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, electrical connection requirements, 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.

J. Heating Work: Refers to Heating, Ventilating and Air Conditioning Systems and Equipment where used in technical specification sections of Division 23.

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.	IBC	International Building Code, New Jersey Edition
10.	IEEE	Institute of Electrical and Electronics Engineers, Inc.
11.	NEC	National Electric Code
12.	NEMA	National Electrical Manufacturers Association
13.	NFPA	National Fire Protection Association
14.	NYBFU	New York Board of Fire Underwriters
15.	SMACNA	Sheet Metal and Air Conditioning Contractors National Association
16.	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, including all system fluid and solid components.
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 the basis of design equipment, and will be installed as specified in Part 3 in the product's technical specification section, and only where allowed as such in submittal portion of product specification, then the "As-Specified Verification Form" (attached to Section 01 33 00 - Submittals) may be used 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 proposed to be incorporated into Project is <u>not</u> the basis of design equipment, 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. Where more than one product is indicated on

manufacturer product literature, strike out products that are not applicable to item being submitted, highlight options selected and proposed, and remove extraneous pages of catalogs not being used in the project..

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. Coordination Drawings: Prepare Coordination Drawings in timely manner to comply with overall construction schedule. Refer to Sections 01 31 00 and 01 33 00 for more details.

a. Prepare drawings coordinating HVAC systems, lighting fixtures, ceiling mounted devices, ceiling heights, materials, structural work, maintenance clearances, electric code clearance, building systems, existing construction, etc. Provide additional details and sections, as required for clarity, at all places of potential conflict.

b. Deliver Coordination Drawings in accordance with requirements specified in Section 01 31 00. Indicate areas of conflicts between HVAC systems and other building components by highlighting locations on drawings and separately listing.

c. Reposition proposed locations of HVAC systems as required to work within project constraints. Adjust exact size, aspect ratio, location and offsets of ducts and pipes as required. Achieve as specified and other reasonable appearance objectives in open areas without ceilings without increase in Contract Sum.

d. Review of Coordination Drawings in accordance with Section 01 31 00 does not relieve Contractor from responsibility for coordinating HVAC systems with Project work, nor does it authorize extra cost, omission or deviation from Contract Document requirements. Costs arising from errors or omissions in Coordination Drawings shall be borne by Contractor.

e. Review Coordination Drawings and compare them with all other drawings to verify that all Work can be installed without interference. Notify Owner's Project Representative in case of unresolved interferences prior to installation of any work. Revise Coordination Drawings as required to eliminate installation interferences upon direction of Architect.

f. 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. 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. Power Train Accessories
2. Concrete Bases, Grout
3. Sealants
4. Fire-stopping.
5. Access doors.
6. Painting and finishing.

D. 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.

4. Valve, and Lubrication charts as described below.

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 Refrigeration (ASHRAE Standard 15 - and ANSI Refrigeration Safety Code B9.1).

   c. Provide all boilers/burners in accordance with applicable requirements of New York State Labor Department Industrial Code Rule No. 4 (cited as 12 NYCRR4) and Code Rule No. 14 (cited as 12 NYCRR14).

   d. Provide all boilers/burners in accordance with applicable requirements of the State of Massachusetts General Laws chapter 146 (also known as MGR 146 section 46-51), and the Code of Massachusetts Regulations 522 (also known as 522 CMR 1-17).

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 at no additional cost to the Owner. Equipment must continue to comply with the requirements of the Energy Conservation Code applicable to the project.

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 by 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 components, valves, 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 Heating Work with existing 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.

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

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

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

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

3. Material Flammability:

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

4. 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 MOTOR POWER TRAIN ACCESSORIES

A. For all new motor installations provide accessories listed below as required for a complete new drive system.

B. Independently Mounted Direct Driven Load Motor Couplings: Interlocking machined and balanced steel spider locked Molded rubber insert and capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. Include EPDM coupling sleeve for variable-speed applications.

C. Provide personnel guards to fit new motor and drive for all new equipment motors, whenever replacement motor and drive do not fit existing guard, or where noted to provide new guard on drawings.

1. Personnel guards shall be of OSHA approved construction surrounding belts, shafts, and pulleys, with tachometer holes for motor and driven shafts.

2.4 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. All Other 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

2.5 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.

2.6 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.

2.7 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.

2.8 PAINT AND FINISHES

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

PART 3 - EXECUTION

3.1 EXISTING CONDITIONS

A. Examine existing conditions in the field prior to beginning demolition or contract Work as required to confirm conditions are appropriate for the work to proceed. Refer to Section 01 73 00 "Execution" and Section 02 41 19 "Selective Demolition" for additional information and general demolition requirements and procedures.

B. 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.

C. 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.

3.2 HVAC DEMOLITION

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

1. Prior to removal of system components, provide for proper working conditions including but not limited to:

a. Electrically shutdown and/or disconnect with lockout / tag as required.
b. Provide Personnel Protection Equipment.
c. Air Systems: seal off portions of systems not under construction as required protecting Owner’s belongings.
d. Hydronic Systems: Properly isolate and drain systems as required protecting Owner’s belongings.

e. Refrigerant Based Systems: Evacuate and retain refrigerant per ASHRAE 15 and 40 CFR 82.

2. 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.

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

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

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

B. Disposition of Removed Components:

1. All material and equipment shown on the drawings to be removed during project Work that is not indicated on the drawings as being either reused or turned over to the Owner becomes the Contractor's property as a part of the project including salvage value and legal disposal cost complete.

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.

3.3 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, chilled water, heating water, drain, vent, refrigerant, and gas 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.

4. Connect equipment complete and ready-to-use, including all valves, piping, piping accessories, 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. Outside air dampers are tight fitting and operational, and damper motors are properly winterized.
4. Air systems are properly balanced.

5. 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. Opening Through Outside Walls:

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

2. Use special waterproof construction as directed.

3. Provide mechanical sleeve seals for piping penetrations.

B. Openings 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 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 PAINTING

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

B. 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).

C. Paint Requirements:

1. Provide painted finish for HVAC components (exposed gas piping). Provide factory painted finishes as specified elsewhere or if not factory painted then field painted. Refer to Division 09 for painting specifications and additional painting requirements if required.

a. Provide touch up painting as required to repair, or replace as directed, damaged factory finishes of HVAC components.

2. Paint all exposed metal surfaces that will be above 150 degrees F when in operation, with two coats of heat resistant paint.

3. Paint all miscellaneous fabricated ferrous supports complete.

4. For piping that will be subject to moisture induced corrosion on the exterior of the piping, provide one full coverage coat of corrosion inhibiter equal to "Polyguard RG-2400" on the following ferrous (steel) piping and fittings before insulation is applied:

   a. All exterior ferrous piping.
   b. All ferrous piping where the fluid in the piping operates at below ambient conditions (all cooling piping)

5. Do not paint

   a. Chrome plated materials, aluminum and brass valves, or brass trim on iron body valves, stainless steel materials, copper indirect waste piping, laboratory waste and vent piping.

   b. Piping above finished ceiling spaces, except un-insulated ferrous piping and supports.

   c. Exposed copper pipe, brass valves, or brass trim on iron body valves, or machinery or equipment with factory-applied finish, unless otherwise specified.

6. Coating Systems: Comply with application and material requirements specified in Division 09.

7. Color Code Identification: Provide color code identification of mechanical piping in Boiler Rooms, Mechanical Rooms and Fan Rooms by painting the following services as listed below.

	Item	Color
a.	Fuel Gas Piping	OSHA Safety Yellow
b.	Heating hot water supply	Dark Red
c.	Heating water return	Light Red
d.	Chilled water supply	Blue
e.	Chilled Water return	Light Blue
f.	Cold water (makeup)	White (ASJ without paint OK)
g.	Chemical treatment	White (ASJ without paint OK)

3.10 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

3.11 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.

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

2. 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. Clean all piping strainers and replace all "startup" screens with permanent screens.
2. Provide written notification to Architect upon completion of all final cleaning procedures and request inspection of final cleaning.

3.13 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. Boilers / Burners.
c. Chiller
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. Valve Identification Chart: Provide a valve chart for all valves installed in contract.

1. Provide 8-1/2 inch x 11 inch minimum size Valve Identification Chart, typed in capital letters, mounted under clear laminated plastic; secure to wall 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. List all valves included in Contract. Obtain necessary information containing the following:

a. Valve number, piping system, system abbreviation (as shown on valve tag) and location of valve.
b. Normal operating position (open, closed, or modulating).
c. Clearly identify special purpose valves (for emergency shutoff, etc.).

C. Lubrication Chart: Provide minimum 8-1/2 inch x 11 inch lubrication chart for all Work in Heating Work Contract, typed in capital letters, mounted under clear laminated plastic, and secured to wall where directed by Architect.

1. List all motors and equipment including following information:

    a. Name and location of equipment.
    b. Type of lubrication recommended by manufacturer.
    c. Lubrication period recommended by manufacturer.

2. Lubricate all motors immediately after installation and perform lubrication maintenance until final acceptance by Owner.

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 drive train accessories 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. Informational Submittals:

1. Motor Efficiency and Rebate Data: Submit copies of forms from applicable utility agencies regarding availability of energy efficiency rebates with minimum motor efficiency requirements, along with tabulated efficiency ratings of all motors provided as a part of this contract work which are of a size applicable to the rebates, demonstrating compliance with project efficiency requirements.

D. 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.Remove paragraph below if applicable

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

C. 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.

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

E. Comply with NEMA MG 1 unless otherwise indicated.

F. 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. Below grade level, 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 MOTOR ACCESSORIES

A. For all new motor installations, whether in new equipment or installed as replacement motors, provide accessories listed below as required for a complete new drive system.

B. Provide personnel guards to fit new motor and drive for all new equipment motors, whenever replacement motor and drive do not fit existing guard, or where noted to provide new guard on drawings.

1. Personnel guards shall be of OSHA approved construction surrounding belts, shafts, and pulleys, with tachometer holes for motor and driven shafts.

C. Direct connected motors: provide with flexible couplings if required by application and OSHA approved belt guards surrounding rotating machinery.

2.6 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 fused disconnect switches. Fuse with class R fuses. 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.

2.7 ELECTRICAL HEAT TRACE

A. Provide heat trace cable for all piping, valves, and fittings installed outdoors or otherwise exposed to freezing temperature, and as shown on drawings.

B. Constructed of nickel plated 16 gauge bus wires connected by semi-conductive heat sensitive heating matrix, with flouropolymer dielectric insulation and nickel plated copper braid protective jacket. Cable to be rated for continuous exposure to steam temperatures, providing minimum 6W/ft at 50 deg F, output to decrease with increasing temperatures in self-limiting fashion.

C. Include all required and recommended accessories including but not limited to electrical fittings, thermal transfer mastic, controls, warning tape, etc.

D. Provide separate thermostat and controls for each separate service, thermostat range designed for freeze protection. Provide field wiring of heat trace cable through factory supplied connectors and controls to power source.

E. 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. Thermon type TSX
2. Chromalox type SRM/E
3. Nelson or equal.

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 and Starters

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 and Accessories

   a. Provide starters and disconnects for all HVAC equipment. Refer to Equipment Schedules.

   b. Furnish properly tagged and identified devices specifically indicated on "Electric Equipment and Control Schedule" as supplied by HVAC systems suppliers and determine coordinated location and time for delivery of devices.

   c. 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.
6. Electromagnetic flowmeters.

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.

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: De-zincification resistant brass, bronze, or stainless-steel needle type, slow opening, bubble tight shutoff, with ASME B1.20.1 pipe threads.

2.5 FLOWMETERS

A. Electromagnetic Flow Meters:

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) Onicon, Inc.
2) Omega Engineering, Inc.
3) Siemens Energy & Automation, Inc.

b. Description: Electromagnetic, no moving parts.
1) Input Power: 20-28 VAC, 50/60 Hz, 250 mA. Maximum.
2) Liquid Temperature Range: 15° to 250°F.
3) Ambient Temperature Range: -20° to 150°F.
4) Operating Pressure: 400 PSI maximum.
5) Pressure Drop: Less than 0.1 PSI and 12 ft./sec. in 3" and larger pipes.
6) Accuracy: +/- 1.0% of reading from 2 to 20 ft./sec., +/- 0.02 ft/sec. below 2 ft/sec.
7) Output Signal:
a) Analog output (Isolated), selectable 4-20 mA, 0-10 V or 0-5 V.
b) Frequency output, 0-15 V peak pulse, 0-500 Hz maximum.
c) Scalable pulse output, isolated dry contact, contact rating 50 VDC @ 100 mA maximum, pulse duration: 0.5, 1, 2 or 6 seconds

c. Construction: 316L stainless steel, Xarec sensor head, powder coat paint cast aluminum, NEMA 4 enclosure.

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.

J. Install flow indicators in piping systems in accessible positions for easy viewing.

K. Assemble and install connections, tubing, wiring, and accessories between flow-measuring elements, flowmeters and their controllers, and integrate with Energy Management and Control System as specified and as shown, all in accordance with manufacturer's written instructions.

3.3 Install flowmeter elements in accessible positions in piping systems.

3.4 LOCATIONS

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

1. Inlet and outlet of each boiler, at boiler.
2. Mixed boiler supply water before reset.
3. Building supply heating water after reset.
4. Boiler water supply and return from domestic water heating tank.
5. Each inlet and outlet of each hydronic heat exchanger.
6. Inlet and outlet of each chiller, at chiller.

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.

3. One pressure gauge for each chiller with 3 isolation ball valves and snubber, piped to read pressure before and after chiller or atmospheric. Valve installed open to atmosphere for zero adjustment of each gauge.

4. One pressure gauge for each boiler with 3 isolation ball valves and snubber, piped to read pressure before and after boiler or atmospheric. Valve installed open to atmosphere for zero adjustment of each gauge.

5. One pressure gauge for each side (heated and cooled) of each heat exchanger, two per heat exchanger, each with 3 isolation ball valves and snubber, piped to read pressure before and after heat exchanger or atmospheric. Valve installed open to atmosphere for zero adjustment of each gauge.

C. Flowmeters

1. Install flowmeters where shown on the drawings.

3.5 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.

3.6 THERMOMETER TYPE SCHEDULE

A. Thermometers in interior locations that are temperature controlled to within the operating limits of the equipment shall be the following:

1. Direct-mounted, light-activated type.

B. 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.

3.7 THERMOMETER SCALE-RANGE SCHEDULE

A. Provide thermometers of approximately the scale range indicated:

1. Scale Range for Chilled-Water Piping: 0 to 100 deg F.
2. Scale Range for Heating, Hot-Water Piping: 30 to 250 deg F .
3. Scale Range for Outside Air: Minus 20 to plus120 deg F.

3.8 PRESSURE-GAUGE TYPE SCHEDULE

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

3.9 PRESSURE-GAUGE SCALE-RANGE SCHEDULE

A. Scale Range for Building Chilled-Water Piping: 0 to 100 psi.
B. 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. Iron, grooved-end butterfly valves.
4. Pump Discharge Valves.
5. Air vent valves
6. 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 not 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 and Differential Pressure Flow Test Kit(s).

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 ball and plug valves open to minimize exposure of functional surfaces.
4. Set butterfly valves closed or slightly open.

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.

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

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 IRON, GROOVED-END BUTTERFLY VALVES

A. 300 CWP, Iron, Grooved-End Butterfly Valves:

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. Anvil International, Inc; “Gruvlock”.
   b. NIBCO INC.
   c. Victaulic Company.

2. Description:

   a. Standard: MSS SP-67, Type I.
   b. NPS 8 and Smaller CWP Rating: 300 psig.
   c. Body Material: Coated, ductile iron.
   d. Stem: Two-piece stainless steel.
   e. Disc: EPDM/Teflon coated ductile iron.
   f. Seat: EPDM/Teflon, reinforced, resilient, for water temperatures up to 250 deg. F at 150 PSI.

2.5 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.

2.6 AIR VENTS

A. Manual Air Vents:

1. For All Pipe Sizes In Accessible Locations Only: Bronze body, quarter turn ball valve with minimum ¼-inch discharge and inlet connections. Provide collection chamber at inlet and ¼-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.

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 special purpose hydronic valves (safety relief valves, reduced pressure zone backflow prevention devices, pressure reducing valves, etc.) as specified in section 23 21 13 – Hydronic Piping.

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

1. Install boiler isolation valves on system side of boiler specialty components especially safety components like relief valves and low water cutoff devices.

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

D. 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 inch and larger: Butterfly Valves.

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

D. 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.

E. 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.

F. 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. Boilers: Provide High Capacity Automatic Air Vent.

c. 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.

d. 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 venting, pipe discharge to chemical feed station as shown, or if not shown to minimum 1 quart clear plastic container, secured and removable for service.

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

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, movement, wind load, or seismic control requirements. Refer to Section 23 05 43 – MECHANICAL VIBRATION AND MOVEMENT CONTROL and Section 23 05 48 – MECHANICAL SEISMIC AND WIND LOAD 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: 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.

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

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

C. 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.

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. 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.

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.

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. 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. 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. 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. New Concrete Connectors:

1. Cast in Place Insert Style:

a. Carbon steel or malleable iron concrete insert, tapered slot retains internally threaded nut. Insert [12-inch x 1/2-inch] [300-mm x 15-mm] reinforcing rod through top of insert in pipes [6 inch] [150 mm] and larger.

b. MSS SP-58 type 18.

2. Cast in Place Threaded Stud Type:

a. Steel threaded rod inserted through steel deck before concrete pour, nut on both sides of deck to retain before pour, with offset at top for positive connection to cured concrete consisting of bent rod, welded top plate, nuts/washer, etc.

b. Similar to “Model No. 370A" by ERICO/Michigan Hanger.

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.

C. 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.

2.5 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.

2.6 MISCELLANEOUS COMPONENTS AND ACCESSORIES

A. 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.

B. 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 Cooling Service	100 ft.
b.	Individual Copper Heating Service.	35 ft.
c.	Trapeze Copper Cooling Service	60 ft.
d.	Trapeze Copper Heating Service.	20 ft
e.	Individual Steel Cooling Service	140 ft.
f.	Individual Steel Heating Service.	60 ft.
g.	Trapeze Steel Cooling Service	80 ft.
h.	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.

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, and flanges 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 connections cast in place to new concrete, assume concrete strength as specified. Do not apply loads to freshly cured concrete until written approval is received from contractor responsible for concrete strength.

5. 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 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.

3.8 PAINTING AND TOUCHUP

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.

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

C. 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:

2. Catalog cuts and data sheets on Vibration isolation hangers, piping, and flexible piping connections.

3. Shop Drawings

a. Submit details of following items

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

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

3) 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. Isolation Mountings

1. Neoprene Mountings: Provide minimum static deflection of 0.35-inch with all metal surfaces neoprene-covered and having friction pads both top and bottom.

   a. Bolt holes provided on base, isolated from tapped bolt hole with cap screw on top.
   b. Steel frame bases used above mountings to compensate for overhang.
   c. Basis-of-Design Product: Mason Industries, Inc.; Type ND or Rails Type DNR.

2. Restrained Neoprene Mountings: OSHPD pre-approved vibration isolation mounts with captive opposed neoprene inserts, minimum static deflection of 0.2-inch.

   a. Restraint rated at 2G minimum in all directions.
   b. Plated steel frame with base mounting holes, isolated from tapped bolt hole with cap screw on top.
   c. Basis-of-Design Product: Mason Industries, Inc.; Type BR.

3. Spring Isolators: Freestanding and laterally stable without housing and complete with molded neoprene cup or 1/4-inch neoprene acoustical friction pad between base plate and support.

    a. All mountings with leveling bolts rigidly bolted to equipment.
    b. Installed heights and operating heights equal.
    c. Ratio of spring diameter divided by compressed spring height no less than 0.8.
    d. Springs have minimum additional travel to solid equal to 50 percent of rated deflection.
    e. Include spring diameters, deflection, compressed spring height and solid spring height in Submittals specified in Part 1 above.
    f. Basis-of-Design Product: Mason Industries, Inc.; Type SLF.

E. 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.

4. Vibration Hangers: Similar to Type A Hangers specified above with following modifications.

    a. Provided with weldless eyebolts top and bottom to facilitate attachment to flat duct straps.
    b. Basis-of-Design Product: Mason Industries, Inc.; Type W30N.

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. Chillers, other Base Mounted Compressor-driven Equipment:

1. Isolate equipment 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 to minimize the propagation of the vibrations.

a. Unless specifically detailed otherwise, isolate equipment having 1 KW motors and larger and/or having a rotating speed of any component under 1800 rpm using restrained spring isolators with minimum 2” deflection, on inverted saddles as required to lower height, all mounted on elastomeric pads.

b. Unless specifically detailed otherwise, isolate equipment having under 1 KW motors and having a rotating speed of all components 1800 rpm or over using restrained elastomeric isolators with minimum 0.3” deflection, on inverted saddles as required to lower height.

c. When installed indoors above occupied space, include floating concrete isolation base.

B. Hydronic Equipment

1. All base mounted pumps 1hp and larger installed above occupied spaces (including roof mounted pumps): Install on floating concrete isolation bases.

2. 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.

C. 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 chillers, heat exchangers, 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.

3.4 ADJUSTING

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

B. Adjust active height of spring isolators.

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

END OF SECTION 23 05 43

SECTION 23 05 48 – MECHANICAL [SEISMIC][AND][WIND]LOAD 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 control of mechanical component movement resulting from seismic or wind generated loads. 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 are included.

B. Considering that the basis of design equipment is not always provided for project work, and that not all acceptable “equals” are the same weight, size, center of mass, cross section profile, and other characteristics that affect the seismic and wind load calculations, these detailed calculations are to be performed once specific to the approved mechanical equipment as part of a delegated design as detailed below.

C. Control of mechanically generated vibrations and sounds and control relative movement of components due to thermal expansion and contraction are covered in Section 23 05 43 – Mechanical Vibration and Movement Control.

1. Securing those vibration and movement control components against seismic and wind loads is covered in this section.

D. Specialized movement control components specified in this section include:

1. Seismic and wind restraints and snubbers.
2. Seismic and wind restraint construction requirements.

1.3 DEFINITIONS

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

D. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. OSHPD: Office of Statewide Health Planning and Development for the State of California.

F. Seismic Restraint: Engineered system including component attachment, building attachment, and all connecting hardware, designed to limit and control component movement during seismic event as required by design criteria.

1.4 SEISMIC RESTRAINT PERFORMANCE REQUIREMENTS

A. Provide restrained 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. Coordinate restraints with vibration and movement control system described in section 23 05 43 – Mechanical Vibration and Movement Control.

B. Provide complete design, detailing, and design documentation of all seismic restraints required and exceptions allowed, 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, allowing all restrained components to withstand seismic forces specified. Design shall be performed by a qualified licensed and registered professional engineer, with all drawings, calculations, and design analysis data signed and sealed by the engineer responsible for their preparation.

C. Design in accordance with the mechanical component seismic design requirements of the Building Code of New York State and applicable local codes. Calculations and design to be based on the following criteria.

D. Wind-Restraint Loading: Refer to Structural Load Notes on drawings.

A. Seismic-Restraint Loading: Refer to Structural Load Notes on drawings.

B. All points of termination/attachment to the building structure (including attachment to walls, decks and slabs) for the mechanical seismic restraints are subject to the review and approval of the Architect. Attachment to the top of steel beams and/or steel joists is the preferred point of attachment, with all beam and joist transverse loading required to be transmitted to the top deck shear plane. Modify mechanical seismic restraint details as required for attachment approval by the Architect (these modifications are to be performed at no additional cost to the Owner).

C. Applicable references to acceptable installation practices include:

1. SMACNA: Seismic Restraint Manual - Guidelines for Mechanical Systems.
2. ASHRAE: A Practical Guide to Seismic Restraint.
3. Mason Industries, Inc.: Seismic Restraint Guidelines.
4. FEMA: Installing Seismic restraints for Mechanical Equipment

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 seismic-restraint components used. Indicate style, material, rated strength in tension and shear, fastening provision, and finish for each device.

b. 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) Seismic restraints and anchors; refer to "Seismic Restraint Submittals" paragraph below.

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.

3. Seismic Restraint Delegated-Design Submittal:

a. Seismic Restraint Shop Drawings: Each drawing and each bound set of calculations and design analysis sheets shall be signed and sealed by the qualified professional engineer responsible for their preparation.

1) Coordination Drawings: May be full size drawings. Submit plans and sections drawn to scale, showing all mechanical components with Seismic Restraint locations required, cross referencing types and sizes on Detailed Fabrication and Attachment Drawings. Show other systems and equipment, including their seismic restraints, in the vicinity, as this might affect the mechanical system's restraint. Coordinate seismic restraints with vibration isolation and expansion compensation systems. Include all mechanical systems seismic restraints on these coordination drawings.

2) Detailed Fabrication and Attachment Drawings: May be full size drawings. Include cross reference keys to details of Seismic Restraint systems for all designated sizes and types. Detail all mechanical vibration isolation and seismic-restraint systems construction and installation criteria as required to demonstrate compliance with project Seismic Restraint Requirements and design criteria. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

3) Pre-approval and Evaluation Documentation: UL Listed and/or OSHPD approved systems with details showing maximum ratings of restraint items and the basis for approval (tests or calculations).

4) Submit an Installation Quality Control Procedure. This must contain all required fastener torque values as well as any other critical installation procedures required to maintain the design integrity of the seismic system.

5) Calculations and Design Analysis: 8½"x11" format. Detail all pertinent calculations and data as required to assign applicable loads to each size and type of restraint, cross referencing types and sizes on Detailed Fabrication and Attachment Drawings.

6) Loading Design Calculations: 8½"x11" format. Provide detailed calculations for static and dynamic loading due to component weight and operation, seismic and wind forces required to select vibration isolators, seismic and wind restraints, and for designing vibration isolation bases.

a) Coordinate seismic-restraint and vibration isolation design with wind load calculations and wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Division 23 Sections for equipment mounted outdoors

b) Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure and mechanical components, spring deflection changes, and seismic loads. Include certification that riser system has been examined for excessive stress and that none will exist.

c) Vibration Isolation Base Details: Detail overall dimensions, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads, power transmission, component misalignment, and cantilever loads.

C. Informational Submittals:

1. Product Certificates:

a. Submit certificates signed by manufacturers of seismic restraints certifying that products furnished comply with requirements. Provide test reports, from a qualified Independent Testing Agency indicating and interpreting test results of seismic control devices for compliance with requirements indicated and as required by the applicable code.

b. Provide certification from mechanical equipment manufacturer(s) per the requirements of the applicable code noted in "Seismic Restraint Requirements" paragraph above.

c. Submit schedule of seismically restrained equipment, including types and sizes of seismic restraints, complete with report numbers and rated strength in combined tension and shear.

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

2. Welding certificates.

3. Qualification Data for testing agency.

4. Qualification Data for Professional Engineer: Document evidence of current New York State Professional Engineering Registration and provide references to three successful seismic restraint design projects of comparable or greater scope to this project within the past three years.

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. Testing Agency Qualifications: An independent Testing Agency, with the experience and capability to conduct the testing and inspecting indicated as documented according to ASTM E 329, that is either a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, or accredited according to NIST's National Voluntary Laboratory Accreditation Program (NVLAP), and that is acceptable to authorities having jurisdiction.

B. Professional Engineer Qualifications: Professional engineer legally qualified to practice in the jurisdiction where the Project is located and experienced in providing engineering services of the kind indicated, including (but not limited to) design and installation of vibration isolation bases and seismic restraints similar in material and extent to those indicated for this Project.

1. Document evidence of current New York State Professional Engineering Registration.

2. Provide detailed references of three successfully completed seismic restraint design projects within the past three years which had comparable or greater scope to this project: include scope description, budget, and contact information.

C. Comply with the more stringent of the seismic-restraint requirements in the Building and Mechanical Codes of New York State, International Building Code, Local Codes and Ordinances, the Authority having jurisdiction, or the requirements in this Section.

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

E. Pre-approved Seismic Restraints shall have horizontal and vertical load testing and analysis and shall bear anchorage pre-approval OPA number from OSHPD, or pre-approval by ICC-ES or Underwriters Laboratories, showing maximum seismic-restraint ratings. Pre-approved Ratings shall be based on independent testing.

1. If pre-approved seismic restraints are not used, submittals based on independent testing (preferred) and calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

1.7 COORDINATION

A. Coordinate layout and installation of wind load control and seismic restraint 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**.** Provide proper dowels in structural slab for housekeeping pads as required to meet seismic criteria. Submit housekeeping pad attachment details for approval, accompanied by a Design Data submittal stamped by a Professional Engineer licensed in the State that the Project is located, in accordance with "Quality Control Submittals" subparagraph in "Seismic Restraint Submittals" paragraph in "Submittals" article above.

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

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

E. Coordinate and design all attachments with building structural system, per the requirements in "Seismic Restraint Requirements" paragraph in "System Description" article above.

PART 2 - PRODUCTS

2.1 SEISMIC-RESTRAINT DEVICES

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. Amber/Booth Company, Inc.
2. Kinetics Noise Control.
3. Loos & Co.; Cableware Division.
4. Mason Industries Inc.

B. General Requirements for Restraint Components:

1. Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of ICC-ES, OSHPD, or UL.

2. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

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

C. 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 [and seismic- and wind-control] devices to indicate capacity range.

D. Manufactured Seismic Snubbers Type II: All-directional, double-acting snubbers consisting of interlocking steel members restrained by a 3/4-inch-thick minimum, replaceable, shock-absorbing neoprene insert and maintaining 1/8-inch minimum, 1/4-inch maximum clearance in all directions between rigid and resilient surfaces.

1. OSHPD Anchorage pre-approval “R” number.

E. Fabricated Seismic Snubbers Type III: Welded structural-steel shapes, conforming to ASTM A 36, designed and fabricated to resist gravity forces and restrain equipment or vibration isolation bases from excessive movement during a seismic event, consisting of interlocking steel members restrained by a 3/4-inch- thick minimum, replaceable, shock-absorbing neoprene insert and maintaining 1/8-inch minimum, 1/4-inch maximum clearance in all directions between rigid and resilient surfaces. Refer to the ASHRAE publication “A Practical Guide to Seismic Restraints” for available designs.

F. Channel Support System: MFMA-3, shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.

G. Cable Restraints: UL listed or OSHPD approved assembly consisting of pre-stretched ASTM A 603 galvanized (ASTM A 492 stainless for exterior) steel aircraft cable and end-fastening devices field bolted to equipment and building structure. All parts of the system including cables, end fastening devices, and installation requirements shall be provided by a single vendor as a system designed to assure seismic compliance.

1. Basis-of-Design Product: Amber/Booth (Loos and Co.); Type LRC.

H. Hanger Rod Stiffener: Steel tube, steel slotted-support-system sleeve with internally bolted connections, or reinforcing steel angle clamped to hanger rod.

I. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.

J. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.

K. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

L. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.

M. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

2.2 WIND LOAD RESTRAINT DEVICES

A. Wind load restraint devices may include all seismic restraint devices listed above as approved and as included in the delegated design seismic restraint calculations submittal, as well as any other custom wind restraint devices designed and approved by delegated design engineer which are required above and beyond specified seismic restraint system.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive seismic restraint [**and wind 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 SEISMIC RESTRAINT INSTALLATIONS

A. General Seismic Restraint Requirements:

1. Provide complete seismic restraint system as specified and as shown and detailed on approved delegated design submittals.

2. Comply with requirements in Division 07 Section "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

3. Install seismic restraint devices in strict accordance with the approved Installation Quality Control Procedure and other applicable submittal data, using methods approved by an evaluation service member of ICC-ES, OSHPD, or required submittals for component.

4. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

5. Install cables so they do not bend across edges of adjacent equipment or building structure.

6. Indicate on submittal drawings, by details, schedules, or a combination of both, the locations where hanger rods require hanger rod stiffeners. Install hanger rod stiffeners where indicated and as required to prevent buckling of hanger rods due to seismic forces.

B. Equipment Restraints:

1. Snubbers: Install the required number of seismic snubbers on each spring-mounted piece of equipment. Locate snubbers as close as possible to the vibration isolators and bolt to equipment base and supporting structure.

2. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolts and mounting hole in concrete base.

3. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

4. Vibration Isolation Bases: Mount equipment on structural-steel bases or concrete inertia bases.

C. Piping Restraint:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c., or closer as detailed in delegated design.
3. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application.
4. Brace at change of direction longer than 12 feet.

D. Structural Attachments:

1. All welding shall be by qualified welders using qualified procedures.

2. If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

3. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

4. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

5. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.

6. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.

7. Set anchors to manufacturer's recommended torque, using a torque wrench.

8. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.3 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Accommodation of Differential Seismic Motion: Make flexible connections in piping and ductwork where they cross expansion and seismic control joints, where adjacent sections or branches are supported by different structural elements, and where they terminate at equipment. Design the system to accommodate the design displacements, and provide a signed and sealed Seismic Restraint Delegated Design Data Submittal attesting to this. Systems can be designed by one of the following methods:

1. Design systems to have the inherent flexibility required to accept the differential motion using pipe loops and/or offsets.
2. Localize the area at which differential motion will occur by anchoring to each building and provide a set of flexible connectors arranged to accept the motion.

B. Flexible Connectors:

1. Basis-of-Design Product: Southeastern Hose, Inc.; Model Seismijoint.

3.4 WIND RESTRAINT INSTALLATIONS

A. General Wind Restraint Requirements:

1. Provide complete wind restraint system as specified and as shown and detailed on approved delegated design submittals.

2. Comply with requirements in Division 07 Section "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

3. Install restraint devices in strict accordance with the approved Installation Quality Control Procedure and other applicable submittal data, using methods approved by an evaluation service member of ICC-ES, OSHPD, or required submittals for component.

4. Strength of Support and Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and wind loads within specified loading limits.

5. Install cables so they do not bend across edges of adjacent equipment or building structure.

B. Equipment Restraints:

1. Snubbers: Install the required number of snubbers on each spring-mounted piece of equipment. Locate snubbers as close as possible to the vibration isolators and bolt to equipment base and supporting structure.

2. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolts and mounting hole in concrete base.

3. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

4. Vibration Isolation Bases: Mount equipment on structural-steel bases or concrete inertia bases.

C. Piping Restraint:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c., or closer as detailed in delegated design.
3. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application.
4. Brace at change of direction longer than 12 feet.

D. Structural Attachments:

1. All welding shall be by qualified welders using qualified procedures.

2. If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

3. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

4. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

5. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.

6. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.

7. Set anchors to manufacturer's recommended torque, using a torque wrench.

8. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

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 air-spring leveling mechanism.

D. Adjust active height of spring isolators.

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

3.6 FIELD QUALITY CONTROL

A. Contractor Requirements:

1. Testing Agency: Engage the services of a qualified Testing Agency to perform Tests and Inspections.

2. Provide access to all places of inspection for representatives Testing Agency(s).

3. Schedule tests with Owner’s Project Representative, and Architect, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days' advance notice.

4. Obtain Architect's approval before transmitting test loads to the structure. Provide temporary load-spreading members as required by the test loads.

5. Perform the following Tests and Inspections:

   a. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
   b. Test at least four of each type and size of installed anchors and fasteners selected by Architect.

c. Test to 90 percent of rated proof load of device.
d. Measure isolator restraint clearance.
e. Measure isolator deflection.
f. Verify snubber minimum clearances.
g. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.
h. Prepare test reports and distribute to Owner and Architect.

6. Remove and replace malfunctioning units and retest as specified above.

B. Remove and replace malfunctioning units and retest as specified above.

C. Walk-through with Owner's Project Representative, Professional Engineer responsible for design of seismic restraints, and Restraint Manufacturer's Representative to verify installation is in accordance with specifications and submittals**.** Provide manufacturer approval letter and Professional Engineer-stamped letter documenting installation is complete and approved by them as in compliance with Project requirements.

D. Owner's Testing Agency: Will perform inspections and tests as required by applicable codes and insurance regulations. Make any corrections as required to meet Owner's Testing Agency's requirements.

END OF SECTION 23 05 48

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. Valve tags.

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

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. Warning Signs and 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.

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**] [**cover full**] 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”

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. Heating Hot Water Supply (HWS)
2. Heating Hot Water Return (HWR)
3. Natural Gas (G)
4. Chilled Water Supply (CHS)
5. Chilled Water Return (CHR)
6. Boiler Blow Down (BBD)

2.4 VALVE TAGS

A. Valve and Hydronic Specialty Identification: Provide 1-1/2-inch diameter brass tags, 0.032-inch minimum thickness, with predrilled or stamped holes for attachment with #16 brass jack chain, factory engraved or stamped with 1/4-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.
2. Stamp "C" and valve number for each main, riser, zone, and branch cooling valve.

3. Provide a special tag at thermal expansion tank(s) shut off valve with legend as follows: "Always keep this valve open except when draining tank".

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. 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.

B. 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. 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 penetrations through walls, floors, ceilings, and inaccessible enclosures.
3. Near major equipment items and other points of origination and termination.
4. Spaced at maximum intervals of **15 feet** along each run.
5. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

B. Pipe Label Color Schedule:

	Item	Color
1.	Heating hot water…….....	Dark Red
2.	Natural gas……......	OSHA Safety Yellow
3.	Chilled water supply……	Blue
4.	Chemical treatment……..	White

3.5 VALVE-TAG INSTALLATION

A. Install tags on new valves, hydronic specialties, and control devices in piping systems. Verify existing valve numbers in field and provide valve numbering avoiding duplication of existing numbers.

B. Valve Identification Chart: Refer to Section 23 05 00 – "Common Work Results for HVAC" for Valve Identification Chart requirements.

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. Perform no work affecting TAB prior to TAB Agency approval and submission of Pre-Construction Inspection and Testing Report.

2. Prior to submittal of any equipment affecting TAB, review with approved TAB Agency and obtain commentary and approval as described in “Summary” Article. Include TAB Agency review commentary with affected submittals.

3. 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. Within 30 days after award of Contract, submit TAB Agency qualifications proposal for approval.

B. Contractor and TAB Agency:

1. Submit Systems Readiness Reports as described more fully below.

C. 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, Evidence of current TAB Agency and TAB Supervisor Certification, Examples of data forms proposed for each system type showing input cells for this Project’s required data, 3 regional references for comparable recent jobs.

c. List of instruments to be used in testing and balancing, with current certification of all instruments’ calibration on calibration agency letterhead, including the following information:

1) Instrument type and make.
2) Serial number.
3) Application.
4) Dates of use.

5) Dates of calibration.
6) Test data points over range qualified – standards and measured values.

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.

5. Certified Six Month System Check / Design Condition TAB Report.

1.6 INFORMATIONAL SUBMITTAL

A. TAB Agency:

1. 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.
2. Include commentary with all Contractor submittals affecting TAB work as described above.
3. 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 Conference: After approval of the TAB Strategies and Procedures Plan and before TAB Work begins, schedule and attend a meeting with Architect, Owner, and Construction Manager, at their convenience, to develop a mutual understanding of the details. Require the participation of the TAB Field Supervisor and Technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:

a. Review the Contract Documents examination report.
b. Review the TAB Strategies and Procedures Plan.
c. Review the System Readiness Report.
d. Coordination and cooperation of trades and subcontractors.
e. Coordination of documentation and communication flow.

D. TAB Report Data Forms: Follow AABC, NEBB, TABB, or SMACNA format as modified by the data requirements of this Project, subject to submittal approval.

E. 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.

F. 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”.

G. 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. Environmental Requirements: Accomplish TAB work under appropriate outdoor temperature conditions. Coordinate with Temperature Controls Contractor to manipulate HVAC systems as required to simulate design conditions for load testing boilers, chillers, terminal load equipment, and similar portions of the systems.

B. 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:

a. 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 report delivered at minimum two calendar weeks prior to contract scheduled Substantial Completion Dates.

b. 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.

c. For phased projects prepare phased partial readiness for TAB coordinated with TAB Agency as required meeting the Owner's construction schedule.

d. Coordinate and report partial systems readiness in writing to TAB agency, Construction Manager, and Engineer, to allow TAB work to proceed in an orderly fashion.

2. TAB Agency:

a. 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 Dates.

b. 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 one calendar week of partial phased work readiness and 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, Owner, Architect/Engineer, Construction Manager, and Commissioning Agent.. 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: return to the site approximately six months after initial TAB Work is complete to perform system checkup and design condition rebalancing as defined below.

I. Contractor and TAB Agency are subject to recall to site to verify report information before acceptance of the report by the Architect.

J. 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.

K. 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.

4. Coordinate timing of six month system check and design condition TAB Work with weather, Contractor, and Owner.

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, sound meters, 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 and submit a TAB plan that includes the following

a. Site specific strategies narrative and step-by-step procedures with this project's equipment identified.
b. Instrumentation to be used.
c. Forms with specific identification for all equipment.

2. Prepare and submit a blank master Systems Readiness Report to Engineer, Commissioning Agent, and Contractors, with itemized checklists for each individual item to receive TAB Work as appropriate for the equipment, with a column for Contractor indicated status and another two columns with room for TAB Agency and Commissioning Agency commentary itemizing deficiencies discovered and confirming all systems preparation and examination has been properly performed. Include, at minimum, the following checks for each piece of equipment as applicable:

a. Hydronic and piping side:

1) Verify leakage and pressure/vacuum tests on distribution systems have been satisfactorily completed.
2) Piping is complete with terminals installed.
3) Water treatment is complete, and systems are flushed, filled, purged, and vented.
4) Refrigerant systems are properly evacuated and filled with the correct refrigerant at the right pressure.
5) Strainers are all clean.
6) Manufacturer's startup checklists have been appended.
7) Shutoff and balance valves have been verified to be 100 percent open.
8) Pumps are started and proper rotation is verified.
9) Pressure gauges, thermometers, and PT plugs are all installed where and as specified.
10) Suitable access to balancing devices and equipment is provided.

b. Energy Management and Controls System:

1) Pressure, temperature, position, electrical current, and other controls system sensors are installed where and as specified.
2) Control valves, dampers, and variable-frequency controllers' are functioning in accordance with the sequence of operation.
3) Controllers are installed and functioning in accordance with the sequence of operation.

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, pulleys are aligned and belts properly tight, and equipment with functioning controls is ready for operation. Make any required modifications to systems 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 piping, boilers, chillers, pumps, valves, required pressure taps, and hydronic specialties are correctly installed, complete, operational, and clean.

7. Hydronic systems have all required vents and drains installed and functional, and are flushed, vented, cleaned, leak free, and filled with specified heat transfer fluid.

8. Hydronic expansion tank has been pre-charged to the proper pressure and systems filled to proper cold fill pressure.

9. System pump suction piping is properly vented to ensure absence of entrained air.

10. All hydronic systems valves are installed with proper direction of flow and operate smoothly, balancing valves are adjusted open, P-T plugs and gauges are installed and functional where required, 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.

11. 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.

12. Clean new final design filters are installed everywhere called for.

13. 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.

14. 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.

15. As the various portions of the system are completed and become ready for TAB, prepare and submit partial Systems Readiness Reports to Engineer, Commissioning Agent, and TAB Agency, with itemized checklists filled out as appropriate for the equipment to receive TAB Work, indicating status and requesting TAB for that portion of work commence.

    a. Include itemized list of all examination and preparation procedures outlined above and as otherwise required by TAB and Commissioning Agencies' 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 any reason, system cannot be properly balanced, report as soon as observed.

16. Report any additional defects or deficiencies observed during performance of TAB procedures.

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. Adjust automatic damper linkages so they all operate smoothly and close tightly.

6. Perform necessary controls operations required for TAB procedures.

7. Make any required additions or changes in types, locations, etc., of balancing equipment.

8. Provide other mechanical adjustments as required in conjunction with TAB procedures.

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. Comply with requirements in ASHRAE 62.1, Section 7.2.2, "Air Balancing."

2. Review, edit, and deliver 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.

3. 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.

4. 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.

5. Take and report testing and balancing measurements in inch-pound (IP) units unless otherwise directed.

6. Promptly report abnormal conditions in mechanical systems or conditions that prevent system balance, for any reason including but not limited to installation, design, or Owner use reasons within 24 hours of discovery.

7. 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.

3.4 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Pre-Construction Testing of Existing HVAC Systems: Prior to system shut down, demolition and modifications associated with existing HVAC systems, and prior to submittal of any replacement equipment, provide testing and recording of existing system operating data as itemized below. Submit copies of existing system operating data to Architect for review. On completion of system modifications, confirm that new or modified system characteristics conform to original data or new requirements by taking new readings and readjusting systems as required.

B. On systems where there are no HVAC component modifications or work other than possible TAB work shown on the contract drawings, no TAB work is required unless specifically called for on the drawings.

C. On systems that are only partially modified, perform TAB work both before and after modifications as required to demonstrate that modified portions of the system are performing as required and unmodified portions of the system are still operating at least as well as they were prior to modifications. Also perform additional TAB work as specifically called for on the drawings.

D. Perform the following operations:

1. Hydronic systems:

a. Pumps: Check and record make and model; suction, discharge, and impeller size; pump discharge, suction and total head pressure; drive frequency if controlled by VFD, and gallons per minute delivery.

b. Balancing fittings: Check and record pressure drop, flowrate, and operating condition.

c. Control valves: pressure drop at flow measured at associate balancing fitting.

3.5 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.

3.6 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.

a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from Architect and comply with requirements in Division 23 Section "Hydronic Pumps."

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. Vary total system flowrate by adjustments at pump.

1. For constant speed single pump operation systems: throttle the system pump balancing/triple-duty valve until the flow in the system is the design flow rate. If the available flow from the pump is less than the design flow using this procedure, report this to the engineer for advisement immediately. Report the pump, valve, and motor data both with the throttling valve in the wide open and at the final, design flowrate position.

2. 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.

3.7 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.

3.8 PROCEDURES FOR WATER CHILLERS

A. Balance water flow through each heat exchanger (evaporator and condenser) to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. For water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
6. Capacity: Calculate in tons of cooling.
7. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.
8. Efficiency: Calculate operating efficiency for comparison to submitted equipment.

3.9 PROCEDURES FOR BOILERS

A. All Boilers:

1. Measure and record relief valve(s) pressure and setting.
2. Capacity: Calculate in Btu/h of heating output.
3. Fuel Consumption: If boiler fuel supply is equipped with flow meter, measure and record consumption.
4. Measure and record combustion air flow and temperature.
5. Measure and record flu gas temperature, flowrate, and combustion gas contents including % O_2, % CO_2, and ppm NO_X.
6. Efficiency: Calculate operating efficiency for comparison to submitted equipment.

7. Fan, motor, and motor controller operating data.

B. Hydronic Boilers:

1. Measure and record entering- and leaving-water temperatures and water flow.
2. Measure and record pressure drop.

3.10 SOUND TESTS

A. After systems are balanced and before Substantial Completion, measure and record sound levels at locations as designated by the Architect as having sound level performance requirements. Include at least the following systems:

1. Each Chiller.

2. Each boiler

3. Each Variable Frequency Drive, integral with the equipment it serves

3.11 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 hydronic systems as follows:

1. Each pump to within 5 percent of the design flow values.

3.12 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.

3.13 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. Manufacturers' test data.
3. Field test reports prepared by system and equipment installers.
4. 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.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
   1. Water flow rates.
   2. Pipe and valve sizes and locations.
   3. Position of balancing devices.

E. Chiller Test Reports:

   1. Test Data (Indicated and Actual Values):

      a. Water flow rate in gpm.
      b. Water pressure differential in feet of head or psig.
      c. Entering-water temperature in deg F.
      d. Leaving-water temperature in deg F.
      e. Refrigerant expansion valve and refrigerant types.
      f. Refrigerant suction pressure in psig.
      g. Refrigerant suction temperature in deg F.
      h. Sound Test Data.

F. 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. Required net positive suction head in feet of head or psig.
      i. Pump rpm.
      j. Design frequency for VSD pumps.
      k. Impeller diameter in inches.
      l. Motor make and frame size.
      m. Motor horsepower and rpm.
      n. Voltage at each connection.
      o. Starter size, rating, heater data.
      p. Amperage for each phase.
      q. Rated efficiency, full-load amperage, and service factor.
      r. 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.

G. 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

H. Flow Measuring Station, 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

I. Hydronic Control Valves Reports:

1. Location
2. Manufacturer
3. Model
4. Flowrate, specified and actual.
5. Pressure drop at full flow condition.

J. 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

K. Controls Sensors Reports:

1. Coordinate work with Energy Management and Control System.

2. Verify that locations shown on Operators Work Station are schematically correct.

3. Identification/number

4. Location

5. Service

6. Manufacturer

7. Temperature, test reading and actual

8. Pressure, test reading and actual

9. **A**ir composition, parts per million, test reading and actual. Test and adjust at normal ambient and alarm conditions.

L. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.14 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. Insulating cements.
b. Adhesives.
c. Mastics.
d. Lagging adhesives.
e. Sealants.
f. Factory-applied jackets.
g. Field-applied fabric-reinforcing mesh.
h. Field-applied cloths.
i. Field-applied jackets.
j. Tapes.
k. Securements.
l. Corner angles.
m. 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, tapes, and cement material containers, 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•^{o}F. For pipe and fitting insulation with conductivity other than 0.27 btu•in/hr•ft2•^{o}F, 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•^{o}F.
5) k = specified conductivity, 0.27 btu•in/hr•ft2•^{o}F.

b. Hydronic Piping for Cooling Only:
1) Pipe sizes 1inch through 6 inch ..... 1 inches
2) Pipe sizes 8 inch and larger ..... 1-½ inches

c. 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

2. Interior Above Grade Hydronic 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. Exterior Above Grade Hydronic 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 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) Exterior Pipe Insulation Protective Jacket specified below.

4. 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.

    b. Aluminum: Circumferentially corrugated 20mil thick or embossed 24 mil thick, with approved moisture barrier, with matching preformed fitting covers by same manufacturer. Similar to Corrolon by Childers.

3. Exterior Pipe and Fitting Insulation Protective Jacket: Modified bituminous, aluminum skinned, peal and stick membrane, similar to Polyguard "Alumaguard 60", with the following properties:

    a. Minimum 60 mils thick
    b. Permeance less than 0.01 Perms
    c. Puncture resistance per ASTM E154 >40lbs.
    d. Overlap bond peal adhesion per ASTM D1000 never less than 11lb/in.
    e. UV stabilized.
    f. Self healing when punctured.

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.

6) For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable closed cell foam gasket material to form a vapor barrier.

D. Mechanical Equipment Insulation:

1. Thickness of insulation:

a. Heating Equipment:
1) Pumps, air separators, suction diffusers: 2 inches (R=8 minimum).

b. Cooling Equipment:
1) Pumps, air separators, suction diffusers: 1-1/2 inches (R=6 minimum).

2. Heating Equipment (Pumps, Suction Diffusers, Heat Exchangers, Tanks, 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.

3. Cooling Equipment (Cold Service Pump Volutes, Chiller Barrels, Air Separators, Tanks, etc):

a. Insulation: fire-resistant, closed cell flexible (elastomeric) foam plastic, similar to Armacell "Armatuf White". May be multiple thicknesses (inner layers may be similar material without facing similar to "Armaflex AP") with offset joints for complex tight curved shapes or single thickness. Provide sheet stock with either PSA or plain backing, with manufacturer's recommended adhesive for all joints and backing, manufacturer's matching protective vapor barrier facing tape, and Corrosion Inhibitor equal to "Polyguard RG-2400".

E. 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.

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 dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. 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 (chilled water systems): 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.

C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 INSTALLATION

A. General:

1. Provide thermal insulation for components shown on the Drawings as specified in this Section for the following:

a.

b. Air separators, exposed boiler supply and/or return drums, risers, and piping connections, and all other HVAC components that operate below, or more than 15 degrees F above ambient conditions.

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, 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. 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.

5. Pumps, Suction Diffusers, 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.

6. 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. Heat generation systems, including hot-water boilers, and auxiliary equipment.

2. Cooling generation systems.

3. Distribution systems, including supply and return air distribution (heating and cooling) systems.

4. Vibration, sound, and movement control systems, including vibration isolation devices, sound attenuation, and seismic restraints.

5. Energy Management and Control System.

6. 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. Cooling-water piping and accessories.
5. Boilers.
6. Chiller.
7. 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 ANS SYSTEM COMMISSIONING TESTS

A. Heat Generation Systems

1. Boiler Testing: Testing requirements are specified in Division 23 Section "Condensing Boilers", Paragraph 3.4.D. Performance Tests. Provide submittals, test data, inspector record, and boiler performance certification to the CxA.

B. Cooling Generation Systems

1. Refrigeration System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of chillers, 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.

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. Vibration, Sound, and Movement Control Systems

1. Coordinate Walk-through with CxA to verify installation is in accordance with specifications and submittals. Provide submittals, test data, inspector record, and Sound Attenuator performance certification to the CxA.

F. 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.

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:

Scott Sullivan
Account Executive, Day Automation Systems, Inc.
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Albany, NY 12205
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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 +/- 1^{o}F of 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°F to 90°F), outside and air temperature sensors (-30°F to 120°F), hot water temperature sensor (0°F to 300°F), chilled water sensors (30°F to 90°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 not 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, not 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 automatic reset and auxiliary contacts to the EMCS. Set for 37 deg. F for "freeze" protection and 55ºF 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. Safety and relief valve piping.
4. Blowdown and system drain piping.
5. Boiler condensate drain piping.
6. Air-vent piping.

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. Air and Pressure Control.

B. Shop Drawings: Include in coordination drawings details of the piping layout showing proposed piping routing including locations of offsets, fittings, elevations with drain and vent fittings, pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to the building structure. Provide enlarged details of congested areas, custom anchor fabrication, and other details as required to clearly delineate the proposed construction.

Retain paragraph below if procedures for welder certification are retained in "Quality Assurance" Article.

C. Welding Quality Control Submittals

1. When welded or brazed pipe 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. Qualification Data: For Mechanical Grooved and Pressure Sealed Joint Installers.

E. LEED Submittal:

Retain subparagraph below if low-emitting materials are required for LEED-NC Credit EQ 4.1; coordinate with requirements selected in Part 2 for solvent cements and adhesive primers.

1. Product Data for Credit EQ 4.1: For solvent cements and adhesive primers, including printed statement of VOC content.

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 by 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. Grooved-End Fittings and Couplings:

a. Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.
b. Couplings: Rigid pattern, unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves.
c. Gaskets: Prelubricated EPDM gasket manufactured by coupling manufacturer, rated for minimum 250 deg F for use with housing, and steel bolts and nuts.

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.

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. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

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.

C. Safety Relief Valves:

1. Designed, manufactured, tested, and labeled in accordance with the requirements of Section IV of the ASME Boiler and Pressure Vessel Code.

2. Valve Body: Bronze, Brass, or Cast-iron, side outlet with all wetted internal working parts made of stainless steel, brass, and elastomers with 125 PSIG working pressure and 250 deg. F maximum operating temperature. Brass valve seat with Glass and carbon-filled PTFE disc.

3. Valve Size: Compliant with Section IV of ASME Boiler and Pressure Vessel Code, selected to suit system in which installed, with operating pressure and capacity factory set at full rated capacity of system at manufacturer's suggested working pressure.

4. 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. Amtrol, Inc.
b. Armstrong Pumps, Inc.
c. Bell & Gossett Domestic Pump; a division of ITT Industries.
d. Conbraco Industries, Inc.

e. Spence Engineering Company, Inc.
f. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

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.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Closed Loop Hydronic Piping, aboveground, NPS 2 and smaller:

1. Type L drawn-temper copper tubing with wrought-copper fittings, and soldered**,** or brazed joints.
2. Schedule 40 steel pipe with welded, threaded, or mechanical grooved fittings and joints.

B. Makeup-water piping installed aboveground: Type L, drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure seal**] joints.

C. Category IV Boiler Vent Condensate Drain Piping: Schedule 40 CPVC plastic pipe and fittings and solvent-welded joints.

D. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

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 REMOVALS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of existing piping systems to be removed. Remove piping as required for neat installation of the indicated work with no extraneous pipe or fittings remaining and back to the point of continued use where reconnection is not indicated.

B. Draining:

1. Refer to section 23 01 20 for draining, filling, flushing and cleaning of existing systems.

2. Drain systems completely as required for the contract Work so as to avoid cross contamination of system’s heat transfer fluids.

3. Protect Owner’s belongings from damage during draining and removals.

4. Install additional drains if necessary to completely drain system. Note that drain valves are required on all new piping low points.

3.3 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.

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. 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.

K. Install sleeve seals for piping penetrations of concrete walls and slabs.

3.4 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. 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.

E. Grooved Joints:

1. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness.

2. Assemble joints with coupling and gasket, lubricant, and bolts in accordance with fitting manufacturers written instructions.

3. Install rigid couplings for normal straight pipe runs.

4. Install flexible type couplings for branch take-offs, elbows, as part of the thermal expansion compensation system design, as vibration isolation flexible connections where specified for that, and as otherwise directed.

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.

G. Plastic Piping Solvent-Welded Joints:

1. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.

2. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672.

3. PVC Non-pressure Piping: Join according to ASTM D 2855.

4. Square cut and ream pipe ends to correct length.

5. Clean exterior of pipe and interior of fittings with rags and water and dry thoroughly before solvent cleaning with primer.

6. Check dry fit for interference fit to ensure pipe can be pushed at least 1/3 of way into fitting by hand. Ensure pipe that “bottoms” is snug.

7. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.

8. Use only approved cement and primer suitable for types of pipes and fittings used and suitable for intended service, including temperature, pressure pipe size, and fluids served. Use only fresh cement; do not use thickened, lumpy, or "jelly like" cement.

9. Clean pipe and fitting with cement manufacturer’s primer or cleaner. Use contrasting color primer and cement

10. Stir or shake cement before use. Apply thin coat of cement in socket, then evenly coat pipe end to socket depth. Avoid puddling, especially on thin walled pipe.

11. Assemble joint by twisting pipe 1/4 turn while pushing to full socket depth. Provide adequate anchorage and leverage to assemble pipe to full socket depth of fittings; hand pressure is inadequate and not acceptable for larger sizes. Hold pressure for 30 seconds or as required avoiding push out. Allow additional time for cement to set in colder weather to ensure cement film cures without blisters. Wipe off excess cement between socket and pipe with clean, dry rag.

12. Keep cement cool in hot weather and work as quickly as possible to avoid cement setting up before joint is assembled. Keep lid on cements, cleaner, and primers when not in use. Do not mix cleaner or primer with cement.

13. Use 3/4-inch dauber on small diameter pipes, 1-1/2 inch dauber up through 3 inch pipe, and natural bristle brush, swab, or roller 1/2 pipe diameter on pipes 4 inch and up.

3.5 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 piping to pumps. Details of near pump piping are specified in Section 23 21 23 – Hydronic Pumps

F. 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.

3.6 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Clean the interior of all piping prior to installation in systems.

2. Leave joints, including welds, uninsulated and exposed for examination during test.

3. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.

4. Fill and flush hydronic piping systems with clean potable water until system is clean, vent all air from systems then remove and clean or replace all affected strainer screens repeatedly until no further debris is captured. Re-fill and re-vent system.

5. 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.

6. 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, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 23 21 13

SECTION 23 21 23 - HYDRONIC PUMPS

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:

1. Inline maintenance free circulator pumps
2. Close-coupled, in-line centrifugal pumps.
3. Separately coupled, base-mounted, end-suction centrifugal pumps.
4. Pump Accessories.

1.3 DEFINITIONS

A. Buna-N: Nitrile rubber.

B. EPT: Ethylene propylene terpolymer.

C. SiC: Silicon Carbide.

1.4 SUBMITTALS

A. Action Submittals:

1. Product Data: Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves. Demonstrate equal or better performance to basis of design equipment in terms of construction, efficiency, dimensions, system connections, etc.

2. Shop Drawings: Show pump layout and connections. Include dimensioned setting drawings for installing foundation and anchor bolts and other anchorages.

3. Motor Data: Motor horsepower, electrical characteristics, and construction details demonstrating compliance with requirements.

4. Machinist’s qualifications.

5. Pump alignment report.

B. Closeout Submittals:

1. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

B. Machinist Qualifications: Pump alignment machinist shall be a mechanician specializing in machine alignment and set-up with demonstrable training and experience achieving the tolerances specified, employed independently of the pump manufacturer or selling representative**.** Include specifications and calibration for alignment equipment proposed for use on this project's alignment work.

C. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated. Refer to specification Section 01 60 00 "Product Requirements."

D. 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.

E. UL Compliance: Comply with UL 778 for motor-operated water pumps.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.

B. Store pumps in dry location.

C. Retain protective covers for flanges and protective coatings during storage.

D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

E. Comply with pump manufacturer's written rigging instructions.

1.7 COORDINATION

A. Coordinate size and location of concrete bases.

1.8 EXTRA MATERIALS

Extra materials may not be allowed for publicly funded projects.

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.

Revise subparagraph below to suit Project.

1. Filter Cartridges: Minimum one extra filter cartridge for each pump with filtered flush.

PART 2 - PRODUCTS

2.1 GENERAL PUMP REQUIREMENTS

A. Materials: Provide materials suitable for fluid, pressures, temperatures, and conditions for each application.

B. Performance: Minimum of design make throughout operating ranges, including capacity, head, NPSHR, and efficiency.

C. Configuration and Characteristics

1. Provide dynamically balanced pumps for all applications.
2. Provide tapped connections for pressure gauges at inlet and outlet, and vent and drain taps at high and low points.
3. Arrange for independent machinist to align each base mounted pump.

D. Motors:

1. Capable of running continuously without undue noise, heat, sparking, or overloading.

2. Extra quiet operating, EPAC “Plus” premium efficiencies for base-mounted pumps and custom premium efficiency for inline pumps.

3. Sized as non-overloading at 60 Hz with pump operating at any point on the impeller curve.

4. All three phase motors for use with variable speed drives shall be special application, inverter duty design of cast iron TEFC construction. Inverter duty design features shall include an inverter grade Class F insulation system meeting NEMA MG-1, Part 31, Class F thermostats, one per phase, premium efficiency design. Motors shall meet all other requirements of this document, the equipment manufacturer, and the adjustable speed drive manufacturer, and be rated for this service with the drive and voltage intended.

E. Pump Seals: Rated for continuous service for the fluid, temperature, conditions, and pressure of the required service. If conditions are not scheduled, verify in field before submitting Bid.

1. SiC/SiC/EPR Mechanical Seals: Silicon carbide rotating and stationary primary faces, bellows of EPT, EPDM, or other elastomer rated for the service, springs and other wetted seal parts of stainless steel.

a. Provide one spare seal for each mechanically sealed pump, same type as specified, turned over in sealed manufacturer’s packaging to Owner. Include receipt with

seal part numbers and contact information for obtaining additional seals in O&M manual.

2. Filters: Provide a filtered flush for seals.

a. Cartridge Filters For Closed Systems: Cartridge type seal flush filters, factory installed and capable of 98 percent removal of particles 25 microns and larger. Includes in-line sight flow indicator and isolation valves as required to facilitate filter changing without system shutdown.

b. Quantity: Provide minimum 3 filter cartridges for each system; minimum 1 for temporary use during system startup and commissioning (change to new filter as required during temporary service before final completion), change to new cartridge immediately following acceptance of Substantial Completion, and provide one spare filter cartridge turned over to Owner for each filtered flush system. Include receipt with filter part numbers and contact information for obtaining additional filters in O&M manual.

2.2 INLINE MAINTENANCE FREE WET ROTOR CIRCULATOR PUMPS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Basis of design is as scheduled. 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. Armstrong Pumps Inc. Series SS or equal
2. ITT Corporation Bell & Gossett Models NBF or equal
3. Grundfos Incorporated Series “UP”, “ASTRO” or equal.

B. Designed for continuous operation between 40° and 240°F.

C. Single stage, in-line suction with all bronze / stainless steel case as required by domestic water service, constructed for 125 psi wp.

D. Enclosed, FRP impeller mounted on a hardened, hollow stainless steel or ceramic shaft, rotating in carbon sleeve product lubricated bearings.

E. Drive motor shall be wet rotor, stainless steel sheathed, directly connected to the shaft, with static o-ring seal. Provide single speed, three speed, or auto-adapt ECM motor as scheduled.

2.3 VERTICAL (OR HORIZONTAL) IN-LINE CENTRIFUGAL PUMPS

Retain "Manufacturers" Paragraph and list of manufacturers below to require products from manufacturers listed or a comparable product from other manufacturers.

A. Manufacturers: Basis of design is as scheduled. 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. Series 4360, 4380 and 4300 by Armstrong Pumps Inc.
2. Series e-90, e-80, and e-80SC by ITT Corporation; Bell & Gossett.
3. Series VL and VLS by PACO –Grundfos CBS Incorporated.

B. Inline Centrifugal Pumps: Factory assembled and tested, centrifugal, overhung-impeller, close-coupled or split coupled as scheduled, in-line (180 degree opposed connections with common axis) pump designed for installation with pump and motor shafts mounted horizontally or vertically. Internal components capable of servicing without disturbing piping connections, designed for continuous operation between 40 deg. and 250 deg. F.

1. Volute: Single stage, radially split, grade 30 cast iron body, bronze fitted construction, replaceable bronze wear rings, designed for installation in the horizontal or vertical axis position in horizontal or vertical piping. Equal size suction and discharge flanges provided with separate tapped flush line and pressure gage connections suction and discharge.

2. Impeller: ASTM B 584 bronze or stainless steel, precision vacuum cast, closed design with pressure balancing internal flush holes, precision machined and finished on all surfaces removing burrs and casting irregularities resulting in smooth hydraulically efficient surfaces, trimmed as required to meet capacity scheduled, dynamically balanced after trimming to ANSI/HI 9.6.4 grade 6.3, secured to shaft with key and locking stainless steel cap screw.

3. Shaft: Heat-treated alloy steel or stainless steel shaft integral with motor. Alloy steel shafts equipped with replaceable SS shaft sleeve covering all wetted shaft areas including mechanical seal area.

4. Motors:

   a. Integral HP three phase motors: Standard NEMA JM or JP ring mounted motor with extended keyed shaft and heavy-duty re-greaseable grease lubricated ball bearings sized for extended service at the maximum load for which the pump is designed, inverter duty as described above. Motor mounted on precision-machined cast iron motor bracket ensuring positive concentric alignment between motor and volute.

   b. Fractional HP single phase motors: 115/230 volt as scheduled with ECM Permanent Magnet Variable Speed motors with motor mounted controller with user interface. Controller able to adjust motor speed to match flow and head requirements thus substantially reducing power consumption, allow for manual local adjustment, or remote control through EMCS via 0-10 VDC input/output.

5. 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.

6. Mechanical Seal as described above.

7. Supports: Pump volute and motor bracket supported independent of piping with motor supported by motor bracket.

2.4 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers: Basis of design is as scheduled. Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

1. Series 4030 by Armstrong Pumps Inc.
2. Series e-1510 by ITT Corporation; Bell & Gossett.
3. Series LF by PACO – Grundfos CBS.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump designed for base mounting, with pump and motor shafts horizontal. Rate pump for 125-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Single stage, radially split allowing true back pull out, grade 30 cast iron body, bronze fitted construction, replaceable bronze or stainless steel wear rings, threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and flanged connections. Provide integrally cast and machined mounting feet with through bolt holes to support and secure the casing and attached piping allowing removal and replacement of seals and impeller without disconnecting piping or requiring the realignment of pump and motor shafts.

2. Impeller: ASTM B 584 bronze or stainless steel, precision vacuum cast, closed design with pressure balancing internal flush holes, precision machined and finished on all surfaces removing burrs and casting irregularities resulting in smooth hydraulically efficient surfaces, trimmed as required to meet capacity scheduled, dynamically balanced after trimming to ANSI/HI 9.6.4 grade 2.5, secured to shaft with key and locking stainless steel cap screw.

3. Pump Shaft: Steel, with copper-alloy shaft sleeve, or stainless steel.

4. Pump Bearings: Grease-lubricated ball bearings contained in cast-iron housing with grease fittings.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. Include EPDM coupling sleeve.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels, angles, and plates. Fabricate to mount pump casing, coupling guard, and motor. Include provisions to facilitate solid grouting.

2.5 PUMP ACCESSORIES

A. Pump Suction Diffuser:

1. Angle pattern pump-inlet fitting.
2. Cast-iron body and end cap with integral size reduction from system piping to pump suction size if difference exists.
3. Bronze fine startup screen and bronze or stainless-steel permanent strainers.
4. Bronze or stainless-steel straightening vanes.
5. Drain plug with magnetic insert; and factory-fabricated support.
6. 175-psig pressure rating.

B. Provide pump discharge valve for each pump as specified in Section 23 05 23 – General Duty Valves for HVAC Piping.

C. Provide concrete bases for all base mounted pumps. Refer to Section 23 05 00 - Common Work Results for HVAC and Division 03 for details of required concrete bases.

D. Provide flexible equipment connections for all base mounted pumps. Refer to Section 23 05 43 – Mechanical Vibration and Movement Control for details.

E. Provide a pressure gauge for each pump as specified and as detailed. Refer to Section 23 05 19 – Meters and Gauges for HVAC Systems for details.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: Examine conditions under which pumps are to be installed and notify Architect in writing of any conditions detrimental to proper and timely installation. Correct unsatisfactory conditions as required, and do not proceed with installation until unsatisfactory conditions have been corrected in an acceptable manner.

1. Insure equipment foundations and anchor-bolt locations are in compliance with installation tolerances and other conditions affecting performance of work and service access.

2. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

3. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.

B. Beginning installation constitutes Contractor’s acceptance of substrates and conditions required to ensure proper and timely installation and to ensure requirements for applicable warranty or guarantee can be satisfied.

3.2 PUMP INSTALLATION

A. Install in accordance with manufacturer's specific recommendations and in accordance with all related sections of technical specifications. Obtain manufacturer's instructions and follow them, using the instructions written below as a minimum standard for comparison.

B. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

C. Support piping adjacent to pump connections independently of pumps such that load from piping is not transmitted through pumps.

1. Support piping adjacent to inline pumps securely as required to support pumps from piping. Support with piping supports as specified, with continuous-thread hanger rods and vibration isolators of size required to support weight of in-line pumps.

D. In-line pump mounting:

1. Install in-line pumps weighing under 30 pounds supported from adjacent piping.

2. Provide additional independent supports for in-line pumps weighing 30 pounds and over, similar to flange supports or volute base bracket mountings as recommended by pump manufacturer.

3. Comply with requirements for vibration isolation devices specified in Section 23 05 43 - Mechanical Vibration and Movement Control.

4. Comply with requirements for hangers and supports specified in Section 23 05 29 - Hangers and Supports for HVAC Components.

E. Base mounted pump mounting: Install all base mounted pumps as follows in the sequence written.

1. Install concrete bases of proper dimensions and configuration as specified for pumps and controllers.

2. Install pumps on a concrete base as outlined in Division 23 Section “Common Work Results for HVAC”.

a. Set adjustable internally threaded concrete inserts at appropriate bolt-down locations before pouring equipment bases.
b. Be responsible for accurate size of base and exact location of mounting bolts.
c. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

3. Fasten all pump bases to concrete bases with foundation bolts.

a. Insure that the pump suction and discharge flanges are orthogonal to the structural base of the pump without shimming. Securely tighten all pump volute mounting bolts to the pump base, and use the discharge flange surface for leveling and the

pump base rails for lateral alignment of the pump to the system. Align the motor to the pump after the pump base is properly grouted.

b. Properly level each pump base. Use metal wedges and/or shims set on both sides of every bolt. Make a minimum gap of three times the grout aggregate size or 1/2-inch, whichever is greater.

c. Securely tighten all pump base bolts.

d. Remove projecting parts of wedges and shims.

4. Properly grout the complete base.

a. Fill all pump bases with grout conforming to CRD-C-621-80 "Corps of Engineers Specification for Non-Shrink Grout", and as detailed in Division 03.

b. Fill base through grouting holes provided in baseplate.

c. After grout has hardened for a minimum of seven (7) days, re-tighten all pump foundation bolts and only then align pumps.

5. Align pumps.

a. Engage an INDEPENDENT MACHINIST to align and verify alignment of each pump and to certify and deliver report on measured alignment tolerances achieved.

b. Submit machinist's name, business address, and qualifications.

c. Do not pipe or start up any pump until after alignment is complete and correct. Do not align pumps until pumps are installed on concrete bases and grouted as specified above.

d. Align all pumps by moving the motor with respect to the fixed impeller housing.

e. If the impeller housing flanges are substantially out of level and/or alignment with respect to the system, bring them into alignment using a minimum of shims and an appropriate thinset grout before aligning the motor.

f. Motor shaft to impeller shaft alignment tolerances:

1) Align to the stricter of:

a) Manufacturer’s printed alignment tolerances.
b) 0.004-inch total indicator reading (TIR) radial and 0.004-inch TIR angular at 3-inch radius.

g. After pumps are aligned, install dowels to prevent shifting and properly re-install coupling and guard.

h. Within two business days of alignment, submit a written report certified by machinist guaranteeing that alignment is complete and stating the alignment tolerances required and obtained.

i. Contractor is responsible for trouble resulting from poor pump alignment.

6. Connect the pipe system to the pumps:

a. Install inlet suction diffusers for all end suction pumps with support legs adjusted to prevent any strain on the pump inlet.

b. Install pipeline flexible connectors at each suction (diffuser) and discharge port of each pump. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

c. Pipe as required by the detail pump connection drawings, including all valves, fittings, gauges, and controls.

7. Three operating months later, have the machinist recheck all alignments, recording data, correcting any changes, and reporting in writing to the Contractor and Architect all data and offering an interpretation of the cause and significance of the changes.

8. Submit letter attesting to completion of alignment.

F. Adjust GPM of each pump to capacity called for during balancing.

3.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Connect piping to pumps. Install isolation valves on both suction and discharge that are same size as piping shown approaching the pumps, prior to any size change required at pump connections.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

E. Install triple-duty valve on discharge side of pumps.

F. Install suction diffuser on suction side of all base mounted pumps.

1. Install suction diffuser on suction side of in-line pumps where a minimum of five pipe diameters straight line size pipe cannot be maintained at and in line with pump inlet.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gauges on pumps as specified.

I. Install electrical connections for power, controls, and devices in accordance with Section 23 29 00 – Variable Speed Motor Controllers, Section 23 05 13 – Common Electrical Requirements for HVAC, and Division 26.

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

2. Check piping connections for tightness.

3. Clean strainers on suction piping.

4. Perform the following startup checks for each pump before starting:

   a. Verify bearing lubrication.
   b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
   c. Verify that pump is rotating in the correct direction.

5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.

6. Start motor.

7. Open discharge valve slowly.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Refer to specification Section 01 79 00 - "Demonstration and Training."

END OF SECTION 23 21 23

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. "Micro-drive": VFC for use with motors of 1HP or less (unless scheduled otherwise), capable of and designed for driving three phase motors with single phase or three phase input line power, as required.
2. "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. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

B. 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. “Micro-Drive” includes all of above features plus:

a. Capable of and designed for converting single-phase input to three phase output.

7. “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. Seismic Qualification Certificates: For VFCs, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.

E. Product Certificates: For each VFC, from manufacturer.

F. 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.

D. IEEE Compliance: Fabricate and test VFC according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

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 F and not exceeding 104 deg F.
2. Ambient Storage Temperature: Not less than minus 4 deg F and 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.

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

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 F and not exceeding 104 deg F.
8. Ambient Storage Temperature Rating: Not less than minus 4 deg F and 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. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.
3. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.
4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
5. NC or NO alarm contact that operates only when circuit breaker has tripped.

2.2 CONTROLS AND INDICATION

A. All VSDs:

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.

B. All “General Purpose” drives, optional for “Micro” drives:

1. 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.

2. 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.

3. 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.

4. 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).

5. 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.

6. 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 PROTECTION:

A. All VSDs:

1. Lockable enclosure containing drive, line reactor, and fused exterior disconnect protecting all components. Enclosure large enough to facilitate ease of service, configured to fit in available mounting location and allow for rapid change-out of micro drive.

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.

2.4 BYPASS SYSTEMS

A. “Micro” Drive: No bypass required. Provide “Spare” drives as follows:

1. For each building in project where “Micro” drives are utilized, provide one spare drive of each unique configuration (voltage/phase/HP) “Micro” Drive installed as part of project,

minimum two if only one configuration is used. Deliver spare drives to Owner and provide Architect with letter signed by owner confirming receipt of spare "Micro" drives.

B. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

C. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

D. Bypass Controller: Three contactor bypass or two-contactor-style bypass that allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, IEC-rated contactor.

2. Output Isolating Contactor: Non-load-break, IEC-rated contactor.

3. Input Isolating Contactor: Non-load-break, IEC-rated contactor.

4. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

E. Bypass Contactor Configuration:

1. NORMAL/BYPASS selector switch.

2. HAND/OFF/AUTO selector switch.

3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.

4. Overload Relays: NEMA ICS 2.

a. Solid-State Overload Relays:

1) Switch or dial selectable for motor-running overload protection.
2) Sensors in each phase.
3) Class 10/20 selectable tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.

b. NO isolated overload alarm contact.

c. External overload reset push button.

2.5 OPTIONAL FEATURES

A. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.

B. Remote digital operator kit.

C. 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 1.

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. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.

H. 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. Seismic Bracing: Comply with requirements specified in Section 23 05 48 - Mechanical Seismic and Wind Load Controls."

D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

E. 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 51 00 - BREECHINGS, CHIMNEYS, AND STACKS

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:
   1. Listed gas vents.
   2. Connectors, fittings, and other accessories.

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 the following:

   1. Type B and BW vents.
   2. Connectors.

B. Calculations: For each venting system, provide stack calculations generated by vent manufacturer's computerized calculation software, demonstrating appropriate venting conditions. Accompany calculations with letter by authorized representative of boiler manufacturer on their letterhead stating venting system as designed is approved for the boiler system proposed.

C. Shop Drawings: For vents include plans, elevations, sections, details, and attachments to other work.

   1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, methods of field assembly, components, hangers and seismic restraints, and location and size of each field connection.

1.5 CLOSEOUT SUBMITTALS

A. Warranty: Special warranty specified in this Section.

1.6 QUALITY ASSURANCE

A. Source Limitations: Obtain listed system components through one source from a single manufacturer.

B. Certified Sizing Calculations:

1. Venting and Boiler Manufacturer shall certify venting system sizing calculations.

2. Include boiler operating data as approved and recommended by Boiler Manufacturer, actual field dimensions measured by Contractor, and actual fitting and duct losses as certified by Vent Manufacturer.

3. Assume an average winter ambient temperature of 20 degrees F, an average winter indoor temperature of 70 degrees F, and boilers operating at the typical design return and supply water conditions indicated on the drawings.

1.7 COORDINATION

A. Coordinate installation of existing vent and intake penetrations thru roof for boiler vent requirements.

1.8 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of venting system that fail in materials or workmanship within specified warranty period. Failures include, but are not limited to, structural failures caused by expansion and contraction.

1. Warranty Period: 15 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 LISTED SPECIAL GAS VENTS

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. Heat-Fab, Inc.
2. Metal-Fab, Inc.
3. Selkirk Inc.; Selkirk Saf-T Vent CI Plus.
4. Z-Flex; Flexmaster Canada Limited.

B. Description: Double-wall metal vents tested according to UL 1738 rated for continuous firing at up to 550 deg F with gas.

C. Listed for ANSI category I, II, III, or IV appliances, with positive or negative flue pressure complying with NFPA 211.

D. Construction: Inner shell and outer jacket separated by at least a 1 inch airspace.

E. Inner Shell: ASTM A 959, Type 29-4C stainless steel.

F. Outer Jacket: Stainless steel.

G. Accessories: Tees, elbows, increasers, connectors, terminations, storm collars, support assemblies, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.

1. Termination: Stack cap designed to exclude minimum 90 percent of rainfall, with drain section incorporated into base of riser.

2.2 PLASTIC VENT AND CONDENSATE PIPE AND FITTINGS

A. CPVC Plastic Pipe: ASTM F 441/F 441M, Schedules 40 and 80, plain ends as indicated in Part 3 "Piping Applications" Article.

B. CPVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe, long radius pattern.

C. Condensate Neutralizing Tank: Provide each condensing boiler system with at least one condensate neutralizing tank. Neutralizing tank(s) size as follows: larger of two gallons or 1.5 gallon per million BTU/hr boiler input capacity (volume measured below level of boiler condensate trap outlet). Condensate neutralizing tank constructed of 4” or 6” diameter schedule 40 PVC pipe assembly with threaded condensate inlet and outlet connections, a threaded side cleanout cover, and supports. Fill with appropriately sized limestone gravel. Provide limestone gravel as required to fill all neutralizing tanks, plus 5 gallons extra per boiler room; leave extra in lidded 5 gallon pail for Owner’s future use. Pipe neutralizing tank with unions for service removal, extend outlet to floor drain.

D. Solvent Cements for Joining Plastic Piping:

1. CPVC Piping: ASTM F 493.

a. Use CPVC solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24), in contrasting color.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of work. Verify locations and sizes of existing vent roof penetrations.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

C. Beginning installation constitutes Contractor's acceptance of substrates and conditions.

3.2 APPLICATION

A. Listed Special Gas Vent: Condensing gas appliances.

B. Plastic Vent and Condensate Piping: for use with high efficiency category IV appliances only where manufacturer's installation instructions include PVC or CPVC vent and condensate drain piping.

3.3 INSTALLATION OF LISTED VENTS AND CHIMNEYS

A. Support vents at intervals recommended by manufacturer to support weight of vents and all accessories, without exceeding appliance loading.
B. Slope vents down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.
C. Lap joints in direction of flow.
D. Join sections with acid-resistant joint cement to provide continuous joint and smooth interior finish.

3.4 INSTALLATION OF UNLISTED, FIELD-FABRICATED BREECHINGS AND CHIMNEYS

A. Suspend breechings and chimneys independent of their appliance connections.

B. Align breechings at connections, with smooth internal surface and a maximum 1/8-inch misalignment tolerance.

C. Slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.

D. Lap joints in direction of flow.

E. Plastic Piping Solvent-Welded Joints:

1. CPVC Vent and Condensate Drain Piping: Join according to ASTM D 2846/D 2846M Appendix.

2. Square cut and ream pipe ends to correct length.

3. Clean exterior of pipe and interior of fittings with rags and water and dry thoroughly before solvent cleaning with primer.

4. Check dry fit for interference fit to ensure pipe can be pushed at least 1/3 of way into fitting by hand. Ensure pipe that "bottoms" is snug.

5. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.

6. Use only approved cement and primer suitable for types of pipes and fittings used and suitable for intended service, including temperature, pressure pipe size, and fluids served. Use only fresh cement; do not use thickened, lumpy, or "jelly like" cement.

7. Clean pipe and fitting with cement manufacturer’s primer or cleaner. Use contrasting color primer and cement

8. Stir or shake cement before use. Apply thin coat of cement in socket, then evenly coat pipe end to socket depth. Avoid puddling, especially on thin walled pipe.

9. Assemble joint by twisting pipe 1/4 turn while pushing to full socket depth. Provide adequate anchorage and leverage to assemble pipe to full socket depth of fittings; hand pressure is inadequate and not acceptable for larger sizes. Hold pressure for 30 seconds or as required avoiding push out. Allow additional time for cement to set in colder weather to ensure cement film cures without blisters. Wipe off excess cement between socket and pipe with clean, dry rag.

10. Keep cement cool in hot weather and work as quickly as possible to avoid cement setting up before joint is assembled. Keep lid on cements, cleaner, and primers when not in use. Do not mix cleaner or primer with cement.

11. Use 3/4-inch dauber on small diameter pipes, 1-1/2 inch dauber up through 3 inch pipe, and natural bristle brush, swab, or roller 1/2 pipe diameter on pipes 4 inch and up.

12. Install vent piping sloped continuously up in the direction of flow, such that any condensate formed counter-flows back towards appliance.

13. Install condensate drain piping sloped continuously down in direction of flow towards drain. Pipe from appliance, breeching, and stack drains through approved condensate neutralizing station to approved indirect waste receptor.

3.5 CLEANING

A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.
B. Clean vents internally, during and after installation, to remove dust and debris.
C. Provide temporary closures at ends of vents that are not completed or connected to equipment.

END OF SECTION 23 51 00

SECTION 23 52 16 - CONDENSING BOILERS

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, factory-fabricated and assembled, gas fired, fire-tube condensing boilers, trim, and accessories for heating water.

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 performance data, operating characteristics, furnished specialties, and accessories.

B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.

1. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Warranty: Special warranty specified in this Section.
B. Other Informational Submittals:

1.6 CLOSEOUT SUBMITTALS

A. Field quality-control test reports.
B. Operation and Maintenance Data: For boilers to include in emergency, operation, and maintenance manuals.
C. Warranty: Executed special warranty specified in this Section.

1.7 QUALITY ASSURANCE

A. Provide all boilers/burners in accordance with applicable requirements of New York State Labor Department Industrial Code Rule No. 4 (cited as 12 NYCRR4) and Code Rule No. 14 (cited as 12 NYCRR14).

B. Provide all boilers/burners in accordance with applicable requirements of New York State Education Department Manual of Planning Standards.

C. 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.

D. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.

E. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."

F. UL Compliance: Test boilers for compliance with UL 795, "Commercial-Industrial Gas Heating Equipment." Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

G. I=B=R Performance Compliance: Condensing boilers must be rated in accordance with applicable federal testing methods and verified by AHRI as capable of achieving the energy efficiency and performance ratings as tested within prescribed tolerances.

H. Do not allow boilers to be operated unsupervised until all operating and safety controls have been verified as properly installed and tested as properly functional.

1.8 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 23 05 00 and Division 03.

1.9 WARRANTY

A. General Warranty: The special warranty specified in this Article shall not deprive the Owner of other rights the Owner may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the Contract Documents. Provide parts and labor warranty covering the complete boiler installation: at no additional charge, correct all defects in workmanship and materials reported within (1) year from the date established on certificate of substantial completion.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of boilers that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Fire-Tube Condensing Boilers:

    a. Leakage and Materials: 10 years from date of Substantial Completion.
    b. Heat Exchanger Damaged by Thermal Stress and Corrosion: Non-prorated for 10 years from date of Substantial Completion.

1.10 MAINTENANCE SERVICE

A. Provide factory authorized service as outlined in Part 3 of this specification for a minimum of one year from date established on certificate of substantial completion.

B. Provide factory authorized maintenance service as required to maintain the boiler and burner system in good operating order at no additional charge for one (1) year from date established on certificate of substantial completion. In addition to initial start-up, a full tune up is required at the start of the first heating season and additionally within one month of the end of this one year service period. Combustion and thermal performance at eleven month tune up must be equal to or better than those set at initial start-up, with combustion reports printed directly off an electronic combustion analyzer. Include all parts and labor, including maintenance parts kits normally required for 24 month tune-up (gasket kit, ignition rods or electrodes as required, etc.).

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. AERCO International.
2. Advanced Thermal Hydronics (a Mestek Company) KN series.
3. Cleaver Brooks – Clear Fire.
4. Heat Transfer Products, Inc.
5. Lochinvar Boiler
6. Thermal solutions

B. Due to differences in size and access clearances, piping connections, working pressures, burner configuration, venting, sequencing, etc.., proposed use of boilers other than the basis of design Boilers and Burners scheduled will require detailed review of required changes and incorporation of this into boiler room shop drawings and design. Refer to Instructions to Bidders, General Conditions, Division 1, and section 23 05 00 – Common Work Results for HVAC, for additional provisions and requirements relating to specified equivalent, proposed equivalent, or substitution products.

2.2 FIRE-TUBE CONDENSING BOILERS

A. Description: Natural gas fired, fully condensing, fire tube design boiler. Power burner with full modulation and discharge into a positive pressure vent. Boiler efficiency shall increase with decreasing load (output), while maintaining setpoint. Factory-fabricated, -assembled, and -tested, fire-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls.

B. Heat Exchanger: Constructed of 439 stainless steel fire tubes and tubesheets, with a one-pass combustion gas flow design. The fire tubes 5/8" OD, with no less than 0.065" wall thickness. The upper and lower stainless steel tubesheet to be no less than 0.25" thick. The pressure vessel/heat exchanger to be welded construction. ASME stamped for a working pressure not less than 150 psig. Access to the tubesheets and heat exchanger shall be available by burner and exhaust manifold removal. Minimum access opening to be no less than 8-inch diameter.

C. Pressure Vessel: Maximum water volume of 55 gallons. The boiler water pressure drop to not exceed 3 psig at 261 gpm. 4-inch flanged 150-pound, boiler water connections ANSI rated. The pressure vessel to be constructed of SA53 carbon steel, with a 0.25-inch thick wall and 0.50-inch thick upper head. Inspection openings in the pressure vessel are be in accordance with ASME Section IV pressure vessel code. Designed so that the thermal efficiency increases as the boiler firing rate decreases.

D. Modulating Air/Fuel Valve and Burner: The boiler burner to be capable of a 15-to-1 turndown ratio of the firing rate without loss of combustion efficiency or staging of gas valves. The burner is to produce less than 20 ppm of NOx corrected to 3 percent excess oxygen. The unit to be certified by the South Coast Air Quality Management District (SCAQMD) as compliant with Rule 1146.1 for boilers and water heaters greater than 2 MBTU's and less than 5 MBTUs. The burner shall be metal-fiber mesh covering a stainless steel body with spark ignition and flame rectification. All burner material exposed to the combustion zone shall be of stainless steel construction. There shall be no moving parts within the burner itself. A modulating air/fuel valve shall meter the air and fuel input. The modulating motor must be linked to both the gas valve body and air valve body with a single linkage. The linkage shall not require any field adjustment. A variable frequency drive (VFD), controlled cast aluminum pre-mix blower shall be used to ensure the optimum mixing of air and fuel between the air/fuel valve and the burner.

E. Minimum Boiler Efficiencies: Minimum boiler efficiencies are to be as follows at a 20 degree delta-T:

EWT	100% Fire	80% Fire	60%	40% Fire	20% Fire	7% Fire
160 °F	86.5%	87%	87%	87%	87%	87%
140 °F	87.5%	87.5%	87.5%	87.5%	87.5%	88%
120 °F	89%	89%	89%	90%	90%	90%
100 °F	93.2%	94.5%	94.6%	95.02%	95.4%	95.4%
80 °F	95.6%	96.3%	96.8%	97.8%	98.%	98.2%

F. Exhaust Manifold: The exhaust manifold to be of corrosion resistant cast aluminum with an 8-inch diameter flue connection. The exhaust manifold shall have a collecting reservoir and a gravity drain for the elimination of condensation.

G. Blower: The boiler to include a variable-speed, DC centrifugal fan to operate during the burner firing sequence and pre-purge the combustion chamber.

1. Motors:

a. 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.

H. Ignition: Ignition shall be via spark or proven pilot ignition with 100 percent main-valve shutoff and electronic flame supervision.

I. Combustion Air: The boiler shall be designed such that the combustion air is drawn from the inside of the boiler enclosure, decoupling it from the combustion air supply and preheating the air to increase efficiency.

J. Combustion Air Filter: The boiler shall be equipped with an automotive high flow air filter to ensure efficient combustion and unhindered burner components operation.

K. O_2 sensor located in the Combustion Chamber: The boiler shall be equipped with an Oxygen sensor. The sensor shall be located in the boiler combustion chamber. Boilers without Oxygen sensor or boilers with an Oxygen sensor in the exhaust shall not be acceptable due to measurement estimation and performance accuracy.

L. Gas Train: Combination gas valve with manual shutoff and pressure regulator.

M. Ignition: Spark ignition with 100 percent main-valve shutoff with electronic flame supervision.

N. Casing:

1. Jacket: Sheet metal, with snap-in or interlocking closures.
2. Control Compartment Enclosures: NEMA 250, Type 1A.
3. Finish: Powder-coated protective finish.
4. Insulation: Minimum 2-inch- thick, mineral-fiber insulation surrounding the heat exchanger.
5. Combustion-Air Connections: Inlet and vent duct collars.
6. Mounting base to secure boiler.

2.3 TRIM

A. Aquastat Controllers: Operating, firing rate, and high limit.

B. Pressure and Temperature Gage: Minimum 3-1/2-inch- diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.

C. Boiler Air Vent: Automatic.

D. Drain Valve: Minimum NPS 3/4 hose-end gate valve.

E. Safety Relief Valve:
   1. ASME rated.

   2. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
   3. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.

F. Pressure Gage: Minimum 3-1/2-inch diameter. Gage shall have normal operating pressure about 50 percent of full range.

G. Water Column: Minimum 12-inch glass gage with shutoff cocks.

H. Drain Valves: Minimum NPS 3/4 or nozzle size with hose-end connection.

I. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle.

J. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than NPS 2 shall have rising stem.

2.4 CONTROLS

A. The boiler shall have an integrated boiler control that is capable of operating the boiler and associated accessories including but not limited to: its pumps, valves and dampers.
   1. The control shall have a 5 inch color touch screen display as well as six function buttons that are separate from the display. User shall have the ability to navigate the menus via touchscreen or navigation buttons. Controls not equipped with navigation button options shall not be permitted.
   2. The control shall be equipped with a multi-color linear LED light to indicate the level of firing and/or air/fuel valve position.
   3. The control shall display two temperatures using two dedicated three-digit seven-segment displays.
   4. The control shall offer an Enable/Disable toggle switch as well as two buttons for Testing and Resetting the Low Water Cutoff.
   5. Software update: The control shall be capable of field software updates without a need for hardware component(s) replacement. This shall be performed either using software on a USB flash drive or via Internet connection. The software update mechanism shall be performed by a trained technician. The software update menus shall be secured using a password level. After the software update, the control shall retain all of its prior field settings.
   6. The control panel shall include:
      a. Setpoint High Limit: Setpoint high limit allows for a selectable maximum boiler outlet temperature and acts as temperature limiting governor. Setpoint limit is based on a PID function that automatically limits firing rate to maintain outlet temperature within a 0 to 10 degree selectable band from the desired maximum boiler outlet temperature.

b. Setpoint Low Limit: Allow for a selectable minimum operating temperature.
c. Failsafe Mode: Failsafe mode allows the boiler to switch its mode to operate from an internal setpoint if its external control signal is lost, rather than shut off. This is a selectable mode, enabling the control can to shut off the unit upon loss of external signal, if so desired.

E. The boiler control system shall incorporate the following additional features for enhanced external system interface:

1. System start temperature feature
2. Pump delay timer
3. Auxiliary start delay timer
4. Auxiliary temperature sensor
5. Analog output feature to enable simple monitoring of temperature setpoint, outlet temperature or fire rate
6. Remote interlock circuit
7. Delayed interlock circuit
8. Easy Setup by providing simplified menu quick settings to expedite plant and boiler setup
9. Delta-T Limiter
10. Freeze protection
11. Fault relay for remote fault alarm
12. Warm-weather shutdown

1. The control shall offer multi-level user security access using different passwords. For additional security, the passwords shall expire if control display was not touched for an extended period 30 minutes.

F. Building Automation: The control shall be able to communicate to Building Management Systems using BACnet and Modbus without the use of external gateways. The control shall be able to communicate over each of the two protocols using IP as well as RS485. The use of external gateways is not acceptable. The control shall be able to communicate to the building management system using:

1. BACnet MS/TP and BACnet IP/Ethernet. When communicating over BACnet IP, the control shall offer an additional layer of IP security by mapping all control BACnet IP communication to the BACnet server's IP and MAC addresses. Not having this level of security shall deem the IP communication insecure and shall not be acceptable.
2. Modbus RTU and Modbus IP.

G. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.

1. High Cutoff: Automatic reset stops burner if operating conditions rise above maximum boiler design temperature.

2. Low-Water Cutoff Switch: Electronic probe shall prevent burner operation on low water. Cutoff switch shall be automatic reset type.

3. Auxiliary Low-Water Cutoff Switch: Float and electronic external listed ALWCO piped and wired to prevent burner operation on low water. Cutoff switch shall be manual reset type.

4. Blocked Inlet Safety Switch: Manual-reset pressure switch field mounted on boiler combustion-air inlet.

5. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

2.5 ELECTRICAL POWER

A. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.

1. House in NEMA 250, Type 1 enclosure.
2. Wiring shall be numbered and color-coded to match wiring diagram.
3. Install factory wiring outside of an enclosure in a metal raceway.
4. Field power interface shall be to circuit breaker.
5. Provide branch power circuit to each motor and to controls with a disconnect switch or circuit breaker.
6. Provide each motor with overcurrent protection.

2.6 VENTING

A. The boiler shall be capable of venting in Polypropylene venting material. The exhaust vent must be UL Listed for use with Category II, III and IV appliances and compatible with condensing flue gas service. UL-listed vents of Polypropylene or Al 29-4C stainless steel must be used with boilers.

B. Combustion-Air Intake: Boilers shall be capable of drawing combustion air from the outdoors via a metal or PVC duct connected between the boiler and the outdoors.

2.7 BURNER BOILER ACCESSORIES AND RELATED EQUIPMENT

A. Burner Emergency Switches: Surface mounted for existing construction or flush mounted with recessed box for new construction; all aluminum construction (NEMA 2, drip proof). Includes normally open switches rated for 10 amps at 125 VAC and engraved nameplate marked “TO STOP GAS BURNERS.”

1. Similar to “Class 9001” with “K-15” operator and “KA1” switch block(s) by Square D.

B. Condensate Control: Provide each boiler with F&T condensate trap and condensate neutralizing tank. One neutralizing tank per boiler or per boiler system will be acceptable. Neutralizing tank(s) size: larger of two gallons or 1.5 gallon per million BTU/hr boiler input capacity (volume measured below level of boiler condensate trap outlet). Condensate neutralizing tank constructed of 4” or 6” diameter schedule 40 PVC pipe assembly with threaded condensate inlet and outlet connections, a threaded side cleanout cover, and supports. Fill with appropriately sized limestone gravel. Provide limestone gravel as required to fill all neutralizing tanks, plus 5 gallons extra per boiler room; leave extra in lidded 5 gallon pail for

Owner's future use. Pipe neutralizing tank with unions for service removal, extend outlet to floor drain.

C. Gas Train Vent Terminations: Internally threaded 90 degree angle fitting of cast aluminum or malleable iron construction, with stainless steel insect (between 10 and 16 mesh) screening disc interference fit to elbow in such a manner as to disengage from fitting under blow off design back pressure, allowing full discharge. Free area through screening not be less than free area of required vent pipe size (reducing elbow required). Screen recessed from termination, forming an integral drip and paint protection edge.

2.8 SOURCE QUALITY CONTROL

A. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.

B. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.

C. Allow Owner access to source quality-control testing of boilers. Notify Architect 14 days in advance of testing.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Before boiler installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting boiler performance, maintenance, and operations.

1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

B. Examine mechanical spaces for suitable conditions where boilers will be installed.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

D. Beginning installation constitutes Contractor's acceptance of substrates and conditions.

3.2 BOILER INSTALLATION

A. Equipment Mounting: Install boilers on concrete equipment pad.

1. Coordinate sizes and locations of concrete bases with actual equipment provided.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floors and pads.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

4. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Coordinate sizes and locations of concrete bases with actual equipment provided.
6. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
7. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Install gas-fired boilers according to NFPA 54.

C. Assemble and install boiler trim.

D. Install electrical devices furnished with boiler but not specified to be factory mounted.

E. Install control wiring to field-mounted electrical devices.

3.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to boiler to allow service and maintenance.

C. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve.

D. Connect piping to boilers, except safety relief valve connections, with flexible connectors of materials suitable for service. Flexible connectors and their installation are specified in Division 23 Section "Hydronic Piping."

E. Connect gas piping to boiler through gas-train. Provide gas line to boiler full size as shown on drawings through drop with isolation valve then lateral tee then full size drip leg with removable cap. Lateral to boiler at least full size of gas train connection with manufacturer’s recommended straight run before and after auxiliary regulator then union located for optimum serviceability. Provide reducers as required.

F. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.

G. Install piping from safety relief valves to nearest floor drain.

H. Boiler Venting:

1. Install flue venting kit and combustion-air intake.
2. Connect full size to boiler connections. Comply with requirements in Division 23 Section "Breechings, Chimneys, and Stacks."

I. Condensate control: Pipe all condensate from boiler condensate drains and breeching / chimney condensate and rain drains through appropriately sized traps, then neutralizing tank, to floor drain. Pipe acidic condensate in CPVC, protected from foot traffic by steel pipe sleeve outside carrier pipe, covered with yellow and black striped safety strips, secured to floor to prevent rolling.

J. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

K. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections, and to provide startup and commissioning service and reports. Start up to be performed only after complete boiler room operation is field verified to offer a substantial load, and complete system circulation. One-year warranty shall be handled by factory authorized tech.

B. Notify Architect minimum two weeks in advance of test dates.

C. Comply with performance requirements indicated, as determined by field performance tests.

1. Repeat tests until results comply with requirements indicated.

D. Provide analysis equipment required to determine performance.

E. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems and weather do not produce adequate demand.

F. Remove and replace malfunctioning components and/or complete units and retest as specified. Adjust, modify, or replace equipment to comply.

3.5 COMMISSIONING

A. Refer to 23 08 00 Commissioning of HVAC.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain boilers. Video training sessions**.** Refer to Division 01 Section "Demonstration and Training."

3.7 WARRANTY PERIOD SERVICE

A. Provide factory authorized service for a minimum of one year from date established on certificate of substantial completion.

1. Provide service, including 24-hour emergency service, as required to maintain the boiler/burner system in optimum operating order.

2. Provide the services of a boiler manufacturer factory-employed and trained boiler and burner service and start-up technician for all regular scheduled service and maintenance

for the first year following substantial completion. In addition to initial start-up, provide full cleaning, tune up service, and combustion performance adjustment and re-testing within one month of the end of this one year service period. Boiler combustion and thermal performance at end of warrantee period tune up must be equal to or better than those set at initial start-up, with combustion reports printed directly off an electronic combustion analyzer. Provide adjustments, repairs, and replacements as required to return boiler to like new performance at this time, including all recommended replacement components.

3. Emergency Service: Provide one year emergency boiler / burner service. If factory employed service technician cannot arrive within 2 hrs of call, contract emergency burner service through an authorized local boiler / burner service organization who can and will respond within 2 hrs to any and all legitimate service calls on a 24 hour / seven day basis, with no charges to the Owner. Factory employed technician to follow-up within 48 hours to insure proper completion of emergency service.

END OF SECTION 23 52 16

SECTION 23 57 00 - HEAT EXCHANGERS 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. This Section includes plate heat exchangers.

1.3 ACTION SUBMITTALS

A. Product Data: Include materials, rated capacities, operating characteristics, furnished specialties, and accessories, demonstrating quality and performance as scheduled and specified.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, center of gravity, loads, required service clearances, method of field assembly, details of support / anchorage, components, and location and size of each field connection.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For heat exchangers to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, performance, and dimensional requirements of heat exchangers and are based on the specific equipment indicated. Refer to Division 01 Section "Product Requirements."

B. ASME Compliance: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2.2 BRAZED PLATE HEAT EXCHANGERS

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

1. Alfa Laval Thermal, Inc.
2. API Heat Transfer Inc.
3. Armstrong Pumps, Inc.
4. FlatPlate, Inc.
5. Invensys APV, Inc.
6. ITT Corporation; Bell & Gossett.
7. Mueller, Paul Company.
8. Polaris Plate Heat Exchangers.
9. Tranter, Inc.

B. Configuration: Brazed assembly consisting of two end plates, one with threaded nozzles and pattern-embossed thermal transfer plates arranged in a close contact counter-flow configuration.

C. End-Plate Material: Type 316 stainless steel.

D. Threaded Nozzles: Type 316 stainless steel.

E. Thermal Transfer Plates: double wall NSF rated for potable domestic hot water on heated side, with treated boiler water on the hot side, 0.024 inch thick before stamping; Type 316 or 316L stainless steel.

F. Brazing Material: Copper.

G. Provide configuration as required meeting capacity, pressure drops, connections, and other performance characteristics as scheduled.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas for compliance with requirements for installation tolerances and for structural rigidity, strength, anchors, and other conditions affecting performance of heat exchangers.

B. Examine roughing-in for heat-exchanger piping to verify actual locations of piping connections before equipment 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 HEAT-EXCHANGER INSTALLATION

A. Install heat exchangers on existing concrete base. Anchor heat exchanger frame to concrete base, and heat exchanger to frame.

1. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
2. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Insulate heat exchangers as specified in section 23 07 00 – "HVAC Insulation".

3.3 CONNECTIONS

A. Coordinate piping installation and specialty arrangement requirements with schematics on Drawings and with requirements specified for piping systems.

1. Provide four valve reversing flush piping on both hot and heated sides of Heat Exchangers.

2. Provide hose end valves on heat exchanger side of main isolation valves, both heating and heated sides, arranged to drain, vent, and flush / descale heat exchanger.

3. Provide thermometers, P/T plugs, pressure gauges, and temperature sensor wells on heat exchangers as detailed and as described in section 23 05 19 – "Meters and Gauges for HVAC Systems".

B. Maintain manufacturer's recommended clearances for service and maintenance. Install piping connections to allow service and maintenance of heat exchangers.

C. Install shutoff valves in serviceable locations isolating heat exchanger specialties at each heat-exchanger inlet and outlet connection.

D. Install relief valves on hot side of both heating and heated-fluid connections and pipe relief valves, full size of valve connection, to floor drain.

E. Install hose end valve to drain low points.

3.4 FIELD QUALITY CONTROL

A. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.5 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

END OF SECTION 23 57 00

SECTION 23 64 26 - SCROLL WATER CHILLER

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. Packaged, air-cooled, electric-motor-driven, scroll water chiller.

1.3 DEFINITIONS

A. BAS: Building automation system, also known as Energy Management and Control System (EMCS).

B. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.

C. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by AHRI 550/590 and referenced to AHRI standard rating conditions.

1.4 PERFORMANCE REQUIREMENTS

A. Cooling Performance Tolerance: In accordance with the AHRI-550/590 standard for each of the following:

1. Allowable Capacity.
2. Allowable EER.
3. Allowable IPLV.

B. Acoustic Performance: Certified in accordance with AHRI-370 standards, with data reported as absolute sound power generated by unit in each of 8 octave bands, and also in sound pressure reported directionally in dBA on each of four sides of unit at 30ft distance open field. Allowable tolerance:

1. Sound power in any octave band no greater than design make equipment.
2. Sound pressure on any side no greater than design make equipment.

1.5 ACTION SUBMITTALS

A. Product Data: Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

B. Coordination Drawings: Submit plans and sections, drawn to scale, on which the following items are shown and coordinated with each other, using input from contract documents, chiller shop drawings, and field verification:

1. Structural support details.
2. Piping roughing-in and connection requirements and details.
3. Wiring roughing-in and connection requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

1.6 INFORMATIONAL SUBMITTALS

A. Certificates: For certification required in "Quality Assurance" Article.
B. Startup service reports.
C. Warranty.

1.7 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.8 QUALITY ASSURANCE

A. AHRI Certification: Certify chiller according to AHRI 590 certification program.

B. AHRI Rating: Rate chiller performance according to requirements in AHRI 550/590.

C. ASHRAE Compliance:

1. ASHRAE 15 for safety code for mechanical refrigeration.
2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

D. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.

E. Comply with NFPA 70.

F. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

1.9 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Provide factory coil shipping covers at factory and keep in place until completion of installation.

B. Acceptance at Site: Do not deliver unit until approved by Architect.

C. Storage and Protection

1. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.
2. Protect units from physical damage. Prevent freeze-up from any cause.

1.10 COORDINATION, SEQUENCING, AND SCHEDULING

A. Coordinate construction of other trades in area adjacent to machine to insure adequate clearances for operating and maintenance service.

B. Coordinate with Electric Work Prime Contractor to ensure electrical components are installed properly and timely to allow installation and timely start-up of chillers.

C. Coordinate sizes, locations, and anchoring attachments of structural-steel support, roof mounted support rails, vibration isolation mounting, roof curbs, and roof penetrations with actual equipment provided.

1.11 WARRANTY

A. Special Materials Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

1. Extended warranties include the complete chiller, specifically including but not limited to, parts and labor for the following:

a. Complete refrigerant circuits, including compressors, piping, heat exchangers, and all specialties including refrigerant and oil charge and loss of charge for any reason.

b. Complete electrical power, control, and drive assemblies.

c. Complete heat rejection system with fans, airflow direction control, and non-refrigerant condenser coil components.

2. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PACKAGED, AIR-COOLED CHILLER

A. Design Basis: Daikin.

1. Acceptable manufacturers
   a. Carrier
   b. Daikin
   c. Johnson Controls/York
   d. Trane
   e. Smardt

B. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.

1. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500-hour salt-spray test according to ASTM B 117.

2. Sound-reduction package designed to reduce sound level without affecting performance and consisting of the following:

   a. Acoustic attenuation enclosure around compressors, with weatherproof nylon cover.
   b. Flexible connections and attenuation material applied to all suction and discharge refrigerant piping.
   c. Reduced-speed fans with acoustic treatment.

C. Compressors:

1. The compressors shall be sealed hermetic, scroll type with crankcase oil heater and suction strainer. The compressor motor shall be refrigerant gas cooled, high torque, hermetic induction type, two-pole, with inherent thermal protection on all three phases and shall be mounted on RIS vibration isolator pads. The compressors shall be equipped with an internal module providing compressor protection and communication capability.

D. Evaporator:

1. The evaporator shall be a compact, high efficiency, dual circuit, brazed plate-to-plate type heat exchanger consisting of parallel stainless steel plates. Vent and drain connections shall be provided in the inlet and outlet chilled water piping by the installing contractor.

2. The evaporator shall be protected with an external, electric resistance heater plate. The evaporator and suction piping to the compressors shall be insulated with 3/4” (19 mm) thick CFC and HCFC-free closed-cell flexible elastomeric foam insulation material with 100% adhesive coverage. The insulation shall have an additional outer protective layer of 3mm thick PE embossed film to provide superior damage resistance. Insulation without the protective outer film shall not be acceptable. UV resistance level shall meet

or exceed a rating of 'Good' in accordance with the UNI ISO 4892 - 2/94 testing method. This combination of a heater plate and insulation shall provide freeze protection down to -20°F (-29°C) ambient air temperature.

3. The water-side maximum design pressure shall be rated at a minimum of 435 psig. Evaporators shall be designed and constructed according to, and listed by Underwriters Laboratories (UL).

E. Condenser:

1. Condenser fans shall be propeller type arranged for vertical air discharge and individually driven by direct-drive fan motors. The fans shall be equipped with a heavy-gauge vinyl-coated fan guard. Fan motors shall be TEAO type with permanently lubricated ball beAHRIngs, inherent overload protection, three-phase, direct-drive, 1140 rpm. Each fan section shall be partitioned to avoid cross circulation.

2. Coil shall be microchannel design and shall have a series of flat tubes containing multiple, parallel flow microchannels layered between the refrigerant manifolds. Tubes shall be 9153 aluminum alloy. Tubes made of 3102 alloy or other alloys of lower corrosion resistance shall not be accepted. Coils shall consist of a two-pass arrangement. Each condenser coil shall be factory leak tested with high-pressure air under water. Coils shall withstand 1000+ hour acidified synthetic sea water fog (SWAAT) test (ASTM G85-02) at 120°F (49°C) with 0% fin loss and develop no leaks.

F. Refrigerant Circuit:

1. Each of the two refrigerant circuits shall include a replaceable-core refrigerant filter-drier, sight glass with moisture indicator, liquid line solenoid valve (no exceptions), expansion valve, and insulated suction line.

G. Control System:

1. A centrally located weatherproof control panel shall contain the field power connection points, control interlock terminals, and control system. Box shall be designed in accordance with NEMA 3R rating. Power and starting components shall include factory circuit breaker for fan motors and control circuit, individual contactors for each fan motor, solid-state compressor three-phase motor overload protection, inherent fan motor overload protection and two power blocks (one per circuit) for connection to remote, contractor supplied disconnect switches. Hinged access doors shall be lockable. Barrier panels or separate enclosures are required to protect against accidental contact with line voltage when accessing the control system.

2. Shall include optional single-point connection to a non-fused disconnect switch with through-the-door handle and compressor circuit breakers.

H. Unit Controller:

1. An advanced DDC microprocessor unit controller with a 5-line by 22-character liquid crystal display provides the operating and protection functions. The controller shall take

preemptive limiting action in case of high discharge pressure or low evaporator pressure. The controller shall contain the following features as a minimum:

a. The unit shall be protected in two ways: (1) by alarms that shut the unit down and require manual reset to restore unit operation and (2) by limit alarms that reduce unit operation in response to some out-of-limit condition. Shut down alarms shall activate an alarm signal.

b. Shutdown Alarms

1) No evaporator water flow (auto-restart)
2) Sensor failures
3) Low evaporator pressure
4) Evaporator freeze protection
5) High condenser pressure
6) Outside ambient temperature (auto-restart)
7) Motor protection system
8) Phase voltage protection (Optional)

c. Limit Alarms

1) Condenser pressure stage down, unloads unit at high discharge pressures.
2) Low ambient lockout, shuts off unit at low ambient temperatures.
3) Low evaporator pressure hold, holds stage #1 until pressure rises.
4) Low evaporator pressure unload, shuts off one compressor.

d. Unit Enable Section

1) Enables unit operation from either local keypad, digital input, or BAS

e. Unit Mode Selection

1) Selects standard cooling, ice, glycol, or test operation mode

f. Analog Inputs:

1) Reset of leaving water temperature, 4-20 mA
2) Current Limit

g. Digital Inputs

1) Unit off switch
2) Remote start/stop
3) Flow switch
4) Motor protection

h. Digital Outputs

1) Shutdown alarm; field wired, activates on an alarm condition, off when alarm is cleared
2) Evaporator pump; field wired, starts pump when unit is set to start

i. Condenser fan control - The unit controller shall provide control of condenser fans based on compressor discharge pressure.

j. Building Automation System (BAS) Interface

1) Factory mounted DDC controller(s) shall support operation on a BACnet® network via one of the data link / physical layers listed below as specified by the successful Building Automation System (BAS) supplier.

2) BACnet MS/TP master (Clause 9)

3) BACnet IP, (Annex J)

4) BACnet ISO 8802-3, (Ethernet)

5) The information communicated between the BAS and the factory mounted unit controllers shall include the reading and writing of data to allow unit monitoring, control and alarm notification as specified in the unit sequence of operation and the unit points list.

6) All communication from the chiller unit controller as specified in the points list shall be via standard BACnet objects. Proprietary BACnet objects shall not be allowed. BACnet communications shall conform to the BACnet protocol (ANSI/ASHRAE135-2001). A BACnet Protocol Implementation Conformance Statement (PICS) shall be provided along with the unit submittal.

I. Options and Accessories:

1. Ground Fault Protection: Factory installed circuit breaker to protect equipment from damage from line-to-ground fault currents less than those required for conductor protection.

2. Phase loss with under/over voltage protection and with LED indication of the fault type to guard against compressor motor burnout.

3. BAS interface module to prove interface with the BACnet MSTP protocol.

4. Rubber-in-shear vibration isolators for field installation

5. Factory-mounted thermal dispersion type flow switch

6. Wye strainer, to be installed at the evaporator inlet and sized for the design flow rate , with perforation diameter of 0.063" with blowdown valve and Victaulic couplings (factory mounted or field installed)

7. 115V GFI convenience outlet

J. Refrigerant Circuits:

1. Refrigerant: As indicated on Drawings.

2. Classified as Safety Group A2L according to ASHRAE 34.

3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

4. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.

5. Pressure Relief Device:

   a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.

6. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.

   a. Power unit-mounted controls where indicated.
   b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.

7. Control Relays: Auxiliary and adjustable time-delay relays.

8. For chiller electrical power supply, indicate the following:

   a. Current and phase to phase for all three phases.
   b. Voltage, phase to phase, and phase to neutral for all three phases.
   c. Three-phase real power (kilowatts).
   d. Three-phase reactive power (kilovolt amperes reactive).
   e. Original power factor, correction capacitor specifications, and corrected power factor.
   f. Running log of total power versus time (kilowatt-hours).
   g. Fault log, with time and date of each.

K. Capacities and Characteristics as scheduled.

2.2 SOURCE QUALITY CONTROL

A. Perform functional tests of chiller before shipping.

B. Factory run test each air-cooled chiller with water flowing through evaporator.

C. Factory performance test air-cooled chiller, before shipping, according to AHRI 550/590.

1. Test the following conditions:

   a. Design conditions indicated.
   b. Reduction in capacity from design to minimum load in steps of 25% with condenser air at design conditions.

2. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

D. Air-cooled chiller shall have acoustic sound power and sound pressure level performance certified in accordance with AHRI 370.

1. Report calculations at the following conditions:

a. Design conditions indicated.
b. Chiller operating at calculated worst-case sound condition.
c. At two point(s) of varying part-load performance to be selected by Owner at time of test.

E. Factory test and inspect evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine chiller before installation. Document any damage with Owner prior to proceeding with installation work. Damage subsequent to joint inspection shall be the responsibility of the contractor.

B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

A. Install chiller on support structure indicated.

B. Maintain manufacturer's recommended clearances for service and maintenance.

C. Install separate devices furnished by manufacturer and not factory installed.

D. Connections:

1. Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems.

2. Comply with requirements for piping specified in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.

3. Install piping adjacent to chiller to allow service and maintenance.

4. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, and drain connection with valve. Make connections to chiller with a flange or mechanical grooved coupling. Include full size chiller bypass with valve.

5. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to glycol fill station. Provide a shutoff valve at each connection.

6. Extend relief piping from outlet of evaporator pressure relief device full size of connection to glycol fill station.

E. Attend and video record the factory representative's demonstration and training sessions. Turn over high quality video recordings of training session, showing detailed sharp images pertinent to all of the training in question.

3.3 STARTUP SERVICE

A. Coordinate with the factory-authorized service representative who will perform the following startup service:

1. Complete installation and startup checks according to manufacturer's written instructions.

2. Verify that refrigerant charge is sufficient, and chiller has been leak tested. Charge chiller with refrigerant and fill with oil if not factory installed.

3. Verify that pumps are installed and functional.

4. Verify that thermometers and gages are installed.

5. Operate chiller for run-in period.

6. Check bearing lubrication and oil levels.

7. Verify that refrigerant pressure relief device is properly vented outdoors.

8. Verify proper motor rotation.

9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.

10. Verify proper integration with building energy management and controls system. Recommend and confirm proper integration of all control point data required for Owner's and Service Technician's diagnostic and control strategies.

11. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

C. Inspect insulation on all cold surfaces for condensation. Repair and/or provide additional insulation as specified and as required to eliminate all surface condensation under operating conditions.

D. Prepare test and inspection startup reports.

E. Demonstration

1. Train Owner's maintenance personnel to adjust, operate, and maintain chiller.

END OF SECTION 23 64 26