabrication of any changes in size required by obstructions and job conditions.
4. Proceed with installation only after unsatisfactory conditions have been corrected in an acceptable manner.
5. Beginning installation constitutes Contractor's acceptance of substrates and conditions.

3.2 DUCT FABRICATION

A. Fabricate and install as shown on Drawings and in manner coordinated with all construction requirements.

B. Sizes shown on plans are clear inside duct dimensions representing the design hydraulic radius of the duct. Generally, fabricate ductwork of sizes shown on plans. During field verification, confirm that duct of aspect ratio shown fits within general construction constraints coordinated with all other trades. Adjust aspect ratio, joint spacing, reinforcement, etc., as required during coordination process to fit duct of equivalent hydraulic radius where shown. If duct of reduced hydraulic radius is required due to field conditions, submit RFI for direction before proceeding.

C. Flexible Connections: Provided at intake and discharge connections to all motor powered fan air handling equipment and other vibration isolated air handling component connections.

D. Fabricate all ductwork to the SMACNA pressure classification reinforcement standards shown on the drawings and to the following minimum standards.

1. Conform to special duct pressure classification requirements for all duct between air handler blowers and last fire or fire/smoke damper in series, and duct after the last fire or fire/smoke damper in series up to the next 90 deg. turn:

a. Fabricate to the SMACNA pressure classification reinforcement standards required by the system supply or return blower dynamic stall pressure; assume the larger of 200% of external operating pressure scheduled or 150% of fan total pressure listed as a minimum. VIF with approved equipment fan curves and adjust pressure classification values accordingly.

2. Where there are no fire or fire / smoke dampers and past the 90 degree turn mentioned above, complete to the last branch duct volume damper, VAV box, induction unit, or other pressure restricting device, fabricate duct to pressure classification as required by the system supply or return operating pressure listed on the drawings, minimum plus or minus two (2) inch water column.

3. Fabricate branch run-out duct between the last pressure restricting device and the air terminal register, grille, or diffuser to minimum plus or minus one (1) inch water column pressure classification.

E. Deliver and store all duct with duct interior clean and all openings sealed with film designed for the purpose of keeping uninstalled duct clean. Unless section of duct is being actively extended during construction, keep all openings and RGD properly sealed and prevent entrance of dust, dirt, construction debris, etc.

F. Extend all access openings, damper rods, and levers to outside of external insulation for convenience of operation and maintenance.

G. Provide all necessary transitions, fittings, aspect ratio changes, etc., as required to install duct work. Where aspect ratio changes are required to fit within structural or other existing construction constraints, provide duct of equal or larger hydraulic radius.

3.3 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install concealed in general construction unless otherwise specified or indicated on Drawings.

C. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

D. Provide all necessary openings, sleeves, hanger inserts, chases, recesses, etc., in general construction work. Coordinate duct openings provided by others in ample time to avoid delays.

E. Provide collars to trim all duct openings in general construction work.

F. Make final ductwork connections to equipment where indicated on the drawings.

G. Install ductwork in all spaces as high as possible and in locations to avoid interference with recessed lights, piping, general construction, etc.

H. Install round and flat-oval ducts in maximum practical lengths.

I. Install ducts with fewest possible joints.

J. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

K. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

L. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

M. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

N. Route ducts to avoid passing through transformer vaults, electrical equipment rooms and enclosures, and stairwells.

O. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

P. Where ducts pass through fire-rated interior partitions and exterior walls, install fire or combination fire-smoke dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

Q. Where duct passes through exterior walls and roofs from interior to exterior, provide water and airtight penetration detailing as required, preserving the thermal, moisture, and vapor penetration resistance of the surrounding assembly.

R. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.4 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds and surrounding heat affected zone to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.5 DUCT SEALING

A. Make system air tight / water tight as required and approved, replacing any poor joints or careless work. Fabricate ductwork to the following SMACNA leakage standards:

1. Seal Class B – 2 inch w.g. and less general supply, return, and exhaust ductwork.

3.6 HANGER AND SUPPORT INSTALLATION

A. Comply with the requirements of the following:

1. SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
2. Section 23 05 29 – Hangers And Supports for HVAC Components.
3. Section 23 05 43 – Mechanical Vibration and Movement Control.

B. Comply with the additional requirements below:

1. SMACNA load tables do not provide for external loads on duct: provide for 200 lb external load on all duct hangers and supports. Increase hanger and support sizes from SMACNA tables accordingly:

    a. Minimum band size 20ga. x 1 inch.

    b. Duct 48” wide and larger; provide trapeze style support of metal channel framing or angle iron, suspended from threaded rods.

c. Hanger bands to extend down sides and turn under bottom 1 inch minimum for all duct sizes. Minimum (2) #10 sheet metal screws per hanger (one each on side and bottom), (2) screws minimum on sides for duct over 12 inches tall, 12 inches on center max.

2. Hangers Exposed to View:

   a. Rectangular duct: threaded rod and angle or channel supports.
   b. Round duct: twin half round bands 14 ga min., and threaded rods.

3. Provide hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

4. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

5. Do not allow flexible duct to rest on general construction. Support flexible duct at maximum 3 feet on center.

3.7 SEISMIC RESTRAINT

A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes.

B. Comply with the requirements of the following:

   1. SMACNA's "SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."

3.8 CONNECTIONS

A. Make connections at all intake and discharge connections between duct and vibration producing equipment with fans, including RTU, FCU, etc.., where duct passes through building expansion joints, and as shown on the drawings, with flexible connectors as specified.

   1. Round connections: Adhesive and approved metal draw bands; ends tightly bolted together.

   2. Rectangular flanges: Material securely held in grooved seam, tightly clipped or screwed on 6 inch centers.

   3. Connections not over 2 inch between duct and equipment, with at least 1 inch excess material.

   4. Install neatly so as not to interfere with air flow through connection. Provide round metal center ring or rectangular metal center collar to prevent flex fabric collapse inside of nominal connected duct dimensions.

B. Registers, Diffusers, and Grilles:

1. Install flexible duct connections to registers, diffusers, and grilles with no more than 20 degree unsupported bend in flex. Where horizontal duct connects to vertical axis collar (ex., ceiling mounted diffuser), provide elbow support as specified or hard elbow.

2. Exposed, duct side mounted: Mount outlet outside of air stream with extension collars full size of register or grille frame outside margin, with turned in duct flange and turned out terminal mounting flange. Provide vaned air extractor with internal mechanism / external rotating knob adjuster.

3. Exposed ductwork hard piped connections: per Duct Manual.

3.9 PAINTING

A. Paint interior of ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

3.10 START UP

A. Air Balance: Comply with requirements in Section 23 05 93 - "Testing, Adjusting, and Balancing for HVAC."

END OF SECTION 23 31 00

SECTION 23 33 00 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Fire dampers.

1.3 SUBMITTALS, GENERAL

A. General: Submit all action submittals and informational submittals required by this Section concurrently.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

a. Fire-damper installations, including sleeves; and duct-mounted access doors.
b. Wiring Diagrams: For power, signal, and control wiring.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.6 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
B. Comply with AMCA 500-D testing for damper rating.

1.7 EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fusible Links: Furnish quantity equal to 10 percent of amount installed.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60.
2. Exposed-Surface Finish: Mill phosphatized.

C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.2 FIRE DAMPERS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Air Balance Inc.; a division of Mestek, Inc.
2. Arrow United Industries; a division of Mestek, Inc.
3. Cesco Products; a division of Mestek, Inc.
4. Greenheck Fan Corporation.
5. Nailor Industries Inc.
6. NCA Manufacturing, Inc.
7. Prefco; Perfect Air Control, Inc.
8. Ruskin Company.
9. Vent Products Company, Inc.
10. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Type: Dynamic; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 4000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: 0.052 or 0.138 inch thick, as indicated, and of length to suit application.

2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch- thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- thick, galvanized-steel blade connectors.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

J. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where air terminal units are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.
B. Proceed with installation only after unsatisfactory conditions have been corrected.
C. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Set dampers to fully open position before testing, adjusting, and balancing.

D. Install test holes at fan inlets and outlets and elsewhere as indicated.

E. Install fire dampers according to UL listing.

3.3 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.

END OF SECTION 23 33 00

SECTION 23 34 00 - HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Centrifugal roof ventilators.
2. In-line centrifugal fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on actual Project site elevations.
B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS, GENERAL

A. General: Submit all action submittals and informational submittals required by this Section concurrently.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Roof curbs.
7. Fan speed controllers.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

2. Wiring Diagrams: For power, signal, and control wiring.

1.6 CLOSEOUT SUBMITTALS

A. Field quality-control reports.
B. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
B. AMCA Compliance: Fans shall have AMCA-Certified performance ratings and shall bear the AMCA-Certified Ratings Seal.
C. UL Standards: Power ventilators shall comply with UL 705.

1.8 COORDINATION

A. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

PART 2 - PRODUCTS

2.2 ROOFTOP CENTRIFUGAL EXHAUST FANS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Acme Engineering & Manufacturing Corporation.
2. Breidert Air Products.
3. Carnes Company.
4. Greenheck Fan Corporation.
5. Hartzell Fan Incorporated.
6. Loren Cook Company.
7. PennBarry.

B. Unit Description: UL listed exhaust fan specifically designed for outdoor installation and service, shipped fully assembled and factory tested prior to shipment.

1. Housing:

a. Spun 16 gauge minimum weather tight marine grade aluminum two piece upper housing, with reinforced rolled edges. Down-blast, up-blast, or wall mounted out-blast type housing as scheduled.

1) Where scheduled, provide low profile louvered penthouse style rectangular housing as specified in Section 23 37 00 – Air Inlets and Outlets, complete with hinged base with retention cables.

b. Quick release stainless steel latches to provide access to motor compartment without use of tools.

c. Fully welded aluminum curb cap

d. Rubber grommeted internal wiring passages unless otherwise specified.

e. Provide aluminum nameplate riveted to housing exterior with manufacturer, model, cfm, static pressure, and electrical characteristics all permanently engraved or stamped.

2. Impellers: Backward inclined, non-overloading, statically and dynamically balanced all aluminum construction, including hubs. Impeller shall overlap a spun aerodynamic inlet cone. Belt or direct drive as shown on Drawings.

3. Power Assemblies:

a. Motor and drive isolated from discharge air stream in forced-air cooled compartment.

b. Power Assembly mounted on minimum 14 gauge plated steel structure, supported on housing with rubber isolators loaded in combination shear and compression.

c. Motors:

1) Refer to Section 23 05 13 Common Electrical requirements for HVAC Components for additional information.

2) Constant Speed Operation: Open drip-proof type with sealed, permanently lubricated ball bearings; pre-wired through to disconnect switch mounted under fan cover with sufficient legs to break all leads to motor.

a) Motors, wiring, and disconnects serving fume hood exhaust fans and other potentially flammable exhaust streams shall be UL listed and in accordance with NEC for explosion proof construction.

3) Variable Speed Operation:

a) Single Phase: Electronically commutated motor (ECM) as manufactured by General Electric. Motor shall be of permanent magnet, brushless DC premium efficiency design with variable speed electronic controller capable of maintaining constant speed, torque, and/or cfm as required by service, capable of accepting 0-10vdc or 4-20mA speed control signal from building management system. Adjustable slow start and gradual speed changes, permanently lubricated ball bearings, and extra quiet operation are all included.

4. Accessories / Options as scheduled:

   a. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

   b. Bird Screen: Removable, 1/2-inch mesh, aluminum or brass wire.

   c. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops. Refer to Section 23 09 00 for damper specifications.

   d. Factory fabricated insulated roof curb meeting the requirements above and of Section 23 05 29 – Hangers and Supports for HVAC Components.

   e. Variable Speed Operation: Provide with motor as described above and ECM motor (single phase) or variable speed drive in accordance with Section 23 29 23 – Variable Frequency Motor Controllers (three phase).

   f. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

5. Manufacturers: Cook, Greenheck, Penn Ventilator, Twin Cities, or Approved Equal.

2.2 IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   1. Acme Engineering & Manufacturing Corporation.
   2. Breidert Air Products.
   3. Carnes Company.
   4. Greenheck Fan Corporation.
   5. Hartzell Fan Incorporated.
   6. Loren Cook Company.
   7. PennBarry.

B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

C. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.

D. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

E. Accessories:

   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Companion Flanges: For inlet and outlet duct connections.

2.3 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Electrical Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

B. Enclosure Type: Totally enclosed, fan cooled.

2.4 SOURCE QUALITY CONTROL

A. Certify sound-power level ratings according to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Certify fan performance ratings, including flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating." Label fans with the AMCA-Certified Ratings Seal.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Beginning installation constitutes Contractor's acceptance of substrates and conditions.

3.2 INSTALLATION

A. Install power ventilators level and plumb.
B. Secure roof-mounted fans to roof curbs with cadmium-plated hardware. See Division 07 Section "Roof Accessories" for installation of roof curbs.
C. Suspended in-line fans: Suspend units from structure; use steel wire or metal straps.
D. Install units with clearances for service and maintenance.
E. Label units according to requirements specified in Division 23 Section "Identification for HVAC Components."

3.3 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Ductwork."

B. Install ducts adjacent to power ventilators to allow service and maintenance.

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Verify that shipping, blocking, and bracing are removed.

2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.

3. Verify that cleaning and adjusting are complete.

4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system.

5. Adjust damper linkages for proper damper operation.

6. Verify lubrication for bearings and other moving parts.

7. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

8. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.

9. Shut unit down and reconnect automatic temperature-control operators.

10. Remove and replace malfunctioning units and retest as specified above.

C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Prepare test and inspection reports.

3.5 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

C. Replace fan and motor as required to achieve design airflow.

D. Lubricate bearings.

END OF SECTION 23 34 00

SECTION 23 37 00 – AIR OUTLETS AND INLETS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Interior Outlets and Inlets:

   a. Registers, grilles, and diffusers

2. Exterior Outlets and inlets:

   a. Air louvers

1.3 SYSTEM DESCRIPTION

A. Design Requirements

1. Registers, Grilles, and Diffusers: Provide all supply, return and exhaust grilles, registers, and diffusers required for all systems.

2. Air Louvers: Provide AMCA-rated louvers for all fresh air intake and exhaust openings, except as otherwise shown or specified in Contract Documents. Cross- reference dimensions of each louver shown on heating drawings with those on the architectural drawings. Notify architect in writing of any discrepancies prior to submitting on louvers.

1.4 PERFORMANCE REQUIREMENTS

A. Interior Outlets and Inlets: Provide outlets and inlets with aspiration ability, temperature mixing, and velocity traverses and decay with distance, throw, pressure drop, and noise criteria ratings equal to or better than specified products.

B. Exterior Outlets and Inlets:

1. Water Entrainment: Limit water penetration through unit to comply with ASHRAE 62.1.

1.5 SUBMITTALS

A. Comply with requirements of Section 01 33 00 - Submittals and as modified below.

B. Product Data: Submit manufacturer's product literature, technical specifications, performance data, installation instructions, and similar information required to demonstrate compliance with specified requirements. Annotate all selected options, cross referenced to specification and drawing designations. Include tabulated data for all proposed outlets and inlets, showing size, type, cfm, aspiration ability, water entrainment, temperature mixing, and velocity traverses and decay with distance, throw, pressure drop, noise criteria ratings and any other applicable data demonstrating performance equal to or better than specified products.

C. Shop Drawings: Submit shop drawings showing sizes, construction details, mounting details, capacity, and air flow characteristics for all equipment. Include complete tabulated schedules as indicated below for each of RGD, Louvers, and roof Top Hoods / Louvered Penthouses.

1. Registers, Grilles, and Diffusers (RGD): Include complete tabulated schedule showing locations for each RGD, type, size, capacity as shown on Drawings, and performance data for each RGD furnished, including throw and noise criteria ratings. Indicate selections on data.

2. Air Louvers: Include complete tabulated schedule showing locations for each Louver, showing type, size, wall and/or roof rough opening size, capacity as shown on Drawings, and performance data for each including pressure drop and water entrainment specifications. Include all this data on coordination drawings and special Mechanical Penetrations of General Construction Envelope coordination drawing.

D. Contract Closeout Submittals: Comply with requirements of Section 01 77 00, including submission of operating and maintenance instructions as item in "Operating and Maintenance Data" manual described in that section.

1.6 SEQUENCING AND SCHEDULING

A. Deliver Exterior Outlets and Inlets (Louvers) to project in sufficient time for installation in walls as wall construction progresses.

1. Coordinate unit selection to meet requirements of other equipment and installation details (automatic dampers, back draft dampers, etc.).
2. Verify all opening sizes, locations and mounting arrangements prior to installation.

PART 2 - PRODUCTS

2.1 REGISTERS, GRILLES, AND DIFFUSERS

A. General

1. Provide registers, grilles, and diffusers with border systems that are compatible with adjacent wall and ceiling systems, and that are specifically manufactured to fit into ceiling modules with accurate fit and adequate support. Refer to general construction drawings and specifications for details of adjacent systems.

2. All performance criteria equal to or better than design make as specified and tagged on drawings.

3. Provide factory baked white enamel finish for steel materials and clear or color anodizing for aluminum material as base bid standard finish unless otherwise specified or noted.

4. Provide products by one of the following:

   a. Krueger or equal.
   b. Price or equal.
   c. Anemostat or equal.

B. Registers:

1. TYPE "R-A": Double deflection wall supply register; vertical front and horizontal rear vanes with 3/4" spacing between blades, rubber gasket to prevent streaking, vanes individually adjustable; extruded aluminum construction, clear anodized finish. Similar to Krueger “5880V”, “5880H (horizontal front)”, “R5880” (round duct register with mounting as shown and as required).

C. Grilles:

1. TYPE "G-A": Eggcrate return grille; 1/2 inch x1/2 inch x1inch deep squares; fabricated aluminum core; flat frame; white baked enamel finish to match ceiling. Neck size and accessories as noted on drawings. Provide frame to fit lay-in ceiling grid or hard ceiling as required. Similar to Krueger “EGC-15.”

2. TYPE "G-C": Single deflection wall return grille; vertical or horizontal vanes, fixed at 0 degrees or 35 degrees (as noted on drawings), with 3/4 inch spacing between blades; aluminum or steel construction as required to match adjoining ductwork. Similar to Krueger “S80" or “S580.”

D. Supply Diffusers:

1. TYPE "D-A": Ceiling air diffuser with stamped steel construction, stamped three ring removable core, 24 inch square face, 4 way pattern, integral round neck of size as noted on drawings. Anti smudge design to prevent streaking. Flush T-bar mount to fit lay-in ceiling grid, coordinate with G.C. Similar to Krueger “1400.”

2.2 AIR LOUVERS

A. Intake and Exhaust Louvers (Fixed Type)

1. Standard Construction Requirements:

   a. Factory constructed high performance drainable (frame, blades, and head as scheduled) aluminum louvers with storm resistant blades of AMCA rated performance equal to or better than the design make.

   b. Frame and blades constructed of extruded aluminum, alloy 6063-T5. Nominal wall thickness of 0.081 inches, depth to be 6 inches as noted on drawings.

c. Blade angle of 37-1/2 degrees, centered nominally at 5-3/32 inches for the 4 inch deep and at 5-29/32 inch for 6 inch deep louvers. Hidden vertical supports shall allow continuous line appearance up to 120 inches.

d. Stainless Steel 1/2 inch mesh x 0.063 inch bird screen secured in a removable frame with SS tamperproof fasteners, on exterior face of louver. Finish same as louver.

e. Extended sills constructed of aluminum, alloy 6063 – T5 with a nominal wall thickness of 0.060 inches in a style selected by Architect.

f. Provide welded construction for all factory assembled louver components. Provide stainless steel fasteners for all field assembled components.

g. Size, type and location as shown on drawings.

h. Provide scheduled factory finish as detailed below.

1) Kynar: Provide factory applied and baked resin based paint coating, minimum 70% fluoropolymer (PVDF) similar to Kynar 500 or Hylar 5000 as manufactured by the Valspar Corporation. Coating shall meet all performance requirements of AAMA 2605 and ASCA 96. Color as selected by Architect from manufacturer's full range of standard or premium colors including minimum 16 "standard" colors and 12 "premium" colors.

i. Provide products by one of the following, with performance as scheduled:

1) Greenheck Model ESD or equal.
2) Similar model by Ruskin, or equal.
3) Similar model by Construction Specialties, Inc. or equal.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which air outlets and inlets are to be installed and notify an Architect in writing of any conditions detrimental to proper and timely installation. Do not proceed with installation until unsatisfactory conditions have been corrected in an acceptable manner.

1. Air Louvers: Coordinate unit selection to meet other equipment and installation details (automatic dampers, back draft dampers, etc.). Verify all opening sizes, locations and mounting arrangements prior to installation.

3.2 INSTALLATION

A. Install air outlets and inlets in strict accordance with manufacturer's recommended installation instructions for applications shown on Drawings.

B. Registers, Grilles and Diffusers (RGD): Install all RGDs in accordance with manufacturer's installation instructions and SMACNA installation manual at locations indicated on Drawings.

1. Adjust each type of RGD as required to achieve even air distribution throughout occupied space, generally free of objectionable drafts and dead air pockets. Demonstrate adjustments of distribution to Owner and additionally adjust as requested by Owner’s representative during or subsequent to initial adjustments. As RGD adjustment and Testing and Air Balancing work affect each other, make preliminary adjustment to all RGDs prior to balancing, and make final RGD adjustment during TAB work in cooperation with TAB agency. Refer to Section 23 05 93 – Testing, Adjusting, And Balancing for HVAC for more detail.

2. Provide final balancing in accordance with Section 23 05 93.

3. Furnish to Owner, with receipt, 3 operating keys for each type of air outlet and inlet that requires them.

C. Air Louvers: Comply with manufacturer's specifications and recommendations for assembly and installation of air louver units, hardware, operators, and other components.

1. Set units plumb, level, and true to line, without warp or rack of frames. Anchor securely in place. Separate aluminum and other corrodible metal surfaces from sources of corrosion or electrolytic action at points of contact with other materials. Use stainless steel fasteners.

2. Set head, jamb, and sill members in bed of compound as shown, or with joint fillers or gaskets as shown to provide weather tight construction.

3. Provide suitable gaskets or coating where dissimilar metals are in contact.

4. Clean aluminum surfaces promptly after installation of units. Remove excess glazing and sealant compounds, dirt, and other substances. Lubricate hardware and other moving parts.

END OF SECTION 23 37 00

SECTION 23 74 00 - PACKAGED, OUTDOOR, CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components and accessories:

1. Direct-expansion cooling.
2. Heat-pump refrigeration components.
3. Economizer outdoor- and return-air damper section.
4. Roof curbs.

1.3 DEFINITIONS

A. DDC: Direct-digital controls.

B. ECM: Electrically commutated motor.

C. Outdoor-Air Refrigerant Coil: Refrigerant coil in the outdoor-air stream to reject heat during cooling operations and to absorb heat during heating operations. "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

D. Outdoor-Air Refrigerant-Coil Fan: The outdoor-air refrigerant-coil fan in RTUs. "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

E. RTU: Rooftop unit. As used in this Section, this abbreviation means packaged, outdoor, central-station air-handling units. This abbreviation is used regardless of whether the unit is mounted on the roof or on a concrete base on ground.

F. Supply-Air Fan: The fan providing supply air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

G. Supply-Air Refrigerant Coil: Refrigerant coil in the supply-air stream to absorb heat (provide cooling) during cooling operations and to reject heat (provide heating) during heating operations. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

H. VVT: Variable-air volume and temperature.

1.4 SUBMITTALS, GENERAL

A. General: Submit all action submittals and informational submittals required by this Section concurrently.

1.5 ACTION SUBMITTALS

A. Product Data: Include manufacturer's technical data for each RTU, including rated capacities, dimensions, required clearances, characteristics, furnished specialties, and accessories.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.

1.6 INFORMATIONAL SUBMITTALS

A. Warranty: Special warranty specified in this Section.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For RTUs to include in emergency, operation, and maintenance manuals.

B. Warranty: Executed special warranty specified in this Section.

1.8 QUALITY ASSURANCE

A. AHRI Compliance:

1. Comply with AHRI 210/240 and AHRI 340/360 for testing and rating energy efficiencies for RTUs.
2. Comply with AHRI 270 for testing and rating sound performance for RTUs.

B. ASHRAE Compliance:

1. Comply with ASHRAE 15 for refrigeration system safety.
2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.

C. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

D. UL Compliance: Comply with UL 1995.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.9 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of RTUs that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than five years from date of Substantial Completion.
2. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

1.10 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Filters: One set of filters for each unit.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. AAON, Inc.
2. Addison Products Company.
3. Carrier Corporation.
4. Engineered Air.
5. Lennox Industries Inc.
6. McQuay International.
7. Trane.
8. YORK International Corporation.

2.2 CASING

A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Casing Material: Galvanized steel with factory-painted finish, with pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.

1. Casing Thickness: 0.079 inch thick.

C. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.

1. Materials: ASTM C 1071, Type I.
2. Thickness: 1/2 inch.
3. Liner materials shall have air-stream surface coated with an erosion- and temperature-resistant coating or faced with a plain or coated fibrous mat or fabric.
4. Liner Adhesive: Comply with ASTM C 916, Type I.

D. Condensate Drain Pans: Formed sections of galvanized-steel sheet, a minimum of 2 inches deep, and complying with ASHRAE 62.1.

1. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight.
2. Drain Connections: Threaded nipple.
3. Pan-Top Surface Coating: Corrosion-resistant compound.

2.3 FANS

A. Size / design for mid-life filter resistance equal to the average of the as specified clean filter resistance at the design flowrate and the filter manufacturer's recommended maximum (in need of changing) filter resistance at the design flow rate.

B. Direct-Driven Supply-Air Fans: Double width, backward inclined, centrifugal; with permanently lubricated, ECM motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.

C. Condenser-Coil Fan: Propeller, mounted on shaft of permanently lubricated motor.

D. Fan Motor: Comply with requirements in Division 23 Section "Common Electrical Requirements for HVAC Equipment."

2.4 COILS

A. Supply-Air Refrigerant Coil:

1. Aluminum-plate fin and seamless copper tube in steel casing with equalizing-type vertical distributor.
2. Coil Split: Interlaced.

B. Outdoor-Air Refrigerant Coil:

1. Aluminum-plate fin and seamless copper tube in steel casing with equalizing-type vertical distributor.

2.5 REFRIGERANT CIRCUIT COMPONENTS

A. Compressor: Hermetic, scroll, mounted on vibration isolators; with internal overcurrent and high-temperature protection, internal pressure relief.

B. Refrigeration Specialties:

1. Refrigerant: R-410A.
2. Expansion valve with replaceable thermostatic element.
3. Refrigerant filter/dryer.
4. Manual-reset high-pressure safety switch.
5. Automatic-reset low-pressure safety switch.
6. Minimum off-time relay.
7. Automatic-reset compressor motor thermal overload.
8. Brass service valves installed in compressor suction and liquid lines.

2.6 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Pleated: Minimum MERV 8.

2.7 DAMPERS

A. Outdoor-Air Damper: Linked damper blades, for 0 to 25 percent outdoor air, with motorized damper filter.

B. Outdoor- and Return-Air Mixing Dampers: Parallel- or opposed-blade galvanized-steel dampers mechanically fastened to cadmium plated for galvanized-steel operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.

1. Damper Motor: Modulating with adjustable minimum position.
2. Relief-Air Damper: Gravity actuated or motorized, as required by ASHRAE/IESNA 90.1, with bird screen and hood.

2.8 ELECTRICAL POWER CONNECTION

A. Provide for single connection of power to unit with unit-mounted disconnect switch accessible from outside unit and control-circuit transformer with built-in overcurrent protection.

2.9 CONTROLS

A. Control equipment and sequence of operation are specified in Division 23 Section "Instrumentation and Control for HVAC."

2.10 ACCESSORIES

A. Disconnect switch.
B. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include transformer if required. Outlet shall be energized even if the unit main disconnect is open.

C. Filter differential pressure switch with sensor tubing on either side of filter. Set for final filter pressure loss.
D. Hail guards of galvanized steel, painted to match casing.

2.11 ROOF CURBS

A. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.

1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.

a. Materials: ASTM C 1071, Type I or II.
b. Thickness: 2 inches.

2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.

a. Liner Adhesive: Comply with ASTM C 916, Type I.

b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.

c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.

d. Liner Adhesive: Comply with ASTM C 916, Type I.

B. Curb Height: 24 inches.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of RTUs.
B. Examine roughing-in for RTUs to verify actual locations of piping and duct connections before equipment installation.
C. Examine roofs for suitable conditions where RTUs will be installed.
D. Proceed with installation only after unsatisfactory conditions have been corrected.
E. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 INSTALLATION

A. Roof Curb: Install on roof structure, level and secure, according to NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts." Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Division 07 Section "Roof Accessories." Secure RTUs to upper curb rail, and secure curb base to roof framing with anchor bolts.

3.3 CONNECTIONS

A. Install condensate drain, minimum connection size, with trap and indirect connection to nearest roof drain or area drain.

B. Duct installation requirements are specified in other Division 23 Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:

1. Install ducts to termination at top of roof curb.
2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
3. Connect supply ducts to RTUs with flexible duct connectors specified in Division 23 Section "Ductwork."
4. Install return-air duct continuously through roof structure.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

B. Perform tests and inspections and prepare test reports.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing. Report results in writing.

C. Tests and Inspections:

1. After installing RTUs and after electrical circuitry has been energized, test units for compliance with requirements.
2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Remove and replace malfunctioning units and retest as specified above.

3.5 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Complete installation and startup checks according to manufacturer's written instructions and do the following:

1. Inspect for visible damage to unit casing.

2. Inspect for visible damage to compressor, coils, and fans.

3. Inspect internal insulation.

4. Verify that labels are clearly visible.

5. Verify that clearances have been provided for servicing.

6. Verify that controls are connected and operable.

7. Verify that filters are installed.

8. Clean condenser coil and inspect for construction debris.

9. Remove packing from vibration isolators.

10. Verify lubrication on fan and motor bearings.

11. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.

12. Start unit according to manufacturer's written instructions.

    a. Start refrigeration system.
    b. Do not operate below recommended low-ambient temperature.
    c. Complete startup sheets and attach copy with Contractor's startup report.

13. Inspect and record performance of interlocks and protective devices; verify sequences.

14. Operate unit for an initial period as recommended or required by manufacturer.

15. Calibrate thermostats.

16. Adjust and inspect high-temperature limits.

17. Inspect outdoor-air dampers for proper stroke and interlock with return-air dampers.

18. After startup and performance testing and prior to Substantial Completion, replace existing filters with new filters.

3.6 CLEANING AND ADJUSTING

A. After completing system installation and testing, adjusting, and balancing RTU and air-distribution systems, clean filter housings and install new filters.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain RTUs. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION 23 74 00

SECTION 23 82 00 – TERMINAL HEATING AND COOLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following types of Terminal Heating and Cooling Equipment, associated accessories, and their installation:

1. Unit Ventilators (UV).
2. Vertical Unit Ventilators (VUV).
3. Fan-Coil Units (FCU).
4. Fin Tube Radiation (FTR).
5. Air Coils (RHC).

1.3 SUBMITTALS, GENERAL

A. General: Submit all action submittals and informational submittals required by this Section concurrently.

1.4 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for each unit type and configuration.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Plans, elevations, sections, and details.
2. Details of anchorages and attachments to structure and to supported equipment.
3. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Warranty: Special warranty specified in this Section.

1.6 CLOSEOUT SUBMITTALS

A. Field quality-control test reports.

B. Operation and Maintenance Data: For unit ventilators blower-coil units, fan-coil units, convectors, fin tube radiation, unit heaters, and air coils to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

C. Warranty: Executed special warranty specified in this Section.

1.7 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with NFPA 70.

1.8 COORDINATION

A. Coordinate layout and installation of all units and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate size and location of wall sleeves for outdoor-air intake and relief dampers.

1.9 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

a. Compressor failure.
b. Condenser coil leak.

2. Warranty Period: Five years from date of Substantial Completion.

1.10 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Unit Ventilator Filters: Furnish two spare filter(s) for each filter installed.
2. Fan-Coil Filters: Furnish two spare filter(s) for each filter installed.

PART 2 - PRODUCTS

2.1 UNIT VENTILATORS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Carrier Corporation.
2. Daikin.
3. Magic Aire.
4. Nesbitt Aire, Inc.
5. Trane.

B. Description: Factory-packaged and -tested units rated according to AHRI 840, ASHRAE 33, and UL 1995, including finished cabinet, dampers, filter, heating and cooling coil, drain pan, supply-air fan and motor in blow- or draw-through configuration.

C. Provide Unit Ventilators constructed to operate quietly in an exposed classroom environment. Cabinet construction, fan speed and quality, and system insulation shall all combine to create units that operate with sound levels that do not exceed those shown below.

Unit Size	Motor Speed	SOUND POWER DATA (db re: 10^{-12} watts)						
	Octave Band:	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Center Frequency:	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*
a. 750	High	57.4	51.8	52.5	52.6	51.2	46.9	35.2
b. 750	Medium	50.1	44.9	45.6	44.8	42.8	34.2	19.9
c. 750	Low	45.6	40.4	40.8	39.1	35.7	24.4	12.0
d. 1000	High	57.0	52.8	53.9	53.7	51.5	46.8	35.9
e. 1000	Medium	52.9	48.6	50.2	49.6	46.5	40.1	27.9
f. 1000	Low	49.4	45.4	47.0	45.5	42.0	33.6	20.7
g. 1250	High	62.4	55.2	55.7	55.3	54.4	49.7	38.5
h. 1250	Medium	59.3	52.1	52.5	51.7	50.4	44.0	31.8
i. 1250	Low	55.6	48.6	49.1	47.2	45.6	37.1	24.0
j. 1500	High	63.8	56.6	58.0	58.2	56.4	52.4	41.9
k. 1500	Medium	58.4	51.3	52.7	52.4	49.5	43.5	30.5
l. 1500	Low	54.8	47.6	49.4	47.5	44.2	36.2	21.5

D. Cabinets

1. Frames: jig welded of heavy gauge steel to insure proper durability, dimensions, and squareness.

2. Finish: sheet metal parts of G-90 galvanized steel to inhibit corrosion, exterior cabinet panels fabricated from 16-ga. Furniture grade galvanized steel, cleaned and phosphatized before applying a baked on polyester powder coat enamel finish. Finish color to be selected by Architect from manufacturer's standard colors.

3. Insulation: Minimum 1-inch thick, matte-finish, closed-cell foam complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

    a. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

    b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in NFPA 90.1 and ASHRAE 62.1.

4. Service Access:

    a. Opening or removing the unit front control and service panels shall not affect unit operation, allowing controls and damper linkage adjustments while the unit is running.

    b. Provide hex-head fasteners designed for repeated use to secure all removable panels.

5. Provide heating only units with coil mounting configuration and drain pan such that the later addition of a cooling coil requires no chassis modification.

E. Floor Units:

1. Provide with three separate removable front panels configured so that it is not necessary to remove the entire unit front cover or disturb the airflow to gain access to the service and control compartments.

2. Provide an integral closed rear pipe tunnel for convenient crossover of piping or electrical wiring in accordance with NEC.

3. Provide with supply discharge grille of continuous round edged steel bars with 10 to 15 degree vertical deflection and adjustable side deflection vanes beneath the discharge grille.

4. Return-Air Inlet: Front toe space where shown with no casework, draft stop deflector panel with rear side panel openings where shown with abutting casework or draft stop enclosure, or as otherwise scheduled.

5. End Panels: Provide where units are shown without UV manufacturer’s new abutting casework, in material and finish matching unit ventilator.

    a. Provide formed steel end panels nominally 1” deep where no connecting casework obstructs side access, and where UVs are shown with new abutting millwork casework.

    b. Provide single thickness 16-ga. sheet steel panels where existing casework or general construction obstructs space available for unit.

6. Provide 1/4” mesh screen beneath the discharge grille to protect against objects being dropped through the discharge grille.

7. Provide leveling legs to compensate for uneven floor surfaces.

8. Provide adaptor back units (21-7/8") consisting of standard depth unit plus approximately five inch deep insulated false back outside air intake plenum wherever manufacturer's standard size OA intake opening in general construction is not directly aligned with unit OA intake and unless standard depth units are specifically called for.

   a. Provide insulation on the rear of the basic unit same as the standard depth unit.

   b. Include full back panel with field cut flanged opening to match wall opening.

   c. Provide dual closed cell foam gasket at rear of the adaptor back as required to provide air tight seal round the wall opening and the unit perimeter when the unit is lagged to the wall.

   d. Insulation:

      1) Provide R-6 minimum, matte-finish closed-cell foam insulation, complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916. Insulate outside air duct on bottom, side, and top walls of adapter back and pipe tunnel as thermal break between outside air intake plenum and occupied space / return air / pipe space.

      2) Fire-Hazard Classification: Insulation and adhesive combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

      3) Surfaces in contact with the airstream: Comply with requirements in ASHRAE 62.1.

   e. Provide with 2" step-down height to match lower window sill height as required. VIF.

9. Provide a durable Charcoal Bronze textured paint finish on the top surface. Provide front end, and all other visible panels with baked enamel finish available in a minimum of (6) decorator colors for selection by the Architect.

F. Ceiling Units:

1. Similar in construction and finish to floor units with the following differences:

   a. Provide two hinged bottom panels for ease of handling. Provide with retainer chains to prevent sudden release of the bottom panels.

   b. Discharge, return, and outside air intake openings fitted with the following trim, as scheduled and as coordinated with the drawings, Owner, and Architect in the field:

      1) Unit flush with ceiling: bottom mounted curved bar stock grille with adjustable side deflection vanes discharge, bar grille return, duct collar OA intake.

      2) Unit end wall exposed: adjustable double deflection register discharge, bar grille return, duct collar OA intake.

3) Unit concealed above ceiling: three duct collars.

c. The center line of the cooling condensate drain shall be a minimum of 4.5 inches above the bottom of the unit.

d. Provide trim flange for recessed units. The trim flange shall be 3-sided or 4-sided as required.

G. Coils:

1. Test and rate unit ventilator coils according to ASHRAE 33.

2. Provide hydronic coils of self-venting design with rows as required by scheduled capacity rated for a minimum working pressure of 200 psig at no less than 220 deg F. Elements of not less than 3/8" seamless copper tubes and return bends on staggered centers in the direction of air flow. Fins of continuous plate aluminum mechanically bonded to all tubes no closer than 0.1 inch. Provide with 7/8" silver brazed copper headers with minimum 4 pass serpentine design and NPT threaded connections as required to achieve a water pressure drop no greater than scheduled. Provide threaded drain plug at low point, and manual air vent at coil high point.

3. Steam Coils: Double copper tube steam distributing freeze resistant type sloped for drainage, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 75 psig. Provide a pressure-equalizing device (vacuum breaker) factory installed to prevent the retention of condensate in the coil, complete with tubing for connecting the equalizing device to the condensate return line beyond the trap.

4. Indoor Refrigerant Coils: (3) or (4) rows deep, as scheduled, copper finned tube coils with 3/8" O.D. nominal, seamless copper tubing, mechanically bonded aluminum fins spaced no closer than 0.1 inch continuous across all tubes, and brazed joints at fittings. Comply with AHRI 210/240, and leak test to minimum 450 psig for a minimum 300-psig working pressure. Provide with thermostatic expansion valve and distributor and quick connect refrigerant couplings. Provide factory dehydrated, evacuated, and charged with operating charge of specified refrigerant, hermetically sealed for use with the unit manufacturer's matching condensing unit.

5. Coil Accessories:

a. Provide a Stainless Steel, all-aluminum, or galvanized steel with plastic liner drain pan beneath all coils to collect all condensate and leakage, formed as required by ASHRAE 62.1, easily removable for cleaning purposes, and drained at the unit end compartment to the condensate disposal system. Insulate the condensate drain pan to prevent external condensation.

b. Provide a factory installed automatic reset freeze-stat (refer to section 23 09 00 for specification) serpentined across the discharge face of the coil. Install tautly extended across and in close proximity to representative areas of coil as required to insure and guarantee against coil freeze-up conditions without freeze-stat nuisance trip.

H. Dampers:

1. Provide with separate room air and outdoor air dampers.

   a. Damper shaft extends through bearings to service compartment designed to accept electronic damper actuator.
   b. Bearings of high-performance polymer similar to delrin which does not require lubrication.
   c. Seals along edges of formed damper blade material fitted into channel with blended silicone rubber and mohair impregnated glass cloth, with mohair seals along all ends.

2. Room air damper: constructed of aluminum, counterbalanced against back pressure to close by wind pressure, thereby positively preventing outdoor air from blowing directly into the room.

3. Outdoor air damper: two-piece double wall torsionally rigid box beam construction with 1/2" thick, 1.5pcf density fiberglass sandwiched between welded 20-ga. galvanized steel blades. Provide additional closed cell foam insulation adhered to the interior and exterior of the outside air dampers and all other surfaces of the outside air chamber, minimum R value of 4.

I. Indoor Fan and Motor Assembly

1. Direct drive multiple fan and motor assembly constructed to assure quiet, uniform air distribution, guaranteed to deliver the unit’s nominal advertised cfm at high speed.

2. All components of the fan/motor assembly including the motor mounting platform mounted on a chassis removable as a single subassembly from the front of the unit.

3. Fans wheels statically and dynamically balanced, constructed of welded galvanized steel or dark, high density, injection molded fiber reinforced polypropylene having high impact strength, chemical resistance and thermal stability. Fan housings constructed of welded galvanized steel, with deep spun bell-mouth entries.

4. Single full length large diameter hollow steel shaft on resiliently mounted precision shaft end sleeve type bearings. Bearings require oiling no more than annually, located outside of the moving air stream with no intermediate bearings allowed.

5. Motors designed specifically for extra quiet unit ventilator operation, 115 volts, single phase 60 Hz unless otherwise scheduled.

   a. Automatic speed control motors: electronically commutated motor (ECM) as manufactured by General Electric. Motor shall be of permanent magnet, brushless DC premium efficiency design with variable speed electronic controller capable of maintaining constant speed, torque, and/or cfm as required by service, capable of accepting 0-10vdc or 4-20mA speed control signal from building management system. Adjustable slow start and gradual speed changes, permanently lubricated ball bearings, and extra quiet operation are all included.

J. Unit Electrical and Controls

1. Provide unit mounted integral disconnect and control boxes with ample room for installing and servicing controllers, control circuit fusing, room air fan speed terminal contacts for ECM motor control by DDC control system, speed selector switch as applicable, freeze-stat switch body, transformers, and fused 120vac duplex outlet. Arrange all electrical components for ease of serviceability.

2. Provide fan motor and controls voltage power transformers for units where power source is other than fan and/or controls voltage.

3. Additional control devices and operational sequences are specified in Division 23 Section "Instrumentation and Control for HVAC" and on the drawings.

K. Accessories

1. Pipe Enclosures:

   a. Provide piping enclosures by UV manufacturer for all horizontal and vertical piping which is in occupied spaces or spaces accessible to the students, such as classroom closets, unless piping is indicated on drawings as being covered by a chase, draft stop, fin tube enclosure, or casework by others.

   b. Approximately 12" high x 3-1/2" deep (standard size of the manufacturer of units).

   c. Provide UV manufacturer's wall mounted face panels constructed of 16-ga. steel finished to match unit ventilators, formed into "U" (flat wall mount) or "L" (corner mount). Provide solid enclosures (no vents / grilles), with all sleeves, fillers, and end caps required to complete the installation. Include 20 gauge steel continuous solid back plates for mounting enclosures to wall, matching face panels for distortion free installation.

2. Sub-base: Sheet metal floor-mounting base with leveling screws and black enamel finish.

3. Duct flanges for supply-, return-, and outdoor-air connections as required.

4. Filters: Minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

   a. 1 inch thick mini-pleated cotton-polyester media MERV 13 filters have a rating based on ASHRAE Standard 52.2.

5. Outside Air Intake:

   a. Provide 1/2" x 1/2" bird screen on inside face of louver, and 12 gauge aluminum outdoor protective grille with square holes of spacing to match louver blades, connected by 1/4" wide frets aligned with louver blades to minimize intake air obstruction.

b. Provide scheduled factory finish as detailed below.

1) Anodized: Provide clear anodized finish complying with Aluminum Association code AA-C22A44, electrolytically deposited onto chemically etched and pretreated aluminum extrusion, minimum thickness of coating .8 mils., with seal coat.

c. Provide galvanized sheet metal OA intake sleeve from louver to unit back complete as detailed and as required to effect airtight seal to unit, in accordance with specification section 23 31 00 – Air Ducts.

d. Provide intakes by unit ventilator manufacturer except as otherwise noted on the Drawings. Provide manufacturer's standard size intake for that size UV unless indicated otherwise on drawings.

L. Remote Condensing Units

1. Provide condensing units matched to respective UV to provide guaranteed performance as a package with UV.

2. Description: Factory assembled and tested; consisting of compressors, condenser coils, fans, motors, refrigerant receiver, and operating controls. Construct, test, and rate condensing units according to AHRI 210/240 and ASHRAE 15.

3. Casing: Steel with baked-enamel finish; removable panels for access to controls, weep holes for water drainage, and mounting holes in base.

a. Casing Finish: Baked enamel, in manufacturer's standard paint color as selected by Architect.

4. Compressor: Hermetic, scroll type; internally isolated for vibration with factory-installed safety devices as follows:

a. Antirecycle timer.
b. High-pressure cutout.
c. Low-pressure cutout or loss-of-charge switch.
d. Internal thermal-overload protection.
e. Current and voltage sensitive safety devices.

5. Compressor Motor: Start capacitor, relay, and contactor. Comply with requirements in Division 23 Section "Common Electrical Requirements for HVAC Equipment."

6. Refrigerant Piping Materials:

a. Drawn-Temper Copper Tube: ASTM B 88, Type L.
b. Annealed-Temper Copper Tube: ASTM B 88, Type L.
c. Wrought-Copper Fittings: ASME B16.22.

7. Refrigerant: R-410A.

8. Crankcase heater.

9. Charging and service fittings on exterior of casing.

10. Filter dryer.

11. Condenser: Copper-tube, aluminum-fin coil, with liquid subcooler.

12. Condenser Fan: Direct-drive, low speed extra quiet and efficient steep pitch aluminum propeller fan; ECM motor with thermal-overload protection.

    a. Motor: Comply with requirements in Division 23 Section "Common Electrical Requirements for HVAC Equipment."

13. Accessories: Concrete pad.

2.2 VERTICAL UNIT VENTILATORS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   1. System Air by ChangeAir.
   2. Airedale or equal.
   3. Temspec or equal.

B. General:

   1. Provide vertical up-flow configuration energy recovery unit ventilator.
   2. Units shall be manufactured in an ISO 9001 registered facility, CSA certified, and CAUL / UL listed.

C. Cabinet and Chassis:

   1. Formed, welded and bolted 16 gauge galvanized steel frame supporting all internal components.

   2. Exterior cabinet panels fabricated from 18 gauge steel, cleaned and phosphatized, with appliance grade powder coated baked enamel textured finish, concealing frame with no visible screws, rivets, or fasteners other than access door cam-locks.

   3. Finish color shall be as selected by Architect from manufacturer's standard colors.

   4. Field connections (hydronic and electrical) shall be located at the top of unit. All service from the front of the unit, accessed by opening two full width / half height hinged removable panels, which are secured with keyed lockable cam-locks. Cam-locks operators shall all have the same tamper resistant key.

   5. Units suitable for alcove or closet installation.

   6. Heating and ventilating only units shall have an insulated cabinet with coil mounting configuration and drain pan so that the later addition of a cooling coil shall not require chassis modification.

7. Provide 1” thick flexible foam plastic closed cell insulation lining the entire interior of the cabinet and drain pans, providing thermal insulation of cold and hot interior components, complete protection against condensation of moisture on or within the unit, and to reduce the radiated sound level of the units.

8. Provide streamlined airfoil aluminum return grille with a four inch thick in line sound attenuator, integral with the lower access door.

9. Provide 24X12 top discharge duct collar as unit discharge.

D. Coils:

1. Steam Coils: Double copper tube steam distributing freeze resistant type sloped for drainage, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 75 psig. Provide a pressure-equalizing device (vacuum breaker) factory installed to prevent the retention of condensate in the coil, complete with tubing for connecting the equalizing device to the condensate return line beyond the trap.

2. Provide a field installed automatic reset freeze-stat (refer to section 23 09 00 for specification) serpentined across the discharge face of the coil. Install tautly extended across and in close proximity to representative areas of coil as required to insure and guarantee against coil freeze-up conditions without freeze-stat trip.

3. Provide a stainless steel double sloped closed cell insulated drain pan with both primary and raised auxiliary connections beneath all coils to collect all condensate and leakage. The condensate drain pan shall be easily removable for cleaning purposes.

E. Fans and Motors:

1. The motor and fan assembly shall be constructed to assure quiet, uniform air distribution, and shall be guaranteed to deliver the unit’s nominal advertised cfm.

2. All components of the fan/motor assemblies including the motor mounting platform shall be removable from the front of the unit.

3. Supply fan assembly shall be direct drive, one or two double inlet centrifugal blower as required by cfm scheduled, with permanently lubricated ball bearing ECM. Motor shall be of permanent magnet, brushless DC design with variable speed drive electronic controller capable of maintaining constant speed, torque, and/or cfm as required by service. Slow start and gradual speed changes, premium efficiency, and extra quiet operation are all included. Fans wheels shall be constructed of statically and dynamically balanced, dark, high density, injection molded polypropylene having high impact strength, chemical resistance and thermal stability. Fan housings shall be constructed of welded galvanized steel, with deep spun bell-mouth entries.

4. Relief and outside air fans shall be direct drive, one double inlet centrifugal blower, permanently lubricated ceramic sleeve bearing. ECM fan control board shall accept either a direct 0-10 VDC analog control signal for full modulated control of the fan output or a 24 VAC digital signal for required fan output.

5. All fans shall have automatic reset internal thermal overload protection.

F. Dampers:

1. Provide with separate room air and outdoor air dampers.

    a. Damper shaft extends through bearings to service compartment designed to accept electronic damper actuator.
    b. Bearings of high-performance polymer similar to delrin which does not require lubrication.
    c. Seals along edges of formed damper blade material fitted into channel with blended silicone rubber and mohair impregnated glass cloth, with mohair seals along all ends.

2. Room air damper: constructed of aluminum, counterbalanced against back pressure to close by wind pressure, thereby positively preventing outdoor air from blowing directly into the room.

3. Outdoor air damper: two-piece double wall torsionally rigid box beam construction with 1/2" thick, 1.5pcf density fiberglass sandwiched between welded 20-ga. galvanized steel blades. Provide additional closed cell foam insulation adhered to the interior and exterior of the outside air dampers and all other surfaces of the outside air chamber, minimum R value of 4.

G. Filters:

1. Provide with 2" thick MERV 13 pleated disposable supply air filters.
2. Provide with ½" thick MERV 8 pleated disposable air filters at the outside air and exhaust air inlet sides of each air-to-air heat exchanger.
3. Filters shall be easily accessible from the front.

H. Electrical Wiring and Controls:

1. Factory wired back to single point of power connection. CAUL / UL listed as a package.

2. Provide factory mounted unit disconnect. The connection box shall allow connection of single or three phase electric power supply, ground wire, and control wires. Unit voltage and power requirements shall be as scheduled on the drawings.

3. Unit mounted control boxes containing control circuit fusing, integral disconnect, low voltage door switch, supply air fan speed controllers switch, freeze-stat switch body, controls voltage transformer for units other than 120vac, receptacles as required to interface with controls and cooling lockout thermostat (to utilize economizer cycle).

I. Accessories:

1. Top Duct Cover:

    a. UV Manufacturer's sheet metal sleeve sized to fit perimeter of UV and to conceal duct, electrical, and piping connections. Height shall be as required to extend from the VUV top to above the finished ceiling or soffit, concealing all mechanical connections while allowing maximized service access. Top Duct Cover shall be same gauge sheet metal and finish as VUV cabinet.

2. Pipe Enclosures:

a. Provide piping enclosures by UV manufacturer for all horizontal and vertical piping which is in occupied spaces or spaces accessible to the students, such as classroom closets, unless piping is indicated on drawings as being covered by a chase, draft stop, fin tube enclosure, or casework by others.

b. Enclosures shall be approximately VUV depth, 8” wide, and height as required to conceal piping complete, constructed of 16 gauge steel same finish as VUV.

3. Energy Recovery Wheel:

a. Casing: Steel with manufacturer's standard paint coating and with the following:

1) Integral purge section.
2) Casing seals on periphery of rotor, on duct divider, and on purge section.
3) Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.

b. Rotor: Corrugated-aluminum or polymer, segmented wheel strengthened with radial spokes, and having nontoxic, noncorrosive silica-gel desiccant coating. Construct media for passing maximum 800-micrometer solids and maximum 0.04 percent cross contamination by volume of exhaust air. Drive rotor with belt around outside of rotor.

2.3 FAN-COIL UNITS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Carrier Corporation.
2. Environmental Technologies, Inc.
3. McQuay International.
4. Trane.
5. YORK International Corporation.

B. Description: Factory-packaged and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.

C. Coil Section Insulation: 1/2-inch thick, matte-finish, closed-cell foam complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

D. Main and Auxiliary Drain Pans: Plastic. Fabricate pans and drain connections to comply with ASHRAE 62.1. Drain pans shall be removable.

E. Chassis: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.

F. Cabinet: Steel with baked-enamel finish in manufacturer's standard paint color as selected by Architect.

1. Vertical Unit Front Panels: Removable, steel, with steel discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
2. Horizontal Unit Bottom Panels: Fastened to unit with cam fasteners and hinge and attached with safety chain; with integral stamped discharge grilles.
3. Steel recessing flanges for recessing fan-coil units into ceiling or wall.

G. Outdoor-Air Wall Box: Minimum 0.1265-inch- thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.

1. Louver Configuration: Horizontal, rain-resistant louver.
2. Louver Material: Aluminum.
3. Bird Screen: 1/2-inch mesh screen on interior side of louver.
4. Decorative Grille: On outside of intake.
5. Finish: Anodized aluminum, color as selected by Architect from manufacturer's standard colors.

H. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with shaft ready to accept electronic, two-position actuators.

I. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. 1 inch thick mini-pleated cotton-polyester media MERV 13 filters have a rating based on ASHRAE Standard 52.2.

J. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve.

K. Steam Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 75 psig.

L. Fan and Motor Board: Removable.

1. Size / design for mid-life filter resistance equal to the average of the as specified clean filter resistance at the design flowrate and the filter manufacturer’s recommended maximum (in need of changing) filter resistance at the design flow rate.

2. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.

3. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Electrical Requirements for HVAC Equipment."

4. Wiring Termination: Connect motor to chassis wiring with plug connection.

M. Control devices are specified in Division 23 Sections "Instrumentation and Control for HVAC."

N. Electrical Connection: Factory wire motors for a single electrical connection. Provide factory mounted unit disconnect.

2.4 HOT-WATER OR STEAM FINNED TUBE RADIATORS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Rittling, a div. of Hydro-Air Components.
2. Slant/Fin.
3. Sterling Hydronics, a Mestek company.

B. Performance Ratings: Rate baseboard radiators according to Hydronics Institute's "I=B=R Testing and Rating Standard for Baseboard Radiation."

C. Fin Radiation: Complete enclosure of heavy-duty, institutional grade construction, continuous supporting channel and back plate, heating element, hangers and accessories as required; factory-boxed and tagged by room number and securely anchored to building in a manufacturers approved manner. Enclosures to run from wall-to-wall, unless otherwise indicated on Drawings, and provided with all necessary corner pieces, end caps, column enclosures, butt joint trims, wall sleeves, and all access doors required.

1. Heating Elements:

   a. Element constructed of seamless drawn copper tubing mechanically expanded into aluminum full collar or full temper embedded fins of size shown and specified.

   b. Provide tube size 3/4” through 1-1/4” as required by flow rate. Use same fin tube element tube size as pipe size shown leading to fin tube on drawings.

   c. Provide elements in lengths, sizes, and capacities as shown on drawings.

      1) For all fin tube shown with 4-1/4” nominal enclosure and as bare element in casework, provide element with forty 3-1/4” x 3-1/4” aluminum fins per foot with bare single element nominal capacity of 680 btu/ft-hr. at 65 deg. F entering air temperature and hot water at EWT 180 deg. F, LWT 160 deg. F.

2. Fin Tube Element and Enclosure types:

   a. Type FTR-A: Bare element installed behind casework. Use nominal 3-1/4” fins of tube size indicated.
   b. Type FTR-B: Wall mounted slope top enclosure nominally 4-1/4” deep x 18” high (unless noted otherwise), with stamped slotted sloped front supply grille.
   c. Type FTR-C: Wall mounted slope top enclosure nominally 4-1/4” deep x 24” high (unless noted otherwise), with stamped slotted sloped front supply grille.

3. Element Supports: Swinging, ball bearing, or sliding type designed to allow for expansion. Supports must allow free noiseless movement of pipe and elements.

4. Enclosures:

   a. Complete enclosures to run from wall-to-wall unless otherwise shown and noted on plans.

   b. Materials:

      1) General service: ASTM A-653/653M-94 G90 lock forming quality galvanized steel, prepared for painting via mill phosphatizing in accordance with ASTM A2092, unless otherwise noted.

   c. Material gauges:

      1) 16 ga.: General service.

   d. Provide continuous enclosure back plate and back hanger channel of 20 ga. roll formed material same as cover, configured for positive support of cover and element. Include continuous urethane foam dirt seal between wall and channel.

   e. Gusset braced cover construction with stamped outlet and inlet of configuration described above. Provide cover support brackets spaced as recommended by manufacturer but on center distances not greater than 4'. Provide brackets within 6" of end of cover and within 6" (on both sides) of each joint between sections or corner joints. All fasteners shall be concealed or tamper resistant. Fasteners shall match enclosure materials.

   f. Provide matching die formed end caps, inside and outside corner pieces, wall sleeves, internal end plates, column enclosures, butt strips, valve compartments, riser chases, access doors and other accessories as shown on drawings and as required to fabricate neat, complete installation.

   g. Enclosures and all trim accessories shall be phosphatized and painted inside and out with one coat of baked on alkyd enamel primer, then finished with baked enamel in color selected by Architect.

5. Valve Access Panel:

   a. 12" wide minimum, full enclosure height access door with tamper resistant closure. Provide for reasonable service access where any of the following must be within enclosure (typical):

      1) Isolation valve.
      2) Air vent or drain.
      3) Shut off valves, unions, P/T plugs, etc.
      4) Temperature control valve.

   b. Alternatively, provide nominally 24" wide section of enclosure at location of piping specialties, with tamper resistant fasteners designed and installed to facilitate ease of repeated maintenance.

2.5 HEATING COILS FOR AIR SYSTEMS

A. General:

1. Size for face velocity and maximum pressure drops scheduled. If not scheduled, size to provide maximum of 500 fpm face velocity for cooling coils, 650 fpm face velocity for heating coils, or higher only if restricted by maximum coil size that can fit within existing units.

2. All coils to be computer optimized as to size and arrangement to meet requirements listed on drawings. Include computer selection sheets in submittal.

3. Certified in accordance with AHRI Standard 410.

4. Rate coils for the type and percentage of glycol solution called for, where applicable.

B. Hydronic Heating Coils:

1. Coils shall have all performance characteristics as scheduled or otherwise required as a minimum, including size, sensible and latent capacity, number of rows, tubing and circuits, headers, connection sizes, and water and air pressure drops.

2. Casings: Constructed of 16 gauge channels with fins tight against or recessed into the channels to minimize air bypass. Channels to have 3/8" holes on 6" centers for flanged to duct mounting. Where required by different existing duct connection conditions, provide flange mounting arrangement to match existing.

    a. Heating coils shall have continuously galvanized steel casing frames.

3. Headers:

    a. Provide copper, steel, or cast iron headers as required to achieve capacity, even discharge air temperatures, and water pressure drop scheduled.

        1) Seamless extra heavy wall copper tubing with brazed brass threaded supply and return connections.

        2) Gray cast iron hydrostatically tested to 400 PSIG before assembly. Headers 12 inch and larger shall be tapered to assure uniform distribution to all tubes. Provide threaded or flanged connections.

        3) Provide system connection sizes same size as connected piping as shown on drawings, unless otherwise scheduled.

        4) Provide drain and vent connections in headers.

4. Tubes, unless otherwise scheduled:

   a. Seamless, 5/8” O.D., 0.024 inch min. wall copper tube primary surface, expanded into the fin collars for a permanent fin tube bond and brazed copper header into the header for a leak tight joint at 250 PSIG air pressure under water.

   b. Return bends shall be .035" min. wall machine die formed and wrinkle free at the bend I.D.

5. Fins:

   a. Continuously configured .006" min. plate type fins with full fin collars for accurate spacing and maximum fin - tube contact.
   b. General heating coil fin material: aluminum.
   c. Cooling coil, and as otherwise noted on drawings, fin material: Heresite coated aluminum or copper.

6. The complete coil core shall be tested with 315 psi min. air (or nitrogen) pressure under warm water and guaranteed for 250 psig working pressure.

7. Bronze spring type turbulators shall be used where necessary to attain required capacity at the available GPM and entering water temperature, without increase in scheduled water pressure drop.

8. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   a. Carrier or equal.
   b. Enviro-tec or equal.
   c. Heatcraft Refrigeration Products LLC; Heat Transfer Division.
   d. McQuay or equal.
   e. Super Radiator Coils.
   f. Trane or equal.
   g. USA Coil & Air.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive equipment for compliance with requirements for installation tolerances and other conditions affecting performance.
B. Examine roughing-in for piping and electrical connections to verify actual locations before unit installation.
C. Proceed with installation only after unsatisfactory conditions have been corrected.
D. Beginning installation constitutes Contractor’s acceptance of substrates and conditions.

3.2 INSTALLATION

A. Install equipment in compliance with NFPA 90A.

B. Install equipment level and plumb.

C. Suspend motorized equipment from structure with threaded steel rods and minimum 0.25-inch static-deflection, elastomeric vibration isolation hanger. Vibration isolators are specified in Section 23 05 43 "Mechanical Vibration, and Movement Control."

3.3 FREEZE-PROTECTION

A. Take all precautions to prevent uncontrolled infiltration of outdoor air to coils and piping, including (but not necessarily limited to) following preventative steps:

B. Provide sleeves, safing, insulation, caulking, etc..., as required to make neat and airtight connection to outside air intakes, with no uncontrolled infiltration permitted.

C. If walls are in such condition that it is impossible to plumb the units with the walls and get correct sealing through standard methods, notify the Owner and Architect of proposed solution, and modify methods as required. Units must seal tightly against the walls and prevent infiltration.

D. Insure that adapter back wall boxes are properly installed and sealed and that no air is permitted to leak past them. Insulate per section 23 07 00 – HVAC Insulation.

E. Adjust outdoor air dampers on the units to close tightly when in the unoccupied position (100% closed).

F. All openings in the outside air intake path between the intake louver and the outside air control damper which could permit the uncontrolled entrance of outdoor air shall be sealed and insulated. This includes but is not limited to unused holes (knockouts, etc.,), spaces around pipes and conduits, sealing wall sleeve to wall, sealing around intake louver, and other openings into piping and air compartments.

G. Insure that all freeze protection controls are in place and functional prior to freezing weather. During initial freezing weather, man job and continuously inspect for freeze concerns, provide report to Architect and Owner immediately and correct any discovered conditions which may result in freeze damage.

3.4 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

1. Install piping adjacent to machine to allow service and maintenance.
2. Unless otherwise indicated, install shutoff valve and union or flange at each connection.

3. Connect piping to equipment using specialties as detailed on drawings, with at minimum isolation valves, unions, and P/T test ports supply and return, with control valve on return as specified.

4. Pipe cooling coil condensate through properly sized accessible p-trap to approved point of indirect waste discharge. Pipe auxiliary drain pan connection to point of conspicuous discharge where minimal damage to building components will occur. Coordinate location of discharge with Owner and Architect in field.

B. Connect supply and return ducts to ducted equipment with flexible duct connectors specified in Section 23 31 00 "Air Ducts." Comply with safety requirements in UL 1995 for duct connections.

C. Ground and wire equipment according to the stricter of manufacturer’s and Division 26 requirements.

3.5 FIELD QUALITY CONTROL

A. Ensure Manufacturers provide:

1. Thorough instruction of installing Contractor’s personnel in installation of units.
2. Instruction for Owner's personnel in operation and care of equipment.
3. Maintenance brochure.
4. Adjustment of air discharge pattern to suit each room as directed and approved.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

C. After installing equipment, inspect for damage to finish. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.

D. Remove and replace malfunctioning and damaged units and retest as specified above.

END OF SECTION 23 82 00