SECTION 23 05 00 - COMMON WORK RESULTS FOR MECHANICAL

PART 1 - GENERAL

1.1. SECTION INCLUDES

A. Basic Mechanical Requirements are applicable to Division 22 and 23 Sections.

1.2. RELATED SECTIONS

A. This section applies to sections of Division 22 and 23, except as may be otherwise modified in each section.

1.3. FEES, PERMITS AND PAYMENTS

A. Fees, Permits and Payments: Contractor shall secure permits and inspections and pay full cost of same.

1.4. RELATED WORK SPECIFIED ELSEWHERE

A. Excavation and backfill, Division 31; Section, “Earthwork.”
B. Concrete, Division 03
C. Access doors, Division 08 Section, “Access Panels.”
D. Finish painting, except as specified or indicated otherwise, is specified under Division 9. Equipment furnished under this section shall be factory finished. If the factory finish is damaged during shipment, installation, etc., it shall be repainted by the Contractor subject to the Architect’s approval.
E. For louvers not connected to sheet metal plenums or ductwork, see Division 08 Section “Louvers”.
F. Electrical connections for motors, line voltage wiring and conduit, and low voltage wiring and conduit except as indicated in Section 23 09 00, see Division 24.
G. Individual motor controllers except when furnished as integral parts of packaged equipment, (See Division 24).
H. Motor Control Centers, (See Division 24).

1.5. EQUIPMENT RESTRICTIONS

A. The proprietary name, and/or model indicated on the drawings, or the first listed for each category in the specifications is the make and/or model used as the basis for design. Bids shall be based on the use of the products of the selected manufacturers. Substitutions will be considered as outlined in General Conditions and Division 01; Section, “Substitutions.”
B. Choice of Equipment: Equipment has been chosen, which will properly fit into the physical spaces provided and indicated, allowing ample room for access, serving, removal and replacement of parts, etc. Adequate space shall be allowed for clearance in accordance with the code requirements and the requirements of the local inspection Department. Physical dimensions and arrangements of equipment to be installed shall be subject to the Owner’s approval. Submit shop drawings of equipment layout for approval where equipment space does not comply with drawings. Changes in piping, motors, wiring, controls, structural or installation procedures required by the substituted product or equipment shall be made at no additional cost to the Owner, and with no reduction in scope.

C. Space Requirements: In the preparation of drawings, a reasonable effort has been made to include equipment manufacturers’ recommendations. Since space requirements and equipment arrangement vary according to manufacturer, the responsibility for initial access and proper fit rests with the Contractor. The final arrangement of the equipment and service connections shall allow the unit to be serviced. This shall include space to pull motors, filters, coils, tubes, etc. Make changes in piping and ductwork to suit actual installed equipment without further instructions or additional cost.

D. Contractor shall be aware that some equipment in the mechanical room must be in place before walls and/or roof is installed and shall schedule the installation of equipment accordingly.

E. Certificates: Execute on behalf of the Owner and deliver to the Owner manufacturers’ warranty certificates and instructions, etc. required to assure that the manufacturers’ warranties are properly documented and in full effect for the warranty period.

F. Installers’ Qualifications:

1. For the actual fabrication, installation and testing of work under this section, use only thoroughly trained and experienced workmen completely familiar with the items required and the manufacturers’ current recommended methods of installation.

2. In acceptance of rejection of the finished installation, no allowance will be made for lack of skill on the part of the installers.

G. Reference to technical societies, trade organizations, governmental agencies are made in Mechanical Sections in accordance with the following abbreviations:

1.6. CODES, ORDINANCES, REGULATIONS AND DEFINITIONS

A. Work and materials shall be in full accordance with the latest rules and regulations of the following Agencies and Codes: Division of the State Architect; the Safety Orders of the Division of Industrial Safety; the California Mechanical Code; California Fire Code; the California Plumbing Code; the California Building Code; Title 24 State Code of Regulations; city ordinances and other applicable laws or regulations.

B. Nothing in the drawings or specifications is to be constructed to permit work not conforming to these codes. Drawings and specifications shall take precedence when work and materials called for exceed code requirements.

C. References to Code Specifications shall mean editions in effect at date of proposals.
D. Reference to technical societies, trade organizations, governmental agencies are made in Mechanical Sections in accordance with the following abbreviations:

AABC  Associated Air Balance Council National Standards for Field Measurement and Instrumentation, Total System Balance
AGA  American Gas Association
AMCA  Air Moving and Conditioning Association
ANSI  American National Standards Institute
ARI  Air Conditioning and Refrigeration Institute
ASHRAE  American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASTM  American Society of Testing and Materials
AWWA  American Water Works Association
CCR  California Code of Regulations
CISPI  Cast Iron Soil Pipe Institute
DSA  Division of the State Architect
ETL  Electrical Testing Laboratory
FM  Factory Mutual
IRI  Industrial Risk Insurers
ISO  Insurance Service Organization
NEBB  National Environmental Balancing Bureau Procedural Standards for Testing, Balancing and Adjusting of Environmental Systems
NEC  National Electrical Code
NFC  National Fire Codes
NFPA  National Fire Protection Association
NRCA  National Roofing Contractor’s Association
OSHA  Occupational Safety and Health Administration
PDI  Plumbing and Drainage Institute
SMACNA  Sheet Metal and Air Conditioning
UL  Underwriter’s Laboratories, Inc.

E. Fees, Permits, Licenses and Payments: Contractor shall secure permits and inspections and pay full cost of same.

F. Definitions:

**APPROVED**  As approved by Owner’s Representative.

**ARCHitect / ENGINEER**  The Architect or Engineer of record for this project. The Architect or Engineer is the Owner’s representative regarding preparation, revisions and interpretation of the contract documents.

**AS DIRECT**  As directed by the Owner’s Representative.

**AS REQUIRED**  As required by applicable Code requirements; by good business practice; by the conditions prevailing; by the Contract Documents; by Owner, or by Owner’s Representative.

**AS SELECTED**  As selected by Owner’s Representative.
| **BATTERY** | A “battery” of fixtures is two or more fixtures served from same branch. |
| **BY OTHERS** | Work on this Project that is outside the Scope of Work to be performed by the Contractor under this Contract, but that will be performed by Owner, other Contractors or other means. |
| **CERTIFIED TEST REPORTS** | Test Reports signed by an authorized official stating that tests were performed in accordance with the test method specified that the results reported are accurate, and that items tested either meet or fail to meet the stated minimum requirements. These Test Reports include those performed by Factory Mutual, Underwriters Laboratories, Inc., and others. |
| **CERTIFIED INSPECTION REPORTS** | Reports signed by approved Inspectors attesting that the items inspected meet the Specification requirements other than exceptions included in the report. |
| **CONCEALED** | Means embedded in masonry, concrete or other construction, installed within furred spaces, or in enclosures. |
| **EQUAL** | The Contract documents are based upon the manufacturer and model number indicated on the drawings or specifications. Bidder may propose alternative product but will be considered only if the bidder has submitted a base Bid, which is in accordance with the specified product. Alternate proposal shall include complete technical data and itemized price adjustments. Bidder shall assume the responsibility that the alternate product meets the physical, mechanical, electrical, structural, acoustical and architectural requirements of the specified product. Acceptance of an alternate product does not entitle the Contractor to a Change Order to modify architectural, structural, mechanical, electrical, control or other systems necessary to accommodate the alternate product. The Owner or his representative may reject ll-alternate products. |
| **EXPOSED** | Means not installed underground or not concealed as defined above. |
| **FIELD TESTS** | Tests or analysis made at, or in the vicinity of the job site in connection with the actual construction. |
| **FURNISH** | Supply and deliver to the Project site only, not install (unless required to be installed elsewhere in the Contract Documents). Product must be delivered |
**COMMON WORK RESULTS**

**INSTALL**

Install (services or labor) only, not furnish (unless required to be furnished elsewhere in the Contract Documents). Install means to place in final position, complete, anchored, connected and ready to operate.

**MAIN**

A “main” of a system of continuous piping is the principal artery of the system, to which branches may be connected.

**MANUFACTURER’S DIRECTIONS, INSTRUCTIONS, RECOMMENDATIONS, SPECIFICATIONS**

Manufacturer’s written directions, instructions, recommendations, specifications.

**PRODUCT**

Means materials, systems, equipment and fixtures.

**MANUFACTURER’S CERTIFICATE CONFORMANCE**

A certificate signed by an authorized manufacturer’s official attesting that the material or equipment delivered meets the specification requirements. Manufacturer’s representative certificate is not acceptable.

**MUST; SHALL; TO; WILL**

When used as a directive to the Contractor, these items indicate a mandatory action.

**NECESSARY**

Essential to completion of work.

**OWNER-FURNISHED, CONTRACTOR-INSTALLED**

To be furnished by the Owner at its cost and installed by the Contractor as part of the work.

**PROVIDE**

Shall include “Furnish and install” which means supply, fabricate, deliver, place and connect, complete in place, ready for operational use. When neither furnish, install or provide is stated, “provide” is implied.

**REMOVE**

Means to remove item completely including attachments, frames, anchors, fittings, bases, pipes, conduits and supports, capping behind finished surfaces and repairing floors, bases and walls to match color and texture and be smooth with existing adjacent surfaces.

**RISER**

A “riser” is vertical waterline supplying two or more fixtures, or batteries of fixtures located in different rooms.

**SHOWN**

As indicated on the Drawings.
SPECIFIED

As written in the Contract Documents.

SUBMIT

Submit to Owner’s Representative.

TESTING LABORATORY

The term “testing laboratory” means a person or organization whose functions include testing, analyzing or inspecting products and/or evaluating the designs or specifications of such products according to the requirements of applicable standards.

WORK

Work of the Contractor or Subcontractor includes labor or materials (including, without limitation, without equipment and appliance) or both, incorporated in, or to be incorporated in the construction covered by the complete Contract.

1.7. SUBMITTALS

A. General: Refer to Division 01.

B. Equipment Submittals:

1. Copies: Submit six copies of data as specified hereafter and in individual sections.

2. Manufacturer’s Data: Give name of manufacturer, brand name, and catalog number of each item. Submit complete submittals, at one time, having items arranged in numerical sequence with each item identified by section and article of the specifications. Listing items “as specified” without both name and model or type designation is not acceptable, except pipe and fitting not specified by brand names may be listed “as specified” without manufacturer’s name, provided proposed materials comply with specification requirements.

3. Descriptive Data: Send copies of complete description, information and performance data covering materials and equipment, which are specified. Brochures submitted to the Architect shall be published by the manufacturers and shall contain complete and detailed engineering and dimensional information. Brochures not compiled in the following manner shall be returned for re-submittal. Brochures submitted shall contain only information relevant to the particular equipment or materials to be furnished. The Contractor shall not submit catalogs, which describe several different items other than those items to be used unless irrelevant information is marked out, or unless relevant information is clearly marked. Brochures from each manufacturer shall be identified.

4. Miscellaneous: Prior to installation, submit to Construction Supervisor on the job site, two copies of the following:

   a. Shop drawings of equipment layouts.

   b. Installation instructions for each piece of mechanical equipment furnished.

   c. Dimension drawings for mechanical equipment pads and curbs including bolt sizes and locations.
5. Submittal Data: Submittal shall be based on manufacturer’s catalog cuts or brochures for items indicated on each section. Pages shall be clearly marked for the particular series, model, configuration, accessories, etc., which apply.

6. Submittals required by these specifications, including drawings, calculations, brochures, samples, etc. shall be submitted as one package. Partial submittals will be returned unprocessed.

7. Substituted Products:
   a. Comply with Division 01, Section “Substitution”.
   b. The contract drawings indicate the installation of the products or equipment of selected manufacturers. Other acceptable manufacturers are named in these specifications.
   c. If the installation of the particular product or equipment the Contractor has submitted requires changes in material or size from that required in the contract drawings and specifications, such changes shall be submitted as shop drawings.
   d. Changes in piping, motors, wiring, controls, structural or installation procedures required by the substituted product or equipment shall be made at no additional cost to the Owner, and with no reduction in scope.

1.8. WELDING PROCEDURES

   A. General: Piping shall comply with the provisions and latest revisions of the applicable sections of the ASME Code for Pressure Piping, ANSI/ASME B31.9, “Building Service Piping.”

   B. Before welding is performed, Contractor shall submit to the Architect and Owner, a copy of his Welding Operator Qualification Tests as required by Section IX of the ASME Boiler and Pressure Vessel Code.

   C. Welding Procedure:

      1. Carbon steel piping chilled water, condenser water, and heating hot water shall be welded in accordance with the National Certified Pipe Welding Bureau (NCPWB) Welding Procedure Specification No. 1-12-1 which requires root pass weld with SMAW using E6010 electrode; second and third pass welds using E7018 electrodes.

      2. Refrigeration Piping: Qualification documents for below 125 psig, WPS, PQR and WPQ for “Refrigeration Piping” shall be in accordance with ASME B31.5

   D. Contractor shall be responsible for the quality of welding done by this organization and shall repair work not in accordance with these specifications.

   E. Plumbing: Plumbing work shall be performed by a state licensed plumbing contractor.
1.9. **EXPLANATION AND PRECEDENCE OF DRAWINGS**

A. For purpose of clearness and legibility, the drawings are essentially diagrammatic although size and location of equipment is drawn to scale wherever possible. The Contractor shall make use of data in contract documents and shall verify this information at building site.

B. Attention is called to the inclusion of flow diagrams and riser diagrams. These diagrams are not for the purpose of giving physical dimensions or locations, but rather to make clear the interconnections, by the piping, of the various units of the process.

C. Other drawings of the contract set are hereby made a part of these specifications and shall be consulted by the Contractor and his work adjusted to meet the conditions shown thereon.

D. Drawings indicate required size and termination of pipes and ducts and suggest proper routes of piping and duct to conform to the structure, to avoid obstructions and to preserve clearance. However, it is not the intention to indicate necessary offsets and it shall be the responsibility of the Contractor, under this section, to install ductwork and piping in such a manner as to conform to structure, avoid obstructions, preserve headroom, keeping openings and passageways clear, and make equipment requiring inspection, maintenance and repair accessible without further instructions or extra cost to the Owner.

E. Coordinate with other trades so that no interferences shall occur, as no extras will be allowed for changes made necessary by interferences with the work between trades.

1.10. **COMPLETE PERFORMANCE OF WORK**

A. Practices of the Trades: Work shall be executed in strict accordance with the best practice of the trades by competent workmen.

B. Complete Functioning of Work: Labor, materials, apparatus, and appliances essential to the complete functioning of the systems described and/or indicated, or which may be reasonably implied as essential, whether mentioned in these contract documents or not, shall be furnished and installed by the Contractor. In cases of doubt as to the work intended, or in the event of need for explanation thereof, the Contractor shall call upon the Architect for supplemental instructions.

1.11. **CONTROL AND OBSERVATION**

A. The Architect, Engineer, and Owner shall have the right to reject materials or workmanship, which in their opinion are not in accordance with this contract, to interpret contract provisions and the meaning of the drawings and specifications. The above named parties shall be allowed access to the work for observation.

B. Defective work or work contrary to the contract documents may be rejected without regard to state of completion, even though said work has been accepted as a result of a previous observation.
1.12. APPROVALS

A. Electrical equipment shall meet the listing requirements and bear a minimum of one of the following agency labels:

1. Underwriter’s Laboratories (UL)

2. Electrical Testing Laboratories (ETL)

B. No equipment will be accepted on the jobsite without prior written approval.

1.13. GUARANTEES

A. In addition to specific guarantee mentioned in these specifications, the Contractor shall leave the entire installation in complete working order and free from defects in materials, workmanship or finish. Contractor shall repair or replace at his own expense a part that may develop defects due to faulty material or workmanship during the tests and within a period of one year after the work is accepted by the Owner. Contractor shall guarantee also to repair or replace with like materials existing work of the building or equipment, which is damaged during the repairing of such defective apparatus, materials or workmanship. The signing of the contract for his work covered by these specifications and of which they shall become a part, shall become a written guarantee on the part of the Contractor to carry out the provisions of this section of these specifications.

1.14. RECORD DRAWINGS AND OPERATING AND MAINTENANCE BOOKS

A. Record Drawings (Refer to Division 01): On completion of work, furnish the Owner through the Architect, with a complete set of reproducible record drawings and shop drawings which properly reflect the locations of equipment, fixtures, piping, ductwork, diffusers, mixing boxes, controls, etc., as actually installed. Where necessary to locate concealed equipment, dimensions, shall be included on these drawings. Maintain a separate set of drawings at the job site for such marking of “As-Built” locations. This set shall be updated as the installation work progresses and shall be available to the Architect at job visits. The Contractor shall indicate on the “Record Drawings As-Built” deletions in green. Additions, relocations, rerouting and modifications shall be indicated in red.

B. As a condition of Architect’s partial and final review of payment requests, the general contractor shall prepare and maintain record drawings in electronic format. The record drawings model space shall be updated monthly.

C. The format shall be AutoCad release 2012 or later. Changes to the drawings shall be made on a layer named “record” and the color shall be green. A copy of the model on CD with “as-built” changes shall be submitted to the Architect along with payment applications.

D. At the end of the project, the Contractor shall take “record” drawings and make corrections, modifying the electronic drawing files to show changes, modification or additions made during construction. These drawings will become Record Drawings to be delivered to the Architect.

E. Final record drawings shall include legends, schedules, plans, sections and details.
F. Record drawings shall be marked on the lower right corner with the following:

1. Name of Contractor
2. Record Drawings
3. Date
4. Building Permit Number

G. Letter shall be bold and print 1/4 inches high minimum.

H. Contractor shall submit to the Architect, Record Drawings as follows:

1. Four CD (AutoCad 2012 or later)
2. One reproducible
3. Four prints

I. The Architect will distribute the final record drawings as follows:

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<th>ARCHITECT</th>
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J. Delivery of complete set of Record Drawings is one condition for the release of Contractor’s final payment under the Contract.

K. Operating and Maintenance Books (Refer to Division 01): Provide the Owner through the Architect, operating instructions and maintenance data books for equipment and materials furnished under this Division.

L. Submit five copies of operating and maintenance data books to the Architect for review two weeks before final inspection of the project. Assemble data in a single complete indexed volume and identify the size, model and features indicated for each item, as follows:

1. Identification readable from the outside of the cover, stating “Heating, Ventilating and Air Conditioning and/or Plumbing and/or Fire Protection Installation. Owner, by (name of company).”

2. Neatly typewritten index near the front of the manual, furnishing immediate information as to location in the manual of emergency data regarding the installation.

3. Complete instructions regarding the operation and maintenance of equipment involved.

4. Complete nomenclature of replaceable parts, their part numbers, current cost and name and address of the nearest vendor of replacement parts.
5. Valve identification table keyed to valve I.D. number (e.g. V-1) on brass tag attached to each valve. Table shall indicate type of valve, product or service (e.g. domestic cold water), and function (e.g. shut-off, balancing, etc.).

6. Copy of guarantees and warranties issued on the installation showing dates of expiration.

7. Copy of the Air and Water Balancing Reports.

1.15. DAMAGE BY LEAKS

A. During the time period from the date of contract until termination date of this guarantee, the Contractor shall be responsible for damages to the ground, walls, roads, building, piping systems, electrical systems, heating, ventilating and air conditioning systems, building equipment, furniture and other building contents caused by leaks in the piping systems or equipment being installed or having been installed by him. Repair work shall be done as directed by, in a manner satisfactory to the Owner at no additional cost to the Owner.

PART 2 - PRODUCTS

2.1. GENERAL

A. Standard of Quality: Materials and equipment shall be new and in good condition. The commercially standard items of equipment and the specific names mentioned in sections of Division 15 are intended to establish the standards of quality and performance necessary for the proper functioning of the mechanical work.

B. Variations: Since manufacturing methods vary, reasonable minor equipment variations are expected; however, performance and material requirements are minimum. The Architect and Engineer retain the right to judge equality of equipment that deviates from the specifications.

C. Symbols are for identification. Symbols, capacities, sizes, and electrical characteristics are indicated on the drawings. Contractor shall make necessary provisions for installation of his equipment and for attaching or connecting his work to other trades.

2.2. FLASHINGS

A. Make pipes and vents passing through roof or outside wall waterproof with flashings and storm collars or counter flashings.

B. Except as otherwise noted or required, extend vent pipes passing through roof at least 12 inches above finished roofline.

C. Furnish and install on each pipe passing through the roof a galvanized sheet metal flashing assembly with eight-inch skirt.

D. Ductwork-penetrating roof or exterior walls shall be flashed and counter flashed with galvanized sheet metal.

E. Furnish and install on each pipe passing through the roof a six-pound seamless lead flashing assembly with eight-inch skirt. Flashing shall have steel reinforced conical boot and be
complete with open top cast iron counter flashing and permaseal waterproofing compound. For sanitary vent, provide a hood with a minimum 2 to 1 free area to vent pipe size.

F. Ductwork-penetrating roof or exterior walls shall be flashed and counter flashed with galvanized sheet metal.

2.3. PIPE SLEEVES

A. Provide pipe sleeves for mechanical piping.

B. Size pipe sleeves to permit placing pipe and specified isolation material for pipes passing through concrete or masonry walls or concrete slabs.

C. Sleeve for pipes through floor slabs standard weight black steel pipe with top of sleeve projecting 3” above finished floor. For waterproof sleeves, use J.R. Smith Fig. 172 or equivalent by Zurn or Josam.

D. Sleeves for pipes through walls shall standard weight black steel Schedule 40 pipe with ends flush with wall surfaces.

E. Seal pipes passing through fire rated walls or floors. Use Dow Corning 3-6548 Silicone RTV Foam in the annular space between pipes and sleeves. Sealant through fire rated walls shall be rated with the same fire rating as the wall.

F. Insulated pipe shall be insulated in sleeves, caulked and sealed as above. Use type CS-CW inserts as manufactured by Pipe Shields, Inc.

G. Pipes passing through exterior walls and concrete walls shall be sealed watertight with “Linkseal” as manufactured by Thunderline Corp. Method of installation as recommended by the manufacturer.

2.4. PIPE ISOLATORS AND COVERING PROTECTION

A. Pipe isolators: Provide each hanger or clamp for uninsulated piping with an isolation material, having metal backing, to isolate sound vibration and electrolysis. Provide Elcen “Isolator or appeared equal.” Isolator not required for fire protection automatic sprinkler piping, waste, vent and natural gas piping.

2.5. ELECTRIC MOTORS

A. Horizontal mounted fan and pump motors (close coupled excepted) shall be of the “Premium” efficiency type. Provide General Electric “Energy Saver,” Westinghouse” Tee 11”, U.S. Motors,”XB”, Baldor “Super E”, “Lincoln” “Ultimate EI” motors or approved equal unless otherwise specified. Guaranteed minimum full load efficiencies shall be certified in accordance with Institute of Electrical and Electronic Engineers (IEEE) Standard 112 Test Method B, National Electric Manufacturers’ Association (NEMA) MG-1-12.53a, and shall meet or exceed the following minimum criteria:
GUARANTEED MINIMUM FULL-LOAD NOMINAL EFFICIENCY

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1.  1/2 HP and Larger: 208 Volt 3 phase, 60 Hertz.

2.  Smaller than 1/2 HP: 115 Volt, 1 phase, 60 Hertz.

B. General:

1.  Motors shall be started across the line unless otherwise specified. Motors shall be selected with low starting current and shall be designed for continuous duty to provide the running torque and pull-in-torque required to suit the load. Unless otherwise specified, motors shall be single speed – 1750 rpm.

2.  Motors shall have standard drip-proof enclosure unless otherwise specified.

3.  Motors exposed to weather shall be of the totally enclosed fan-cooled type.

4.  Motors shall have at least 1.15 service factor. Motors shall be selected to operate at design conditions without exceeding nameplate ratings without operating using the service factor.

5.  Motors shall be sealed or field-lubricated in which case the latter shall be provided with grease fittings.

6.  Pump motors shall be selected to drive the pump through its characteristic curve, from zero to 25% above the design flow, without exceeding rated full load nameplate
horsepower. Pump motor nameplate rating shall not be exceeded in pump operation anywhere in the pump curve.

C. Three-Phase: Three-phase motors 10 horsepower and smaller shall have cast iron or steel housings and shall be of the squirrel cage induction type. Three-phase motors 15 horsepower and larger shall have cast iron housings and shall be of the squirrel cage induction type.

D. Single Phase: Single phase motors shall be capacitor-start type having internal thermal overload protection and with starting, pull-in and running characteristics to suit the load.

E. Where motor is an integral part of equipment, motor manufacturer shall be as recommended by the equipment manufacturer. However, other items shall comply with these specifications.

F. Nameplate: A motor nameplate shall be securely affixed to each motor and shall clearly indicate the class of insulation and the service factor in addition to the usual electrical data.

G. Special Requirements: Refer to various sections of this Division for special requirement for specific items of equipment requiring motors.

H. Submittals: Manufacturer’s data for equipment requiring motors shall be submitted for review. Indicate the motor manufacturer, motor horsepower, voltage, speed, efficiency, special torque requirements, enclosure and other special requirements.

2.6. MOTOR CONTROLLERS

A. Where required: In general, motor controllers for motors shall be furnished and installed under Division 16 unless indicated or specified otherwise. Motor controller that is not an integral part of a piece of equipment shall be furnished under this Division and shall be installed in accordance with the following specifications.

B. General: The motor controller shall be steel mounted. Controllers shall be front wired and terminals shall be accessible for wiring directly from the front. No slate or ebony asbestos shall be permitted on a controller from size 00 through size 8. Contacts shall be solid silver cadmium oxide alloy. Bare copper or silver flashed contacts shall not be permitted. Operating coils shall be pressure molded and so designed that if accidentally connected to excessive voltage, they will not expand, bubble or melt. When a coil fails under over-voltage condition, the motor controller shall definitely drop and not freeze the contacts in the “on” position.

C. Overload Relays: Overload relays shall be furnished for each of the three phases and shall be of the hand-reset variety so that blocking the reset mechanism in the reset position will not prevent the starter from dropping out if the motor is overloaded. This specifically excludes those overload relays which change to automatic reset from hand-reset when the reset mechanism is blocked unless the automatic reset feature can be removed or voided. Accidental depressing of the reset button or mechanism shall not shut off the motor. Overload relays shall not be field convertible from hand to automatic reset type.

D. Interlocks: Provide space to field-add one or more extra N.O. or N.C. interlocks to (except size 00) motor controllers without removing existing wiring or removing the controller from its enclosure.
E. Bulletin Numbers: Full voltage magnetic motor controller to be furnished under this Division shall be similar and approved equal to Allen-Bradley (AB) Bulletin Numbers as follows:

1. Individual three phase motor controller – AB Bul. 709.
2. Individual single phase motor controller – AB Bul. 709SP.
3. Combination three phase motor controller with fusible or nonfusible disconnect switch – AB Bul. 712.
4. Combination three motor controller with circuit breaker – AB Bu. 713.
5. Individual three multi-speed motor controller for two speed, single or two winding motors – AB Bul. 716.
6. Combination three phase multi-speed controller with circuit breakers for two speed, single or two winding motors – AB Bul. 717.

F. NEMA Type: In general, motor controller enclosures shall be NEMA Type 1 general purpose unless exposed to the weather or otherwise indicated on the drawings. Motor controller, including variable frequency drives, exposed to the weather shall have NEMA Type 3R watertight enclosure.

G. Holding Coils: General holding coils in full voltage magnetic motor controllers shall be suitable for use on 120 Volt A.C. control voltage.

H. Overload Protection: Three phase full voltage magnetic motor controller shall be suitable for use on 120 Volt A.C. control voltage.

I. Manual Controllers: Manual motor controllers where indicated on the drawings, required and/or specified shall be similar and equal to Allen Bradley Bul. 600 in NEMA Type 1 enclosure or otherwise required for the location of the installation.

J. Accessories: Motor controllers shall be provided with accessories such as control power transformers, push buttons, selector switches, pilot lights, etc., as indicated on the drawings and as specified herein. In general, most motor controllers shall include a maintain-contract start-stop button or run switch.

K. Manufacturer: Allen-Bradley or approved equal.

2.7. BELT DRIVES AND GUARDS

A. Belt Driven Equipment: Provide with V-belt type, adjustable-pitch driving sheaves for up through 25 HP motors. 30 HP and above shall have fixed pitch. Provide additional drive changes for motors when necessary to meet specified CFM for final air balance (one change minimum) at no additional cost to owner.

B. Drives: Minimum HP rating of 1.5 times motor nameplate HP.
C. Sheaves: Cast iron, machined and balanced, and keyed to shaft and locked with Allen type set screws.

D. Pitch Diameters: Minimum 3.0 inches for A section belts, minimum 5.0 inches for B section belts.

E. Guards: Provide belt drives with guards per OSHA requirements, metal construction, with angle iron framework with 1/2 inch expanded metal front panels and removable section held in place with studs and wing nuts for easy replacement of belts. Provide openings at shaft ends for tachometer readings.

2.8. ESCUTCHEONS

A. Provide heavy chrome-plated or nickel plated plates or approved pattern on pipe passing through floors, walls and ceilings in finished areas. Escutcheons shall be chrome-plated steel plates with concealed hinges and setscrew. Pattern shall be approved by the Architect.

2.9. CORROSION PROTECTION

A. Prior to delivery to the job site, wrap buried steel pipe with corrosion protective wrap of pressure sensitive polyvinyl chloride or polyethylene tape applied after pipe has been thoroughly cleaned. Tape shall be nominal thickness of 20 mils consisting of one layer of 20 mil tape or two separate layers of 10 mil tape. Apply with suitable primer adhesive recommended by manufacturer.

B. Tightly apply tapes with 1/2 inch minimum uniform lap, free from wrinkles and voids. Use approved wrapping machines and experienced operators.

C. Tapes: “Chasekote” No. 775, Plicoflex No. 340-25, Polyker 922 and 923, “Scotchwrap” No. 51 or equal. Apply tape after pipe is cleaned as recommended by the tape manufacturer.

D. Cover filed joints and fittings by wrapping polyethylene or polyvinyl tape specified for wrapping piping, except use two layers of 10 mil thick tape. Wrap joints to provide minimum of six-inches over adjacent pipe covering. Where fittings are wrapped, width of tape shall not exceed two inches. Apply adequate tension so tape will conform tightly to contours of fittings. Use putty tape insulation compounds such as “Scotchfil” or equal to fill voids and provide smooth even surface for application of tape wrap.

E. Alternate: In lieu of tape wrap, factory applied plastic coating on steel pipe will be acceptable. Use tapes for field joints, fittings and valves same as specified above. Pipe Coating: “X-Tru Coat” (20 mil thick) as manufactured by Standard Pipe Protection, Republic, Pipe Line Service Corp., Scotchkote 202 (12 mil thick) as manufactured by 3M Company, or equal, with “X-Tru-Tape”, or equal, for joints and valves.

F. Test wrapped or coated pipe, fittings and field joints on job site, after assembly, with approved high voltage holiday detector Tinker and Rasor, or equal, with positive signaling device to indicate flaws, holes or breaks in wrapping. Set peak voltage to 10,000 volts. If Scotchkote 202 is used, set peak voltage to 1,000 volts. Place piping on temporary blocks to allow testing to run along underside of pipe. Repair defects before covering. Conduct testing in presence of [Architect] [Engineer] or his representative.
G. No special precautions are required for copper or plastic piping below grade.

H. Special wrapping is required for contact with concrete such as thrust blocks or floor slabs. Piping shall be wrapped with minimum 8 mil thick polyethylene plastic sheets.

2.10. ACCESS COVER AND ACCESS DOORS

A. Provide access covers over under floor buried mechanical valves, controls, cleanouts, located in interior and exterior floor and grade areas.

B. Provide access door over concealed mechanical valves, controls, duct coils, dampers, fire dampers, pipe chases, concealed mechanical equipment through fire rated walls and ceilings.

C. Provide fire rated doors for access to mechanical equipment valves.

D. Access covers – Interior concrete floors:
   1. Type: Square or rectangular frame with hinged and secured cover.
   2. Size: Nominal 10” x 10”.
   3. Construction: Aluminum alloy frame and hinged score rated XH cover with lifting device. Secure with vandal proof screws.
   4. Marking: Cast cover with words “CLEANOUT”, “GAS SHUT-OFF” or “WATER SHUT-OFF” when used for these services.
   5. Acceptable manufacturers: Smith No. 4915, Zurn, Josam.

E. Access Covers – Interior vinyl/asbestos tile floors:
   1. Type: Square or rectangular frame with recessed cover.
   2. Size: Nominal 10” x 10”.
   3. Construction: Aluminum alloy frame and tile recess XH cover with lifting device. Secure with vandal proof screws at each corner.

F. Access Doors – Walls and ceilings:
   1. Type: Flush or recessed panel.
   2. Size: Minimum 12” x 12” nominal door for hand access, minimum 16” x 20” nominal door for personal access.
   3. Location and style:
      - Masonry/concrete walls: Milcor “M” Standard
      - Gypsum wallboard walls and ceilings: Milcor “M” Standard
Plastered surfaces (except toilet and kitchen walls)
Tile/terrazzo/kitchen/toilet room walls
(with casing bead stainless)
Acoustical tile (check type of ceiling system)
General areas
Fire rated shafts, rated walls and ceilings

4. Material:
   a. Stainless Steel, No. 302 with No. 4 finish.
   b. Standard manufacturer’s standard construction and finish for type specified.

5. Locking:
   a. Screwdriver: Flush screwdriver operated with case hardened cam.

6. Acceptable Manufacturers Milcor, Zurn, Miami, Carey, Potter-Roemer.

END OF SECTION 23 05 00
SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1. RELATED DOCUMENTS

A. Division 23 specification sections, drawings, and general provisions of the contract apply to work of this section, as do other documents referred to in this section.

1.2. SCOPE OF WORK

A. The owner’s representative will directly retain a qualified test and balance firm for the HVAC system. This independent test requirement shall not be procured at the subcontractor level.

B. The work included in this section consists of furnishing labor, instruments, and tools required in testing, adjusting and balancing the HVAC systems, as described in these specifications or shown on accompanying drawings. Services shall include checking equipment performance, taking the specified measurements, and recording and reporting the results.

C. The items requiring testing, adjusting and balancing include the following:

<table>
<thead>
<tr>
<th>AIR SYSTEMS:</th>
<th>HYDRONIC SYSTEMS:</th>
</tr>
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<tbody>
<tr>
<td>Supply Fan AHU</td>
<td>Pumps</td>
</tr>
<tr>
<td>Return Fans</td>
<td>System Mains and Branches</td>
</tr>
<tr>
<td>Relief Fans</td>
<td>Pumps</td>
</tr>
<tr>
<td>Exhaust Fans</td>
<td>Coils</td>
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<tr>
<td>Zone Branch and Main Ducts</td>
<td>Boilers</td>
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<tr>
<td>VAV Systems</td>
<td></td>
</tr>
<tr>
<td>Diffusers, Registers and Grilles</td>
<td></td>
</tr>
<tr>
<td>Coils (Air Temperatures)</td>
<td></td>
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</tbody>
</table>

1.3. DEFINITIONS, REFERENCES, STANDARDS

A. Work shall be in accordance with the latest edition of the AABC National Standards. If these contract documents set forth more stringent requirements than the AABC National Standards, these contract documents shall prevail.

1. AABC: The Associated Air Balance Council is a nonprofit association of independent, certified agency specializing in testing, adjusting, and balancing HVAC systems. The AABC National Standards (latest edition), provides standards and operational criteria for HVAC Systems

1.4. QUALIFICATIONS

A. Agency Qualifications: The TAB Agency shall be a current member of the Associated Air Balance Council (AABC).
1.5. **SUBMITTALS**

A. **Qualifications:** The TAB Agency shall submit a company resume listing personnel and project experience in air and hydronic system balancing and a copy of the agency Test and Balance Engineer (TBE) certificates.

B. **Procedures and Agenda:** The TAB Agency shall submit the TAB procedures and agenda proposed to be used.

C. **Sample Forms:** The TAB Agency shall submit sample forms, which shall include the minimum data required by the AABC National Standards.

1.6. **TAB PREPARATION AND COORDINATION**

A. Shop drawings, submittal data, up-to-date revisions, change orders, and other data required for planning, preparation, and execution of the TAB work shall be provided to the TAB Agency no later than 30 days prior to the start of TAB work.

B. System installation and equipment startups shall be complete prior to the TAB Agency being notified to begin.

C. The Building Control System shall be complete and operational. The Building Control System contractor shall install necessary computers and computer programs, and make these operational. Assistance shall be provided as required for reprogramming, coordination, and problem resolution.

D. Test points, balancing devices, identification tags, valves, and dampers shall be accessible and clear of insulation and other obstructions that would impede TAB procedures.

E. Qualified installation or startup personnel shall be readily available for the operation and adjustment of the systems. Assistance shall be provided as required for coordination and problem resolution.

1.7. **REPORTS**

A. **Final TAB Report** – The TAB Agency shall submit the final TAB report for review by the engineer. Outlets, devices, and equipment shall be identified, along with a numbering system corresponding to report unit identification. The TAB Agency shall submit an AABC “National Project Performance Guaranty” assuring that the project systems were tested, adjusted and balanced in accordance with the project specifications and AABC National Standards.

B. Submit five copies of the Final TAB Report.

1.8. **DEFICIENCIES**

A. Any deficiencies in the installation or performance of a system or component observed by the TAB Agency shall be brought to the attention of the appropriate responsible person.
B. The work necessary to correct items on the deficiency listing shall be performed and verified by the affected contractor before the TAB Agency returns to retest. Unresolved deficiencies shall be noted in the final report.

1.9. ACOUSTICAL TESTING

A. Acoustical Performance Requirements

1. Noise levels shall be quantified in project spaces and compared with the specified maximum allowable Background Noise Criteria (NC). Insofar as possible under the jurisdiction of the Air Balance Contractor and the Mechanical Contractor, adjustments shall be made to air handling equipment to insure that maximum NC are not exceeded in project spaces.

B. ACOUSTICAL Submittals

1. Submit proposed test procedure and measurement equipment before beginning work.

2. Submit as part of the final air balance report the following:

3. Project space by room number.

4. Specified maximum NC (see below).

5. Measured NC at each measurement location.

6. Octave band sound levels in dB from 63 Hz to 8000 Hz. plotted on NC curves at each measurement location.

7. Notes relating to additional noise sources (other than HVAC) encountered.

C. Acoustical Quality Assurance

1. The same Air Balance Contractor shall be responsible for all aspects of air balancing including all sound level measurements.

2. The Air Balance Contractor shall have successful experience in air balancing and sound level measurements including no less than five years experience on projects equal to the size and complexity of this work.

3. Measurement equipment shall be of the class specified below and shall have been calibrated within six months prior to this work.

4. Sound Level Meter and Filters: Type 1 Sound Level Meter with Class II Octave Band Filters as defined in ANSI Standards S1.4 and S1.11.

5. Measurement Microphone: Measurement microphone shall be 1/2" diameter, random-incidence type, calibrated in accordance with ANSI S1.10.
PART 2 - PRODUCTS

2.1. INSTRUMENTATION

A. Instruments used for measurements shall be accurate and calibrated. Calibration and maintenance of instruments shall be in accordance with the requirements of AABC National Standards.

END OF SECTION 23 05 93
SECTION 23 08 00 - COMMISSIONING

PART 1 - GENERAL

1.1. GENERAL

A. Commissioning (Cx): Comprehensive and systematic process to verify building systems perform as designed to meet owner’s requirements.

B. Commissioning Agent (CA): Independent and knowledgeable third party hired to verify that systems work as intended per design intent and contract documents.

C. Design Intent: Ideas, concepts and criteria for the project that are considered important to the owner relative to performance and sustainability of energy-related systems.

D. Commissioning during construction, acceptance, and warranty phases is intended to achieve following objectives:

1. Verify and document Owner’s Project Requirements (OPR) goals are achievable.
2. Verify and document Basis of Design (BoD) will meet OPR.
3. Verify and document equipment is installed and started per manufacturer’s recommendations and to industry accepted minimum standards.
4. Verify and document equipment and systems receive complete operational checkout by installing contractors.
5. Verify and document equipment and system performance in accordance with design intent.
6. Verify completeness of operations and maintenance documents.
7. Ensure owner’s operating personnel are trained on operation and maintenance of building equipment by factory representatives.

E. Commissioning process does not take away from or reduce responsibility of system designers or installing contractors to provide finished and fully functioning product.

1.2. RELATED SECTIONS

A. Section 01310 – Project Management and Coordination
B. Section 01330 – Submittal Procedures
C. Section 01750 – Starting and Adjusting
D. Section 01770 – Closeout Procedures
E. Section 01780 – Closeout Submittals
F. Section 01820 – Demonstration and Training
G. Section 01830 – Operation and Maintenance
H. Section 15015 – Mechanical Design Requirements
I. Section 16015 – Electrical Design Requirements
J. Section 15050 – Basic Mechanical Materials and Methods
K. Section 16050 – Basic Electrical Materials and Methods

1.3. COORDINATION

A. Commissioning Team.
   1. Commissioning Authority (CA)
   2. Owner’s Technical Staff (Owner or OTS)
   3. General Contractor (C)
   4. Prime Contractor (PC)
   5. Manufacturer’s Representatives/Vendors
   6. Architect (A) and design Engineers (E)
   7. Mechanical Contractor (MC) / Electrical Contractor (EC)
   8. Test and Balance representative (TAB)
   9. Controls Contractor (CC)
   10. Installing subcontractors (C)

B. Management.
   1. Commissioning Authority:
      a. Under contract with Owner
      b. Manages commissioning process with assistance of Commissioning Team: Prime Contractor.

C. Scheduling: CA to work with OTS, PC to schedule commissioning activities.
   1. Contractor (C) to integrate commissioning activities into master construction schedule.
   2. Involved parties to address scheduling issues in timely manner to expedite commissioning process.
1.4. COMMISSIONING PROCESS

A. Following activities describe commissioning tasks coordinated by CA and C during construction in order of occurrence.

1. Cx Kickoff Meeting: Members of design and construction team involved in the commissioning process to meet and agree on scope of work, tasks, schedules, deliverables, and responsibilities for implementation of Commissioning Plan.

2. Commissioning Plan: Provides guidance in execution of commissioning process.
   a. Project Manual (Specifications) takes precedence over Cx Plan.

3. Submittals: Equipment documentation submitted to CA during normal submittals, including detailed start-up procedures.

4. Start-Up/Pre-Functional Checklists: CA works with PCs to develop or approve startup plans and documentation formats, including providing Subs with pre-functional checklists to be completed during startup process, if necessary.

   a. Contractor and Subs review procedures.
   b. Procedures to be executed by CA or by PCs, under direction of, and documented by, the CA.

6. Deficiencies and Resolution: CA documents items of non-compliance in materials, installation or operation.
   a. Items are corrected at PC expense and equipment or systems are retested.

7. Operations and Maintenance Documentation: CA reviews O&M documentation for completeness.

8. Training: CA reviews and coordinates training provided by PC and verifies it is completed.

9. Seasonal Testing: Deferred or seasonal testing is conducted, as required.

1.5. COMMISSIONING RESPONSIBILITIES

A. Services for Owner’s Technical Staff (OTS), Design Team, and Commissioning Authority (CA) are not a part of this contract and Contractor (C) not responsible for providing their services. Their responsibilities are listed here to clarify commissioning process.
B. Commissioning Authority (CA):

1. Primary Role: Develop and coordinate execution of testing plan to verify and document systems are functioning in accordance with design intent and Construction Documents.

2. May assist with problem-solving deficiencies, but ultimately that responsibility resides with Contractor (C), PC, and Architect/Engineer.

3. Not responsible for design concept, design criteria, code compliance, general construction scheduling, cost estimating, or construction management.

4. Construction and Acceptance Phase:
   a. Coordinates and direct commissioning activities.
   b. Work with C and PC to ensure commissioning activities are scheduled.
   c. Maintain up-to-date Commissioning Plan.
   d. Help plan and conduct commissioning kickoff meeting and controls integration meetings.
   e. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures, and sequences of operation.
   f. Review Contractor submittals applicable to commissioned systems, concurrent with Architect and Engineer reviews.
   g. Develop start-up and checkout plans with Contractor (C) and Subs.
   h. Write and distribute pre-functional checklists, tests and start-up forms.
   i. Perform site visits to observe component and system installations.
   j. Attend construction job-site meetings to monitor construction and commissioning progress.
   k. Review completed pre-functional checklist and start-up reports.
   l. Assist with coordination of start-up requirements with TAB requirements.
   m. Write functional performance test procedures for equipment and systems.
   o. Coordinate retesting as necessary until satisfactory performance is verified.
   p. Maintain master deficiency and resolution record and provide OTS with written progress reports and test results with recommended actions.
q. Review training proposed by Contractor (C) and Subs for Owner’s operating personnel.
r. Review O&M manuals.
s. Prepare Final Commissioning Report.

5. Warranty Period:
a. Coordinate and supervise seasonal or deferred testing and deficiency corrections.
b. Assist in review of record documentation.
c. Assist in end of warranty review/walk-through inspection.

C. Design Team (A/E):

1. Construction and Acceptance Phase:
a. Attend commissioning kickoff meeting, controls integration meeting and additional meetings, as necessary.
b. Provide design intent and sequence of operation documentation as required by CA.
c. Assist in resolution of system deficiencies identified during commissioning.
d. Review and approve operations and maintenance manuals (O&M).
e. Optional: Witness equipment start-up and performance testing.

2. Warranty Period:
a. Assist in resolution of system deficiencies identified during warranty period commissioning.

D. Owner’s Technical Staff (OTS):

1. Construction and Acceptance Phase:
a. Plan/Attend commissioning kickoff meeting, controls integration meeting and additional meetings, as necessary.
b. Arrange for facility operating and maintenance personnel to participate in commissioning activities and training sessions.
c. Provide final acceptance for commissioning work.

2. Warranty Period:
a. Ensure seasonal or deferred testing and deficiency issues are addressed.
E. Contractor (C, Contractor or Prime):

1. Construction and Acceptance Phase:
   a. Facilitate coordination of commissioning work by CA.
   b. Attend commissioning kickoff meeting, controls integration meeting and additional meetings, as necessary.
   c. Furnish copies of construction documents, addenda, change orders and approved submittals and design drawings related to commissioned equipment to CA.
   d. Ensure PCs execute their commissioning responsibilities according to Project Manual (Specifications) and Commissioning Plan.
   e. Coordinate training of owner personnel.
   f. Work with Subs to prepare O&M manuals, according to Project Manual, including updating original sequences of operation to Record (As-built) conditions.
   g. Develop start-up and checkout plan for commissioned equipment.
      1) Startups shall be based on manufacturer’s recommendations and pre-functional checklists from CA.
      2) Submit to CA for review and approval prior to start-up.

2. Warranty Period:
   a. Ensure Subs execute required seasonal or deferred functional performance testing.
   b. Ensure Subs correct deficiencies and make necessary adjustments to O&M manuals and Record Drawings for issues identified during warranty period.

F. Mechanical MC, Electrical EC, Controls CC and TAB Contractor:

1. Construction and Acceptance Phases:
   a. Attend commissioning kickoff meeting, controls integration meeting and additional meetings, as necessary.
   b. Provide additional requested documentation, prior to normal O&M manual submittals, to CA for development of start-up and functional testing procedures.
   c. Assist in clarification of operation and control of commissioned equipment where Project
   d. Manual, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
e. Help develop start-up and checkout plan for commissioned equipment based on manufacturer’s recommendations and pre-functional checklists from CA.

f. During startup and checkout process, execute pre-functional checklists for commissioned equipment.
   1) Perform and document completed startup and system operational checkout procedures.
   2) Provide documentation to CA for review

g. Resolve punch list items before functional testing.
   1) Air and water TAB to be completed with discrepancies and problems resolved before functional testing.
   2) Provide documentation to CA for review

h. Perform functional performance testing, under direction of CA, for commissioned equipment.

i. Resolve equipment or system deficiencies and retest as required to verify modified performance.

j. Prepare O&M manuals according to Project Manual, including updating original sequences of operation to record conditions.

k. Provide training of Owner’s operating personnel.

l. Coordinate with equipment manufacturers to determine requirements to maintain validity of warranties.

2. Warranty Period

   a. Execute seasonal or deferred functional performance testing
   b. Correct deficiencies and make necessary adjustments to O&M manuals and record drawings for issues identified during warranty period.

G. Controls Contractor (CC). Commissioning responsibilities of CC, during construction and acceptance phases in addition to those listed in Paragraph (F) are:

   1. Sequences of Operation Submittals. Temperature controls submittals to include complete and detailed sequences of operation for each piece of equipment, regardless of completeness and clarity of sequences in Project Manual and include:
      a. Narrative description of system, describing its purpose, components and function.
      b. Interactions and interlocks with other systems.
c. Delineation of control interactions between packaged controls and building automation system, including listing of monitored points, controlled points, and adjustable points.

d. Written sequences of control for packaged controlled equipment.

e. Sequences of control for modes of operation (Start-up, Warm-up, Cool-down, Normal occupied, Unoccupied, Emergency Shutdown, etc.).

f. Capacity control sequences and equipment staging.

g. Temperature and pressure control sequences (setbacks, resets, etc.).

h. Sequences for control strategies (economizer control, optimum start/stop, optimization, demand limiting, etc.).

i. Effects of power or equipment failure with standby component functions.

j. Sequences for alarms and emergency shutdowns.

k. Seasonal operational requirements.

2. Control Drawings Submittal

a. Control Drawings: Provide graphic schematic depictions of systems and each component.

b. Control drawings to have key to abbreviations.

c. Schematics to include system and component layout of equipment that control system monitors, enables or controls, even if equipment is primarily controlled by packaged or integral controls.

d. Provide full points list with following included for each point:
   1) Controlled system
   2) Point abbreviation
   3) Point description
   4) Point type (digital/analog, input/output)
   5) Display unit
   6) Control point or setpoint (Yes/No)
   7) Monitoring point (Yes/No)
   8) Intermediate point (Yes/No)
9) Calculated point (Yes / No)

3. Control drawings of record and sequences of operation to be included in final controls O&M manual submittal.

4. Controls Contractor to prepare written plan indicating step-by-step manner, and procedures that will be followed to test, checkout and adjust control system prior to functional performance testing.

5. Signed and dated certification to CA and Owner upon completion of control system checkout.

H. Equipment Suppliers

1. Provide requested submittal data, including detailed start-up procedures and specific responsibilities of Owner to keep warranties in effect.

2. Provide information requested by CA regarding equipment sequence of operation and testing procedures.

3. Assist in equipment testing per agreements with Subs.

1.6. COMMISSIONING SCOPE

A. Equipment to be commissioned in this project checked.

<table>
<thead>
<tr>
<th>System</th>
<th>Equipment</th>
<th>Check</th>
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<tbody>
<tr>
<td>HVAC System</td>
<td>Pumps</td>
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</tr>
<tr>
<td></td>
<td>Computer Room Units</td>
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<td></td>
<td>Boilers</td>
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<td>Chemical Treatment Systems</td>
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</tr>
<tr>
<td></td>
<td>HVAC Control System</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Fire and Smoke Dampers</td>
<td>X</td>
</tr>
<tr>
<td>Electrical System</td>
<td>Sweep or Scheduled Lighting Controls</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Daylight Dimming Controls</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Lighting Occupancy Sensors</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Fire and Smoke Alarm Systems</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Fire Protection Systems</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>UPS Systems</td>
<td>X</td>
</tr>
<tr>
<td>System</td>
<td>Equipment</td>
<td>Check</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Other</td>
<td>Vestibule Pressurization</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Service Water Heaters &amp; Recirc Pumps</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Refrigeration System Exhaust</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Compressed Air System</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Vacuum Pump System</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Deionized Water Systems</td>
<td>X</td>
</tr>
</tbody>
</table>

**PART 2 - PRODUCTS**

2.1. TEST EQUIPMENT

A. Standard testing equipment required to perform startup and initial checkout and required functional performance testing to be provided by Division Contractor for equipment being tested.

B. Testing equipment to be of sufficient quality and accuracy to test or measure system performance as required by Project Manual.

C. Datalogging equipment or software required to test equipment to be provided by CC but shall not become property of Owner.

END OF SECTION 23 08 00
SECTION 23 09 00 - DIRECT DIGITAL CONTROLS FOR HVAC

PART 1 - GENERAL

1.1. PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Sensors and Transmitters:
   1. Airflow stations
   2. Flowmeters
   3. Flow switches
   4. Press and temp sensor wells & sockets
   5. Temp sensor wells and sockets
   6. Control valves

B. Section 23 60 00 – Heating, Ventilation, and Air Conditioning:
   1. Air terminal unit controls

1.2. PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

A. Sensors and Transmitters:
   1. Duct static pressure sensors
   2. H2O Pressure Differential/Flow Switches

B. Section 23 60 00 – Heating, Ventilation, and Air Conditioning:
   1. Refrigerant leak detection system

C. Section 28 31 00 - Fire Detection and Alarm:
   1. Smoke Detectors/Fire Stats

1.3. PRODUCTS NOT FURNISHED OR INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION

A. General:
   1. Coordination Meeting: The Installer furnishing the DDC network shall meet with the Installer(s) furnishing each of the following products to coordinate details of the interface between these products and the DDC network. The Owner or his designated representative shall be present at this meeting. Each Installer shall provide the Owner and other Installers with details of the proposed interface including PICS for BACnet equipment, hardware and software identifiers for the interface points, network identifiers,
wiring requirements, communication speeds, and required network accessories. The purpose of this meeting shall be to insure there are no unresolved issues regarding the integration of these products into the DDC network. Submittals for these products shall not be approved prior to the completion of this meeting.

B. Section 23 60 00 – Heating, Ventilation, and Air Conditioning:

1. Air Terminal Units: Air terminal Units shall be furnished configured to accept control inputs from an external building automation system controller as specified in Section 23 09 00. Factory mounted safeties and other controls shall not interfere with this controller.

2. Air Handling Unit or Make Up Air Unit controls: Unit shall be furnished configured to accept control inputs from an external building automation system controller as specified in Section 23 09 00. Factory mounted safeties and other controls shall not interfere with this controller.

3. Decentralized HVAC Equipment: Unit ventilators, unit heaters, fan coils, etc.: Unit ventilators, unit heaters, fan coils, cabinet heaters, convective or fin tube heaters, zone reheat, and similar terminal units: These units shall be furnished configured to accept control inputs from an external building automation system controller as specified in Section 23 09 00. Factory mounted safeties and other controls shall not interfere with this controller.

4. Communications with Third Party Equipment: Additional integral control systems included with the products integrated with the work of this section shall be furnished with a BACnet interface for integration into the Direct Digital Control System described in this section.

1.4. RELATED SECTIONS

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

B. The following sections constitute related work:

1. Section 01 30 00 - Administrative Requirements
2. Section 01 60 00 - Product Requirements
3. Section 01 80 00 - Performance Requirements
4. Section 01 90 00 - Life Cycle Activities
5. Section 23 05 00 - Common Work Results for HVAC
6. Section 23 60 00 – Heating, Ventilation, and Air Conditioning
7. Section 26 05 00 - Common Work Results for Electrical
8. Section 26 06 00 - Schedules for Electrical
9. Section 26 09 00 - Instrumentation and Control for Electrical Systems
10. Section 26 20 00 - Low Voltage Electrical Transmission
11. Section 26 29 00 - Low-Voltage Controllers (Motor Controllers and VFD Drives)
12. Section 26 30 00 - Facility Electrical Power Generating and Storing Equipment (UPS, Backup Generators)
13. Section 26 50 00 - Lighting
14. Section 28 00 00 - Electronic Safety and Security (includes Fire and Smoke)

1.5. DEFINITIONS AND ABBREVIATIONS

A. Terms used within the Specification Text:

1. **Advanced Application Controller (AAC):** A fully programmable control module. This control module may be capable of some of the advanced features found in Building Controllers (storing trends, initiating read and write requests, etc.) but it does not serve as a master controller. Advanced Application Controllers may reside on either the Ethernet/IP backbone or on a subnet.

2. **Application Specific Controller (ASC):** A pre-programmed control module which is intended for use in a specific application. ASCs may be configurable, in that the user can choose between various pre-programmed options, but it does not support full custom programming. ASCs are often used on terminal equipment such as VAV boxes or fan coil units. In many vendors' architectures ASCs do not store trends or schedules but instead rely upon a Building Controller to provide those functions.

3. **BACnet/IP:** An approved BACnet network type which uses an Ethernet carrier and IP addressing.

4. **BACnet MS/TP:** An approved BACnet network type which uses a Master-Slave Token Passing configuration. MS/TP networks are unique to BACnet and utilize EIA485 twisted pair topology running at 9600 to 76,800 bps.

5. **BACnet over ARCNET:** An approved BACnet network type which uses an ARCNET (attached resource computer network) carrier. ARCNET is an industry standard that can utilize several speeds and wiring standards. The most common configuration used by BACnet controllers is an EIA485 twisted pair topology running at 156,000 bps.

6. **Building Controller (BC):** A fully programmable control module which is capable of storing trends and schedules, serving as a router to devices on a subnet, and initiating read and write requests to other controllers. Typically this controller is located on the Ethernet/IP backbone of the BAS. In many vendors' architectures a Building Controller will serve as a master controller, storing schedules and trends for controllers on a subnet underneath the Building Controller.
7. **Direct Digital Control (DDC):** A control system in which a digital computer or microprocessor is directly connected to the valves, dampers, and other actuators which control the system, as opposed to indirectly controlling a system by resetting setpoints on an analog pneumatic or electronic controller.

8. **PICS - Protocol Implementation Conformance Statement:** A written document, created by the manufacturer of a device, which identifies the particular options specified by BACnet that are implemented in the device.

9. **Smart Actuator (SA):** An actuator which is controlled by a network connection rather than a binary or analog signal. (0-10v, 4-20mA, relay, etc.)

10. **Smart Sensor (SS):** A sensor which provides information to the BAS via network connection rather than a binary or analog signal. (0-10000 ohm, 4-20mA, dry contact, etc.)

11. **Web services:** Web services are a standard method of exchanging data between computer systems using the XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services can be used at any level within a Building Automation System (BAS), but most commonly they are used to transfer data between BAS using different protocols or between a BAS and a non-BAS system such as a tenant billing system or a utility management system.

**B. Contracting Terms:**

1. **Furnished or Provided:** The act of supplying a device or piece of equipment as required meeting the scope of work specified and making that device or equipment operational. All costs required to furnish the specified device or equipment and make it operational are borne by the division specified to be responsible for providing the device or equipment.

2. **Install or Installed:** The physical act of mounting, piping or wiring a device or piece of equipment in accordance with the manufacturer's instructions and the scope of work as specified. All costs required to complete the installation are borne by the division specified to include labor and any ancillary materials.

3. **Interface:** The physical device required to provide integration capabilities from an equipment vendor's product to the control system. The equipment vendor most normally furnishes the interface device. An example of an interface is the chilled water temperature reset interface card provided by the chiller manufacturer in order to allow the control system to integrate the chilled water temperature reset function into the control system.

4. **Integrate:** The physical connections from a control system to all specified equipment through an interface as required to allow the specified control and monitoring functions of the equipment to be performed via the control system.

**C. Abbreviations:** The following abbreviations may be used in graphics, schematics, point names, and other UI applications where space is at a premium.

1. **AC - Air Conditioning**
2. ACU - Air Conditioning Unit
3. AHU - Air Handling Unit
4. AI - Analog Input
5. AO - Analog Output
6. AUTO - Automatic
7. AUX - Auxiliary
8. BI - Binary Input
9. BO - Binary Output
10. C - Common
11. CHW - Chilled Water
12. CHWP - Chilled Water Pump
13. CHR - Chilled Water Return
14. CHS - Chilled Water Supply
15. COND - Condenser
16. DA - Discharge Air
17. EA - Exhaust Air
18. EF - Exhaust Fan
19. EVAP - Evaporators
20. FCU - Fan Coil Unit
21. HOA - Hand / Off / Auto
22. HP - Heat Pump
23. HRU - Heat Recovery Unit
24. HTEX - Heat Exchanger
25. HW - Hot Water
26. HWP - Hot Water Pump
27. HR - Hot Water Return
28. HS - Hot Water Supply
29. MAX - Maximum
30. MIN - Minimum
31. MISC - Miscellaneous
32. NC - Normally Closed
33. NO - Normally Open
34. OA - Outdoor Air
35. PIU - Powered Induction Unit
36. RA - Return Air
37. RF - Return Fan
38. RH - Relative Humidity
39. RTU - Roof-top Unit
40. SA - Supply Air
41. SF - Supply Fan
42. SP - Static Pressure
43. TEMP - Temperature
44. UH - Unit Heater
45. UV - Unit Ventilator
46. VAV - Variable Air Volume
47. VVTU - Variable Volume Terminal Unit
48. W/ - with
49. W/O - without
50. WSHP - Water Source Heat Pump

1.6. DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphic. A web server with a network interface card shall gather
data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface.

B. The system shall directly control HVAC equipment as specified in Sequence of Operation on drawings. Each zone controller shall provide occupied and unoccupied modes of operation by individual zone. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified in the sequence.

C. Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

D. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends, and alarms specified in Sequence of Operation on drawings shall be BACnet objects.

1.7. APPROVED CONTROL SYSTEMS

A. Use control system hardware and software that meet the requirements of this specification.

1.8. QUALITY ASSURANCE

A. System Manufacturer

1. The system manufacturer shall be the same as existing main campus’ control system and a firm regularly engaged in the manufacture of a full line of pneumatic, electronic and computer based controls of the type required by this project. System manufacturer shall have maintained an installing, contracting and servicing field office, either factory owner or an exclusive factory authorized representative, in the local of this project for at least five years. The system manufacturer is “Distech Controls.”

B. System Contractor

1. The system contractor shall be the field office of the system manufacturer or system manufacturer certified contractor in the locale of this project. Contractors, wholesalers, dealers or any other firm that is not the field office of the system manufacturer or system manufacturer certified contractor will not be acceptable as the system contractor. Acceptable system contractors is “Distech Controls” certified contractor.

C. Installer shall have an established working relationship with Control System Manufacturer.

D. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
1.9. CODES AND STANDARDS

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:

1. National Electric Code (NEC)
2. California Building Code (CBC)
3. California Mechanical Code (CMC)

1.10. SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 sec of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
Table 1 Reporting Accuracy

<table>
<thead>
<tr>
<th>Measured Variable</th>
<th>Reported Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Temperature</td>
<td>±0.5°C (±1°F)</td>
</tr>
<tr>
<td>Ducted Air</td>
<td>±0.5°C (±1°F)</td>
</tr>
<tr>
<td>Outside Air</td>
<td>±1.0°C (±2°F)</td>
</tr>
<tr>
<td>Dew Point</td>
<td>±1.5°C (±3°F)</td>
</tr>
<tr>
<td>Water Temperature</td>
<td>±0.5°C (±1°F)</td>
</tr>
<tr>
<td>Delta-T</td>
<td>±0.15°C (±0.25°F)</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>±5% RH</td>
</tr>
<tr>
<td>Water Flow</td>
<td>±2% of full scale</td>
</tr>
<tr>
<td>Airflow (terminal)</td>
<td>±10% of full scale (see Note 1)</td>
</tr>
<tr>
<td>Airflow (measuring stations)</td>
<td>±5% of full scale</td>
</tr>
<tr>
<td>Airflow (pressurized spaces)</td>
<td>±3% of full scale</td>
</tr>
<tr>
<td>Air Pressure (ducts)</td>
<td>±25 Pa (±0.1 in. w.g.)</td>
</tr>
<tr>
<td>Air Pressure (space)</td>
<td>±3 Pa (±0.01 in. w.g.)</td>
</tr>
<tr>
<td>Water Pressure</td>
<td>±2% of full scale (see Note 2)</td>
</tr>
<tr>
<td>Electrical (A, V, W, Power Factor)</td>
<td>±1% of reading (see Note 3)</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>±5% of reading</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>±50 ppm</td>
</tr>
</tbody>
</table>

Note 1: Accuracy applies to 10% - 100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

1. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table 2 Control Stability and Accuracy

<table>
<thead>
<tr>
<th>Controlled Variable</th>
<th>Control Accuracy</th>
<th>Range of Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Pressure</td>
<td>±50 Pa (±0.2 in. w.g.)</td>
<td>0-1.5 kPa (0-6 in. w.g.)</td>
</tr>
<tr>
<td></td>
<td>±3 Pa (±0.01 in. w.g.)</td>
<td>-25 to 25 Pa (-0.1 to 0.1 in. w.g.)</td>
</tr>
<tr>
<td>Airflow</td>
<td>±10% of full scale</td>
<td></td>
</tr>
<tr>
<td>Space Temperature</td>
<td>±1.0°C (±2.0°F)</td>
<td></td>
</tr>
<tr>
<td>Duct Temperature</td>
<td>±1.5°C (±3°F)</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>±5% RH</td>
<td></td>
</tr>
<tr>
<td>Fluid Pressure</td>
<td>±10 kPa (±1.5 psi)</td>
<td>MPa (1-150 psi)</td>
</tr>
<tr>
<td></td>
<td>±250 Pa (±1.0 in. w.g.)</td>
<td>0-12.5 kPa (0-50 in. w.g.) differential</td>
</tr>
</tbody>
</table>

1.11. SUBMITTALS

A. Product Submittal Requirements: Meet requirements of Section 01 30 00 on Shop Drawings, Product Data, and Samples. Provide six copies of shop drawings and other submittals on hardware, software, and equipment to be installed or furnished. Begin no work until submittals are approved.
have been approved for conformity with design intent. Provide drawings as AutoCAD 2012 (or newer) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and 3 prints of each drawing on 11" x 17" paper. When manufacturer's cutsheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered specification and drawing on each submittal. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Provide submittals within 12 weeks of contract award on the following:

1. Direct Digital Control System Hardware
   
a. Complete bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.

b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
   
1) Direct digital controllers (controller panels)
2) Transducers and transmitters
3) Sensors (include accuracy data)
4) Actuators
5) Valves
6) Relays and switches
7) Control panels
8) Power supplies
9) Batteries
10) Operator interface equipment
11) Wiring

c. Wiring diagrams and layouts for each control panel. Show termination numbers.

d. Floor plan schematic diagrams indicating field sensor and controller locations.

e. Riser diagrams showing control network layout, communication protocol, and wire types.
2. Central System Hardware and Software
   a. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
   b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
      1) Central Processing Unit (CPU) or web server
      2) Monitors
      3) Keyboards
      4) Power supplies
      5) Battery backups
      6) Interface equipment between CPU or server and control panels
      7) Operating System software
      8) Operator interface software
      9) Color graphic software
      10) Third-party software
   c. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
   d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems
   a. Riser diagrams showing control network layout, communication protocol, and wire types.
   b. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
   c. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
d. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

e. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified in drawings and specifications. Indicate alarmed and trended points.

4. Description of process, report formats, and checklists to be used in Section 23 09 00 Article 3.16 (Control System Demonstration and Acceptance).

5. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules

1. Schedule of work provided within one month of contract award, indicating:
   a. Intended sequence of work items
   b. Start date of each work item
   c. Duration of each work item
   d. Planned delivery dates for ordered material and equipment and expected lead times
   e. Milestones indicating possible restraints on work by other trades or situations

2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

C. Project Record Documents. Submit three copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:

1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2006 (or newer) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and 6 prints of each drawing on 11" x 17" paper.

2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 23 09 00 Article 3.16 (Control System Demonstration and Acceptance).

3. Operation and Maintenance (O&M) Manual. Printed, electronic, or online help documentation of the following:
   a. As-built versions of submittal product data.
   b. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
c. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.

d. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.

e. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.

f. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.

g. Graphic files, programs, and database on magnetic or optical media.

h. List of recommended spare parts with part numbers and suppliers.

i. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.

j. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.

k. Licenses, guarantees, and warranty documents for equipment and systems.

l. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

D. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Engineer will modify course outlines and materials if necessary to meet Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

1.12. WARRANTY

A. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
B. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.

C. If Engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.

D. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.

E. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.13. OWNERSHIP OF PROPRIETARY MATERIAL

A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

1. Graphics
2. Record drawings
3. Database
4. Application programming code
5. Documentation

PART 2 - PRODUCTS

2.1. MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2. COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2004, BACnet.
B. Install new wiring and network devices as required to provide a complete and workable control network. Use existing Ethernet backbone for network segments marked "existing" on project drawings. Project drawings indicate remote buildings or sites to be connected by a nominal 56,000 baud modem over voice-grade telephone lines. In each remote location a modem and field device connection shall allow communication with each controller on the internetwork as specified in Paragraph 2.2.4.

C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
   1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
   2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 23 09 00. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

E. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

G. System shall support Web services data exchange with any other system that complies with XML (extensible markup language) and SOAP (simple object access protocol) standards specified by the Web Services Interoperability Organization (WS-I) Basic Profile 1.0 or higher. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.
   1. System shall support Web services read data requests by retrieving requested trend data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.
   2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the specified object.
   3. For read or write requests, the system shall require user name and password authentication and shall support SSL (Secure Socket Layer) or equivalent data encryption.
4. System shall support discovery through a Web services connection or shall provide a tool available through the Operator Interface that will reveal the path/identifier needed to allow a third party Web services device to read data from or write data to any object in the system which supports this service.

2.3. OPERATOR INTERFACE

A. Operator Interface: Web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.

B. Communication: Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135-2004, BACnet Annex J.

C. Hardware: Each workstation or web server shall consist of the following:

1. Hardware Base: Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified in Section 23 09 00 Paragraph 1.9. Hard disk shall have sufficient memory to store system software, one year of data for trended points specified in Section 23 09 00, and a system database at least twice the size of the existing database at system acceptance. Configure computers and network connections if multiple computers are required to meet specified memory and performance. Web server or workstations shall be IBM-compatible PCs with a minimum of:

a. Intel Quad Core 2 3.10 GHz processor
b. 120 GB RAM
c. 500 GB hard disk providing data at 100 MB/sec
d. 8x DVD drive
e. Serial, parallel, and network communication ports and cables required for proper system operation

2. Modem: Auto-dial modem and associated cables shall transmit over voice-grade telephone lines at a nominal 56,000 baud and shall provide communication between workstation or web server and remote buildings and workstations.

D. Operator Functions: Operator interface shall allow each authorized operator to execute the following functions as a minimum:

1. Log In and Log Out: System shall require user name and password to log in to operator interface.

2. Point-and-click Navigation: Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
3. View and Adjust Equipment Properties: Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.

4. View and Adjust Operating Schedules: Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.

5. View and Respond to Alarms: Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.

6. View and Configure Trends: Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.

7. View and Configure Reports: Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.

8. Manage Control System Hardware: Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.

9. Manage Operator Access: Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

E. System Software

1. Operating System: Web server shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows 8, Red Hat Linux, or Sun Solaris.

2. System Graphics: Operator interface shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

   a. Functionality: Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.

   b. Animation: Graphics shall be able to animate by displaying different image files for changed object status.
c. Alarm Indication: Indicate areas or equipment in an alarm condition using color or other visual indicator.

d. Format: Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

F. System Tools: System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

1. Automatic System Database Configuration: Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

2. Controller Memory Download: Operators shall be able to download memory from the system database to each controller.

3. System Configuration: Operators shall be able to configure the system.

4. Online Help: Context-sensitive online help for each tool shall assist operators in operating and editing the system.

5. Security: System shall require a user name and password to view, edit, add, or delete data.

   a. Operator Access: Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object. Authorized operators shall be able to vary and deny each operator's accessible functions based on equipment or geographic location.

   b. Automatic Log Out: Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.

   c. Encrypted Security Data: Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

6. System Diagnostics: System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).

7. Alarm Processing: System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states,
and alarm reactions for each system object. Configure and enable alarm points as specified in Sequence of Operation on drawings. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.

8. Alarm Messages: Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.

9. Alarm Reactions: Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.

10. Alarm Maintenance: Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.

11. Trend Configuration: Operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified in Sequence of Operation on drawings or as requested by the Owner. Trends shall be BACnet trend objects.

12. Object and Property Status and Control: Operator shall be able to view, and to edit if applicable, the status of each system object and property by menu, on graphics, or through custom programs.

13. Reports and Logs: Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

14. Standard Reports: Furnish the following standard system reports:

   a. Objects: System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.

   b. Alarm Summary: Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.

   c. Logs: System shall log the following to a database or text file and shall retain data for an adjustable period:

      1) Alarm History

      2) Trend Data: Operator shall be able to select trends to be logged.

      3) Operator Activity: At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm
acknowledgment and deletion. System shall date and time stamp logged activity.

15. **Environmental Index:** System shall monitor occupied zones and compile an index that provides a numerical indication of the environmental comfort within the zone. As a minimum, this indication shall be based upon the deviation of the zone temperature from the heating or cooling setpoint. If humidity is being measured within the zone then the environmental index shall be adjusted to reflect a lower comfort level for high or low humidity levels. Similarly, if carbon dioxide levels are being measured as an indication of ventilation effectiveness then the environmental index shall be adjusted to indicate degraded comfort at high carbon dioxide levels. Other adjustments may be made to the environmental index based upon additional measurements. The system shall maintain a trend of the environmental index for each zone in the trend log. The system shall also compute an average comfort index for every building included in this contract and maintain trend logs of these building environmental indices. Similarly, the system shall compute the percentage of occupied time that comfortable conditions were maintained within the zones. Through the UI the user shall be able to add a weighting factor to adjust the contribution of each zone to the average index based upon the floor area of the zone, importance of the zone, or other static criteria.

16. **Custom Reports:** Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.

17. **Graphics Generation:** Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.

18. **Graphics Library:** Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.

19. **Custom Application Programming:** Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

   a. Language shall be graphically based and shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks.

   b. Tool shall provide a full screen, cursor and mouse driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming
code, and to copy blocks of code to a file library for reuse in other control programs.

c. Independent Program Modules: Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.

d. Debugging and Simulation: Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.

e. Conditional Statements: Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

f. Mathematical Functions: Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.

g. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.

1) Time Variables: Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.

2) System Variables: Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

G. Portable Operator's Terminal: Provide necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

H. BACnet: Web server or workstation shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Operator Workstation (B-OWS) device profile as specified in ASHRAE/ANSI 135-2001, BACnet Annex L.
2.4. CONTROLLER SOFTWARE

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security: See Paragraph 2.3.6.5 (Security) and Paragraph 2.3.6.15.3 (Operator Activity).

C. Scheduling: See Paragraph 2.3.4.4 (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:

1. Weekly: Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).

2. Exception: Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.

3. Holiday: Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

D. System Coordination: Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. Binary and Analog Alarms: See Paragraph 2.3.6.7 (Alarm Processing).

F. Alarm Reporting: See Paragraph 2.3.6.9 (Alarm Reactions).

G. Remote Communication: System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.

H. Demand Limiting

1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.

2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified in Sequence of Operation on drawings. When demand drops below adjustable levels, system shall restore loads as specified.

I. Maintenance Management: System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Sequence of Operation on drawings.

J. Sequencing: Application software shall sequence chillers, boilers, and pumps as specified in Sequence of Operation on drawings.
K. PID Control: System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.

L. Staggered Start: System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

M. Energy Calculations
   1. System shall accumulate and convert instantaneous power (kW) or flow rates (gpm) to energy usage data.
   2. System shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

N. Anti-Short Cycling: Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

O. On and Off Control with Differential: System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

P. Runtime Totalization: System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Sequence of Operation on drawings.

2.5. CONTROLLERS

A. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 23 09 00 Article 1.9 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

B. BACnet
   2. Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
3. Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.

4. Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.

5. Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.

6. BACnet Communication
   a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
   b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
   c. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
   d. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
   e. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
   f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

C. Communication

1. Service Port: Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.

2. Signal Management: BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

3. Data Sharing: Each BC and AAC shall share data as required with each networked BC and AAC.

4. Stand-Alone Operation: Each piece of equipment specified in Section 23 09 00 shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral.
to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.

D. Environment: Controller hardware shall be suitable for anticipated ambient conditions.

1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -20°F to 140°F.

2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 32°F to 120°F.

E. Keypad: Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.

F. Real-Time Clock: Controllers that perform scheduling shall have a real-time clock.

G. Serviceability

1. Controllers shall have diagnostic LEDs for power, communication, and processor.

2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.

3. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

H. Memory

1. Controller memory shall support operating system, database, and programming requirements.

2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.

3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

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

J. Transformer: ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.
2.6. INPUT AND OUTPUT INTERFACE

A. General: Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

B. Protection: Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

C. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

E. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary outputs shall send an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

H. Tri-State Outputs: Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. Universal Inputs and Outputs: Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.7. POWER SUPPLIES AND LINE FILTERING

A. Power Supplies: Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
a. Unit shall operate between 32°F and 120°F. EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering

1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

2. Dielectric strength of 1000 V minimum

3. Response time of 10 nanoseconds or less

4. Transverse mode noise attenuation of 65 dB or greater

5. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.8. AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers

1. Type: Control dampers shall have linear flow characteristics and shall be parallel- or opposed-blade type as specified below or as scheduled on drawings.

a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.

b. Other modulating dampers shall be opposed-blade.

c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.

2. Damper frames shall be 13 gauge galvanized steel channel or 1/8 in. extruded aluminum with reinforced corner bracing.

3. Damper blades shall not exceed 8 in. wide or 48 in. long. Blades shall be suitable for medium velocity (2000 fpm) performance. Blades shall be not less than 16 gauge.

4. Shaft Bearings: Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.

5. Seals: Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 10 cfm per ft² at 4 in. w.g. differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 1500 fpm.

6. Sections: Damper sections shall not exceed 48 in. - 60 in. Each section shall have at least one damper actuator.
7. Linkages: Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators

1. Stall Protection: Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.

2. Spring-return Mechanism: Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).

3. Signal and Range: Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6.8.)

4. Wiring: 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.

5. Manual Positioning: Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 60 in.-lb torque capacity shall have a manual crank.

C. CONTROL VALVES

1. General: Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.

2. Type: Provide two- or three-way control valves for two-position or modulating service as shown.

3. Water Valves

   a. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball.

   b. Valve actuator and trim shall provide the following minimum close-off pressure ratings.

      1) Two-way: 150% of total system (pump) head.

      2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

   c. Valves providing modulating service shall have equal percentage ports.

   d. Sizing

      1) Two-position service: line size.
2) Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi.

3) Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 5 psi.

e. Water valves shall fail normally open or closed as follows unless otherwise specified.

1) Water zone valves: normally open.

2) Heating coils in air handlers: normally open.

3) Chilled water control valves: normally closed.

4) Other applications: as scheduled or as required by sequences of operation.

D. Binary Temperature Devices

1. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.

2. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.

3. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 20 ft long. Element shall sense temperature in each 1 ft section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

E. Temperature Sensors

1. Type: Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.

2. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 5 ft in length per 10 ft² of duct cross-section.

3. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.

4. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.

F. Humidity Sensors
   1. Duct and room sensors shall have a sensing range of 20%-80%.
   2. Duct sensors shall have a sampling chamber.
   3. Outdoor air humidity sensors shall have a sensing range of 20%-95% RH and shall be suitable for ambient conditions of 40°F-170°F.
   4. Humidity sensors shall not drift more than 1% of full scale annually.

G. Flow Switches: Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
   1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
   2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

H. Relays
   1. Control Relays: Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
   2. Time Delay Relays: Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

I. Override Timers
   1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0-6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

J. Current Transmitters
   1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
   2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

K. Current Transformers
1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

L. Voltage Transmitters
1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

M. Voltage Transformers
1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 40°F-130°F and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

N. Power Monitors
1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

O. Current Switches
1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.
P. Pressure Transducers

1. Transducers shall have linear output signal and field-adjustable zero and span.

2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.

3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 150 psi. Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.

4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 150 psi. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

Q. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

R. Pressure-Electric (PE) Switches: PE switches shall be UL listed, pilot duty rated (125 VA minimum) or motor control rated, metal or neoprene diaphragm actuated, operating pressure rated for 0-25 psig, with calibrated scale minimum setpoint range of 2-18 psig.

1. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application.

2. Switches shall be open type (panel-mounted). Exception: Switches shall be enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.

3. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

S. Local Control Panels

1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.

2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.

3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

2.9. WIRING AND RACEWAYS

A. General: Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.
B. Insulated wire shall use copper conductors and shall be UL listed for 200°F minimum service.

2.10. FIBER OPTIC CABLE SYSTEM

A. Optical Cable: Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors: Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

END OF SECTION 23 09 00
SECTION 23 60 00 - HEATING, VENTILATION, AND AIR CONDITIONING

PART 1 - GENERAL

1.1. SECTION INCLUDES

   A. Section 23 05 00, “Common Work Results For Mechanical” applies to the work of this Section.

   B. The work listed or required by this section of the specifications is not intended to limit or establish the extent of the Heating, Ventilating and Air Conditioning work. The General Contractor shall be responsible for determining the extent of work to be done under a subcontract.

1.2. DESCRIPTION

   A. Work included: Provide labor, materials, appliances and tools necessary for the installation of the systems as herein specified and indicated on the drawings. The items of work shall include, but shall not be limited to, the following principal items:

      1. Equipment including, air handling units, air conditioning units, boilers, pumps, fan coil units, fans, etc.

      2. Air distribution system, including ductwork, diffusers, registers, dampers, terminal units, etc.

      3. New clean filters for air handling units prior to tests.

      4. Chilled water and hot water piping systems, including valves, fittings and expansion tanks.

      5. Insulation for ductwork and piping.

      6. Condensate drain piping from fan coil units and air handling units to the drain receptors.

      7. Exhaust systems including fans, drives, ductwork, registers, etc.

      8. Miscellaneous hangers, supports, sleeves, inserts, isolators, flexible connections, seismic bracings, and other auxiliary equipment for systems under this section.

      9. Equipment identification, operations and maintenance instructions.

     10. Testing, adjustment and balancing of air systems.

     11. Testing, adjustment and balancing of hydronic systems.

     12. Duct leak test of air systems, not to exceed 1% of each system.


     14. Sound measurement of equipment operating conditions.
15. Vibration measurement of equipment operation conditions.

B. Apparatus, piping, ductwork, etc. shall be installed and interconnected so as to form complete systems.

C. One four-hour day of instructional time to Owner’s maintenance of personnel by Contractor’s start-up mechanic.

D. Other work herein specified and shown on the accompanying drawings, including addendum, change orders and approved shop drawings.

1.3. RELATED WORK SPECIFIED ELSEWHERE

A. Work designated on drawings to be installed or performed by other sections of the specifications.

B. Motor starters and disconnects shall be furnished and installed under Division 16 of the specifications, unless otherwise specified or shown.

C. Finish painting of equipment, piping and ductwork, except as noted otherwise.

D. Equipment foundations, curbs, equipment pads, sumps and pits. Coordinate exact foundation sizes and elevations and anchor bolt sizes and locations.

E. Air intake and discharge louvers in the building’s exterior walls.

1.4. EQUIPMENT RESTRICTIONS

A. Names of selected manufacturers have been specified for items of equipment and materials. Bids shall be based on the use of the product of one of the selected manufacturers, and only such products may be submitted for approval.

1.5. SUBMITTALS

A. In addition to the requirements of Section 23 05 00, the submittal brochures shall include the following items:

1. Air Distribution System:
   - Duct Sealer
   - Flexible Connections
   - Flexible Duct
   - Balancing Dampers
   - Duct Turns
   - VAV Boxes
   - Spin-In Fittings
   - Diffusers
   - Registers
   - Fire Dampers
   - Duct Access Doors
   - Combination Smoke/Fire Dampers
   - Smoke Detectors

2. Piping System
   - Chilled Water and Hot Water Pipe Material and Fittings
### Cold Water Make-Up Pipe Materials and Fittings
- Condensate Drain Pipe Material and Fittings
- Valves, Separators and Expansion Tanks
- Pipe Hangers and Supports

### Insulation:
- **Ductwork:**
  - Interior
  - Exterior
  - Plenums
  - Ductliner
- **Piping:**
  - Chilled Water
  - Hot Water
  - Condensate Drain
  - Insulation Jacketing

### Accessories:
- **Pressure Gauges:**
  - Water
  - Air
- **Thermometers:**
  - Water
  - Air

### Equipment:
- **Fan Coil Units**
- **Exhaust Fans**
- **Variable Speed Drives**
- **Air Conditioning Units**
- **Air Terminal Units**
- **Boilers**
- **Pumps**
- **Filters**
- **Air Handling Units**

### Shop Drawings:
1. Shop drawings shall be 1/4” scale minimum.
2. Dimension Drawings for concrete pad, curb and equipment foundation (1/4” scale minimum) including bolt sizes and locations.
3. Seismic Shop Drawings
   a. Submit fabrication details for equipment bases including dimensions, structural member sizes and support point locations. (1/4” scale minimum).
   b. Provide details of suspension and support for ceiling hung equipment.
   c. Where walls, floors, slabs or supplementary steel work are used for seismic restraint locations, details of acceptable attachment methods for ducts, conduit and pipe must be included and approved before the condition is accepted for installation. Restraint manufacturers’ submittals must include spacing, static loads and seismic loads at attachment and support points.
d. Provide details of seismic restraints and anchors; include number, size and locations for each piece of equipment.

e. Provide calculations (including the combining of tensile and shear loadings) to support seismic restraint design.

f. Testing and calculations must include both shear and tensile loads as well as one test or analysis at 45° to the weakest mode. Analysis must indicate calculated dead loads, static seismic loads and capacity of materials utilized for connections to equipment and structure. Analysis must detail anchoring methods, bolt diameters, embedment and/or welded length. Seismic restraint devices shall be designed to accept, without failure, the forces acting through the equipment center of gravity. Overturning moments may exceed forces at ground level.

g. Provide calculations to determine strain loads resulting from seismic forces presented in CMC and CBC, governing codes, and project seismic requirements. Seismic calculations shall be certified by a licensed engineer experienced in the design of restraints.

h. Seismic restraint calculations must be provided for connections of equipment to the structure. Calculations must be stamped by a registered professional engineer with at least five years of seismic design experience, licensed in the state of the job location.

1) Provide chilled, condenser and hot water piping, plans and sections at 1/4” scale.

2) Show sections of the piping systems indicating routing and clearances between other trades.

4. Provide complete scale (1/4” minimum) duct fabrication drawings for duct systems and equipment to be installed on this project to the Architect for approval prior to fabrication and installation.

a. Duct offsets, transitions, sizes, routing and appurtenances shall be included in the scale drawings. Duct system installed locations shall be coordinated with Divisions of work included in this project prior to installation.

b. The Mechanical Engineers Contract drawings shall not be used as the duct fabrication drawings. Drawings submitted in this format will be rejected and returned not reviewed to the contractor for re-submittal.

5. The submittal drawings shall include one reproducible tracing, and six sets of prints. The original tracing shall be returned to the contractor with comments and approvals as noted.

C. Certified Report

1. Air Handling Units

2. Pumps
1.6. CONCRETE AND STEEL FOUNDATIONS

A. Rough and finished concrete and/or steel work required for the installation of the work in this division shall be installed in accordance with the applicable portions of the Division 03 and Section 23 05 00 of these specifications.

B. Concrete Foundations: Contractor shall provide foundation bolts for the equipment furnished and shall advise the proper size concrete foundation and bolt location for foundations to be installed under the Concrete Section of the specifications.

C. Steel Foundation: Contractor shall provide foundation bolts for the equipment furnished; advise the steel fabricator of the proper size and configuration for platforms.

D. Provide concrete foundation and/or steel foundation for the following equipment:

1. Air Handling Units
2. Pumps
3. Boilers
4. Expansion Tanks
5. Air Separators
6. Exhaust Fans
7. Where required by contract drawings.

E. Inertia Pad: The base depth of rectangular steel concrete forms need not exceed 12” unless specifically recommended by the base manufacturer for mass or rigidity. In general, bases shall be at minimum 1/12 of the longest dimension concrete with reinforcement consisting of one half-inch bars or angles welded in place on 6” centers running both ways in a layer 1-1/2” above the bottom with additional steel as required. Forms shall be furnished with steel members to hold anchor-bolt sleeves when the anchor bolts fall in concrete locations. Height saving brackets shall be employed in mounting locations to maintain a 1” minimum clearance below the base. Provide for the following equipment:

1. Pumps

1.7. VIBRATION ISOLATION AND SEISMIC RESTRAINT

A. Mechanical equipment, piping and ductwork shall be mounted on vibration isolators to prevent the transmission of vibration and mechanically transmitted sound to the building structure. Vibration isolators shall be selected in accordance with the weight distribution so as to produce reasonable uniform deflections.

B. Isolators shall have integral seismic restraints and be selected for minimum static deflection of 1” or as otherwise noted and in accordance with the equipment manufacturer’s weight distribution so as to produce reasonable uniform deflection.
C. Vibration isolators and Seismic Restraints shall be a system by a manufacturer as listed by the Office of Statewide Health Planning Development (OSHPD); with an anchorage pre-approval OPA-number for the system and components.

D. Isolators and isolation materials shall be of the same manufacturer and shall be certified by the manufacturer.

E. Provide housekeeping pads 4” minimum height for equipment. See Structural Drawings and Specifications.

F. It is the intent of the seismic portion of this specification to keep mechanical building system components in place during a seismic event. Such systems must be installed in strict accordance with seismic codes, component manufacturers and building construction standards. Whenever a conflict occurs between the manufacturers, codes or construction standards, the most stringent shall apply.

G. This specification is to be a minimum requirement for seismic consideration and is not intended as a substitute for legislated, more stringent, national, state or local construction requirements (i.e., California Title 24) or other requirements.

H. A variance or noncompliance with these specification requirements shall be corrected by the Contractor in an approved manner.

PART 2 - PRODUCTS

2.1. VIBRATION ISOLATORS

A. Vibration isolators and seismic restraints described in this section shall be the product of a single manufacturer. Mason Industries, Inc. products are the basis of these specifications; products of other manufacturers are acceptable provided their systems comply with the specification and have the approval of the Architect.

B. Two layers of 3/4” thick neoprene pad consisting of 2” square waffle modules separated horizontally by a 16 gauge-galvanized shim. Load distribution plates shall be used as required. Pads shall be Type Super “W” as manufactured by Mason, Industries, Inc.

C. Bridge-bearing neoprene mountings shall have a minimum static deflection of 0.2” and all-directional seismic capability. The mount shall consist of a ductile iron casting containing two separated and opposing mode neoprene elements. The elements shall prevent the central threaded sleeve and attachment bolt from contacting the casting during normal operation. The shock absorbing neoprene materials shall be compounded to bridge-bearing specifications. Mountings shall be Type BR as manufactured by Mason Industries, Inc.

D. Sheet metal panels shall be bolted to the walls or supporting structure by assemblies consisting of a neoprene bushing cushioned between two steal sleeves. The outer sleeve prevents the sheet metal from cutting into the neoprene. Enlarge panel holes as required. Neoprene elements pass over the bushing to horizontally cushion the back panel. A steel disc covers the inside neoprene element and the inner steel sleeve is elongated to act as a stop so tightening the anchor bolts does not interfere with panel isolation in three planes. Bushing assemblies can be applied to the
ends of steel cross members where applicable. Neoprene shall be bridge bearing quality. Bushing assemblies shall be type PB as manufactured by Mason Industries, Inc.

E. A one piece molded bridge bearing neoprene washer/bushing. The bushing shall surround the anchor bolt and have a flat washer face to avoid metal to metal contact. Neoprene bushings shall be type HG as manufactured by Mason Industries, Inc.

F. Spring isolators shall be free standing and laterally stable without a housing and complete with a mode neoprene cup or 1/4” neoprene acoustical friction pad between the base plate and the support. Mountings shall have leveling bolts that must be rigidly bolted to the equipment. Springs shall have a minimum additional travel to a solid equal to 50% of the rated deflection. Submittals shall include spring diameters, deflection, compressed spring height and loading spring height. Mountings shall be type SLF as manufactured by Mason Industries, Inc.

G. Restrained spring mounting shall have an SLF mounting as described above within a rigid housing that includes vertical limit stops to prevent spring extension when weight is removed. The housing shall serve as blocking during erection. A steel spacer shall be removed after adjustment. Installed and operating heights are equal. A minimum clearance of 1/2” shall be maintained around restraining bolts and between the housing and the spring so as not to interfere with the spring action. Limit stops shall be out of contact during normal operation. Since housing will be bolted or welded in position there must be an internal isolation pad. Housing shall be designed to resist seismic forces. Mounting shall be SLR as manufactured by Mason Industries, Inc.

H. Spring mounting shall be SFL as specified above as in specification five built into a ductile iron or steel housing to provide all-directional seismic snubbing. The snubber shall be adjustable vertically and allow a maximum of 1/4 inch travel in each direction before contacting the resilient snubbing callers. Mountings shall be SSLFH as manufactured by Mason Industries, Inc.

I. Air springs shall be manufactured with upper and lower steel sections connected by a replaceable flexible nylon reinforced neoprene element. Air spring configuration shall be multiple bellows to achieve a maximum natural frequency of 3 Hz. Air springs shall be designed for a burst pressure that is a minimum of three times the published maximum operating pressure. Air spring systems shall be connected to either the building control air or a supplementary air supply and equipped with three leveling valves to maintain a leveling within plus or minus 1/8”. Submittals shall include natural frequency, load and damping tests performed by an independent lab or acoustician. Air springs shall be Type MT and leveling valves Type LV as manufactured by Mason Industries, Inc.

J. Restrained air spring mountings shall have a MT air spring as described above within a rigid housing that includes vertical limit stops to prevent air spring extension when weight is removed. The housing shall serve as blocking during erection. A steel spacer shall be removed after adjustment. Installed and operating heights are equal. A minimum clearance of 1/2” shall be maintained around restraining bolts and between the housing and the air spring so as not to interfere with the air spring action. Limit stops shall be out of contact during normal operation. Housing shall be designed to resist seismic forces. Mountings shall be SLR-MT as manufactured by Mason Industries, Inc.
K. Hangers shall consist of rigid steel frames containing minimum 1-1/4” thick neoprene elements at the top and a steel spring type SLF with general characteristics as specified above seated in a steel washer reinforced neoprene cup on the bottom. The neoprene element and the cup shall have neoprene bushing projecting through the steel box. To maintain stability, the boxes shall not be articulated as clevis hangers and do not stack the neoprene element on top of the spring. Spring diameters and hanger boxes lower hole, and sizes shall be large enough to permit the hanger rod to swing through a 30º capability. Hangers shall be type 30N as manufactured by Mason Industries, Inc.

L. Hangers shall be type 30N, but they shall be recompressed and locked at the rated deflection by means of a resilient seismic up-stop to keep the piping or equipment at a fixed elevation during installation. The handlers shall be designed with a release mechanism to free the spring after the installation is complete and the hanger is subjected to its full load. Deflection shall be clearly indicated by means of a scale. Submittals shall include a drawing of the hanger showing the 30 degree capability. Hangers shall be type PC30N as manufactured by Mason Industries, Inc.

M. Seismic Code Restraints shall consist of galvanized steel aircraft cables sized to resist seismic loads with a minimum safety factor of two and arranged to provide all-directional restraint. Cable end connections shall be steel assemblies that swivel for a final installation angle and utilized two clamping bolts to provide proper cable engagement. Cables must not be allowed to bend across sharp edges. Cable assemblies shall be Type SCB at the ceiling and at the clevis bolt, SCBH between the hanger rod nut and the clevis or SCBV, if clamped to a beam, as manufactured by Mason Industries, Inc.

N. Seismic solid braces shall consist of steel angles or channels to resist seismic loads with a minimum safety factor of two and arranged to provide all-directional restraint. Seismic solid brace end connectors shall be steel assemblies that swivel to the final installation angle and utilize two through bolts to provide proper attachment. Solid seismic brace assemblies shall be type SSB as manufactured by Mason Industries, Inc.

O. Steel angles, sized to prevent buckling, shall be clamped to pipe or rod, utilizing a minimum of three ductile iron clamps at each restraint location when required. Welding of support rods is not acceptable. Rod clamp assemblies shall be Type SRC as manufactured by Mason Industries, Inc.

P. Pipe clevis cross bolt braces and are required in restraint locations. They shall be special purpose preformed channels deep enough to be held in place by bolts passing over the cross bolt. Clevis cross braces shall be type CCB as manufactured by Mason Industries, Inc.

Q. All-directional seismic snubbers shall consist of interlocking steel members restrained by a one-piece molded neoprene bushing of bridge bearing neoprene. Bushing shall be replaceable and a minimum of 1/4 inch thick. Rated loadings shall not exceed 1,000 psi. A minimum air gap of 1/8 inch shall be incorporated in the snubber design in each direction before contact is made between the rigid and resilient surfaces. Snubber end caps shall be removable to allow inspection of internal clearances. The snubber shall be Type Z-1225 as manufactured by Mason Industries, Inc.

R. All-directional seismic snubbers shall consist of interlocking steel members restrained by shock absorbent rubber materials compound to bridge bearing specifications. Elastomeric materials
shall be replaceable and a minimum of 3/4” thick. Rated loadings shall not exceed 1,000 psi. Snubbers shall be manufactured with an air gap between hard and resilient material or not less than 1/8 inch nor more than 1/4 inch. Snubbers shall be installed with factory set clearances. The capacity of the seismic snubber at 3/8 inch deflection shall be equal or greater than the load assigned to the mounting grouping controlled by the snubber multiplied by the applicable “G” force. Submittals shall include the load deflection curves up to 1/2 inch deflection in the s, y and z planes. Snubbers shall be series Z-1011 as manufactured by Mason Industries, Inc.

S. Stud wedge anchors shall be manufactured from full diameter wire masts, from undersized wire that is “rolled up” to create the thread. The stud anchor shall also have a safety shoulder which fully supports the wedge ring under the load. The stud anchors shall have an evaluation report number from ICBO Evaluation Service, Inc. verifying its allowable loads. Drill in stud wedge anchors shall be type Z as manufactured by Mason Industries, Inc.

T. Female wedge anchors are preferred in floor locations so isolators or equipment can be slid into place after the anchors are installed. Anchors shall be manufactured from full diameter wire, and shall have a safety shoulder to fully support the wedge ring under the load. Female wedge anchors shall have an evaluation report number from the ICBO Evaluation Service, Inc. verifying to its allowable load. Drill in female wedge anchors shall be type SAB as manufactured by Mason Industries, Inc.

U. Vibration isolation manufacturer shall furnish integral structural steel bases. Rectangular bases are preferred for equipment. Centrifugal refrigeration machines and pump bases may be T or L shaped where space is a problem. Pump bases for split case pumps shall include supports for suction and discharge elbows. Perimeter members shall be steel beams with a minimum depth equal to 1/10 of the longest dimensions of the base. Base depth need not exceed 14” provided that the deflection and misalignment are kept within acceptable limits as determined by the manufacturer. Height saving brackets shall be employed at mounting locations to provide a base clearance of 1” bases shall be type WF as manufactured by Mason Industries.

V. Vibration isolation manufacturer shall furnish rectangular steel concrete pouring forms for floating and inertia foundations. Bases for split case pumps shall be large enough to provide for suction and discharge elbows. Bases shall be a minimum of 1/12 of the longest dimension of the base not less than 6”. The base depth need not exceed 12” unless specifically recommended by the base manufacturer for mass (three times pump weight minimum) or rigidity. Forms shall include minimum concrete reinforcing consisting of 12” bars welded in place on 6” centers running both ways in a layer 1-12/” above the bottom. Form shall be furnished with steel templates to hold the anchor bolt’s sleeves and anchors while concrete is being poured. Height saving brackets (for SLR springs) shall be employed in mounting locations to maintain a 1” clearance below the base. Wooden formed bases leaving concrete rather than a steel finish is not acceptable. Base shall be type BMK as manufactured by Mason Industries, Inc.

W. Flexible expansion joints shall employ peroxide cured, EPDM in the covers, liners and Dacron tire cord fractioning. Solid steel rings shall be used within the raised face rubber ends to prevent a pullout. Flexible cable bead wire is not acceptable. Sizes 2” and larger shall have two spheres reinforced with a ring between spheres to maintain shape and complete with split ductile iron or steel flanges with hooded or similar interlocks. Sizes 16” or 24” may be single sphere. Sizes 3/4” to 1-1/2” may have threaded bolted flange assemblies, one sphere and cable retention. Size 14 inches and smaller connectors shall be rated at 250°F. Size 16 inches and larger connectors are rated 180 psi at 190°F and 135 psi at 250°F. Safety factors to burst and a
flange pullout shall be a minimum of 3 to 1. Joints must have permanent markings verifying a five minute factory test at twice the rated pressure. Concentric reducers to the above specifications may be substituted for equal ended expansion joints.

1. Expansion joints shall be installed in piping gaps equal to the length of the expansion joints under pressure. Control rods need only be used in unanchored piping locations where the manufacturer determines the installation exceeds the pressure requirement without control rods, as control rods are not desirable in seismic work. If control rods are used, they must have 1/2” thick Neoprene washer bushings large enough in area to take the thrust at 1,000 psi maximum on the washer area. Expansion joints shall be installed on the equipment side of the shut-off valves.

2. Submittals shall include two test reports by independent consultants showing minimum reductions of 20 DB in vibration accelerations and 10 DB in sound pressure levels at typical blade passage frequencies or a similar product by the same manufacturer. Expansion joints shall be installed on the equipment side of the shut off valves. Expansion joints shall be SAFLEX SFDEJ, SFEJ, SFDCR or SFU and Control Rods CR as manufactured by Mason Industries, Inc.

X. Flexible stainless steel hose shall have stainless steel braid and carbon steel fittings. Sizes 3” and larger shall be flanged. Smaller sizes shall have male nipples. Minimum lengths shall be as tabulated:

<table>
<thead>
<tr>
<th>Flanged</th>
<th>Male Nipple</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 14</td>
<td>10 x 26</td>
</tr>
<tr>
<td>4 x 15</td>
<td>12 x 28</td>
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<tr>
<td>5 x 19</td>
<td>14 x 30</td>
</tr>
<tr>
<td>6 x 20</td>
<td>16 x 32</td>
</tr>
<tr>
<td>8 x 22</td>
<td></td>
</tr>
<tr>
<td>12 x 9</td>
<td>1-1/2 x 13</td>
</tr>
<tr>
<td>⅛ x 10</td>
<td>2 x 14</td>
</tr>
<tr>
<td>1 x 11</td>
<td>2-1/2 x 18</td>
</tr>
<tr>
<td>1-1/4 x 12</td>
<td></td>
</tr>
</tbody>
</table>

1. Hoses shall be installed on the equipment side of the shut-off valves horizontally and parallel to the equipment shafts whenever possible. Hoses shall be type BSS as manufactured by Mason Industries, Inc.

Y. All-directional acoustical pipe anchors, consisting of two sizes of steel tubing separated by a minimum 1/2” thick 60 durometer neoprene. Vertical restraint shall be provided by similar material arranged to prevent vertical travel in either direction. Allowable loads on the isolation material should not exceed 500 psi and the design shall be balanced for equal resistance in each direction. All-directional anchors shall be typed ADA as manufactured by Mason Industries, Inc.

Z. Pipe guides shall consist of a telescopic arrangement of two sizes of steel tubing separated by a minimum 1/2” thickness of 60 durometer neoprene. The height of the guides shall be preset with a shear pin to allow vertical motion due to pipe expansion or contraction. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of ±1-5/8” motion or to meet G6. Pipe guides shall be type VSG as manufactured by Mason Industries, Inc.

AA. Split Wall Seals consist of two bolted pipe halves with minimum 3/4” thick neoprene sponge bonded to the inner faces. The seal shall be tightened around the pipe to eliminate clearance.
between the inner sponge face and the piping. Concrete may be packed around the seal to make it integral with the floor, wall or ceiling if the seal is not already in place around the pipe to the construction of the building member. Seals shall project a minimum of 1” past either face of the surface. Where temperatures exceed 240ºF, a number 10 density, fiberglass may be used in lieu of the sponge. Seals shall be Type SWS as manufactured by Mason Industries, Inc.

BB. The horizontal thrust restraint shall consist of a spring element in series with a neoprene-molded cup type SLF [as previously specified] with the same deflection as specified for the mountings for hangers. The spring element shall be designed so it can be preset for thrust at the factory and adjusted in the field to allow for a maximum of 1/4” movement at start and stop. The assembly shall be furnished with one rod and angle brackets for attachment to both the equipment and the ductwork or the equipment and the structure. Horizontal restraints shall be attached at the centerline of thrust and symmetrical on either side of the unit. Horizontal thrust restraints shall be type WBI/WBD as manufactured by Mason Industries, Inc.

CC. Housekeeping pad anchors shall consist of a ductile iron casting that is tapered and hexagonal, smaller at its base than at its top. The upper portion shall have holes for rebar to pass thru. The anchor shall be continuously threaded from top to bottom for the attachment of soleplates. Housekeeping pad anchors shall be attached to the structural slab using a stud wedge anchor. Housekeeping pad anchors shall be type HPA and stud wedge anchor shall be type SAS both as manufactured by Mason Industries, Inc.

2.2. DUCTWORK MATERIALS

A. General:

1. Ductwork shown on the drawings unless otherwise indicated or specified shall be constructed of zinc-coated steel.

2. Galvanized steel sheets (Min. 24 gage) shall be first quality cold rolled, galvanized, open hearth soft steel sheets, capable of double seaming without fracture, meeting ASTM A525-87.

3. Aluminum sheets shall meet requirements of ASTM B209, 2, 1.4 mil finish.

4. Steel shapes shall be hot rolled, galvanized.

5. Screws and bolts shall be cadmium plated.

6. Materials and fabrication shall be incompliance with California Code of Regulations as a minimum.

B. Materials, Application:

1. Pressure: Unless otherwise indicated, ductwork shall be constructed for 2” pressure class. Materials and construction shall be in accordance with tables listed in SMACNA HVAC Duct Construction Standards and California Code of Regulations (Title 24, Part 4). The most stringent of the SMACNA Standards or the California Code of Regulations, shall be applicable.
2. Ducts shall be sealed to SMACNA seal class “A”, UL 555 and shall be Division of the State Architect approved. No duct tape shall be permitted.

3. Special Exhaust Systems:
   a. Ducts connected to toilet exhaust systems shall be aluminum sheets.
   b. Unless otherwise required, metal gauge fabrication and installation shall be two sizes less than as specified for galvanized steel ductwork.
   c. Fume Hoods, Anatomy Laboratory, Anatomy/Physiology Laboratory, Cadaver Room and Cat Storage Room Ductwork:
      1) Ductwork shall be welded construction with No. 304 stainless steel material.

C. Circular Ducts:
   1. Circular (cross section) sheets shall be galvanized steel of spiral seam construction.
   2. Joints between two ducts shall be made with beaded sleeve joint having duct sealer applied to joint. Mechanically fasten joints with sheet metal screws or pop rivets.
   3. The radius of elbows shall be at minimum 150% of the diameter or maximum width of duct. Gored elbows are not acceptable.
   4. The fittings shall be of conical type change in shape from round to rectangular mode with transformation joint with minimum of 1 to 7 taper.
   5. Corrugated or flexible metal duct circular ducts will not be acceptable.

D. Access Doors:
   1. Non-walk-in access doors in rectangular sheet metal ducts shall conform to SMACNA Duct Construction Standards, Fig. 2-10, plus accompanying description, except that the following shall be provided:
      a. Use #140 “Ventlok”, “Duro-Dyne” or equal latch for access doors in ductwork too small to permit entrance of a man. Hinges: Use two hinges on doors where the hinged edge is under 24”, three hinges on doors where the hinged edge is 24” and over. Doors under 14” x 14” size shall be No. 24 gauge with piano hinge and edge stiffeners.
      b. Access Door Thickness: Doors shall be double thickness. Provide full thickness of insulation inside door panels in insulated ducts.
      c. Gasketing: The door shall have a compressible gasket seal of incombustible material.
      d. Dimensions: Minimum 12” X 12” in furred spaces and 18” X 18” in equipment rooms.
2. Non-walk-in access doors for circular ducts shall conform to SMACNA Duct Construction Standards, Figure 2-13 and accompanying description, except other items shall be the same as for rectangular ducts.

E. Insulated Flexible Ductwork and Branch Takeoff:

1. General:
   a. Insulated flexible ductwork shall be a factory fabricated assembly composed of a coated spring steel wire spiral helix permanently bounded to a CPE interior liner, and supporting a fiberglass insulating blanket with a fiberglass scrim vapor barrier. Working pressure: Plus 6” W.G. minimum.
   b. Length of flex ducts shall be 6’-0” maximum. Suspend at maximum 3’-0” O.C. with 1-1/2” wide galvanized sheet metal straps.
   c. Manufacturer: Ductwork shall be “Thermaflex” Model G-KM. Other acceptable manufacturers are “Wiremold”, “Genflex”, “Glass-Flex” or approved equal.
   d. Ductwork shall have precut lengths with continuous inner liner.
   e. Round duct takeoffs from main ducts shall be provided with “Spin-In” or “Twist-Lok” fittings and a factory installed manual balancing damper assembly complete with a level position indicator and a positive locking device.

2. The flexible duct shall be listed in accordance with UL 181, Class 1 flexible air duct requirements and comply with NFPA 90A and 90B with a flame and smoke spread rating not in excess of 25/50.

3. Submittals are required to include product data sheets and installation instruction sheets in order to assure awareness of the proper installation technique.

4. Insulation must achieve a minimal thermal conductance (c) rating of 0.23 and must be completely shielded from the airstream.

F. Dampers: Products of “Pottorff”, “Ruskin”, “Ventlok”, or “Airstream” are acceptable.

1. Manual volume dampers in ducts up to 48” in width shall conform to SMACNA Duct Construction Standards Fig. 2-12 or 2-13 plus its accompanying description except that the following shall be provided:
   a. Gauge and rod size: The gauge of leaf shall be equal to that of duct in which damper is located, except that it shall never be less than 22 gauge. Fasten damper leaves to square rods using damper blade clips. Use a 3/8” square rod for leaves up to 18” long and 1/2” square rod for leaves 19” to 48” long. Damper leaves shall not exceed 8” in width. Use multiple leaves when required.
   b. For accessible locations in low pressure ducts, provide each leaf with No. 607 “Ventlok” end bearing and a No. 640 or No. 641 “Ventlok” self-locking regulator or approved equal by “Young Regulator” or “Duro-Dyne”.

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c. For inaccessible locations above the ceiling, provide opposed blade volume damper with frame conforming to SMACNA Duct Construction Standards Figure 2-15 and accompanying description, plus No. 680 “Ventlok” miter gears, No. 666 or No. 667 concealed damper regulator and universal joints as required or approved equal by “Young Regulator” or Pottorff No. RCS210. Concealed regulator cover plate shall be suitable for field painting. When a single leaf of 8” is used, use two end bearings of type previously described, in lieu of a frame.

d. Steel parts shall be galvanized.

e. For insulated ductwork, the operator arm shall be set on an extension bracket flush with the outside of the insulation. Notch damper rod ends to indicate position of installed damper blades.

f. Dampers shall be stiffened where necessary to prevent noise. A damper causing noise shall be replaced by new ones or additional stiffeners added so as to eliminate the noise. Individual damper blades shall not exceed 8 inches wide by length required.

g. Volume dampers above new or existing suspended ceilings shall be marked by attaching a bright yellow, 12” length strip of cloth attached to damper rods.

h. Products of “Pottorff”, “Ruskin”, “Ventlok”, or “Airstream” are acceptable.

2. Manual Volume Dampers over 48” are to be sectioned horizontally and constructed as specified previously.

3. Backdraft Dampers: Backdraft dampers shall be low-leakage type with aluminum blades with neoprene seals mounted in a 16-gauge minimum steel frame. Bearings shall be oil-impregnated bronze, Teflon or nylon of the sleeve type. The steel frame shall be a factory finished with a mill galvanized finish.

a. Manufacturer shall be Pottorff series 60 Model BD64 or approved equal by Ruskin or C & S.

4. CFSD (Combination Fire/Smoke Damper)

a. CFSD shall be designed and constructed in accordance with NFPA Standard 90A, 92A, UL555S and DSA requirements.

b. Manufacturer’s approved installation instructions shall be shipped with each CFSD.

c. Rating 1-1/2 hour fire-resistive rating.

d. Provide access doors in ducts on each CFSD.

e. Damper shall also close and mechanically lock upon signals from smoke detector or loss of power. Each damper assembly shall be provided with a Pottorff PI-50 indicator switch package having two blade position indicator switches to indicate
the status of the dampers as to full open or full closed and Pottorff Model RCP-1 remote command station to reset CFSD.

f. Smoke/Fire Closure “Motor with Bimetal Links” Combination fire and smoke dampers will be louver bladed type. Dampers must be tested and listed under both UL 555 and UL 555S. Units must be factory supplied assemblies that consist of damper, sleeve and 1 cycle/year actuator. Dampers must have a minimum class II leakage and dynamic closure rating under UL 555S. Provide units as power-open unless otherwise noted. Actuators to have a minimum operating temperature of 350º F. Seals should be metal to metal without the use of synthetic gasket. Dual temperature thermal switches (DRS-30) rated for 212º F and 350º F, unless otherwise noted. Install in accordance with manufacturer’s installation instructions provided with units. Provide suitable access for inspection and servicing of each damper. Provide integrated CSFM listed duct smoke detector model 2151 or DH-100 AC/DC except in the city of LA.

g. Motor actuators must be by ISO 9000 recognized control manufacturer and certified by ETL laboratories for 1 year continuous power applications such. Stall motors will not be accepted. Dual temperature thermal switches shall be equipped with auxiliary contacts for remote annunciation. Pottorff Model FSD 142. (CSFM No. 3225-0368: 110 & 3230 – 368: 111) or approved equal.

h. Manufacturer:

1) Square or rectangular duct type shall be “Pottorff” FSD Model FSD-142 or approved equal.

2) Round duct type shall be “Pottorff” FSD Model FSD-125r or approved equal.

5. Locations: The drawings attempt to give reasonable indications of the locations and size of CFSD and fire dampers. Each location shall be determined by reference to the Architectural and Structural drawings and by actual measurements at the building, and shall comply with California Building Code and Division of State Architects requirements. Since ductwork layouts may vary, the responsibility for location of dampers at each duct penetration through a fire rated wall, slab or ceiling rests with the Contractor at no additional cost to the Contract. The final arrangement

G. Door Grilles

1. V-shaped louvers of 20 gage steel, one inch deep on 1/2 inch centers.

2. Provide 20 gage steel frame with auxiliary frame to give finished appearance on both sides of door, with factory prime coat finish.

H. Louvers
1. Manufacturer based upon Ruskin. Equal products by Greenheck or Pottorff may be submitted for approval.

2. Louvers shall be stationary type with downspouts in jams and mullions. Louver shall have a minimum of 52% free area. Blades and frame shall be extruded 6063T5 aluminum alloy.

3. Provide birdscreen.

4. Finish shall be prime coat ready for field painting.

I. Relief doors shall be constructed utilizing 12 gauge, galvanized steel, for frame and doors. Door seals shall be sealed with 1/4” thick compressible noncombustible gasket (minimum). Door seals shall have field adjustable door release mechanisms with coiled springs to automatically return the door to closed position when pressure is relieved. Mount in vertical position only. Use high pressure sealing cement and screws. Manufacturer: Pottorff Model PPR or NPR.

J. Flexible Connections: Provide where called for on drawings, and at the ducted discharge and inlet of every fan.

1. At least 12” wide flexible connections with 1” to 4” slack in ventilating and air conditioning systems located indoors shall be Vent fabrics Ventfab waterproof and fire retardant canvas, “Duro-Dyne” or equal.

K. Duct Sealer: Shall be Tuff Bond No. 12, “Duro-Dyne” S-2 “Spec Seal” or approved equal. Duct tape is unacceptable.

2.3. MOTORIZED DAMPERS

A. Dampers shall be ultra-low-leakage (damper leakage shall be no more than 3 CFM per square foot at 1” W.C. differential pressure), opposed blade type. Frame: Extruded aluminum hat channel, minimum 0.125” thick. Blades: Extruded aluminum airfoil shape with extruded vinyl edge seals. Jamb seals and linkage: Stainless steel type.

B. Each damper section shall have an operator rod for connection to a damper motor linkage. Provide a bearing and bracket to support the free end of each damper section operator rod. Provide concealed linkage hardware for blades in a section.

C. Provide a maximum of 6” wide steel damper blades with replaceable vinyl end seal inserts.

D. Provide 5” by 1” by 16 gauge “hat channel” formed galvanized steel section frames with reinforcing stabilizers and corner bracing for structural rigidity.

E. Provide stainless steel sleeve bearings with molded hexagonal synthetic inserts, ½” plated steel hex angles, 1/8” x 5/16” plated steel concealed linkage and stainless steel closure stops. Drive axles shall protrude at least 6” from the side of the frame. Provide outboard shaft support bearings for single section dampers driven by crankarms.
F. With blade lengths of 30” or less, single damper section heights can be extended to 60” maximum.

G. Configure large damper sections horizontally utilizing a single 1” OD steel pipe jack shaft with ball bearing support brackets at each section header. Link each end of the driven damper blade to the jack shaft with ball and pivot hardware. Attachments to the blade shall be bolted via hardware, which cannot pull out of the blade.

H. Driven damper blades (one each section) shall drive other blades in the section via end linkages. Provide concealed blade linkages at each end of the damper blades in each section so that blades will receive symmetrical drive force.

I. Design based on “Ruskin” Model CD-50. Equal products by “Air Balance Co.”, “Pacific Air Products” or “Pottorff” may be submitted for approval.

J. Notch damper rod ends to indicate position of damper blades. Seal around damper frame and duct walls.

2.4. DIRECT-COUPLED ELECTRONIC ACTUATOR

A. Damper and valve actuation shall be accomplished using “Belimo” electric/electronic control actuators.

B. Provide Belimo direct-coupled actuators mounted directly to the damper shaft or valve gear train without the need for connecting crank arm linkage. The fastening clamp shall use a “V” shaped, toothed cradle to attach to the control shaft with two bolts for maximum holding strength. Single bolt or set screw type fasteners are not acceptable.

C. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator or motor throughout its rotational arc, even if stalled. The end switches to deactivate the actuator motor at the ends of rotation or magnetic clutches are not acceptable.

D. Proportional actuators shall accept a 2-10 VDC or 4-20 DC signal and shall provide a 2-10 VDC position feedback signal.

E. 24 VAC/DC actuators shall not require more than 12 VA on AC powered applications or eight watts on DC powered applications.

F. Provide an external manual gear release button to aid in an initial travel calibration and to permit manual positioning when the actuator is not powered.

G. Provide an external switch to change direction of rotation to establish proper actuator response to control signal.

H. Provide spring return actuators where shown, called out or required, capable of both clockwise and counterclockwise spring return operation by changing the mounting orientation.

I. For power failure/safety applications, a mechanical spring returning mechanism shall be used. Non-mechanical forms of fail-safe operation are not acceptable, except for a central emergency power backup source.
J. Provide “Form C” end-switch kits where required to signal the status of either or both travel limits.

K. Provide each actuator with a factory installed three conductor electrical cable inside a BX type sheath with conduit fitting on the end to make an easy connection to an electrical junction box.

L. The actuators shall be listed with Underwriters Laboratories under Standard 873. They must be manufactured in an ISO 9001 certified plant.

M. Actuators shall have a two year manufacturer’s warranty starting from the date of acceptance by the Owner.

2.5. DUCT SUPPORTS

A. Duct hangers, spacing of hangers, upper and lower attachments, etc. shall conform to the most stringent requirements of the SMACNA or California Mechanical Code. See Part 3.0 for seismic requirements.

B. Provide additional supports for upper attachments for ductwork utilizing a secondary steel support system consisting of roll-formed channel, “Unistrut” Series P-1002 (back-to-back 1-5/8” X 0.010”) roll formed channels) members securely attached between support beams or purlins in accordance with structural engineers approval. Attach duct mounting straps to steel channels using “Unistrut” type spring-loaded, matching nuts and bolts. Furnish additional “Unistrut” channel, clamps, brackets, etc., for complete support of ductwork and diffusers. Do not penetrate a metal duct with fasteners.

2.6. CONDENSATE DRAIN PIPING

A. ASTM B88, Type “L” hard drawn, seamless copper tubing with ANSI B16.22 wrought copper fittings. Joints shall be solder sweat type. Solder shall be lead nickel-bearing and antimony free such as “Harris” Bridget.

2.7. CLASSES AND MAXIMUM WORKING PRESSURE

A. Except as specified otherwise, piping components shall be suitable for use under the maximum working pressures indicated. Excepted as modified herein, the pressure temperature limitations shall be as specified in the referenced standards and specifications. Pressures in this specification are pressures in pounds per square inch (psi) above atmospheric pressure and temperatures in degrees Fahrenheit (°F).

2.8. CHILLED WATER AND HEATING HOT WATER PIPING

A. Pipe: ASTM A-53 Grade A or B, Schedule 40, black steel, seamless.

B. Fittings:

1. 2” and under: Screwed, malleable iron, black, 150 lb.
2. 2-1/2” and over: Butt-welded, 3-pass, V-weld with beveled pipe ends. Flanges shall be provided where required for servicing and/or removal of equipment and valves. Flanges shall be Class 150, ANSI B16.5, raised face, forged steel, weld neck type.

C. Copper Pipe: ASTM B88, type L hard drawn, seamless copper pipe and ANSI B 16.22 wrot copper fittings. Utilize “Semco” Trisolator Heavy Hair felt isolators at points of piping support not protected by rigid insulation inserts.

1. Joints shall be soldered with lead free, tin silver 95-5 alloy solder. Flanges, silver solder joint ANSI 150 lb.

2.9. REFRIGERANT PIPING

A. Copper Tubing: ASTM B280, Type ACR hard drawn.
C. Joints: ANSI/ASTM B32, solder Grade 95TA.

2.10. PRE-FABRICATED UNDERGROUND CHILLED WATER PIPE (PVC)

A. Manufacturer based upon Thermal Pipe Systems, Inc. Equal products by Ricwil or Urecon may be submitted for approval.

B. The prefabricated underground pipe system shall include a prefabricated assembly consisting of service pipe, insulated pipe supports and guides, end seals, field closure sleeves for a conduit and anchors. Loops, elbows, tees and laterals shall be provided in accordance with the specifications and shall be provided by the prefabricated underground pipe manufacturer. Straight sections of pipe shall be manufactured in 20’-0” lengths. The system shall be a standard product of the manufacturer for not less than five years.

C. Service Pipe:

1. Pipe: PVC SDR-18 industrial pipe per AWWA C900 STD.
3. Fittings: Fittings shall be consistent with that of core pipe.

D. Shut-Off Valves, 2” and larger:

1. Gate Valves:

   a. Gate valves shall be designed for a working pressure of not less than 150 psi and conform to AWWA C509. Valve connections shall be as required for piping in which they are installed. Valves shall have a clear waterway equal to full nominal diameter of valve, and shall be opened by turning counterclockwise. Operating nut or wheel shall have an arrow cast in the metal, indicating direction of opening.
b. In compliance with ANSI/AWWA C509 Standard and is certified to ANSI/NSF 61.

c. Valves 3” and larger shall be iron body, bronze mounted and shall conform to AWWA C500. Flanges shall not be buried. An approved pit shall be provided for all flanged connections.

d. Cast iron wedge shall have sealing surfaces of the wedge permanently bonded with resilient material to meet ASTM tests for rubber to metal bond ASTM D429. All body bolts shall be type 316 stainless steel. Valves shall be Mueller “RS” or equal. All underground valves shall be NS and all above ground valves shall be OS&Y.

e. Valve Boxes: Valve boxes shall be cast iron or concrete, except that concrete boxes may be installed only in locations not subjected to vehicular traffic. Cast-iron boxes shall be extension type with slide-type adjustment and with flared base. Minimum thickness of metal shall be 3/16”. Concrete boxes shall be standard product of a manufacturer of precast concrete equipment. Word “WATER” shall be cast in cover. Boxes shall be of such length as will be adapted, without full extension, to depth of cover required over pipe at valve location. The valve box and the installation of the gate valve shall conform to AWWA C509.

f. AWWA C500, non-rising stem, IBBM, double disc, parallel seat, mechanical joint ends, Stockham #G-743-0, EPDM O-Rings.

g. Valves shall be provided with non-rising extension with 2” square wrench nut “Mueller’ Model No. A-26441 or approved equal.

h. Valve extensions shall be enclosed in a cast iron box “Mueller” improved extension with arch pattern base and cast-iron foot piece, or approved equal. Provide sleeves for cast iron boxes installed in cement.

i. Provide two “Mueller” shut-off rods or approved equal: One end of crossbar handle shall be flattened like a chisel and the other end shall be pointed.

j. Provide two valve-operating wrenches with tee handle and socket for a 2” square wrench nut “Mueller” Model A-24610 or approved equal.

E. Insulation:

1. Carrier pipe insulation shall be rigid polyurethane foam for straight sections and preformed kits or poured in place polyurethane foam for all fittings. The foam shall have the following minimum properties:

a. 2.2 pounds per cubic foot density

b. 90% closed cell content

c. Initial thermal conductivity K = 0.15 BTU/SF/IN-/HR (70°F at 72 hours).
2. Pipe with PVC jacket: the minimum insulation thickness shall be as follows:

<table>
<thead>
<tr>
<th>Nominal Pipe Size (Inches)</th>
<th>Jacket Diameter (Inches)</th>
<th>Insulation Thickness (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
<td>1.67</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
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<td>1.49</td>
</tr>
<tr>
<td>12</td>
<td>16</td>
<td>1.38</td>
</tr>
</tbody>
</table>

3. Polyurethane foam insulation and coatings for field joints shall be provided by the underground pipe manufacturer. If the core pipe has gasket type joints, the insulation pipe joint shall not be sealed in the field. The ends of the insulation shall only be mastic coated prior to performing the bell and spigot joint assembly.

4. Valves shall be insulated with insulation kits as specified, or by encasing them in plastic bags and injecting “Instafoam” polyurethane insulation into the bags. Cover the polyurethane foam insulation with mastic tape and “Zeston” PVC covers. Prior to insulation the valves shall be coated with either factory-applied epoxy or coated in the field with “Wasser MC-TAR” Wasser high tech coating for corrosion protection.

F. Protective Jacket:

1. The protective jacket shall be seamless PVC, Type 1, Grade 1, conforming to ASTM D-1784.

2. The minimum thickness for PVC jacket shall be 2 percent of the jacket diameter.

G. Accessories: End seals shall be provided at each end of prefabricated pipe lengths and fittings.

2.11. FLEXIBLE PIPING CONNECTORS

A. Provide “Resistoflex” Model R6904, Mason Safeflex single sphere SFEJ standard for pipe size 1-1/2” to 24” and Safeflex for pipe size 3/4” to 1-1/4” or approved equal at each air handling unit coil connection, pump connections, and piping connections to chillers and equipment.

2.12. VALVES AND PIPING ACCESSORIES [Above Grade]

A. Valves: Provide valves required for draining, servicing, and full control of piping and equipment. Reference to valves by one manufacturer’s model number is to establish the type and quality required. Equal products of other named manufacturers will be accepted. Valves of one type shall be of one manufacturer.

B. Gate Valves: Crane, Walworth, Jenkins, Nibco or Kennedy:

1. 2” and smaller: Crane No. 438, bronze, non-rising stem, solid wedge disk

2. 2-1/2 and larger: Crane No. 461 (flanged), iron body with bronze trim, non-rising stem
C. Ball Valves
   1. Dynaquip, Walworth, Jenkins, Nibco, Keystone or Crane.
   2. 2” and smaller: Dynaquip Model VPB, three-piece body, stainless steel ball, Delrin seats and level handle with vinyl grip and RTFE stem seal.

D. Manual Butterfly Valves: Keystone, Crane, DeZurk, Nibco or Jenkins:
   1. 2-1/2” and larger: Keystone No. 222, wafer lug style, bi-directional drop tight service to 250 psig with one-piece stem with replaceable EPDM seat, Type 416 stainless steel shaft, aluminum-bronze ASTM B1488 Grade A disk, bronze stem bearings, Buna-N stem packing.

E. Globe Valves:
   1. Crane, Walworth, Lunkenheimer, Jenkins or Kennedy:
      a. 2-1/2” and larger: Crane No. 351 (flanged), OS&Y iron body with a bronze trim, disc guide stem

F. Check Valves:
   1. For Chilled Water and Heating Hot Water Applications:
      b. For use with copper piping: Provide bronze, Class 150, solder joint ends, Y-pattern, swing disc type. Valve shall comply with MSS SP-80, Type 3 Standard Practice. Valve body shall be bronze conforming to the requirements of ASTM B62. Provide “Crane” Figure 1342 or equal by “Bell & Gossett”, “Nibco.”
      c. For use with steel piping transporting steam, water, noncorrosive oil and gas, and other fluids that do not corrode bronze: Provide iron body, Class 125, bolted cap, flanged ends with bronze trim, swing disc type. Valve shall conform to applicable requirements of ANSI B16.10 and ANSI B16.1. Valve shall have replaceable bronze seat rings and solid bronze disc for valves 6” and smaller or a bronze faced cast iron disc for valve sizes larger than 6”. Provide “Crane” Figure 373 or equal by “Bell & Gossett”, “Nibco.”

G. Calibrated Balance Valve: Bell & Gossett Circuit Setter Plus calibrated balance valve or approved equal. Valves to be designed to allow installing contractor to preset balance points for proportional system balance prior to a system star-up in accordance with a preset balance schedule. Valves 1/2” to 3” pipe size to be of bronze body brass ball construction with glass and carbon filled TFE seating rings. Valves to have differential pressure read out ports across valve seat area. Readout ports to be fitted with internal EPT inserts and check valves. Valve bodies to have 1/4” NPT tapped drain/purge port. The valve to have memory stop features allows the valve to be closed for service and then reopened to set point without disturbing
balance position. Valves to have calibrated name plates to assure specific valve settings. Valves shall be designed for positive shut-off.

1. Furnish Owner with one portable Bell & Gossett readout kit and calibrated charts for valves furnished and capable to check differential pressures across other system components including B&G pumps, Suction Diffusers, strainers, coils, etc. Provide readout kits with full over range protection and hoses, readout probes, carrying case and Circuit Setter Balance Valve Calculator.

H. Automatic Flow Control Valves

1. Valves shall be warranted by the manufacturer to be free of defects in materials and workmanship for a period of five years.

2. Valves shall control flow within plus or minus five percent of design.

3. The valve flow curve shall be smooth over its entire nominal control range. Gaps, bumps and dips in flow curves shall not be acceptable.

4. Upon request, the manufacturer shall provide certified, independent laboratory tests verifying performance.

5. Valves with single nonadjustable flow cartridges
   a. Non-adjustable flow cartridges shall be 100% stainless steel. Parts made of soft metals, such as brass with only a coating of a hard metal such as nickel, will not be allowed.
   b. The cartridges shall have many segmented ports through which water can pass, rather than a continuous large port to eliminate noise.
   c. The cartridge movement shall result in a shearing action that will dislodge or shear a particle that may tend to lodge in a port.

6. Valves with Internally Adjustable Cartridges
   a. Internally adjustable cartridges shall include only nonabrasive and non-corrosive thermoplastic materials, whose shape and properties will not change over the life of the valve.
   b. The cartridge shall be removable, without removing the valve or disturbing the line plumbing, by unscrewing a plug on the valve body. The cartridge shall remain attached to the inside of the removed plug to ensure it does not get misplaced and the plug is not reinstalled without the cartridge.

7. Valves with Externally Adjustable Cartridges
   a. Externally adjustable cartridges shall include only nonabrasive and noncorrosive thermoplastic materials whose shape and properties will not change over the life of the valve.
b. The valve flow rate shall be field adjustable from the outside by turning a key provided by the valve manufacturer. The cartridge shall not have to be removed from the valve body to adjust the flow rate.

c. The valve flow rate shall be easily determined by first reading the two digit numeric display next to the key hole and then, reading the actual flow rate from a chart. The numeric display (setting) versus a flow rate chart shall be provided by the manufacturer.

8. Multifunction Valves

a. Multifunction valves that incorporate an isolation ball valve, a 20-mesh strainer and a flow control cartridge in the same body, may be substituted on the supply side of the coil for the same three items shown separately on the supply/return side of the coil. The valve manufacturer shall give the same five year warranty on these multifunction valves.

b. Multifunction valves such as the Ultra Z or the Flowcon Y, indicated on the drawings, shall not be replaced by functionally equivalent separate components that increase the material and labor cost of the project.

9. Wafer Valves

a. Water valves shall be available for pipe sizes ranging from 3” to 30” in diameter.

b. Wafer valves shall have a choice of cartridges in six different control ranges. They shall be available to control flow with pressure differential as low as 1.3 psi and as high as 128 psi.

10. Coil Piping Packages: Factory assembled, coil-piping packages may be installed in lieu of separate field plumbed components indicated on drawings. “Griswold Controls” coil piping packages Model No. CPP-3QIS.

11. No Adverse Effect on System Performance: None of the valves, whether single or multifunction and whether installed on the supply or the return side of the coil, shall be the cause of noise, cavitation or air bubbles in the entire hydronic system.

12. Manufacturer: The manufacturer of automatic flow control (balancing) valves and coil piping packages shall be Griswold Controls or approved equal.

I. Union: Provide adjacent to screwed valves. “Crane” No. 519

J. Strainers: Crane, Armstrong, or Zurn Y-pattern with removable basket sediment separators made of 20 mesh Monel metal screens.

   1. 2” and smaller Crane No. 988-1/2, iron body and cap

   2. 2-1/2” and larger Crane No. 989-1/2, iron body and cap
K. Safety Relief Valves: Provide for chilled water and hot water systems. Valves shall be diaphragm operated, ASME labeled, wetted parts brass or bronze. Fluid shall not discharge into the spring chamber. Pipe relief valve discharge full size to nearest drain receptor.


2.13. MODULATING CONTROL VALVES

A. Manufacturer: “Flow Control Industries” or approved equal.
B. Modulating control valves shall be from the same manufacturer.
C. Modulating control valves shall be of the “pressure independent” type configured with one integrated valve body that incorporates one chamber with an adjustable Cv and a separate pressure regulating chamber used to maintain a constant differential pressure across the control surface.
D. Each control valve shall be individually flow tested at the factory and verified to not deviate more than ±5% through the selected operating pressure range. A calibrated performance tag shall be provided with each valve that verifies the flow rate in 10° rotation increments up to full rated flow (option with 1/2”). Testing shall be performed with instruments calibrated to the requirements of ANSI/ISA-S75.11-1985, with traceability to NIST and/or ISO standards.
E. Control valve rangeability shall be 100:1 minimum.
F. The minimum pressure drop across the control valve shall be 2 psi and the maximum pressure drop across the control valve shall be 5 psi.
G. Each control valve shall be subjected to 70 psi pressure drop and tested to exceed ANSI/FCI 70-2-1998 leakage ratings. Class IV leakage or better is required for control valves 2” nominal size and less. Class III leakage or better is required for control valves larger than 2”.
H. The control valve bodies shall be cast iron, steel or bronze and rated at 150 psig working pressure or greater. Internal parts shall be stainless steel, steel, Teflon, brass, or bronze. Plastic internal parts are not acceptable.
I. In control valves 8” and smaller, it shall be possible to modify the valve flow characteristics without removing the valve from the piping system.
J. Balancing valves and associated balancing shall not be required where pressure independent modulating control valves are installed.
K. The control valve actuator shall modulate valves up to 8” in nominal size from 0 to 100% design flow while rotating the valve stem a maximum of 90°.

1. The valve actuators may be specified in the control section of this specification and shall be capable of opening and closing the valve against the rated shutoff head of the pump(s) serving the loop.
2. The actuators shall be mounted on valves at the factory.

3. The valve shall be compatible with actuators from major manufacturers.

4. The end stroke of the actuator shall be set on site with the software (limit control signal) at full design flow for the heating or cooling coil or from data listed on the performance tag.

L. The control valve flow adjustment stem (for valves 8" and less) shall extend out from the control valve and have an indicator that may be used to verify valve position. The control valve shall have tapped mounting holes for mounting the control valve actuator bracket. The actuator shall rotate the valve stem to provide the required flow independent of pressure across the valve. Torque requirements for actuator selection shall be provided by the valve manufacturer.

M. There shall be three ports installed at the factory integral to each valve and capable of being used to measure pressure or temperature. The first port shall be installed at the inlet to the valve. The second shall be installed between the Cv chamber and the pressure regulating chamber. The third shall be installed at the outlet of the valve. Should the ports not be provided as part of the valve body than they shall be installed in a spool piece and attached to the body.

N. The differential pressure between the first and the third port shall be used in commissioning to verify that the minimum differential pressure required for pressure independent operation is available. The differential pressure between the first and second ports shall be used to verify proper valve operation and flow regulation.

O. It shall be possible to verify the flow rate through the control valve using the valve stem position and the differential pressure measurement between the first and second port in the valve. If these valve features are not available, a flow meter shall be installed to verify actual flow rate in operation through the valve.

P. The basis of design for the “pressure independent” modulating control valves is the “DeltaPValve” as manufactured by Flow Control Industries, Inc.

1. Valves shall be warranted by the manufacturer for no less than 5 years from the date of purchase. The warranty provided by the actuator manufacturer shall apply to actuators.

2. Should an alternate manufacturer be considered, a line by line concordance summary to the above referenced specification shall be submitted 2 weeks prior to the bid submission with supporting documentation. The above basis of design shall be included in the base bid the pricing; substitutions shall be listed as an alternate line item.

2.14. AIR ELIMINATION

A. Air Vents: Provide manual air vents at piping systems high points and coil headers for proper elimination of air from the piping system. Air vents shall be “Hoffman” Model 500 with 1/8” NPT straight shank connection. For air vents located inside the building, extend ½” copper drain pipe from vent to nearest drain receptor.
2.15. **AIR SEPARATOR**

A. Manufacturer: Bell & Gossett “Rolairtrol”, Spirotherm, Armstrong, or equal.

B. General: Unit shall be a centrifugal type air separator. The unit shall have flanged inlet and outlet connections tangential to the vessel shell. The unit shall have an internal stainless steel air collector tube with 5/32” diameter perforations and 63% open area designed to direct accumulated air to the compression tank on an air control system or an air vent on an air elimination system via an NPT vent connection at top of unit.

C. The unit shall have a removable galvanized system strainer with 3/16” diameter perforations and a free area of not less than five times the cross-sectional area of the connecting pipe. The strainer shall be located at the bottom of the vessel to reduce floor space required for strainer removal.

D. A blow down connection shall be provided to facilitate routine cleaning of the strainer and the separator. Manufacturer to furnish data sheet specifying air collection efficiency and pressure drop at rated flow.

E. Vessel shell diameter is to be three times the nominal inlet/outlet pipe diameter, with a minimum vessel volume for sufficient velocity reduction. The air separator must be designed, constructed and stamped for 125 psig at 350°F in accordance with Section VIII, Division I of the ASME Boiler and Pressure Vessel Code, and registered with the National Board of Boiler and Pressure Vessel Inspectors. The air separator shall be painted with one shop coat of light gray air dry enamel.

F. A manufacturer's Data Report for Pressure Vessels, Form U-1 as required by the provisions of the ASME Boiler and Pressure Vessel Code, shall be furnished for each air separator.

2.16. **EXPANSION TANK**

A. Manufacturer: Bell & Gossett, Armstrong, or equal.

B. Unit shall be pre-charged steel expansion tank with replaceable heavy duty Butyl rubber bladder. The tank shall have a 1” or 1-1/2” NPT system connection, ¼” NPT drain, and a .302”-32 charging valve connection (standard tire valve) to facilitate the on-site charging of the tank to meet system requirements. The tank shall be fitted with lifting rings and a floor mounting skirt for vertical installation. The tank must be constructed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code and stamped 125 PSI working pressure.

2.17. **COMBINATION TEMPERATURE/PRESSURE SENSING STATION**

A. Install combined connection known as “Pete's Plug,” as manufactured by Peterson Engineering Company, Richardson, Texas or equal where shown on drawings and in entering and leaving water to each coil, chiller, condenser, pump and boiler. Each plug shall have a gasketed cap.
2.18. INSULATION

A. General: Pipe fittings and valves and duct thickness shall conform to Title 24 as a minimum. Use thickness specified, if greater than Title 24 requirements. Insulation shall have a flame spread of not more than 25 and a smoke density not exceeding 50 when tested as a composite.

B. Pipe Insulations

1. Manufacturers: Johns Manville Corporation or approved equal.

2. Glass Fiber: Micro-Lok meeting ASTM C547; rigid molded, noncombustible.
   a. ‘k’ (ksi) Value: 0.23 at 75°F.
   b. Maximum Service Temperature: 850°F.
   c. Vapor Retarder Jacket: AP-T PLUS White kraft paper reinforced with glass fiber yarn and bonded to aluminum foil, secures with self sealing longitudinal laps and butt strips or AP jacket with outward clinch expanding staples or vapor barrier mastic as needed.

3. Elastomeric Foam: ASTM C534; flexible, cellular elastomeric, molded or sheet.
   a. ‘k’ (ksi) Value: 0.28 at 75°F.
   b. Maximum Service Temperature:
   d. Maximum Smoke Developed: 50 (3/4” thick and below) 100 (above 3/4” thick).
   e. Connection: Water vapor retarder adhesive as needed; Rubatex R-373 adhesive.
   f. UV-Protection: Outdoor protective coating; Rubatex 374 Coating.

4. Field Applied Jackets:
   a. PVC Plastic Zeston 2000 One piece of molded type-fitting covers and jacketing material, gloss white.
      1) Connections: Tacks; Pressure sensitive color matching vinyl tape.
   c. Aluminum Jacket: 0.016 inches thick sheet, embossed finish with longitudinal slip joints and 2 inches laps, die shaped fitting covers with factory attached protective liner.
   d. Stainless Steel Jacket: Type 304 stainless steel, 0.010 inches, corrugated finish.
C. Equipment Insulation

1. Manufacturers: Johns Manville Corporation or approved equal.

2. Flexible Fiber Glass Blanket: 812 Spin-Glas meeting ASTM C533; flexible.
   a. ‘k’ (ksi) Value: 0.24 at 75ºF.
   b. Maximum Service Temperature: 450ºF.
   c. Density: 1.5 lb/cu ft density.
   d. Vapor Retarder Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft, paper secured with UL listed pressure sensitive tape and/or outward clinch expanding staples and vapor barrier mastic as needed.

   a. ‘k’ (ksi) value: 0.23 at 75ºF.
   b. Maximum Service Temperature: 450ºF.
   c. Density 3.0 lb/cu ft density.
   d. Vapor Retarder Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft, secured with UL listed pressure sensitive tape and/or outward clinch expanding staples and vapor barrier mastic as needed.
   e. Facing: 1 inch galvanized hexagonal wire mesh stitched on one face of insulation.

4. Hydrous Calcium Silicate: Thermo-12/Gold meeting ASTM C533; rigid molded block; asbestos free color coded throughout material thickness and maintained throughout temperature range.
   a. ‘k’ (ksi) Value: 0.40 at 300ºF.
   b. Maximum Service Temperature: 1200ºF.
   c. Compressive Strength (block): Minimum of 200 psi to produce 5% compression based on 1-1/2” thickness.
   e. Securement: Insulation shall be securely banded in place, tightly butted, joints staggered and secured with 16 gage galvanized or stainless steel wire or 1/2” x 0.015” galvanized steel bands on 12” maximum centers for large areas.

D. Ductwork Insulation

1. Manufacturers: Johns Manville Corporation or approved equal.
2. Flexible Fiber Glass Blanket: Microlite Type 75 meeting ASTM C553, flexible blanket.
   a. ‘k’ (ksi) Value: 0.27 at 75°F installed.
   b. Density: 0.75 lb/cu ft.
   c. Vapor Barrier Jacket: FSK, aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft, paper secured with UL listed pressure sensitive tape and/or outward clinched expanded staples and vapor barrier mastic as needed.

   a. ‘k’ (ksi) Value: 0.23 at 75°F.
   b. Density: 3.0 lb/cu ft.
   c. Vapor Retardant Jacket: AP, bleached kraft paper bonded to aluminum foil, reinforced with fiberglass yarn; or FSK, aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft, paper secured with UL listed pressure sensitive tape and/or outward clinched expanded staples and vapor barrier mastic as needed.


5. Ducts Located Outdoor:
   a. Aluminum Jackets: 0.016 inches thick sheet, smooth/embossed finish, with longitudinal slip joints and 2 inches laps.
   b. Johns Manville Insulate ET, a non-water vapor retarder, nonburning, weatherproof coating for use over insulation where “breathing” is required.

E. Duct and Plenum Lining

1. The sound absorbing characteristics of duct and plenum lining shall comply with this specification. Representative samples shall be subjected to tests in accordance with applicable standards and procedures in order to demonstrate such compliance. A special test for this project is not required if the manufacturer has certified test results for proposed products.

2. Submittals shall include octave band absorption coefficients and NRC values for specified thicknesses and densities of lining determined in accordance with the requirements of ASTM C 423 in an F-25 Mounting configuration. Submittals shall also
include, but shall not be limited to, a complete description of the tested material and the test conditions, methods, and procedures.

3. Sound absorption measurements and calculations shall be made in complete conformance with the latest revision of ASTM C 423, *Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method*, and ASTM E795, *Standard Practice for Mounting Specimens during Sound Absorption Tests*. Test specimens shall be tested in an F-25 Mounting configuration. Tests shall be conducted by a laboratory that is accredited under the National Voluntary Laboratory Accreditation Program (NVLAP) to conduct the test.

4. Duct or plenum lining at specified thicknesses and densities shall have the following minimum octave band sound absorption coefficients when tested in the F-25 Mounting configuration in accordance with ASTM E 795:

<table>
<thead>
<tr>
<th>Size and Density</th>
<th>Octave Band Center Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td>1” thick, 2.0 pcf</td>
<td>.15</td>
</tr>
<tr>
<td>2” thick, 2.0 pcf</td>
<td>.25</td>
</tr>
<tr>
<td>4” thick, 2.0 pcf</td>
<td>.60</td>
</tr>
</tbody>
</table>

5. Rectangular Duct Liner: Permacote Linacoustic meeting ASTM C1071 with air surface coated with acrylic coating treated with EPA registered anti-microbial agent proven to resist microbial growth as determined by ASTM G 21 and G 22.
   a. ‘k’ (ksi) value: ASTM C 518, 0.25 at 75°F.
   b. Noise Reduction Coefficient: .70 or higher based on “Type A mounting” and tested in accordance to ASTM C423.
   c. Maximum Velocity: 5,000 ft/min.
   d. Adhesive: Meeting ASTM C 916.
   e. Fasteners: Duct Liner galvanized steel pins, welded or mechanically fastened.

   a. ‘k’ (ksi) Value: ASTM C 518, 0.23 at 75°F.
   b. Noise Reduction Coefficient of .70 as per ASTM C 423. (Type A mounting).
   c. Maximum Velocity: 5,000 ft/min.
F. Insulation Schedules:

1. Pipe Insulation Schedule:
   a. Fiber Glass Insulation:

<table>
<thead>
<tr>
<th>Service</th>
<th>Pipe Size (Inch)</th>
<th>Thickness (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cold Water</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>2. Chilled or Hot Water Supply and</td>
<td>Up to 8</td>
<td>2</td>
</tr>
<tr>
<td>Return</td>
<td>10 and over</td>
<td>3</td>
</tr>
<tr>
<td>3. Piping Exposed to Freezing</td>
<td>All Sizes</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

   b. Elastomeric Foam

<table>
<thead>
<tr>
<th>Service</th>
<th>Pipe Size (Inch)</th>
<th>Thickness (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Refrigerant Suction Line</td>
<td>All Sizes</td>
<td>1</td>
</tr>
<tr>
<td>2. Refrigerant Hot Gas Line</td>
<td>All Sizes</td>
<td>3/4</td>
</tr>
</tbody>
</table>

G. Equipment Insulation Schedule:

1. Flexible Fiber Glass Blanket

<table>
<thead>
<tr>
<th>Service</th>
<th>Thickness (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Air Separators</td>
<td>1-1/2</td>
</tr>
<tr>
<td>2. Pump Bodes</td>
<td>Same as pipe</td>
</tr>
<tr>
<td>3. Valves</td>
<td>Same as pipe</td>
</tr>
</tbody>
</table>

2. Elastomeric Foam

<table>
<thead>
<tr>
<th>Service</th>
<th>Thickness (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chiller Cold Surfaces (not factory insulated)</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

H. Ductwork Insulation Schedule:

1. Flexible Fiber Glass

<table>
<thead>
<tr>
<th>Service</th>
<th>Thickness (Inch)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exhaust Ducts within 10 ft of Exterior Opening</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
<tr>
<td>2. Exhaust Ducts Exposed to Outdoor Air Ventilation</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
<tr>
<td>3. Air Ventilation Equipment Casings</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
<tr>
<td>4. Supply Ducts (Cooling Systems)</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
<tr>
<td>5. Return Ducts in Unconditioned Spaces and in Ceiling Space</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
</tbody>
</table>
2. Rigid Fiber Glass

<table>
<thead>
<tr>
<th>Service</th>
<th>Thickness (Inch)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Combustion Air Ducts</td>
<td>3</td>
<td>AP</td>
</tr>
<tr>
<td>2. Outside Air Intake Ducts</td>
<td>2</td>
<td>FSK</td>
</tr>
<tr>
<td>3. Plenums (Cooling Systems)</td>
<td>2</td>
<td>FSK</td>
</tr>
<tr>
<td>4. Return and Relief Ducts in Mechanical Rooms</td>
<td>1-1/2</td>
<td>FSK</td>
</tr>
<tr>
<td>5. Ducts Located Outside</td>
<td>2</td>
<td>FSK</td>
</tr>
</tbody>
</table>

3. Duct Liner

<table>
<thead>
<tr>
<th>Service</th>
<th>Thickness (Inch)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where indicated</td>
<td>1</td>
<td>Linacoustic or Permacote</td>
</tr>
<tr>
<td>2. 50'-0” minimum from fan coil or air handling unit intake and discharge</td>
<td>1</td>
<td>Linacoustic or Permacote</td>
</tr>
</tbody>
</table>

I. Condensate Drain Piping: Insulate condensate drain piping located inside the building from air cooling coil to drain receptors same as the chilled water piping except use 1” thick insulation.

J. Duct and pipe insulation located outside shall be 1” thicker than shown in Schedule.

2.19. SMOKE DETECTORS

A. Refer to Division 26 for the specification of duct smoke detectors.

2.20. ACCESSORIES

A. Equipment Labels: See Section 23 05 00. In addition, major equipment (i.e., pumps, air handling units, exhaust fans, etc.) shall have equipment symbol number neatly spray-paint stenciled in 4-inch high letters in a position easily visible. Equipment above ceilings not accessible shall have stenciled identification on both sides.

B. Name Tags:

1. Provide engraved bakelite name tags with 3/16” high white letters on black for thermostats, humidistat, switches, control panels, indicating air handling unit and zone numbers. Also provide nametags for air handling unit filter differential pressure gauges as noted below.

2. Install zone damper operations with 1-1/2” high-stenciled letters to match zone thermostat designations. Mount damper operator labels so they are readable from the floor. Both surfaces shall be clean.
C. Instrument Test Holes: Test holes shall be “Vent fabric” Model 699-2 or approved equal by Durodyne or Young Regulator. Provide test holes as needed in both horizontal and vertical positions at the following locations:

1. Supply air ducts at each air-handling unit.
2. Return air duct at each air-handling unit.
3. Fresh air duct at each air-handling unit.
4. Exhaust air duct at each exhaust fan.

D. Filter Pressure Gauges (for Air Handling Units):

1. Gauges shall be “Dwyer” Magnehelic Series 2000, range 0-20” wg, diaphragm actuated, 3-7/8” diameter dial face, and zero pointer adjustment. Furnish complete with two static pressure tips, fittings for 1/4” metal tubing, and mounting kit.

2. Provide a differential pressure gauge at each air handling unit filter bank with separate gauges to read pressure drop across each type of filter. Mount gauges at eye level with brackets attached to air handling unit. Provide engraved “Name Tag” for “Filter” as specified above.

E. Water Pressure Gauges:

1. Dial type, 4-1/2” face, 0-100 psig, fiberglass reinforced polypropylene case with “O” ring weatherproof seals, liquid filled (glycerin), stainless steel movement, phosphor bronze bourdon tube silver brazed to socket and tip, and a replaceable acrylic window with “O” ring seal for weatherproof service. Accuracy: + 1% of full scale. Manufacturer: “Weiss” Model LF 4 UGY or approved equal by “Trerice”, “Marsh” or “Tycos.”

2. Provide one gauge at each device. Mainfold gauge to each of the following locations with 1/4” IPS galvanized steel pipe and individual shut-off needle valves at each location as follows:

   a. Inlet of Y-body strainer ahead of the pump.
   b. Gauge tapping at suction flange of the pump.
   c. Gauge tapping at discharge flange of the pump.
   d. Upstream and downstream of pressure regulators.
   e. Inlet and outlet of each coil.
   f. Where indicated on drawings.
   g. Needle valves shall be used for pressure gauges; brass construction, Teflon packing, maximum, operating pressure of 2,000 psig at 300°F. “Terrice type FFG, Model 735-2.”
F. Thermometers:

1. Instrument: Vertical 9” inch digital reading scale, adjustable angle type, direct insertion into piping with a thermometer well. Manufacturer: “Weiss” Vari-angle Digital thermometer or approved equal by “Trerice”, “Marsh” or “Tycos.”

2. Range: -30 to 240°F.

3. Chilled Water, condenser water, and hot water: Provide as indicated on piping flow diagrams and coil details, but as a minimum at hot water, chilled water, and condenser water supply and return piping at each air handling unit and fan-coil unit.

2.21. DIFFUSERS, REGISTERS, AND GRILLES

A. Acoustical

1. Noise generation from diffusers, registers, and grilles shall be comply with requirements of this specification. Representative samples shall be subjected to tests in accordance with applicable standards and procedures in order to demonstrate such compliance. A special test for this project is not required if the manufacturer has certified test results for proposed products.

2. Submit a tabulation of proposed products, maximum allowable noise criteria, and product noise criteria (at specified air volumes) for all project spaces. Proposed products shall have been tested in accordance with latest editions of ASHRAE Standard 70 and ADC Standard 1062:GRD-84 and shall meet the maximum allowable noise criteria (NC) requirements specified below.

3. Maximum allowable Background Noise Criteria (NC) in project spaces due to operation of HVAC, plumbing or electrical equipment are listed below. The specific octave band noise levels for the specified Noise Criteria shall be as defined by ASHRAE.

<table>
<thead>
<tr>
<th>Space</th>
<th>Required NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Listening Classrooms</td>
<td>25</td>
</tr>
<tr>
<td>Classrooms</td>
<td>30</td>
</tr>
<tr>
<td>Individual Study Rooms, Typical Private Offices</td>
<td>35</td>
</tr>
<tr>
<td>Workrooms, Lobbies, Circulation, Reception</td>
<td>40</td>
</tr>
<tr>
<td>Storage and Toilet Rooms</td>
<td>45</td>
</tr>
</tbody>
</table>

B. Manufacturer: Krueger, Price, Anemostat, or equal.

C. Diffuser, register, and grille sizes are indicated on drawings.

D. Diffusers (Krueger model 1240PE):

1. Modular snap-in cores with nominal 24” x 24” perforated panel for mounting in 24” x 24” lay-in tee grid ceiling suspension system or for surface mounting. Steel construction. Provide a round neck adaptor.
E. Return and Exhaust Air Grilles (Krueger model 6590):

1. Perforated face type of steel construction. The frame shall be nominal 24” x 24” for mounting in 24” x 24” lay-in tee grid ceiling suspension system. For hard ceilings, provide return and exhaust air registers of neck size.

2. Anatomy Labs, Cadaver Room and Cat Storage Room shall have stainless grilles.

F. Sidewall Supply Registers (Krueger model 880H):


G. Sidewall Return Registers (Krueger model S85H):


H. Sidewall Linear Bar Grilles (Anemostat TL-1N)

1. Aluminum linear bar grilles shall be model TL (1/8” bars) by Anemostat.

2. The grilles shall consist of an outer border or frame, and core configuration as scheduled. Core bars shall be either 1/8” wide, fixed on 1/4” centers, with a 0 degree deflection angle

3. Grille lengths shall be provided up to 8’ as a single assembly without joints, and up to 18” in height as a single core. Longer continuous runs shall be constructed from multiple units, and aligned with alignment hardware from the grille manufacturer.

4. Cores shall be constructed from extruded aluminum, and shall be removable from the outer frame for cleaning, access, and servicing.

5. Designs utilizing a non-removable swaged core/frame assembly, or using auxiliary frames are not acceptable.

I. Linear Air Bars (Krueger model DFL):

1. Linear slot diffusers shall be for supply or return with slot widths as indicated on the drawings.

2. Linear slot diffusers shall be available in single piece construction up to 12’. Slot diffuser lengths greater than 12’ shall be furnished in multiple sections and will be joined together with end alignment strips to form a continuous slot appearance. Alignment strips to be provided by the manufacturer.

3. The linear slot diffuser shall have the ability to support the ceiling with which it comes in contact. Brackets which are integral to the diffuser must allow mounting in hard ceilings and suspended ceilings. Linear diffusers supported by the plenum are not acceptable.

4. The plenums shall be manufactured by the same manufacturer as the linear slot diffuser.
5. Pattern controllers shall be of two piece extruded aluminum construction. Pattern controllers shall be assembled on 24” centers and supported by permanently lubricated fire retardant polymer spacers. The pair of pattern controllers shall allow for the airstream to be directed along the ceiling in either direction. The pattern controllers must also allow the airflow to be adjusted. Airflow rate can be varied without changing the air pattern. The pattern controllers in the diffuser that control the air pattern and flow rate shall perform these functions satisfactorily without the use of an additional damper.

6. The design of the spacers shall allow for removal and installation of pattern controllers without disassembly of the slot diffuser. The spacers shall be self lubricating, allowing for easy adjustment of pattern controllers. The region of the spacer which is in direct contact with plenum supply air shall have an airfoil design.

7. The face of the linear diffuser shall be White. Other surfaces including pattern controllers shall be black.

8. Performance: The manufacturer shall provide published (printed or electronic) performance data for the diffuser. Performance data shall include 2 - 7 octave band sound power levels. The diffuser shall be tested in accordance to the data standards at the time of product introduction or ANSI/ASHRAE Standard 70.

J. Submit one sample of each type, tagged for identification to the Architect for approval. Install one of each type and obtain written approval from Architect prior to ordering.

K. Sheet metal duct collars or plenum boxes for diffuses and registers shall be painted black prior installation of the diffuser and register. Unless otherwise noted, diffusers and registers shall be furnished with off-white baked enamel finish. After balancing and testing, the Contractor shall refinish damaged spots and screw heads.

2.22. AIR TERMINAL UNITS

A. Manufacturer: Krueger, Price, Anemostat, or equal.

B. General: Unit shall be single duct, variable volume, pressure independent terminal units. Terminals shall be certified by use of the ARI Standard 880-98 Certification Program and carry the ARI seal. Unit casing shall be constructed of not less than 22 gage galvanized steel. Round air inlet collars shall accommodate standard flex duct sizes. Unit discharge shall be slip and drive construction for field attachment to downstream ductwork.

C. Unit labels shall be adhered to each unit including model size, airflow in CFM, balancing chart, and tagged data.

D. Sound Attenuator: The unit shall be provided with a one piece integral sound attenuator section. The sound attenuator section shall consist of a continuous extension of the standard galvanized coated steel casing. Separate slip and drive attached attenuator will not be accepted.

E. The control air damper assembly shall be constructed of heavy gage galvanized steel with solid ½” shaft rotating in Delrin bearings. Damper shaft shall be marked on the end to indicate damper position. Damper blade shall incorporate a flexible gasket for tight airflow shutoff and operate over a full 90° rotation.
F. Unit shall be provided with a four quadrant, multipoint center averaging sensor with an amplified signal.

G. Unit shall be provided with balancing taps to allow for easy airflow verification.

H. The radiated and discharge attenuation factors for the specified NC levels shall be based on either room absorption, plus an environmental adjustment factor or the attenuation factors from ARI Standard 885-98 Appendix E, which includes room absorption, environmental adjustment factor, duct insertion, end reflection and duct branching.

I. Insulation: Unit casing shall be internally lined with glued and riveted 3/8” thick, 1½- lb. density, smooth surface, polyolefin, closed-cell insulation for fiber free application; cellular insulation; meets UL 181, NFPA 90A and does not support mold or bacteria growth.

J. Hot Water Coils: Hot water coil casing shall be constructed with minimum 20 gauge galvanized steel with slip and drive discharge for attachment to downstream ductwork. Coils shall be factory attached to the terminal unit. Fins shall be rippled and corrugated heavy gage aluminum, mechanically bonded to tubes. Tubes shall be copper with minimum wall thickness of 0.016-inch and with male solder header connections. Coils shall be leak tested to 400 psi. Number of coil rows and circuits shall be selected to provide performance as required by the plans. Coil performance data shall be based on tests run in accordance with ARI Standard 410.

K. Access panel shall be in the unit casing for viewing of damper components and/or for upstream cleaning of the hot water coil fins.

L. Air Terminal Unit Controllers shall be provided by the Controls Contractor and shipped to the air terminal unit manufacturer for installation at the factory.

2.23. Underfloor Fan & Coil Units:

A. Cabinet shall be 20 Gauge Galvanized steel lined with 1” thick, 1-1/2 lb./ft³ density, dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements and U.L. 181 erosion control requirements.

B. Insulation shall be protected with continuous vapor barrier.

C. Casing shall have a removable side or top panel suitable for equipment service.

D. Cabinet’s leakage not to exceed 2% of design flow at 2.0” wg.

E. Unit shall have air inlet and discharge flange connection for quick duct connection to ducting.

F. The control panel shall be provided by the building control contractor under Section 15950 and have connectors for attachment of thermostat input and output to underfloor air terminals in zone.

G. Fan shall be direct drive centrifugal forward curved blades, internally suspended on rubber isolators. Motor to be permanent split capacitor with thermal overload protection and toggle disconnect.
H. Return air filter frame with 1” throw-away filter.

I. Two row hot water heating coil shall construct with 3/8” O.D. copper circuit tube with with 0.020” wall thickness and 10 aluminum fins per inch. Maximum working rating shall be 225 psig at 325 F.

J. Manufacturer shall be York HCW Model, Price or Carrier.

2.24. Perimeter Zone, Variable Underfloor Air Terminals:
   A. Perimeter zone heating and cooling variable air volume terminal units.
   B. Chassis and Volume damper shall be 20 Gauge Galvanized steel construction.
   C. The chassis design shall include an end panel for attachment of a supply air duct using standard duct size of 6 inches round for the a 10 inch deep unit.
   D. Chassis construction shall admit plenum supply air from only one direction to provide a method of adjusting delivery volume for floor velocity pressure. Plenum supply air admittance openings shall be on opposite end of the chassis from the duct connection.
   E. Diffuser grille and trim ring construction shall be die cast aluminum conforming to NFPA 90A and grille shall support a load strength of 1250 LBS.
   F. Diffuser grilles shall be removable and adjustable for direction of airflow. The grille shall fit securely within the trim ring and chassis without mechanical fasteners.
   G. Grille openings shall not larger than 0.30” for shoe heel penetration protection.
   H. Integral pulse-modulation damper actuator with stainless steel threaded actuator rod and motor (air valve) that is designed for low static pressure air distribution.
   I. Unit damper shall be sequenced to admit heating air from duct connection and cooling air from the supply air plenum. In switchover mode, unit shall also act as a return air grille to remove air form the space and deliver it through the duct connection to heating terminal under the floor.
   J. Controls shall be furnished and installed under Section 23 09 00.
   K. Manufacturer shall be York MIT_G Model, Price or Carrier.

2.25. Constant Underfloor Air Terminals:
   A. Chassis and Volume damper shall be 20 Gauge Galvanized steel construction.
   B. Chassis construction shall admit plenum supply air from only one direction to provide a method of adjusting delivery volume for floor velocity pressure.
   C. Diffuser grille and trim ring construction shall be die cast aluminum conforming to NFPA 90A and grille shall support a load strength of 1250 LBS.
D. Diffuser grilles shall be removable and adjustable for direction of airflow. The grille shall fit securely within the trim ring and chassis without mechanical fasteners.

E. Grille openings shall not larger than 0.30” for shoe heel penetration protection.

F. Unit shall have a means to vary the air volume by removing an air grill and adjusting a damper from above the floor.

G. Controls shall be furnished and installed under Section 23 09 00.

H. Manufacturer shall be York Model MIT-H, Price or Carrier.

2.26. Variable Underfloor Air Terminals:

A. Chassis and Volume damper shall be 20 Gauge Galvanized steel construction.

B. The chassis design shall include an removable end panel for attachment of a supply air duct using standard duct size of 6 inches round for the a 10 inch deep unit.

C. Chassis construction shall admit plenum supply air from only one direction to provide a method of adjusting delivery volume for floor velocity pressure.

D. Diffuser grille and trim ring construction shall be die cast aluminum conforming to NFPA 90A and grille shall support a load strength of 1250 LBS.

E. Diffuser grilles shall be removable and adjustable for direction of airflow. The grille shall fit securely within the trim ring and chassis without mechanical fasteners.

F. Grille openings shall not larger than 0.30” for shoe heel penetration protection.

G. Integral pulse-modulation damper actuator with stainless steel threaded actuator rod and motor (air valve) that is designed for low static pressure air distribution.

H. Damper operation shall provide a throttling of the airflow that produce a nominal constant velocity, variable volume flow from full shut-off to full open condition. The damper shall vary the active outlet area of the grilles while maintaining velocity of the supply air through the grille.

I. Controls shall be furnished and installed under Section 23 09 00.

J. Manufacturer shall be York Model MIT-C/G, Price or Carrier Trane.

2.27. Underfloor Communication Cable for Underfloor Units & Terminals:

A. Plug and Play cable set for terminal unit connection:
   1. Plenum rated, 4 conductor, 18 gauge, 25 feet long, with Plug and Play wiring connectors attached on each end.
   2. Factory tested for continuity, shorts, opens and proper impedance.
B. Plug and Play cable set between controllers:

1. Plenum rated, 4 conductor, 18 gauge, 50 feet long, with Plug and Play wiring connector attached on one end and pig tail on the other.

C. Factory tested for continuity, shorts, opens and proper impedance.

2.28. UNDERFLOOR SYSTEM CONSTRUCTION

A. The selected manufacturer of the underfloor HVAC system must provide System Project Management during the pre-construction, construction and commissioning phases of the project.

B. System Project Management shall coordinate with the General Contractor and the Mechanical Contractor to ensure the following items are completed:

1. Floor slabs completed, sealed, and checked for level (floor height at perimeter).
2. Core walls are constructed with sheet-rock just below level of floors.
3. Ceiling and above ceiling systems are installed.
4. Raised floor pedestal support grid layout is marked on floor slab. All fan-powered terminal units and ducts are installed at perimeter and in accordance with the manufacturer’s instructions.
5. All wiring systems on the slab are installed and coordinated with the floor pedestal marks.
6. All power and control wiring for the underfloor air distribution system shall be installed under Division 23 and 26.
7. Slab is cleaned and vacuumed of all dirt and construction debris.
8. Floor pedestals and panels are installed.
9. Plug and play wiring is installed to terminal units, controller and Thermostat locations.
10. All fan & coil units and terminal units are inspected to ensure proper continuity between T-stat, controller and units. A systems check will be conducted at each phase to determine if the underfloor system is connected properly. All T-stats will utilize a system test kit to ensure proper signal to the terminal and fan & coil units for opening and closing.
11. Finishes are applied to all walls with specific consideration to Thermostat areas to ensure no air leakage is transferred to the T-stat from the wall.
12. Carpet is laid on panels, terminal units installed and Plug and Play wiring is connected.
13. All construction debris in terminal units is vacuumed out.
C. System Project Management with the approval from the Architect shall provide General contractor with guidance on proper sealing of the floor plenum.

D. Contractors shall be aware that the ceiling and walls are the structure of the supply and return plenums and therefore close attention must be made of sealing for air leakage.

E. The interior wall structures are to provide no pathway for air to travel between supply and return plenums and close attention should be made of electrical rooms and bathroom plumbing chases.

F. Changes to the architectural layout such as adding a soffit or enclosing a column must be built with zero tolerance for air leakage between floor and ceiling plenums.

G. System Project Management shall coordinate with General Contractor to ensure partition walls to be sheet-rocked below the level of the raised floor to avoid blocking airflow to areas.

H. Testing:
   1. Upon completion of all installation activities, perform the manufacturer’s pre-start checkout instructions.
   2. Start-up and operate underfloor Airway distribution system components to demonstrate functional operation and compliance with specifications.
   3. Perform testing, adjustment and balancing of hydronic piping systems serving fan-powered terminal units.
   4. Perform testing, adjustment and balancing of the supply-side of the duct work served by the fan-powered terminal units.

I. Occupied Space to Return Airway Differential Static Pressure Test
   1. After supply Airway leakage is verified within acceptable limits, and with the system operating in its normal configuration, the Mechanical Contractor shall measure the static air pressure drop between the occupied space and the return Airway space. The pressure difference shall not exceed 0.02 inches w.g. (5 Pa). If the return air pressure differential is greater than 0.02 inches w.g. (5 Pa), then additional return air terminals or larger return air terminals must be installed in the system.

J. Building Pressurization Test:
   1. The return Airway space pressure shall be verified as slightly positive relative to outside ambient in the range of 0.008 to 0.01 inches w.g. (2 to 2.5 Pa). This requires the system to be operating normally with the Airways complete and all fixtures in place. With variable-airvolume systems, the Mechanical Contractor shall demonstrate the pressure controller and associated controls are capable of maintaining a stable building pressure as the system supply volume modulates.
   2. For constant-volume systems, the outside air damper and exhaust dampers shall modulate to maintain a stable building pressure during both unoccupied and occupied operating
modes and throughout the modulating range of outside air damper if a demand control ventilation sequence (carbon dioxide measurement) is used.

K. Supply Airway Function Test and Zoning Verification:

1. The purpose of this test is the assurance that the supply airway terminals are correctly installed and functional. Each supply airway terminal is checked to be sure that it is installed properly and secured to the floor. Refer to the appropriate installation instructions. The trim ring should be tight to the floor with no gaps or rocking motion. The grilles should be open (no casting flash or debris), and correctly oriented as required on the drawings.

2. Using the project documents, each zone is tested to verify the supply airway terminal units with automatic dampers are correctly wired to a thermostat, and the dampers within the supply airway terminals are operating correctly. Using the thermostat test mode each thermostat location has its connected supply airway driven open and closed with the drawing marked up indicating pass/fail of each unit. MIT\(^2\)-G units connected to fan-powered terminals should demonstrate little or no airflow in the heating position with the fan off and the damper in the full heating position.

3. Each thermostat should be verified as being the correct style and type for the location. If thermostats are connected to a Building Automation System, then each thermostat should be observed as communicating correctly. The drawings should identify where each thermostat is located by address.

4. A plenum leak test must be conducted once floor is installed. System must operate at 0.05” static pressure under the floor.

L. Commissioning:

1. After all control devices have been commissioned (i.e. calibrated, tested and signed off), each DDC program shall be put on line and commissioned. The contractor shall, in the presence of the Architect, Construction Manager, and System Project Manager, demonstrate each programmed sequence of operation and compare the results in writing. In additional each control loop shall be tested to verify proper response and stable control, within specified accuracies. System program test results shall be recorded on commission sheets by Mechanical contractor and reviewed by Architect to ensure compliance with the system. Any discrepancies between the specification and actual performance will be immediately rectified and retested.

2.29. LABORATORY EXHAUST CONTROL VALVE TERMINAL UNITS AND SYSTEMS

A. A laboratory airflow control system shall be furnished and installed to control the airflow into and out of laboratory rooms. The exhaust flow rate of a laboratory fume hood shall be precisely controlled to maintain a constant average face velocity into the fume hood at either a standard/in-use or standby level based on an operator being present in front of the fume hood. The laboratory control system shall vary the mount of supply air into the room to operate the laboratories at the lowest possible airflow rated necessary to maintain temperature control, achieve minimum ventilation rates, and maintain laboratory pressurization in relation to adjacent spaces (negative).
B. Each individual laboratory shall have a dedicated laboratory airflow control system to control the VAV terminal and ECV terminals to maintain proper room pressurization polarity (negative).

C. ECV (Exhaust Control Valve) terminals

1. Air valves shall be round, venturi shaped, volume control valve or a constant volume valve with a spring-controlled cone. The valves are completely self-contained. The required air volume is maintained independent of duct system pressure variations at a given shaft position and over a specified differential static pressure operating range (0.3 to 3.0 in H2O). The stainless steel control rod shall be modulated by an electric actuator in variable air volume applications or shall be fixed to a calibration dial in constant volume applications. The cone adjusts automatically to pressure variations before or after the valve to provide accurate air volume minimizing actuator motion given flow rate. The valves shall be shipped factory calibrated with dial positions corresponding to specific volume flow rates displayed in a table fixed to the valve. The valve shall be oriented according to its label.

2. Variable Air Volume Venturi Valves:
   a. The valve is designed to maintain a constant flow rate in the face of changing duct static pressure at a given shaft position.
   b. The specified differential static pressure operating range: 0.3 to 3.0 in H2O.

3. Variable Air Volume Venturi with Shut Off Valves:
   a. The valve is airflow variable volume control air valve with minimum flow being zero. The valve is designed to maintain a constant flow rate in the face of changing duct static pressure at a given shaft position.
   b. The specified differential static pressure operating range: 0.4 to 3.0 in H2O.

4. Materials:
   a. For non-corrosive air streams, the valve housing will be constructed of aluminum and will incorporate a complete venturi containing an aluminum aerodynamic moving cone. The cone rod, the connecting links and the spring will be made of stainless steel. The cone shaft bearing surfaces will be made of Teflon. Inlet and outlet connections will be circular and of similar dimensions. In order to prevent dust accumulation and bacterial development, interior acoustic insulation will not be permitted.
   b. For corrosive air streams, the valve housing will be constructed of aluminum and will incorporate a complete venturi containing an aluminum aerodynamic moving cone. The cone rod, the connecting links and the spring will be made of stainless steel. The cone shaft bearing surfaces will be made of Teflon. The control rod will be Teflon coated stainless steel. Internal and external components will have a baked Heresite coating. Inlet and outlet connections will be circular and of similar dimensions.
dimensions. In order to prevent dust accumulation and bacterial development, interior insulation will not be permitted.

5. Performance Requirements: The air volume (CFM) will be regulated using venturi valves. The controlled air volume will be mechanically independent of static pressure variation at all actuator positions. Following a pressure variation, CFM correction will be achieved through the spring loaded cone within one second. To increase actuator life, the pressure variation corrective action (new cone position) will be independent of the actuator. External air speed sensors are not acceptable. The air volume will be proportional to the valve cone position and have near-linear characteristics. All venturi valves will be factory calibrated with a mechanical dial to permit direct reading of air volume. Future modifications will not require special calibrating tools. The valve actuator will be supplied and installed at the factory.

6. The airflow controllers will be certified as required after installation and significant completion of the space being controlled.

D. Fume Hood Face Velocity Controller:

1. A fume hood face velocity control system shall be furnished and installed to monitor and control the measured face velocity of a fume hood independent of sash position and duct static pressure. The system shall continuously monitor and display face velocity to comply with the recommendation set forth in Appendix A of OSHA regulation 29 CFR 1910.1450. The system shall also indicate the presence of airflow to comply with the NFPA 45 Standard.

2. The fume hood face velocity controller system shall use a sidewall sensor to measure the average fume hood face velocity. The sidewall sensor shall use a precision platinum RTD, ceramic coated for corrosion resistance and ease of maintenance. The sidewall sensor shall be temperature compensated over a range of 55°F to 95°F. Systems employing a thermistor-based face velocity sensor or measuring the exhaust flow volume and open sash area to calculate face velocity are not allowed.

3. The fume hood face velocity controller shall have a digital display of the measured average face velocity and all configuration parameters. Configuration shall be done through a keypad integral to the controller. Password protection shall limit unauthorized access to configuration parameters. The controller shall have indicator lights for alarm, caution, mute, or normal operating conditions. High, low or no flow alarm contacts shall close in the appropriate alarm condition. An analog output of face velocity shall be user-configurable to either 0-10V or 4-20mA. The room controller shall have a communication port supporting common open protocols, coordinate exact protocol with BAS contractor for seamless integration into the building automation system.

4. The fume hood face velocity controller shall control the ECV terminals.

5. The fume hood face velocity control system shall use a sidewall sensor to measure the average fume hood face velocity. The sidewall sensor shall have the sensitivity to measure the effects of obstructions and duct static pressure fluctuations on the average fume hood face velocity. The fume hood sensor shall have a resolution of 1 foot per minute velocity and shall detect any change in the face velocity within 0.05 second.
Volumetric airflow measurements used to imply fume hood face velocity shall not be acceptable.

6. The fume hood face velocity control system shall be completely independent for each individual fume hood. The fume hood control system shall control the face velocity independent of other fume hood and laboratory control systems. The fume hood control system shall be able to respond to face velocity disturbances caused by events including but not limited to sash movement.

7. Room air shall be drawn across the sensing element. If hood design or installation prohibits room air from being drawn across the sensor, a fume hood sensor venting kit shall vent room air through an orifice in the front of the hood to the sensing element. Fume hoods needing vent kits include but are not limited to those hoods where the chase is connected to the plenum or extends up to the ceiling.

8. To ensure fast, accurate control, the face velocity controller shall have a PID control algorithm with two sets of tuning constants. The two sets of tuning constants enable fast response to large disturbances while maintaining stability at setpoint. The control sensitivity defining the breakpoint between input and steady state response shall be adjustable. The fume hood face velocity control system shall update the control output 20 times per second.

9. Local audible and visual alarms and relay contacts shall be enabled whenever the measured face velocity falls below a user configurable low alarm set point or rises above a user configurable high alarm set point. A mute key shall silence the audible alarm.

10. Calibration shall be done electronically through the use of the integral keypad. Calibration shall consist of adjusting the sensor zero point and sensor span to match a reference measurement. Password protection of the calibration items shall limit unauthorized access. Neither remote calibration nor calibrating through the use of potentiometers is acceptable. Factory calibration alone is not permitted.

11. The face velocity controller shall have an emergency key and an emergency input contact, either of which shall completely open that fume hood’s damper (or variable speed drive) for maximum exhaust in the event of a spill.

12. For energy-efficiency, the face velocity controller shall have a setback input contact and a setback key, either of which shall initiate control for that fume hood at a reduced face velocity setpoint. The fume hood face velocity control system shall automatically adjust high and low alarm set points to avoid nuisance alarms when setback mode is enabled. Setback of individual fume hoods within a lab through the use of individual occupancy sensors is not allowed.

E. Room Offset Controller

1. A room controller system shall be furnished and installed to maintain the measured laboratory pressurization independent of supply and exhaust flow volumes. The system shall ensure that the air flows into the laboratory space from areas of low hazard to comply with the requirement for air flow monitors in ANSI Z9.5.
2. The room control system shall measure the supply flow volume, exhaust flow volume, and room pressure differential. Systems that exclusively measure the room pressure or supply and exhaust flow volumes are not allowed.

3. The room control system shall accept up to 1 supply, 1 general exhaust, and 2 other exhaust flow measurements. The flow measurements shall be 0-10V signals, linear with respect to either velocity pressure or velocity.

4. The room controller shall have a digital display of all configuration parameters. Configuration shall be done through a keypad integral to the controller. Password protection shall limit unauthorized access to configuration parameters. The controller shall also have indicator lights for low and high alarm and normal operating conditions. The room controller shall have an RS-485 communications port, supporting the MODBUS or Johnson Controls N2 protocols for seamless integration to the building automation system.

5. The room pressure sensor shall be bi-directional. The sensor shall be capable of being mounted in the corridor (reference space) or the laboratory (controlled space). The room pressure sensor shall use two in-line ceramic coated RTDs to measure the pressure differential. The room pressure sensor shall be temperature compensated over a range of 55°F to 95°F. Sensors employing a thermistor-based sensor or that cannot differentiate between positive and negative pressures are not allowed. Field-calibration of the sensor shall be performed through the keypad on the room controller.

6. The room control system shall be completely independent for each individual laboratory. The room control system shall not depend on measurements from other laboratory control systems.

7. The room control system shall independently control the supply and the general exhaust with 0-10 VDC signals to maintain a difference between the supply and exhaust flow volumes (offset). If the offset is greater than setpoint, then the room controller shall decrease the general exhaust flow rate and then increase the supply flow rate to its maximum set point until the desired offset is achieved. If the offset is less than setpoint, the room controller shall decrease the supply flow rate to its ventilation minimum setpoint and then increase the general exhaust flow rate until the desired offset is achieved. The room controller shall receive voltage signals related to the supply, general exhaust, and fume hood or total exhaust air flow volumes.

8. The room control system shall measure the pressure differential between the laboratory and reference space. The room control system shall reset the offset within user-configured limits to maintain room pressure set point. The room pressure sensor shall have a resolution of 5% of the measured value and shall detect any change in the room pressure within 0.1 second, with a minimum reading of 0.0001 inches H₂O.

9. The room controller shall control the space temperature by modulating the reheat valve with a 0-10 VDC control signal and the supply air volume. When the space is too warm, the room controller shall close the reheat valve and then increase the supply air volume. When the space is too cool, the room controller shall reduce the supply air volume to its ventilation minimum set point and then open the reheat valve. The exhaust air volume will follow the supply air volume to maintain room balance. The room controller shall
accept a 1000 Ω platinum RTD temperature sensor. The room controller shall always provide additional supply air as needed to maintain room balance.

10. To ensure fast, accurate control, the room control system shall have a PID control algorithm with two sets of tuning constants. The two sets of tuning constants enable fast response to large disturbances while maintaining stability at setpoint. The control sensitivity defining the breakpoint between input and steady state response shall be adjustable. The room control system shall update the control output 10 times per second.

11. Local audible and visual alarms and relay contacts shall be enabled whenever the measured room pressure differential falls below a user configurable low alarm set point or rises above a user configurable high alarm set point, after a configurable delay. A mute key shall temporarily silence the audible alarm. Manual or automatic reset of the alarms shall be configurable.

12. Local audible and visual alarms shall be enabled whenever the supply or exhaust air volume falls below the configurable low alarm set point, after a configurable delay. A mute key shall temporarily silence the audible alarm. Manual or automatic reset of the alarms shall be configurable.

13. The room control system shall have an emergency key to enable emergency mode. The room control system will drive the supply and general exhaust dampers to achieve maximum pressurization in emergency mode.

14. The room controller shall have an unoccupied mode, enabled through RS-485 communications. In unoccupied conditions, the room controller shall utilize a second minimum supply flow set point and will not increase the supply flow rate for cooling.

15. Calibration of room pressure differential and air flows shall be done electronically through the use of the integral keypad. Calibration shall consist of adjusting the sensor zero point and sensor span to match a reference measurement. Password protection of the calibration items shall limit unauthorized access. Neither remote calibration nor calibrating through the use of potentiometers is acceptable.

F. Room Pressure Controllers

1. A room controller system shall be furnished and installed to measure and display the measured laboratory pressurization independent of supply and exhaust flow volumes. The system shall ensure that the air pressure of the space is negative with respect to the corridor or pressure reference point.

2. The room control system shall measure the room pressure differential. Systems that exclusively measure the room pressure or supply and exhaust flow volumes are not allowed.

3. The room pressure control system shall accept up 2 supply flow measurements. The flow measurements shall be 0-10V signals, linear with respect to either velocity pressure or velocity.
4. The room pressure controller shall have a digital display of all configuration parameters. Configuration shall be done through a keypad integral to the controller. Password protection shall limit unauthorized access to configuration parameters. The controller shall also have indicator lights for low and high alarm and normal operating conditions. The room controller shall have an RS-485 communications port, supporting the MODBUS or Johnson Controls N2 protocols for seamless integration to the building automation system.

5. The room pressure sensor shall be bi-directional. The sensor shall be capable of being mounted in the corridor (reference space) or the laboratory (controlled space). The room pressure sensor shall use two in-line ceramic coated RTDs to measure the pressure differential. The room pressure sensor shall be temperature compensated over a range of 55°F to 95°F. Sensors employing a thermistor-based sensor or that cannot differentiate between positive and negative pressures are not allowed. Field-calibration of the sensor shall be performed through the keypad on the room pressure controller.

6. The room pressure control system shall be completely independent for each individual laboratory. The room pressure control system shall not depend on measurements from other laboratory pressure control systems.

7. The room pressure control system shall measure the room pressure differential between the space and reference space. The room pressure control system shall detect any change in the room pressure within 0.1 second. The room pressure control system shall use a thermal room pressure sensor with a resolution of 1% of the measured valve and a minimum reading of 0.0001 inches H2O.

8. The room pressure control system shall control the exhaust with 0-10 VDC signals to maintain room pressurization. The room pressure control system shall control the supply air to a constant volume. The room pressure controller shall receive a voltage signal related to the supply air flow volume in order to maintain a minimum flow rate. Control systems that track the supply and exhaust air volumes to infer room balance are unacceptable.

9. TSI Model 8636: The room controller shall control the space temperature by modulating the reheat valve with a 0-10 VDC control signal and the supply air volume. When the space is too warm, the room controller shall close the reheat valve and then increase the supply air volume. When the space is too cool, the room controller shall reduce the supply air volume to its ventilation minimum set point and then open the reheat valve. The exhaust air volume will follow the supply air volume to maintain room balance. The room controller shall accept a 1000 Ω platinum RTD temperature sensor. The room controller shall always provide additional supply air as needed for to maintain room balance.

10. The pressure control system shall accept up to two pressure sensor inputs. The primary sensor shall measure the pressure differential between the rooms. The secondary sensor shall measure the pressure differential between the room and corridor.

11. To ensure fast, accurate control, the room control system shall have a PID control algorithm with two sets of tuning constants. The two sets of tuning constants enable fast response to large disturbances while maintaining stability at setpoint. The control
12. Local audible and visual alarms and relay contacts shall be enabled whenever the measured room pressure differential falls below a user configurable low alarm set point or rises above a user configurable high alarm set point, after a configurable delay. A mute key shall temporarily silence the audible alarm. Manual or automatic reset of the alarms shall be configurable.

13. Local audible and visual alarms shall be enabled whenever the supply or exhaust air volume falls below the configurable low alarm set point, after a configurable delay. A mute key shall temporarily silence the audible alarm. Manual or automatic reset of the alarms shall be configurable.

14. The room pressure control system shall accept inputs from flow stations mounted in the supply ducts. The room pressure controller will use the flow station to calculate the Air Change per Hour ventilation rate for the space. Local audible and visual alarms and relay contacts shall be enabled whenever the measured air volume falls below the configurable low alarm set point, after a configurable delay. The audible alarm shall have a mute key to temporarily silence the alarm for a user-configured delay. Manual or automatic reset of the alarm shall be configurable.

15. Calibration of room pressure differential and air flows shall be done electronically through the use of the integral keypad. Calibration shall consist of adjusting the sensor zero point and sensor span to match a reference measurement. Password protection of the calibration items shall limit unauthorized access. Neither remote calibration nor calibrating through the use of potentiometers is acceptable.

G. Electronic Air Flow Measuring Probes (Supply VAV Terminal at Laboratory)

1. Duct airflow measuring probes shall be of the electronic glass bead thermistor multiple averaging sensors type with sensors distributed for equal-area averaging of flow.

2. They shall be installed for a total duct traverse.

3. Internal sensors shall be constructed of glass bead thermistors.

4. The sensors shall be enclosed in aluminum hosing and shall be provided with a microprocessor which provides local four digit LED display and outputs of both current and voltage.

5. Manufacturer shall be “ULTRATECH Industries, Inc.” Model “Ultraprobe ET/AMP” or approved equal.

6. The control unit shall provide linear signals that are proportional to all airflow sources, sash sensors, and flow alarms. The signals shall be available for hard wired connection to the campus direct digital control (DDC) system, or through an integrated control unit that interfaces directly into the campus DDC system.
H. System Start-up and Training:

1. System startup shall be provided by a factory authorized representative of the laboratory airflow control system manufacturer. Startup shall include calibrating the fume hood monitor and any combination sash sensing equipment as required. Start-up shall also provide electronic verification of airflow (fume hood exhaust, supply and general exhaust).

2. The balancing contractor shall be responsible for final verification and reporting of all airflow.

3. The laboratory airflow control system supplier shall furnish a minimum of eight hours of owner training, by factory trained and certified personnel. The training will provide an overview of the job specific airflow control components, verification of initial fume hood monitor calibration, general procedures for verifying airflow of air valves, and general troubleshooting procedures.

I. Manufacturer shall be “TSI”, “Triatek” or AccuValve.

2.30. AIR HANDLING UNITS

A. Manufacturer: Energy Labs, Temtrol, or York “Pace”.

B. Unit Base: Each unit shall be constructed on a base fabricated from ASTM A36 welded structural steel channel. Heavy removable lifting lugs shall be added to the perimeter channel along the longest length of the unit. Floor shall be 16 gauge minimum hot rolled galvanized steel sheets. The floor is supported by structural galvanized steel members. Floor skin shall maintain water and airtight seal. Fans, coils and major components shall be supported with structural steel members.

C. Housing: The unit housing side and roof outer panels shall be constructed of 16 gauge minimum galvanized steel, and utilize a standing seam modular panel type construction. Panels caulked and attached to each other, to the roof, and to the floor using nuts and bolts. Panels shall be removable. Seams shall be sealed with an acrylic latex sealant prior to assembling the panels and after completion of assembly. Inner liner 20 gauge minimum perforated bright galvanized installed over insulation. Floor openings shall have 12-gauge minimum galvanized steel-framed flange around the entire perimeter of opening for duct connection. Roof on outdoor units shall be bowed or pitched for drainage.

1. Minimum sound transmission loss (STL) through unit panels as follows:

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D. Hinged, double wall, insulated, man size access doors provided in sections requiring access for maintenance or service. Doorframe is one piece, 14 gauge minimum galvanized steel welded with integral gutter lip. Access doors fully gasketed with a closed cell, replaceable neoprene gasket. The gasketing material shall be installed to allow for easy removal and replacement.
Access door must not leak more than 25 CFM at 6-inch static pressure. Submit test results from independent testing laboratory for engineer review.

1. Door hinges and latches easily adjustable, without the use of shims or special tools, to allow for a tight seal between the door and the doorframe as the gasketing material compresses over time. The door hinge design shall allow for field modification of door swing and doors shall be easily removable. Provide door detail drawing with submittal package.

2. The latch assembly shall incorporate a built-in safety catch to release cabinet operating pressure prior to opening the door.

3. Doors entering into any section of the air handler that contains rotating fans provided with zinc-plated nuts in lieu of knurled knobs. The nuts shall limit access to personnel with proper tools.

4. Include a 10” x 10” wire reinforced glass view window in each fan access door.

5. A door switch shall be interlocked with fan starter or VFD to stop the fan before access door is opened.

E. Insulation: Insulation shall be minimum 2” thick, 1½ lbs per cubic foot density, neoprene coated fiberglass to cover all walls, ceilings and under floors. Insulation shall meet NFPA-90A smoke and flame spread requirements. Plenum fan sections shall have a 20-gauge perforated galvanized sheet metal liner covering all walls and ceiling surfaces in the blast area of fan.

F. Unit Configuration:

1. Underfloor air system, the unit shall consist of minimum sections as follows:
   a. Supply fan section.
   b. Return air bypass section with bypass damper and filters.
   c. Chilled water coil and Pre-Heat water coil sections.
   d. Filter section.
   e. Outside air section with dampers.

2. Overhead air system, the unit shall consist of minimum sections as follows:
   a. Supply fan section.
   b. Chilled water coil and Pre-Heat water coil sections.
   c. Filter section.
   d. Economizer section with dampers.
e. Exhaust/Return fan section.

3. Make-up air system, the unit shall consist of minimum sections as follows:
   a. Supply fan section.
   b. Chilled water coil and Pre-Heat water coil sections.
   c. Filter section.
   d. Outside Air Hood section with damper.

G. Drain Pans: Drain pans constructed from 16 gauge, 304-stainless steel. Galvanized steel drain pans are not acceptable. The drain pan shall be insulated with 2” thick, 1½ lb per cubic foot density insulation to prevent condensation under the drain pan. Insulation shall be protected with an 18-gauge galvanized steel liner. Drain pans must be sized such that the entire coil, including headers and return bends, are inside the drain pan. Drain pans must slope in two directions so there is no standing water in drain pan. Stainless steel condensate connection shall be provided on one side of the unit. Coils shall be supported on 10-gauge stainless steel members to prevent immersion of the coil in condensate and allow for complete cleaning of drain pan beneath the coils.

H. Paint Finish: After final assembly the unit exterior shall be coated with an industrial marine grade, high solids, and polyurethane paint. In addition, all fan bases, springs and structural steel supports shall be coated with the same finish. The paint system shall meet ASTM B117. Salt spray test for a minimum of 2000 hours in a 5% solution.

I. Fan Assembly

1. Fan performance based on tests run in an AMCA certified laboratory and administered in accordance with AMCA Standard 210. Fan performance tests shall be taken with fans running inside the cabinet to include any affects from the unit cabinet and other internal components. Fans shall bear AMCA seal for air and sound.

2. Plenum fans configured so both fan bearings are on the drive side of the wheel with the wheel over hung (Arrangement #1 for belt drive and Arrangement #4 for direct drive fans). There shall be no obstructions (i.e., bearings or bearing supports, etc..) at the inlet of the fan. Fan wheel aluminum with aluminum extruded airfoil blades. Fan bearings shall have a minimum L10-200,000 Hr. operating life and be mounted on a structural steel channel or machined surface. On DWDI fans the structure supporting the bearing shall be fabricated from structural steel and be detachable to allow for removal of the fan wheel and shaft as one piece. The fan discharge shall be isolated from the cabinet by means of a neoprene-coated flexible connection. Plenum fans shall be provided with spring-style thrust restraints. Arrangement #3 fans are not acceptable.

3. Each fan sized to perform as indicated on the equipment schedule. The wheel diameter shall not be less than that shown on the equipment schedule. The fan shall be constructed to AMCA Standards for the Class Rating as indicated on the Equipment Schedule.
4. Provide grease fittings and extend lubrication lines to the motor side of the fan just inside the access door.

5. Fan Base, Spring Isolation, and Support Framing: Mount fan and motor on an internal, fully welded, rigid structural steel base, free-floating at all four corners on spring type isolators with seismic Zone 4 earthquake restraints. The fan assembly shall be isolated from the cabinet by steel springs with minimum deflection of 2” or as indicated on schedules. The spring isolators shall be mounted to structural steel members and on a waffle pad for vibration isolation.

J. Balancing: The fan shaft sized not to exceed 75% of the first critical speed for maximum RPM of Class specified. The critical speed will refer to the top of the speed range of the fans’ AMCA class. The lateral static deflection shall not exceed 0.003-inch per foot of the length of the shaft. Fans shall be balanced to ISO standard G6.3. A copy of the above balance test data showing calculations for deflection and critical speed of the shaft and wheel assembly shall be submitted to the engineer and a copy forwarded to the Owner.

K. Motors and Drive: Premium-efficiency, inverter duty, open drip proof, NEMA frame, ball bearing type motors. Marathon “XRI” or Reliance, with grease lubricated bearings and alemite fittings are acceptable. The Horsepower values as shown on the schedule are minimum allowable. The motor shall be mounted on an adjustable slide rail motor base with two adjusting bolts per side. The fan motors shall be factory wired to an external junction box or VFD’s with flexible conduit of adequate length so that it will not have any effect on the vibration isolation. Provide V-belt type, cast-iron sheaves, and reinforced rubber belts. The belts shall be selected for 150% of the motor nameplate horsepower. Drives shall be “Browning” or equal by “Woods.”

L. Coils:

1. Chilled water coils plate fin extended surface type. Tubes shall be 5/8” outside diameter seamless copper, 0.020” minimum wall thickness. Each coil shall have individually replaceable return bends of 0.025” wall thickness on both sides of the coil. Coils incorporating a “hairpin” type design are not acceptable. Tubes shall be expanded into the fin collars to provide a permanent mechanical bond.

2. The secondary surface shall be formed of .010 aluminum fins and shall be spaced not closer than 12-fins per inch with integral spacing collars that cover the tube surface. Headers non-ferrous seamless copper, outside the airstream and provided with brazed copper male pipe connections. Drain and vent tubes extended to the exterior of the air-handling unit.

3. Coils shall have counter-flow construction with connections left or right hand as shown on the drawings. The use of internal restrictive devices to obtain turbulent flow will not be accepted.

4. Cooling coil casings shall be minimum 16 gauge, 304-stainless steel with double-formed 1¼” stacking flanges and ¾” flanges on the side plates. Flanged tube sheets shall have extruded tube holes to prevent raw edges of tube sheets cut into copper tubes because of thermal expansion of tubes in tube holes. Tube holes with raw sheet metal edges are not acceptable. Reinforcing shall be furnished so that the unsupported length is not over 60-
inch. Coil assemblies shall be tested under water at 300 psi and rated for 150-psi working pressure. Headers are to be located inside the cabinet casing with only the pipe vent and drain connections extending through the casing. Sides of coils shall be carefully blanked off on both to ensure all air passes through the coil.

5. Intermediate 16 gauge, 304-stainless steel condensate drain pans shall be furnished on multiple coil units and single coils greater than 48” high and drain to the main drain pan through copper downspouts.

6. Water coils shall be rated in accordance with ARI Standard 410.

M. Filters: Filter sections as part of the air-handling unit. Filters arranged for upstream, downstream, or side loading as shown on the drawings. Provide 16 gauge, fully welded, filter-holding frames and clips to accommodate scheduled filters. Frame shall be Energy Labs or Burke Environmental only.

N. Install at each filter bank a Dwyer Magnehelic “Series 2000” differential pressure gauge with static pressure tips, access hardware and fittings. Enclose the gauge in a protective sheet metal box with a hinged inspection door. Paint to match unit.

O. Dampers and Louvers

1. Dampers with low leak extruded aluminum airfoil blades, rubber edge seals and stainless steel are end seals. Edge seals backed by the damper blade to assure a positive seal in the closed position. Dampers provided with nylon bearings within extruded openings, not to exceed 6 CFM/ft² at 5.0-inch w.g. of static pressure. Leakage testing in accordance with AMCA standard 500 figure 5.5. Test results must be from independent testing laboratory.

2. Provide louvers for outside air and exhaust air for units located outdoors. OSA Louvers sized for a maximum face velocity of 500 fpm on gross louver area. Louvers shall have zero water penetration at 600-ft/min air velocity. Maximum louver pressure drop shall be 0.03-inch w.g. at 500 ft/min. Provide test results from independent testing laboratory, per AMCA Standard 500 figure 5.5. Louver water carry over must be less than 0.01 oz/ft² at 1100 ft/min of free louver area, per AMCA 500-89 figure 5.6. Hoods in lieu of louvers are not acceptable.

P. Economizer / Mixing Box: Economizer section shall include opposed blade dampers for return air, fresh air and exhaust air, sized for not greater than 1200 fpm face velocity based upon gross damper area. Furnish full height 24-inch wide access doors for damper and linkage service.

Q. Air Flow Measuring Stations

1. Provide fans with a complete flow measuring system capable of supplying a 4–20mA. Output signal to the EMS system that is proportional to airflow. The flow measuring station and a flow transmitter shall be factory mounted.

2. The flow measuring station shall consist of pressure taps pick-ups located in the inlet cone of each fan, with no obstruction created on the inlet of the fan by installation of flow
measuring device. Flow measuring stations installed in the inlet of fan will obstruct the fan inlet and are not acceptable.

3. Provide a gauge with CFM scale on external side of the fan sections, which indicates the fan flow volume, along with electronic flow transmitter, mounted on the exterior of the fan section. Transmitter capable of receiving signals of total and static pressure from a flow element, of amplifying, extracting the square root, and scaling to produce a 4-20 mA or 0-5 VDC output signal linear and scaled to air volume or velocity.

4. Output signal 4-20 mA or 0-5 VDC standard. Integral zeroing means 3-way zeroing valve with manual switch. Temperature effect ± 2.0% of full span from 40° to 120°F.

5. The transmitter shall not be damaged by over-pressurization up to 200 times greater than span, and be furnished with a factory calibrated span and integral zeroing means. The transmitter housed in a NEMA 12 enclosure with external signal tubing, power, and output signal connections.

6. The electronic differential pressure transmitter shall be Setra Model 264 or equal.

R. Ultraviolet Lights:

1. Manufacturer: Ultra Violet Devices, Steril-Aire, or equal.

2. Germicidal UVC Emitters and fixtures shall be of the single-ended tube type and be factory assembled and tested. Each UVC device shall consist of a NEMA 4x rated housing, power source, power cover, sockets, spring wire holders and Emitters and shall be constructed to withstand the environments of HVAC equipment.

3. Housing shall be constructed of type 304 stainless steel and equipped with both male and female power plugs with one type at each end to facilitate simple fixture to fixture plug in for AC power. Each housing shall be equipped with an internal wire loom sufficient to allow the UVC Emitter to be powered by the A/C unit. Each fixture incorporates all components into one integral assembly that maximizes serviceability. Fixtures are to be mounted downstream of the cooling coil on a stainless steel array supported by uni-strut bracing. Array configuration must be capable of covering the entire coil and drain pan area with UV light without any shadowed surfaces.

4. The power source shall be Class P2 type and be capable of firing and maximizing radiance from each UVC Emitter at temperatures ranging from 32° to 170° F. The power source is to be optimized for each Emitter such that the power conversion efficiency shall not be less than 7. A door interlock switch that disconnects power to the lights in the event of door opening during operation must be supplied on all doors entering UV light plenum.

5. Access Cover shall be constructed of heavy gauge stainless steel and equipped with a NEMA 4 rated gasket to enclose the entire housing and be removable for service. Access Cover shall be provided with signage indicating the UVC lights must be turned off before access cover is opened.
6. Sockets shall be medium bi-pin, single click safety, twist lock type, and constructed of a UV-C resistant polycarbonate.

7. Emitter shall be of the high output, hot cathode, T8 (15mm) diameter, single-ended Circline base type. They shall produce no ozone and be constructed of thick wall, type “L”, hard glass quartz with an initial minimum UVC transmittance of 83%. Igniters shall be connected to a nickel inner lead and be 8mm wide, triple-coiled and tungsten coated clamped-filament type to preclude quartz soiling and enhance plasma convection and stability. The base shall consist of four power pins cast into hard ceramic to eliminate any deterioration. Emitters shall be capable of producing the specified output at temperatures of 32-170º F.

8. Bulbs shall contain 3 milligrams or less of mercury (Hg).

9. Independent Testing:
   a. Fixture and Emitter (device), as submitted, is to be independently tested to verify output under the variable operating conditions typically found in HVAC equipment. When tested total output per inch arc length shall not be less than 10 µW/cm² at 1 meter in moving air of 45°F and 400 fpm.
   b. Systems shall have been independently tested to verify conformance to UL/C-UL Listed under category code ABQK (Accessories, Air Duct Mounted), UL Standards 153, 1598, and 1995.

10. IAQ Performance:
    a. Emitters and fixtures are to be of the very high output, HVAC type. Output shall be measured in an ASME nozzled, test apparatus, consisting of a 45°F moving air stream of not less than 400 fpm. Output shall not be less than 10 (µW/cm²), at 1 meter, per each inch of Emitter arc length.
    b. Power supplies shall be of the high efficiency electronic type, matched to the Emitter, and capable of producing the specified intensity at no more than 80 Watts of power consumption per 4 square feet of coil surface area.
    c. Emitters and fixtures are to be installed in sufficient quantity and in such an arrangement so as to provide an equal distribution of UVC energy on the coil and in the drain pan. To maintain energy efficiency, the UVC energy produced shall be of the lowest possible reflected and shadowed losses.
    d. The minimal UVC energy striking the leading edge of all the coil fins shall not be less than 1400 (µW/cm²) at the closest point and through placement, not less than 70% of that value at the farthest point. This therefore sets the minimum quantity of fixtures to be installed and their placement. Additionally, equal amounts are to strike the drain, either directly or indirectly through reflection.
    e. Emitters and fixtures shall be installed, such that through incident angle reflection, UVC energy bathes all surfaces of the coil and drain pan as well as all of the line of sight air stream.
11. Warranty: Fixtures shall be warranted to be free from defects for a period of one year. Lamps shall be warranted to be free from defects for a period of one year. Lamps shall last 8,700 hrs prior to replacement.

S. Electrical Requirements:

1. Provide vapor tight marine lights in each access section, factory wired to a single weatherproof switch located on exterior of cabinet. Provide weatherproof, 15 amps, GFIC receptacle near the light switch wired to the lighting circuit. The Electrical Contractor shall bring separate 120/1/60 power to the light switch.

2. The main control panel shall have access door(s) for direct access to the controls. The panel shall be NEMA type 3R (rainproof) and shall contain a single externally operated, non-fused disconnect, suitable for copper wire up to and including 3” conduit. The electrical contractor shall bring separate 460/3/60 power to the single source power panel.

3. Wiring shall be run in EMT conduit, raceways are not acceptable.

4. If the unit requires splits, junction boxes shall be furnished on each section to allow the electrical contractor to make final connections in the field. Wiring shall be clearly labeled to allow ease in final interconnections.

T. Unit Mounted Controls

1. Controls shall be factory mounted by the Air Handling Unit manufacturer. Controls include damper actuators, temperature sensors, pressure sensors, and airflow measuring sensors, filter switches, smoke and fire detectors as indicated on the control drawings, within the confines of the unit.

2. Electric and electronic controls shall be wired to a terminal block in a sheet metal enclosure located at a common location mounted on the air-handling unit. Pressure sensing controls shall be piped to a common point on the unit with ¼” compression fittings.

3. Controls shall be supplied by the temperature controls contractor and shipped to the Air Handling Unit Manufacturer for installation. Control contractor to provide wiring diagrams and check and test at manufacturer’s plant prior to unit shipment.

U. Acoustical Requirements

1. The sound generating characteristics of air handling shall be tested to, and comply with the requirements of this specification. Representative samples shall be subjected to tests in accordance with applicable standards and procedures in order to demonstrate such compliance. A special test for this project is not required if the manufacturer has previous certified test results that can be made applicable to this project.

2. Maximum allowable sound power levels for supply discharge, return intake, and outdoor radiated noise shall not exceed the values listed in the project drawings with equipment operating at design airflow and static pressure conditions.
V. Sound Power and Performance Certification

1. The manufacturer shall perform actual sound test on one selected AHU in accordance with AMCA Standard 300-96. Reverberant Room Method for sound testing of fans, and AMCA Standard 210, Laboratory Methods of Testing Fans for rating. The mechanical engineer shall select the test AHU after review of the submittal.

2. Air handling unit sound power data shall be submitted for review by Owner’s representative. Sound power data shall be given at the supply connection(s) (outlet) and return connection(s) (inlet) in addition to radiated sound power from the cabinet. Raw fan sound power data shall be derived from tests done in accordance with AMCA Standard 300-96. Data extrapolated from non-like fan sizes and types scheduled are not acceptable. Attenuation assumed for the cabinet configuration, type of insulation, opening locations and sizes, etc., shall be verified through actual test measurements. The mechanical engineer may, at his option, request copies of such tests.

3. If the AHU manufacturer is incapable of performing the AMCA Standard 300 sound test, substitute method shall be proposed for review by the mechanical engineer. The proposed substitute method shall clearly identify the measurement instrumentation, the test reference to a nationally known test standard and qualifications of personnel who will perform the test.

4. The mechanical and acoustics engineers shall be allowed to witness the sound test. The AHU manufacturer shall notify the mechanical engineer a minimum of ten days prior to test as to the location and date of the sound test. The travel costs incurred by test witnesses shall be borne by the equipment manufacturer.

5. If the sound test indicates the AHU noise levels exceed levels of units specified, the Contractor shall take corrective measures to reduce the sound. Any modifications that are necessary to meet scheduled sound levels shall be applied to all AHU’s represented by the test unit. Test results shall be submitted to the Owner’s Representative for approval prior to shipment of any equipment.

W. Warranty and Start-Up Service: Manufacturer shall provide factory start-up service for each air-handling unit. Manufacturer shall provide a one year parts and labor warranty.

2.31. CHILLED WATER FAN COIL UNIT

A. Manufacturer: Trane BCHC or equal by York or Magic-Aire.

B. Unit shall be tested in accordance with ARI 430 and ARI 260. The unit complies with NFPA 90A and is UL listed. Unit shall consist of a hydronic coil, drain pan, and centrifugal fan with motor and drive mounted in a common cabinet. Drive location and coil connections are independent for the same or opposite side location. Unit shall have with knockouts in all four corners for installing the unit suspended from the ceiling with threaded rods.

C. Casings (structural components) shall be constructed of 18-gauge galvanized steel, insulated with 1”, 1-1/2 lb density fiberglass fire resistant and odorless glass fiber material to provide thermal and acoustical insulation. Fan housing sides shall be directly attached to the top and bottom panels strengthening the entire unit assembly. Coil access panels shall be located on
both sides of the unit and allow easy removal of the internal coils and drain pan. Main access panels shall provide access to the fan, motor and drive from both sides of the air handler.

D. Water Coils

1. Cooling coils shall be chilled water with number of rows as scheduled.

2. Heating coils shall be hot water with number of rows as scheduled. Heating coils shall be factory installed in the reheat position.

3. Coils shall be 12 fins per inch with aluminum fins, mechanically bonded to seamless copper tubes. Coils shall be factory tested with 450 psi air under water. Maximum standard operating conditions are: 300 psig, 200°F. Sweat type connections are standard.

E. Fan shall be forward curved, centrifugal blower type equipped with heavy-duty adjustable speed V-belt drive. The fan shaft shall be supported by heavy-duty, permanently sealed ball bearings. Fans shall be dynamically balanced.

F. The drain pan shall be stainless steel and double-sloped to allow condensate drainage. Coils shall mount above the drain pan. The drain pan shall be removable for cleaning. The drain pan connection shall be ¾” NPT schedule 40 stainless steel pipe. The main drain connection shall be at the lowest point of the drain pan. An auxiliary drain connection shall be provided on the same side as the main connection.

G. Filters: 2” pleated standard efficiency (30%) filters shall be provided. Provide an angle filter rack sized for less than 300 feet per minute at nominal airflow. Units and filter racks shall use standard filter sizes.

H. Control Interface

1. The control interface shall be provided for use with a field supplied controller. The control box shall contain: line voltage to 24 volt transformer; a one, two, or three-pole contactor; and a disconnect switch. The wires from the fan contactor and the low voltage side of the transformer shall be pulled and terminated on the inside of the two-sided terminal strip. Customer connections other than power shall be on the outside of the two-sided terminal strips.

2.32. CENTRIFUGAL VENT SET FAN

A. Manufacturer:

1. Airfoil Wheel: Greenheck Model AFSW-21, or equal by Cook or Twin City.

2. Backward Inclined Wheel: Greenheck Model BISW-21, or equal by Cook or Twin City

B. General: Fans are to be equipped with lifting lugs. After fabrication carbon steel components shall be cleaned and chemically treated by a phosphatizing process to insure proper removal of grease, oil, scale, etc. Fan shall then be coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked. Finish color shall be industrial gray. Coating must exceed 1,000-hour salt spray under ASTM B117 test method.
C. Fan Housing and Outlet: Fan housing is to be aerodynamically designed with high-efficiency inlet, engineered to reduce incoming air turbulence. Fan sizes 7 through 49 shall be of airtight construction with the scroll panel material formed and embedded into the side panels. The housings on all fan sizes greater than 49 shall be of continuously welded heavy gauge steel. Interior and exterior surface steel shall be coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked. Finish color shall be gray. No uncoated metal fan parts will be allowed. Housing and bearing support shall be constructed of welded structural steel members to prevent vibration and rigidly support the shaft and bearings. An OSHA compliant belt guard shall be included to completely cover the motor pulley and belt(s).

D. Fan Wheel: The fan wheel shall be of the non-overloading single width airfoil centrifugal type. Wheels shall be statically and dynamically balanced to balance grade G6.3 per ANSI S2.19. Fan wheel shall be manufactured with continuously welded steel airfoils and coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked. Finish color shall be industrial gray. The wheel and fan inlet shall be carefully matched and shall have precise running tolerances for maximum performance and operating efficiency.

E. Fan Motors and Drive:

1. Drive belts and sheaves shall be sized for 150% of the fan operating brake horsepower, and shall be readily and easily accessible for service, if required.

2. Fan shaft to be turned and polished steel that is sized so the first critical speed is at least 25% over the maximum operating speed for each pressure class.

3. Fan shaft bearings shall heavy-duty grease lubricated, self-aligning or roller pillow block type. Bearings shall be designed with low swivel torque to allow the outer race of the bearing to pivot or swivel within the cast pillow block. Bearings shall be 100% tested for noise and vibration by the manufacturer. Bearings shall be 100% tested to insure the inner race diameter is within tolerance to prevent vibration. Bearings shall be selected for a basic rating fatigue life (L-10) of 80,000 hours at maximum operating speed for each pressure class {Average Life or (L-50) of 400,000 hours}. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, which reduce vibration, increase service life, and improve serviceability. Bearings that use set screws shall not be allowed. Bearings shall have Zerk fittings to allow for lubrication.

2.33. CENTRIFUGAL IN-LINE FAN

A. Manufacturer: Greenheck Model BSQ, or equal by Cook or Twin City.

B. General Description: Backward inclined centrifugal in-line fan. Each fan shall bear a permanently affixed manufacture's engraved metal nameplate containing the model number and individual serial number.

C. Wheel: Wheel shall be non-overloading, backward inclined centrifugal type, constructed of aluminum, statically and dynamically balanced in accordance to AMCA Standard 204-05. The wheel cone and fan inlet will be matched and shall have precise running tolerances for maximum performance and operating efficiency. Single thickness blades are securely riveted or welded to a heavy gauge back plate and wheel cone.
D. Motors: Motor enclosures shall be as indicated on equipment schedule. Motors shall be permanently lubricated, heavy duty ball bearing type to match with the fan load and pre-wired to the specific voltage and phase.

E. Shafts and Bearings: Fan shaft shall be ground and polished solid steel with an anti-corrosive coating. Bearing shall be permanently sealed bearings or pillow block ball bearings. Bearing shall be selected for a minimum L10 life in excess of 100,000 hours (equivalent to L50 average life of 500,000 hours), at maximum cataloged operating speed. Fan Shaft first critical speed is at least 25 percent over maximum operating speed.

F. Housing/Cabinet Construction: Square design constructed of heavy gauge galvanized steel and shall include square duct mounting collars. Housing and bearing supports shall be constructed of heavy gauge bolted and welded steel construction to prevent vibration and to rigidly support the shaft and bearing assembly.

G. Housing Supports and Drive Frame: Housing supports are constructed of structural steel with formed flanges. Drive frame is welded steel which supports the shaft and bearings and reinforcement for the housing. Pivoting motor plate with adjusting screws to make belt tensioning operations.

H. Drive Assembly:
   1. Belts, pulleys, and keys shall be sized for a minimum of 150 percent of driven horsepower
   2. Belts: Static free and oil resistant
   3. Pulleys: Cast type, keyed, and securely attached to wheel and motor shafts. Motor pulleys are adjustable for final system balancing
   4. Readily accessible for maintenance

I. Duct Collars: Square design to provide a large discharge area. Inlet and discharge collars provide easy duct connection.

J. Access Panel: Two sided access panels shall permit easy access to internal components and shall be located perpendicular to the motor mounting panel.

K. Options:
   2. Belt Type: Grip Notch
   3. Finish: Coating type: Polyester Urethane
   4. Inlet and Outlet Guards: Constructed of expanded metal mounted in a steel frame to provide protection for non-ducted installations.
2.34. ROOF MOUNTED TUBULAR CENTRIFUGAL IN-LINE FAN

A. Manufacturer:

1. Suspended: Greenheck Model TCB, or equal by Cook or Twin City.

2. Roof Mounted: Greenheck Model TCB-RU, or equal by Cook or Twin City.

B. General: Each fan shall be belt driven in AMCA arrangement 9 only with wheel secured to the fan shaft. Fans are to be equipped with lifting lugs. After fabrication carbon steel components shall be cleaned and chemically treated by a phosphatizing process to insure proper removal of grease, oil, scale, etc. Fan shall then be coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked. Finish color shall be industrial gray. Coating must exceed 1,000-hour salt spray under ASTM B117 test method.

C. Fan Housing and Outlet:

1. Fan housing shall be aerodynamically designed with punched inlet and outlet flanges for ductwork connection on inline fans. Fan housing shall be constructed of rolled steel with a continuous seam weld. Housing and bearing support shall be constructed of welded structural steel members to prevent vibration and rigidly support the shaft and bearings. Either an OSHA compliant weatherhood, or an OSHA compliant belt guard shall be included to completely cover the motor pulley and belt(s).

2. Roof mounted fans shall have the following additional requirements:
   a. Curb cap shall be constructed of painted steel and welded to the fan housing.
   b. Windbands shall be constructed of heavy gauge painted steel with reinforced edges and bolted seams.
   c. Butterfly dampers are to be supplied on all fans size 18 and greater. For fans smaller than size 18, stack cap dampers shall be provided. Dampers shall be constructed of aluminum.

D. Fan Wheel: The fan wheel shall be of the non-overloading backward inclined centrifugal type. Wheels shall be statically and dynamically balanced to balance grade G6.3 per ANSI S2.19. Wheel shall be constructed with completely welded aluminum. The maximum pressure capabilities shall be 4.5 inches W.G. The wheel and fan inlet shall be carefully matched and shall have precise running tolerances for maximum performance and operating efficiency.

E. Fan Motors and Drive:

1. Drive belts and sheaves shall be sized for 150% of the fan operating brake horsepower, and shall be readily and easily accessible for service, if required.

2. Fan shaft to be turned and polished steel that is sized so the first critical speed is at least 25% over the maximum operating speed for each pressure class.
3. Fan shaft bearings shall be heavy-duty grease lubricated, self-aligning or roller pillow block type. Bearings shall be designed with low swivel torque to allow the outer race of the bearing to pivot or swivel within the cast pillow block. Bearings shall be 100% tested for noise and vibration by the manufacturer. Bearings shall be 100% tested to insure the inner race diameter is within tolerance to prevent vibration. Bearings shall be selected for a basic rating fatigue life (L-10) of 80,000 hours at maximum operating speed for each pressure class {Average Life or (L-50) of 400,000 hours}. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, which reduce vibration, increase service life, and improve serviceability. Bearings that use set screws shall not be allowed. Bearings shall have extended lube lines with Zerk fittings to allow for lubrication.

2.35. LABORATORY EXHAUST FANS

A. Manufacturer: Greenheck Model Vector-H, Cook or approved equal.

B. General: Each fan shall be belt driven. Fans shall be equipped with lifting lugs. Fan to be coated steel with a minimum of 4 mils of Hi-Pro Polyester Resin. Color to be gray. Fasteners shall be stainless steel. Fan assembly shall be designed for a minimum of 125 MPH wind loading, without the use of guy wires.

C. Corrosion Resistant Coating

1. Fan and system components (fan, nozzle, wind band, plenum) shall be corrosion resistant coated with a two part electrostatically applied and baked, sustainable, corrosion resistant coating system; or Heresite P-413C. Standard finish color to be gray.

2. Parts shall be cleaned and chemically prepared for coating using a multi-stage wash system which includes acid pickling that removes oxide, increases surface area, and improves coating bond to the substrate.

3. The first powder coat applied over the prepared surface shall be a zinc rich epoxy primer (no less than 70% zinc) and heated to a gelatinous consistency (partial cure) at which the second powder coat of polyester resin shall be electrostatically applied and simultaneously be cured at a uniform temperature of 400°F.

4. The coating system shall not be less than a total thickness of 6 mils, is not affected by the UV component of sunlight (does not chalk), and has superior corrosion resistance to acid, alkali, and solvents. Coating system shall exceed 4000 hour ASTM B117 Salt Spray Resistance.

D. Fan Housing and Outlet:

1. Fan housing shall be aerodynamically designed with high-efficiency inlet, engineered to reduce incoming air turbulence. Fan housing shall be welded steel with a minimum of 4 mils of Hi-Pro Polyester Resin. No uncoated metal fan parts shall be acceptable.

2. A high velocity conical discharge nozzle shall be supplied by the fan manufacturer and be designed to efficiently handle an outlet velocity of up to 6000 FPM. Discharge stack caps or hinged covers, impeding exhaust flow shall not be permitted.
3. Provide housing drain for removal of rain and condensation.

4. A bolted and gasketed access door shall be supplied in the fan housing allowing for impeller inspection or removal of impeller, shaft and bearings without removal of the fan housing.

E. Fan Impeller shall be centrifugal, backward inclined, with non-stall characteristics. The impeller shall be electronically balanced both statically and dynamically per AMCA Standard 204. Fan impeller shall be manufactured of aluminum (AMCA type B spark resistant), fully welded and meet specification section 2.15 for corrosion resistant coating.

F. Bypass Air Plenum:

1. The plenum shall be equipped with a bypass air damper and intake air hood with bird screen for introducing outside air at roof level upstream of the fan. The plenum shall be constructed of fully welded steel, meet specification section 2.32.3 for corrosion resistant coating, and mount on roof curb as shown on the project drawings. Plenums that are fabricated of plastics or resins that are combustible and have mechanical properties less than steel shall not be acceptable.

2. The bypass air plenum shall be mounted on factory fabricated roof curb provided by the fan manufacturer.

3. Bypass air dampers shall be opposed-blade design, and coated with a minimum of 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked.

4. A fan isolation damper, either gravity back draft or two position actuated, fabricated of steel or aluminum and coated with minimum 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked, shall be provided as shown on the project documents.

5. Vibration isolation shall be limited to neoprene / cork vibration pads.

G. Bypass Air Plenum Curb: Exhaust system manufacturer shall supply a structural support curb for the plenum, of specified height, as shown on the drawings. Curb shall be fabricated of a minimum of 12 gauge corrosion resistant coated steel and structurally reinforced. Curbs shall be insulated. When properly anchored to the roof structure, the standard curb / plenum / blower assembly shall withstand wind loads of up to 125 mph without additional structural support.

H. Fan Motors and Drive

1. Motors shall be premium efficiency, standard NEMA frame, TEFC with a 1.15 service factor. A factory mounted NEMA 3R disconnect switch shall be provided for each fan. Motor maintenance shall be accomplished without fan impeller removal or requiring maintenance personnel to access the contaminated exhaust components.

2. Drive belts and sheaves shall be sized for 200% of the motor horsepower, and shall be readily and easily accessible for service, if required. Drive shall consist of a minimum of two belts under all circumstances.

3. Shaft to be polished and ground steel.
4. Fan shaft bearings shall be ball or roller pillow block type and be sized for an L-10 life of no less than 100,000 hours. Bearings shall be fixed to the fan shaft using concentric mounting locking collars, which reduce vibration, increase service life, and improve serviceability. Bearings that use set screws shall not be allowed. Bearings shall have extended lube lines with Zerk fittings.

2.36. GRAVITY VENTILATOR

A. Manufacturer:

1. Intake: Greenheck Model FHI, or equal by Cook or Twin City.

2. Relief: Greenheck Model FHR, or equal by Cook or Twin City.

B. Gravity roof ventilators shall be constructed of heavy gauge aluminum or galvanized steel as specified.

C. Hoods shall be constructed of precision formed, arched panels with interlocking seams.

D. Bases shall be constructed so that the curb cap is 8” larger than the throat size. Standard base height shall be 5”.

1. 12” bases shall be furnished for intake applications to restrict entry of moisture and for all applications where rain and snow may accumulate on the roof deck.

E. Hood support members shall be constructed of galvanized steel and fastened so that the hood can be either removed completely from the base or hinged open.

F. Birdscreens constructed of ½” galvanized steel mesh shall be mounted horizontally across the intake/discharge area of the hood.

2.37. UPBLAST CENTRIFUGAL ROOF EXHAUST FAN

A. Manufacturer: Greenheck Model CUBE, or equal by Cook or Twin City.

B. General Description: Upblast fan shall be for roof mounted applications to discharge air up and away from the mounting surface. Each fan shall bear a permanently affixed manufacturer's engraved metal nameplate containing the model number and individual serial number.

C. Wheel shall be aluminum, non-overloading, backward inclined centrifugal, statically and dynamically balanced in accordance to AMCA Standard 204-05. The wheel cone and fan inlet will be matched and shall have precise running tolerances for maximum performance and operating efficiency.

D. Motors: Motor enclosures shall be as scheduled. Motors are permanently lubricated, heavy duty ball bearing type to match with the fan load and furnished at the specific voltage and phase. Motors shall be mounted on vibration isolators, out of the airstream. For motor cooling there shall be fresh air drawn into the motor compartment through an area free of discharge contaminants. Motors shall be accessible for maintenance.
E. Shafts and Bearings:

1. Fan shaft shall be ground and polished solid steel with an anti corrosive coating. Fan Shaft first critical speed shall be at least 25 percent over maximum operating speed.

2. Bearings shall be permanently sealed bearings or pillow block ball bearings. Bearing shall be selected for a minimum L10 life in excess of 100,000 hours (equivalent to L50 average life of 500,000 hours), at maximum cataloged operating speed. Bearings are 100 percent factory tested

F. Housing:

1. Housing shall be constructed of heavy gauge aluminum includes exterior housing, curb cap, windband, and motor compartment housing. Galvanized material is not acceptable. Housing shall have a rigid internal support structure.

2. Windband to be one piece uniquely spun aluminum construction and maintain original material thickness throughout the housing. Windband to include an integral rolled bead for strength.

3. Curb cap base to be fully welded to windband to ensure a leak proof construction. Tack welding, bolting, and caulking are not acceptable. Curb cap to have integral deep spun inlet venturi and pre-punched mounting holes to ensure correct attachment to curb.

4. Drive frame assemblies shall be constructed of heavy gauge steel and mounted on vibration isolators.

5. Breather tube shall be 10 square inches in size for fresh air motor cooling, and designed to allow wiring to be run through it.

G. Drive Assembly: Belts, pulleys, and keys oversized for a minimum of 150 percent of driven horsepower. Belts shall be static free and oil resistant. Pulleys shall be fully machined cast iron type, keyed and securely attached to the wheel and motor shafts. The motor pulley shall be adjustable for final system balancing. The drive assembly shall be readily accessible for maintenance

H. Options/Accessories:

1. Auto Belt Tensioner

2. Aluminum Birdscreen

3. Curb Seal

4. Dampers: Gravity type, balanced for minimal resistance to flow with galvanized frames having pre-punched mounting holes

5. Aluminum Hinge Base

6. Heat Baffle: 1 inch thick insulation shield
7. Roof Curbs: galvanized with 1-inch insulation

2.38. HOT WATER BOILER

A. The boiler shall be constructed for indoor use and forced draft, factory "packaged" low pressure hot water boilers. Each boiler shall be complete with components, accessories and appurtenances necessary for a complete and operable boiler as hereinafter specified. Each unit shall be furnished factory assembled with required wiring and piping as a self-contained unit. Each unit shall be readily transported and ready for installation. Complete unit shall comply with all requirements of state and local codes. Boiler shall be equipped for IRI approval.

B. Each boiler, including pressure vessel, trim, valve trains, burner, control system, and related components, accessories and appurtenances as herein specified shall be assembled and furnished by the boiler manufacturer. The boiler manufacturer shall provide unit responsibility for the workmanship, performance, warranties, and field services for each boiler as specified herein. The boiler manufacturer shall be fully responsible for components assembled and furnished by him whether or not they are of his own manufacture.

C. Performance Criteria:

1. Each boiler shall be capable of operating continuously at rated capacity while maintaining CSA certified thermal efficiency of not less than 85 %.

2. Boiler operating pressure shall be 100 psig.

3. Boiler design pressure shall be 160 psig.

4. Fuel shall be natural gas with an assumed higher heating value of 1,030 Btu/Cu Ft and an assumed specific gravity of 0.60 (relative to air). Natural gas shall be supplied at a pressure of no less than (4 in wc with a flue gas back pressure \( \leq 1 \) in wc or 5 in wc with flue gas back pressure \( > 1 \) in wc) and no more than 14” w.c. to the inlet of the gas train.

D. Boiler Design:

1. Each hot water boiler shall be of the vertical, water-tube, copper fin tube heat exchanger type complete with trim, valve trains, burner, and boiler control system. The boiler manufacturer shall fully coordinate the boiler as to the interaction of its elements with the burner and the boiler control system in order to provide the required capacities, efficiencies, and performance as specified.

2. Each boiler heat exchanger shall be of the vertical, concentric, copper fin tube type with three pass, counter-flow design.

3. Boiler pressure parts shall be constructed in accordance with the latest revision of the ASME Boiler and Pressure Vessel Code, Section IV, and shall be so stamped along with a National Board Registration number.

4. Boiler heat exchanger tubes shall be not less than 7/8” I.D. with a wall thickness of not less than 0.065" thick. Boiler heat exchanger tubes shall be straight, solid copper tubes and shall incorporate an "extended" finned surface of integral, extruded, copper fins
spaced not less than 7 fins per inch. Boiler heat exchanger tubes shall be arranged vertically. Tubes must be full size for the entire length of each tube and extend from the upper header to the lower header with no tube bends. Boiler tubes shall be arranged and spaced for the most effective distribution of combustion gas flow through the entire boiler heat exchanger to provide for maximum heat transfer. Baffles between tubes shall be unacceptable.

5. Boiler heat exchanger headers shall be cast gray iron with end covers completely removable for inspection. Seals shall be EPDM o-rings, rated for 400°F service. Gaskets are not acceptable.

6. Boiler heat exchanger tubes shall be rolled into the top and bottom header collectors.

7. Boiler combustion chamber shall be fabricated from minimum 14 gauge aluminum, shall completely enclose the boiler heat exchanger and shall be sealed for positive pressure operation. The combustion chamber access panel shall be readily removable and reinstalled.

8. Boiler shall be enclosed with a single wall outer casing. It shall completely enclose the boiler combustion chamber. It shall be fabricated from carbon steel with aluminum access panels. Steel casing sections shall be secured in place with bolts (sheet metal screws are not acceptable). Access panels shall be secured with push-to-close, quarter turn to open fasteners. The complete outer casing shall be finished inside and out with a powder coated finish. Combustion air shall be drawn from the insulating air space between the combustion chamber and the outer casing. The composite structure of the boiler combustion chamber, insulating air gap and outer casing shall be of such thickness and materials to assure an outer casing temperature of not more than 50°F above ambient temperature when the boiler is operated at full rated load. Boiler shall be fully capable of operation with all casing access panels removed.

9. An observation port shall be located on the boiler to allow for observation of the burner flame.

10. A flue gas outlet shall be located on the rear of the boiler. Boiler to be certified for installation with Category IV venting (stack) as defined in NFPA 54 (ANSI Z221). Forced draft burner shall be capable of firing against a back pressure of 2.0 in wc, using 6 inch diameter vent.

E. Boiler Trim:

1. Each boiler shall be provided with necessary trim. Boiler trim shall be as follows:
   a. One safety valve shall be provided in compliance with the ASME code.
   b. One water pressure-temperature gauge.
   c. One primary low water flow fuel cutoff. The primary low water flow cutoff shall be a flow switch as required by ASME Code.
d. One high limit water temperature controller to stop burner operation at excess water temperature (shall be manually reset).

e. One operating temperature control to control the sequential operation of the burner.

f. One secondary low water level fuel cutoff. The secondary low water level cutoff shall be a separate manual reset probe type controller.

F. Boiler Fuel Burning System:

1. The boiler manufacturer shall furnish each boiler with an integral, pre-mixed, forced draft, gas, fully automatic fuel burner. The fuel burner shall be an assembly of gas burner, combustion air blower, valve train, and ignition system. The boiler manufacturer shall fully coordinate the burner as to the interaction of its elements with the boiler heat exchanger and the boiler control system in order to provide the required capacities, efficiencies, and performance as specified.

2. Each burner shall be provided with an integral gas firing combustion head, properly sized to admit the fuel gas to the burner. The gas combustion head shall be provided with an orifice plate to meter the air flow to the burner and maintain precise fuel-to-air mixture. Air and gas shall be mixed as they pass through the blower to assure maximum combustion efficiency. Each burner shall provide adequate turbulence and mixing to achieve proper combustion without producing smoke or producing combustibles in the flue gases.

3. Each boiler shall be provided with an integral power blower to supply combustion air. The combustion air blower shall have sufficient capacity at the rated firing rate to provide air for stoichiometric combustion plus the necessary excess air. Static and total pressure capability shall comply with the requirements of the boiler. The blower motor shall be a maximum of 1 motor horsepower and operate without undue vibration and noise and shall be designed and constructed for exposure to temperatures normal to its location on the boiler. The fan impeller shall be the non-sparking type, high efficiency, airfoil, backward inclined design.

4. Each burner shall of the radial-fired type and constructed of steel with a stainless steel inner and woven stainless steel mesh outer screen, designed to produce a complete 360° flame pattern.

5. Each boiler shall be provided with a “Full Modulating” firing control system whereby the firing rate is infinitely proportional at any point between 20% and 100% of maximum firing rate as determined by the input control signal. Fuel flow shall be controlled by air flow with cross-linked combination gas valve and air-fuel ratio controller. Both fuel and air control shall be completely “linkageless” to assure the proper fuel/air ratios to achieve maximum combustion efficiency.

6. The combustion control system shall automatically compensate for changes to atmospheric pressure and/or inlet air temperature.

7. Burner shall incorporate soft start controls, which controls the ramp up speed of the burner.
8. The burners shall be supplied with a fan assisted, clean burning, highly efficient fuel-air mixture. The boiler shall comply with all local and national air quality regulations for low NOX boilers and shall emit less than 20 PPM NOX.

G. Main Gas Valve Train:

1. Each boiler shall be provided with an integral main gas valve train. The main gas valve trains shall be factory assembled, piped, and wired. Each gas valve train shall include at least the following:
   
a. Two manual shutoff valves (gas train inlet connection & mixer inlet).
   
b. Two safety shutoff valves.
   
c. Linkageless Air: Gas ratio control (maximum inlet pressure 14” w.c.).
   
d. One low and one high gas pressure switch (manual reset).
   
e. Air gas mixer.
   
f. Gas pressure regulator.

H. Ignition System:

1. Each boiler shall be provided with a factory installed, integral, interrupted electronic ignition system. Ignition system shall be removable for maintenance or replacement. Each ignition system shall include at least the following:
   
a. A back pressure limit switch to shut down the burner in the event of a blocked vent.
   
b. An electronic spark generator with ignition cable and ignition electrode.

I. Combustion Air Control System:

1. Each boiler shall be provided with an integral combustion air control system. The combustion air system shall be factory assembled. Each combustion air control system shall include at least the following:
   
a. A variable speed combustion air blower controlled using water temperature as the process variable.
   
b. A low airflow differential pressure switch to insure that combustion air is supplied.
   
c. An air inlet check valve shall be installed on the inlet flange to prevent reverse airflow in the cabinet.
J. Burner Control System:

1. A microprocessor based controller shall control burner functioning. If burner fails to light within 5 minutes after call for heat, the inverter shall enter a lockout condition requiring a manual reset. The controller shall perform the following control functions:
   a. Modulation controller.
   b. Boiler circulator time delay relay (off delay).
   c. Flame status and firing rate output.
   d. Operating temperature control shall be selectable for one of the following points:
      1) Boiler outlet temperature
      2) Header temperature
      3) Domestic hot water
      4) Remote control
      5) Boiler outdoor air reset
   e. Recycle the flame safeguard controller at least once in each 24 hour time period to reset the self check circuit of the UV scanner as required by the UV scanner manufacturer.

2. Main flame shall be monitored and controlled by an ultra violet scanner. The boiler shall have a CSA approved, commercial-type, microprocessor based flame safeguard programmer with a flame failure response time of 0.8 seconds maximum. Controller shall have non-volatile diagnostic memory capable of maintaining operational history.

3. Each boiler shall be provided with necessary controls, necessary programming sequences, and safety interlocks. Each boiler control system shall be properly interlocked with safeties.

4. Each boiler control system shall provide timed sequence pre- and post-purge of boiler combustion chamber. The combustion airflow sensor shall monitor and prove the airflow purge.

K. Boiler Control Panel:

1. The boiler manufacturer shall provide each boiler with an integral factory prewired control panel. The control panel shall contain at least the following components, prewired to a numbered terminal strip:
   a. Inverter/Combustion Air Blower Speed Controller.
   b. Burner "on-off" switch.
c. Electronic flame safeguard programmer.

d. Control switches to select between local or BMS control of the following functions:

1) Enable-Disable

2) Modulation

e. A auto-manual firing rate controller

f. Diagnostic annunciator indicating lights to signal "Power On", "Demand for Heat", "Low Water Flow", "Low Gas Pressure", "Low Combustion Air", and "Flame Failure".

g. Air Flow Switch.

h. High Water Temperature Limit.

i. Necessary control switches, pushbuttons, relays, timers, terminal strips, etc.

L. Factory Testing

1. Each boiler shall be hydrostatically tested. The boiler manufacturer shall perform a hydrostatic test in the presence of an inspector having a National Board Commission. The inspector shall certify a data report which shall be submitted to the engineer as evidence of ASME compliance.

2. The boiler manufacturer shall perform a fire test under simulated operating conditions, with the boiler attached to a working chimney system and with water circulating through the heat exchanger. Controls and limits shall be tested. Results of combustion testing shall be recorded on a label, which is permanently attached to the boiler.

M. The start-up of boiler shall be performed by a certified manufacturer’s technician. The technician shall start-up, adjust, calibrate the boiler and instruct the owner’s operation personnel. Provide combustion and start-up report after the completion of start-up.

N. Manufacturer shall be “Patterson-Kelly” or approved equal.

2.39. PUMPS BASE MOUNTED

A. General: Pumps shall be base mounted, end suction, single stage, centrifugal type, bronze fitted. Capacities and horsepower shall be as indicated in the equipment schedule on the drawings. Each pump shall be factory tested. Provide factory certified report.

B. Casing shall be cast iron, vertical split, designed for maximum working pressure of 175 psig with 125 lb. ANSI flange drilling, and suction and discharge. Casing shall be furnished with tappings for gauge, vent and drain fittings.
C. The impeller shall be cast bronze, enclosed type, dynamically balanced for vibration less operation. The impeller shall be keyed to the shaft and secured with a locking cap screw.

D. Motor: The motor shall meet NEMA TEFC weatherproof specifications and shall be the size and voltage called for on the plans. Pump and motor shall be factory aligned and shall be realigned by Contractor after installation. The motor shall have maximum speed of 1750 rpm and shall pump through its characteristics curve without exceeding rated full load nameplate horsepower. Nameplate rating shall not be exceeded in pump operation anywhere on pump curve. Minimum design life for regreasable ball bearings shall be 15,000 hours based on AFBMA B-10 rating.

E. Motor Coupling: Flexible type coupler equipped with OSHA approved coupling guard.

F. Seals shall be standard, single mechanical type with ceramic seal seat and carbon seal ring, suitable for 225°F water circulating service.

G. Shaft: Bronze.

H. Manufacturer: Design based on “Bell and Gossett” Series 1510. Equal products by “Paco”, or “Aurora”, may be submitted for approval, but must fit in space allotted.

2.40. IN-LINE PUMPS

A. General: The pump shall be in-line, centrifugal type, bronze fitted. The unit shall be arranged for vertically mounted motor. Capacities and horsepower shall be as indicated in the Equipment Schedule on the drawings. Each pump shall be factory tested.

B. Casing shall be cast iron, designed for maximum working pressure of 175 PSIG with 125 lb., ANSI flange drilling and suction and discharge of equal size. Casing shall be furnished with tapings for gauge and drain fittings.

C. The impeller shall be bronze, dynamically and hydraulically balanced for vibration less operation. The impeller shall be keyed to the shaft and secured with a locknut and impeller washer.

D. Motor shall be standard NEMA JM and JP vertical solid shaft.

E. Manufacturer: Design based on “Bell and Gossett” Series 80. Equal products by “Paco”, or “Aurora” may be submitted for approval, but must fit in space allotted.

2.41. AIR-COOLED CONDENSING UNIT (5 TON AND UNDER)

A. Manufacturers: Trane Model 4TTB or equal by Carrier or York.

B. General: Factory assembled and tested air cooled condensing units, consisting of casing, compressors, condensers, coils, condenser fans and motors, and unit controls.

C. Unit Casings: Exposed casing surfaces constructed of galvanized steel with manufacturer's standard baked enamel finish. Designed for outdoor installation and complete with weather...
protection for components and controls, and complete with removable panels for required access to compressors, controls, condenser fans, motors, and drives.

D. Compressor: Single refrigeration circuit with hermetic reciprocating type compressors, resiliently mounted, with positive lubrication, and internal motor overload protection.

E. Condenser Coil: Constructed of copper tubing mechanically bonded to copper fins, factory leak and pressure tested.

F. Controls: Furnish operating and safety controls including high and low pressure cutouts. Control transformer. Furnish magnetic contactors for compressor and condenser fan motors.


H. Condensing Unit Accessories: Furnish the following accessories:
   1. Time delay relay.
   2. Anti-short cycle timer.
   3. Disconnect switch.
   5. Coil with corrosion resistant coating capable of withstanding salt spray test of 1000 hours in accordance with ASTM B117.

I. Refrigeration specialties: Furnish the following:
   1. Charge of compressor oil.
   2. Holding charge of refrigerant.
   3. Replaceable core type filter drier.
   4. Liquid line sight glass and moisture indicator.
   5. Shut-off valves on suction and liquid piping.
   6. Liquid line solenoid valve.
   7. Charging valve.
   8. Oil level sight glass.
   9. Crankcase heater.
11. Pressure relief device.

J. Refrigerant: Furnish charge of refrigerant R-410A.

2.42. DIRECT EXPANSION FAN COIL (5 TON AND UNDER)

A. Manufacturers: Trane Model 4TEC or equal by Carrier or York.

B. Configuration: As indicated on Drawings.

C. Cabinet:


2. Insulation: Factory applied to each surface to insulate entire cabinet. One inch thick aluminum foil faced glass fiber with edges protected from erosion.

D. Evaporator Fan: Forward curved centrifugal type, resiliently mounted with direct drive and high efficiency motor. Motor permanently lubricated with built-in thermal overload protection.

E. Evaporator Coil: Constructed of copper tubes expanded onto aluminum fins. Factory leak tested under water. Removable, PVC construction, double-sloped drain pan with piping connections on both sides.

F. Refrigeration System: Single refrigeration circuits controlled by factory installed thermal expansion valve.

G. Air Filters: 2” thick glass fiber disposable media in metal frames.

2.43. DUCT-FREE SPLIT SYSTEM

A. Manufacturer: Mitsubishi “Mr Slim” or approved equal.

B. System Description: The system shall be a split system with Variable Speed Inverter Compressor technology. The system shall consist of a wall mounted indoor section with wired, wall mounted controller and a horizontal discharge, single phase outdoor unit.

C. Quality Assurance:

1. The units shall be tested by a Nationally Recognized Testing Laboratory (NRTL) and shall bear the ETL label.

2. The units shall be rated in accordance with ARI Standard 210 and bear the ARI Certification label.

3. The units shall be manufactured in a facility registered to ISO 9001 and ISO 14001.
D. Indoor Unit

1. The indoor unit cabinet shall be wall mounted by means of a factory supplied mounting plate. The cabinet shall be formed from high strength molded plastic with front panel access for filter. The indoor unit shall be factory assembled, wired and tested. Contained within the unit shall be factory wiring and internal piping, control circuit board and fan motor.

2. The unit in conjunction with the wired, wall mounted controller shall have a self-diagnostic function, 3-minute time delay mechanism, an auto restart function, and a test run switch. Indoor unit and refrigerant pipes shall be purged with dry nitrogen before shipment from the factory.

3. Fan: The evaporator fan shall be high performance, double inlet, forward curve, direct drive sirocco fan. The fans shall be statically and dynamically balanced and run on a motor with permanently lubricated bearings.

4. Vane: There shall be a motorized horizontal vane to automatically direct air flow in a horizontal and downward direction for uniform air distribution. The horizontal vane shall significantly decrease downward air resistance for lower noise levels, and shall close the outlet port when operation is stopped. There shall also be a set of vertical vanes to provide horizontal swing airflow movement selected by remote control.

5. Filter: Return air shall be filtered by means of an easily removable washable filter.

6. The evaporator coil shall be of nonferrous construction with pre-coated aluminum strake fins on copper tubing. The multi-angled heat exchanger shall have a modified fin shape that reduces air resistance for a smoother, quieter airflow. Tube joints shall be brazed with PhosCopper or silver alloy. The coils shall be pressure tested at the factory. A condensate pan and drain shall be provided under the coil.

7. Control System:
   a. The control system shall consist of two microprocessors, one on each indoor and outdoor unit. Field wiring shall run directly from the indoor unit interconnected by a single non-polar two-wire AWG-16 stranded cable to the wall mounted controller with no splices. The control system between the outdoor unit and indoor unit shall be supplied from the outdoor unit.
   b. The system shall be capable of automatic restart when power is restored after power interruption. The system shall have self-diagnostics ability, including total hours of compressor run time. Diagnostics codes for indoor and outdoor units shall be displayed on the wired controller panel.
   c. The microprocessor located in the indoor unit shall have the capability of monitoring return air temperature and indoor coil temperature, receiving and processing commands from the wired controller, providing emergency operation and controlling the outdoor unit.
d. The indoor unit shall be connected to a wall mounted wired controller to perform input functions necessary to operate the system. The wired controller shall have a large multi-language DOT liquid crystal display (LCD). There shall be a built-in weekly timer with up to eight pattern settings per day. The controller shall consist of an On/Off button, Increase/Decrease Set Temperature buttons, a Cool/Dry/Fan mode selector, a Timer Menu button, a Timer On/Off button, Set Time buttons, a Fan Speed selector, a Vane Position selector, a Louver Swing button, a Ventilation button, a Test Run button, and a Check Mode button. The controller shall have a built-in temperature sensor. Temperature shall be displayed in either Fahrenheit (°F) or Celsius (°C). Temperature changes shall be by increments of 1°F with a range of 67°F to 87°F.

e. The wired controller shall display operating conditions such as set temperature, room temperature, pipe temperatures (i.e. liquid, discharge, indoor and outdoor), compressor operating conditions (including running current, frequency, input voltage, On/Off status and operating time), LEV opening pulses, sub cooling and discharge super heat.

f. Normal operation of the wired controller shall provide individual system control in which one wired controller and one indoor unit are installed in the same room. The controller shall have the capability of controlling up to a maximum of sixteen systems at a maximum developed control cable distance of 1,500 feet.

g. The control voltage from the wired controller to the indoor unit shall be 12 volts, DC. The control signal between the indoor and outdoor unit shall be pulse signal 24 volts DC. Up to two wired controllers shall be able to be used to control one unit.

h. Control system shall control the continued operation of the air sweep louvers, as well as provide On/Off and mode switching. The controller shall have the capability to provide sequential starting with up to fifty seconds delay.

E. Outdoor Unit

1. The connected indoor unit must be of the same capacity as the outdoor unit. The outdoor unit shall be equipped with a control board that interfaces with the indoor unit to perform necessary operation functions.

2. The outdoor unit shall be capable of operating at 0°F ambient temperature without additional low ambient controls (optional wind baffle may be required).

3. The outdoor unit shall be able to operate with a maximum height difference of 100 feet indoor unit to outdoor unit,

4. System shall have a maximum refrigerant tubing length of 100 feet for the 12,000 and 18,000 and 165 feet for the 24,000, 30,000 and 36,000 between indoor and outdoor units without the need for line size changes, traps or additional oil.
5. Units shall be pre-charged for a maximum of 70 feet of refrigerant tubing. The outdoor unit shall be completely factory assembled, piped, and wired. Each unit must be test run at the factory.

6. Cabinet: The casing shall be constructed from galvanized steel plate, coated with a finished with an electrostatically applied, thermally fused acrylic or polyester powder coating for corrosion protection. The fan grille shall be of ABS plastic.

7. Fan: Units shall be furnished with an AC fan motor. The fan motor shall be of aerodynamic design for quiet operation, and the fan motor bearings shall be permanently lubricated. The outdoor unit shall have horizontal discharge airflow. The fan shall be mounted in front of the coil, pulling air across it from the rear and dispelling it through the front. The fan shall be provided with a raised guard to prevent contact with moving parts.

8. Coil: The L shaped condenser coil shall be of copper tubing with flat aluminum fins to reduce debris build up. The coil shall be protected with an integral metal guard. Refrigerant flow from the condenser shall be controlled by means of linear expansion valve (LEV) metering orifice. The LEV shall be control by a microprocessor controlled step motor.

9. Compressor: The compressor shall be a DC rotary compressor with Variable Compressor Speed Inverter Technology. The compressor shall be driven by inverter circuit to control compressor speed. The compressor speed shall dynamically vary to match the room load for significantly increasing the efficiency of the system which results in vast energy savings. To prevent liquid from accumulating in the compressor during the off cycle, a minimal amount of current shall be intermittently applied to the compressor motor to maintain enough heat. The outdoor unit shall have an accumulator and high pressure safety switch. The compressor shall be mounted to avoid the transmission of vibration.

2.44. VARIABLE FREQUENCY DRIVES

A. Manufacturer based upon ABB ACH Series. Equal product by Cutler-Hammer, Danfoss, or Reliance may be submitted for approval.

1. The drive manufacturer shall supply the drive and necessary controls as herein specified.

2. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of twenty years.

B. General:

1. This specification is to cover a complete Variable Frequency Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use on a standard NEMA Design B induction motor.

2. The VFD package as specified herein shall be enclosed in a NEMA 1 enclosure, completely assembled and tested by the manufacturer in an ISO9001 facility. The VFD tolerated voltage window shall allow the VFD to operate from a line of +30% nominal, and -35% nominal voltage as a minimum.
a. VFD located outdoors shall be enclosed in a NEMA 3R enclosure.

3. VFD’s located in the airstream shall be UL listed as a plenum rated VFD.

C. Environmental operating conditions:

1. 32°F to 104°F continuous. VFD’s that can operate at 104°F intermittently (during a 24 hour period) are not acceptable and must be oversized.

2. Altitude 0 to 3300 feet above sea level, less than 95% humidity, non-condensing.

D. Quality Assurance

1. Referenced Standards:
   a. Institute of Electrical and Electronic Engineers (IEEE)
   b. Underwriters laboratories
      1) UL508C
   c. National Electrical Manufacturer’s Association (NEMA)
      1) ICS 7.0, AC Adjustable Speed Drives
   d. IEC 16800 Parts 1 and 2

2. Qualifications:
   a. VFDs and options shall be UL listed as a complete assembly. VFD’s that require the customer to supply external fuses for the VFD to be UL listed are not acceptable. The base VFD shall be UL listed for 100 KAIC without the need for input fuses.

E. Frequency Control Specifications: VFD input voltage shall be adjustable at 440/460/480/500 VAC, 3 phase, 48 – 63 Hertz to meet the actual line voltage at the site. Voltage tolerance shall be 500 VAC + 10% (550) and 440 VAC – 10% (396).

F. VFDs shall have the following standard features:

1. VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.

2. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate “bumpless transfer” of speed reference when switching between “Hand”
and “Auto” modes. There shall be fault reset and “Help” buttons on the keypad. The Help button shall include “on-line” assistance for programming and troubleshooting.

3. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. If the battery fails, the VFD shall automatically revert to hours of operation since initial power up. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter sets and output relays. The VFD shall have a digital input that allows an override to the time clock (when in the off mode) for a programmable time frame. There shall be four separate, independent timer functions that have both weekday and weekend settings.

4. The VFD’s shall utilize pre-programmed application macros specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.

5. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required. To extend the fan and bearing operating life, operating temperature will be monitored and used to cycle the fans on and off as required.

6. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to setpoint without safety tripping or component damage (flying start).

7. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.

8. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430-150 for 4-pole motors.

9. The VFD shall have integral 5% impedance line reactors to reduce the harmonics to the power line and to add protection from AC line transients. The 5% impedance may be from dual (positive and negative DC bus) reactors, or 5% AC line reactors. VFD’s with only one DC reactor shall add AC line reactors.

10. The input current rating of the VFD shall be no more than 3% greater than the output current rating. VFD’s with higher input current ratings require the upstream wiring, protection devices and source transformers to be oversized per NEC 430-2.

11. The VFD shall include a coordinated AC transient protection system consisting of 4-120 joule rated MOV’s (phase to phase and phase to ground), a capacitor clamp, and 5% impedance reactors.
12. The VFD shall be capable of sensing a loss of load (broken belt / broken coupling) and signal the loss of load condition. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. Relay outputs shall include programmable time delays that will allow for drive acceleration from zero speed without signaling a false underload condition.

13. If the input reference (4-20mA or 2-10V) is lost, the VFD shall be programmable to signal the condition via keypad warning, relay output, and/or over the serial communication bus and shall give the user the option of either:

   a. Stopping and displaying a fault
   b. Running at a programmable preset speed

14. Hold the VFD speed based on the last good reference received

   a. Cause a warning to be issued, as selected by the user.

15. The VFD shall have programmable “Sleep” and “Wake up” functions to allow the drive to be started and stopped from the level of a process feedback signal.

G. VFDs to have the following adjustments:

1. Three programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.

2. Two PID Setpoint controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. The VFD shall have 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID setpoint shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two parameter sets for the first PID that allow the sets to be switched via a digital input, serial communications or from the keypad for night setback, summer/winter setpoints, etc. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain setpoint of an independent process (i.e. valves, dampers, etc.). Setpoints, process variables, etc. to be accessible from the serial communication network. The setpoints shall be set in Engineering units and not require a percentage of the transducer input.

3. Two programmable analog inputs shall accept current or voltage signals.

4. Two programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, and other data.

5. Six programmable digital inputs for maximum flexibility in interfacing with external devices, typically programmed as follows:
a. There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications) the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to an VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. The keypad shall display “start enable 1 (or 2) missing”. The safety status shall also be transmitted over the serial communications bus. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC.

6. Three programmable digital Form-C relay outputs. The relays shall include programmable on and off delay times and adjustable hysteresis. Default settings shall be for run, not faulted (fail safe), and run permissive. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating 2 amps RMS. Outputs shall be true form C type contacts; open collector outputs are not acceptable.

7. Seven programmable preset speeds.

8. Two independently adjustable accel and decel ramps with 1–1800 seconds adjustable time ramps.

9. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and audible motor noise.

10. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows the highest carrier frequency without derating the VFD or operating at high carrier frequency only at low speeds.

11. The VFD shall include password protection against parameter changes.

H. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). The keypad shall utilize the following assistants:

1. Start-up assistants.

2. Parameter assistants

3. Maintenance assistant

4. Troubleshooting assistant

I. Applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed. The display shall be in complete English words (alpha-numeric codes are not acceptable):
1. Output Frequency
2. Motor Speed (RPM, %, or Engineering units)
3. Motor Current
4. Calculated Motor Torque
5. Calculated Motor Power (kW)
6. DC Bus Voltage
7. Output Voltage

J. The VFD shall include a firefighter’s override input. Upon receipt of a contact closure from the firefighter’s control station, the VFD shall operate at an adjustable preset speed. The mode shall override other inputs (analog/digital, serial communication, and keypad commands) and force the motor to run at the adjustable, preset speed. “Override Mode” shall be displayed on the keypad. Upon removal of the override signal, the VFD shall resume normal operation.

K. Serial Communications

1. The VFD shall have an RS-485 port as standard. The standard protocols shall be Modbus. Optional protocols for LonWorks and BACnet shall be available. Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. Protocols shall be “certified” by the governing authority. Use of non-certified protocols is not allowed.

2. The BACnet connection shall be an RS485, MSTP interface operating at 9.6, 19.2, 38.4, or 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:
   a. Data Sharing – Read Property – B.
   b. Data Sharing – Write Property – B.
   e. Device Management – Communication Control – B.

3. If additional hardware is required to obtain the BACnet interface, the VFD manufacturer shall supply one BACnet gateway per drive. Multiple VFDs sharing one gateway shall not be acceptable.

4. Serial communication capabilities shall include, but not be limited to; run-stop control, speed set adjustment, proportional/integral/derivative PID control adjustments, current
The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The DDC shall also be capable of monitoring the VFD relay output status, digital input status, and analog input and analog output values. Diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote VFD fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus – keypad “Hand” or “Auto” selected, bypass selected, the ability to change the PID setpoint, and the ability to force the unit to bypass (if bypass is specified). The DDC system shall also be able to monitor if the motor is running in the VFD mode or bypass mode (if bypass is specified) over serial communications. A minimum of 15 field parameters shall be capable of being monitored.

5. The VFD shall allow the DDC to control the drive’s digital and analog outputs via the serial interface. This control shall be independent of any VFD function. For example, the analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive’s digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, the drive’s digital and analog inputs shall be capable of being monitored by the DDC system.

6. The VFD shall include an independent PID loop for customer use. The independent PID loop may be used for cooling tower bypass value control, chilled water value control, etc. Both the VFD control PID loop and the independent PID loop shall continue functioning even if the serial communications connection is lost. The VFD shall keep the last good set-point command and last good DO & AO commands in memory in the event the serial communications connection is lost.

L. EMI / RFI filters. VFD’s shall include EMI/RFI filters. The onboard filters shall allow the VFD assemble to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level.

M. VFD’s through 50HP shall be protected from input and output power mis-wiring. The VFD shall sense this condition and display an alarm on the keypad.

N. Bypass. Provide factory mounted enhanced bypass with following features. Bypass shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

1. A complete factory wired and tested bypass system consisting of an output contactor, bypass contactor and service switch. Three contactor bypass schemes are not acceptable. Overload protection and shall be provided in both drive and bypass modes.

2. Provide door interlocked, padlockable disconnect or circuit breaker that will disconnect input power from the drive and internally mounted options.

3. Fast acting fuses exclusive to the VFD: Fast acting fuses allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs, which have no such fuses, or that incorporate fuses common
to both the VFD and the bypass will not be accepted. Three contactor bypass schemes are not acceptable.

4. The drive / bypass shall provide single-phase motor protection in both the VFD and bypass modes.

5. The following operators shall be provided:
   a. Bypass Hand-Off-Auto
   b. Drive mode selector
   c. Bypass mode selector
   d. Bypass fault reset

6. The following indicating lights (LED type) shall be provided. A test mode or push to test feature shall be provided.
   a. Power-on (Ready)
   b. Run enable (safeties) open
   c. Drive mode select damper opening
   d. Bypass mode selected
   e. Drive running
   f. Bypass running
   g. Drive fault
   h. Bypass fault
   i. Bypass H-O-A mode
   j. Automatic transfer to bypass selected
   k. Safety open

7. The following relay (form C) outputs from the bypass shall be provided:
   a. System started
   b. System running
   c. Bypass override enabled
   d. Drive fault
e. Bypass fault (motor overload or underload (broken belt))

f. Bypass H-O-A position

8. The digital inputs for the system shall accept 24V or 115VAC (selectable). The bypass shall incorporate internally sourced power supply and not require an external control power source.

9. Customer Interlock Terminal Strip: Provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass modes (not functional in Firefighter’s Override 2). The remote start/stop contact shall operate in VFD and bypass modes.

10. Dedicated digital input that will transfer motor from VFD mode to bypass mode upon dry contact closure for fireman’s override. Two modes of operation are required.

   a. One mode forces the motor to bypass operation and overrides both the VFD and bypass H-O-A switches and forces the motor to operate across the line (test mode). The system will only respond to the digital inputs and motor protections.

   b. The second firefighter’s override mode remains as above, but will also defeat the overload and single-phase protection for bypass and ignore keypad and digital inputs to the system (run until destruction).

11. The VFD shall include a “run permissive circuit” that will provide a normally open contact whenever a run command is provided (local or remote start command in VFD or bypass mode). The VFD system (VFD or bypass) shall not operate the motor until it receives a dry contact closure from a damper or valve end-switch. When the VFD system safety interlock (fire detector, freezeastat, high static pressure switch, etc) opens, the motor shall coast to a stop and the run permissive contact shall open, closing the damper or valve.

12. Class 20 electronic motor overload protection shall be included.

13. There shall be an internal switch to select manual or automatic bypass.

14. There shall be an adjustable current sensing circuit for the bypass to provide loss of load indication (broken belt) when in the bypass mode.

O. Installation

1. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

2. Power wiring shall be completed by the electrical contractor. The contractor shall complete wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
P. Certified factory start-up shall be provided for each drive by a factory authorized service center. A certified start-up form shall be filled out for each drive with a copy provided to the owner, and a copy kept on file at the manufacturer.

Q. Product Support

1. Factory trained application engineering and service personnel that are thoroughly familiar with the VFD products offered shall be locally available at both the specifying and installation locations. A 24/365 technical support line shall be available on a toll-free line.

2. A computer based training CD or 8-hour professionally generated video (VCR format) shall be provided to the owner at the time of project closeout. The training shall include installation, programming and operation of the VFD, bypass and serial communication.

R. Warranty shall be 24 months from the date of certified start-up, not to exceed 30 months from the date of shipment. The warranty shall include parts, labor, travel time and expenses. There shall be 365/24 support available via a toll free phone number.

2.45. HEAT TRACE

A. Furnish and install a complete UL Listed, CSA Certified, or FM Approved system of heating cables, components, and controls to prevent pipes from freezing.

B. The self-regulating heating cable shall consist of two 16 AWG nickel-copper bus wires embedded in parallel in a self-regulating polymer core that varies its power output to respond to temperature all along its length, allowing the heating cable to be cut to length in the field. The heating cable shall be covered by a radiation-crosslinked, modified polyolefin dielectric jacket. To provide a ground path and to enhance the heating cable’s ruggedness, the heating cable shall have a braid of tinned copper and an outer jacket of modified polyolefin.

C. In order to conserve energy and to prevent overheating, the heating cable shall have a self-regulating factor of at least 90 percent. The self-regulating factor is defined as the percentage reduction, without thermostatic control, of the heating cable output going from 40ºF pipe temperature operation to 150ºF pipe temperature operation.

D. Heating cable shall operate on line voltages of 120 volts without the use of transformers.

E. Heating cable for metal-pipe freeze protection shall be sized according to the table below. The required heating cable output rating is in watts per foot at 50ºF. Heating cable selection based on 2” fiberglass insulation on metal piping.

F. Power connection, end seal, splice and tee kit components shall be applied in the field.

G. Heating-cable circuit shall be protected by a ground-fault device for equipment protection. This requirement is in accordance with Section 427-22 of the latest NEC.

H. Heating-cable components shall be UL Listed, CSA Certified, or FM Approved for use as part of the system to provide pipe freeze protection. Component enclosures shall be rated NEMA 4X to prevent water ingress and corrosion. Installation shall not require the installing contractor
to cut into the heating-cable core to expose the bus wires. Connection systems that require the installing contractor to strip the bus wires, or that use crimps or terminal blocks, shall not be acceptable. Components that make an electrical connection shall be re-enterable for servicing. No component shall use silicone to seal the electrical connections. An exception will be made in areas where a conduit transition is required.

I. Thermostatic Control Ambient Sensing System shall be controlled by an ambient sensing thermostat AMC-1A set at 40°F either directly or through an appropriate contractor.

J. System must be installed per manufacturer’s recommendations.

K. Apply the heating cable linearly on the pipe after piping has been successfully pressure-tested. Secure the heating cable to piping with cable ties or fiberglass tape.

L. Apply “Electric Traced” labels on the outside of the thermal insulation.

M. After installation and before and after installing the thermal insulation, subject heating cable to testing using a 2500-Vdc Megger. Minimum insulation resistance shall be 20 megohms or greater.

N. Heating cable shall be manufactured by Raychem Corporation or approved equal.

END OF SECTION 23 60 00
SECTION 23 60 50 UNDERGROUND DUCTWORK

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. PVC coated steel ducts.
   2. Buried underground duct fabrication.
   3. Duct cleaning.

B. Related Sections:
   1. Division 1 & 2- Cast-In-Place Concrete: Product requirements for concrete for placement by this section.
   2. Division 1 & 2 - Paints and Coatings: Execution requirements for Weld priming, weather resistant, paint or coating specified by this section.
   3. Section 23 05 00 – Common Work Results for Mechanical.
   4. Section 23 60 00 – Heating, Ventilation and Air Conditions: Ductwork materials and execution.

1.2 REFERENCES

A. ASTM International:
   2. ASTM A90/A90M - Standard Test Method for Weight Mass of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.
   5. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   6. ASTM A1008/A1008M - Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability.

B. National Fire Protection Association:
   2. NFPA 90B - Standard for the Installation of Warm Air Heating and Air Conditioning Systems.

C. Sheet Metal and Air Conditioning Contractors:
   2. SMACNA - HVAC Duct Construction Standard - Metal and Flexible.

D. Underwriters Laboratories Inc.:
   1. UL 181 - Factory-Made Air Ducts and Connectors.

1.3 PERFORMANCE REQUIREMENTS

A. Variation of duct configuration or sizes other than those of equivalent or lower loss coefficient is not permitted except by written permission. Size round ducts installed in place of rectangular ducts in accordance with ASHRAE table of equivalent rectangular and round ducts.

1.4 SUBMITTALS

A. Division 1 & 2 - Submittal Procedures: Submit shop drawings, shop drawings, and dimension data for duct materials, duct connectors, and fittings.

B. Shop Drawings: Submit shop drawings, shop drawings, and dimension data for duct materials, duct connectors, and fittings.

   1. Fabrication, assembly, and installation details, including plans, elevations, sections, details of components, and attachments to other work.
   2. Duct layout, indicating pressure classifications and sizes in plan view. For exhaust duct systems, indicate classification of materials handled as defined in this section.
   3. Fittings.
   4. Reinforcing details and spacing.
   5. Seam and joint construction details.

C. Product Data: Submit product data, drawings, and dimension data for duct materials, duct connectors, and fittings.

D. Test Reports: Indicate pressure tests performed. Include date, section tested, test pressure, and leakage rate, following SMACNA HVAC Air Duct Leakage Test Manual.

E. Manufacturer's Installation Instructions: Submit special procedures for underground ducts.
1.5 CLOSEOUT SUBMITTALS
   A. Division 1 & 2 - Execution Requirements: Closeout procedures.
   B. Project Record Documents: Record actual locations of ducts and duct fittings. Record changes in fitting location and type. Show additional fittings used.

1.6 QUALITY ASSURANCE
   A. Perform Work in accordance with SMACNA - HVAC Duct Construction Standards - Metal and flexible.
   B. Construct ductwork to NFPA 90A standards.

1.7 QUALIFICATIONS
   A. Manufacturer:
      1. Company specializing in manufacturing products specified in this section with minimum three years documented experience.
      2. Manufactured duct and fittings covered by this specification are to be manufactured by a single company, which must be identified when the bid is submitted.
   B. Installer: Company specializing in performing Work of this section with minimum ten years experience approved by manufacturer.

1.8 PRE-INSTALLATION MEETINGS
   A. Division 1 & 2 - Administrative Requirements: Pre-installation meeting.
   B. Convene minimum one week prior to commencing work of this section.

1.9 ENVIRONMENTAL REQUIREMENTS
   A. Division 1 & 2 - Product Requirements.
   B. Do not install duct sealant when temperatures are less than those recommended by sealant manufacturers.
   C. Maintain temperatures during and after installation of duct sealant.

1.10 FIELD MEASUREMENTS
   A. Verify field measurements prior to fabrication.

1.11 WARRANTY
   A. Division 1 & 2 - Execution Requirements: Product warranties and product bonds.
Part 2 - PRODUCT

2.1 DUCT MATERIALS

A. Galvanized Steel Ducts: ASTM A653/A653M galvanized steel sheet, lock-forming quality, having G90 zinc coating of in conformance with ASTM A90/A90M.

B. Ductwork shall be welded construction with No. 304 stainless steel material for Fume Hood, Anatomy Labs, Cadaver Room and Cat Storage Room Ductwork.

C. Fasteners: Rivets, bolts, or sheet metal screws.

2.2 PVC COATED SINGLE WALL SPIRAL ROUND DUCTS

A. Manufacturers:

B. Product Description:
   1. UL 181, Class 1, round spiral lockseam duct constructed of G-60 galvanized steel.
   2. Ducts greater than 14 inches diameter shall have two corrugations, ¾ inch wide, between lockseams on the finished duct.
   3. PVC gauges shall be identical to those set for galvanized steel.

C. Duct Coating: Polyvinyl chloride (PVC) plastic, 4 mil thick on exterior surface and 1 mil thick epoxy wash coat on interior surface. Temperature range: minus 30 degrees F to 200 degrees F.

D. Construct duct with the following minimum gages:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Gauge (Galvanized Steel/Stainless Steel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inches to 8 inches</td>
<td>26/24</td>
</tr>
<tr>
<td>8 1/2 inches to 16 inches</td>
<td>24/22</td>
</tr>
<tr>
<td>18 inches to 24 inches</td>
<td>22/20</td>
</tr>
<tr>
<td>26 inches to 32 inches</td>
<td>20/18</td>
</tr>
<tr>
<td>34 inches to 60 inches</td>
<td>18/16</td>
</tr>
</tbody>
</table>

E. Fittings:
   1. Fittings shall be factory fabricated with PVC coating as specified above.
   2. Fittings shall be constructed according to the following:

<table>
<thead>
<tr>
<th>Diameter (inches)</th>
<th>PVC-Coated Fitting Duct Gauge (Galvanized Steel/Stainless Steel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 8</td>
<td>24/22</td>
</tr>
<tr>
<td>8-1/2 to 24</td>
<td>22/20</td>
</tr>
<tr>
<td>25 to 32</td>
<td>20/18</td>
</tr>
</tbody>
</table>
3. Standing seam joints shall be used on fittings, unless otherwise specified. Standing seam joints shall be sealed with a UL listed cement.
   a. In lieu of standing seam construction, joints may be riveted, button punched, or fastened with stainless steel sheet metal screws and bonded and sealed with a UL listed cement.

4. Elbows shall be of gored construction.
   a. Elbows 4 inches through 8 inches and 31 inches through 60 inches shall have joints that are riveted, button punched, or fastened with stainless steel sheet metal screws.
   b. Elbows 9 inches through 30 inches shall be standing seam construction.

5. Diverging flow fittings shall be constructed with a radiused entrance to all branch taps and without excess material projecting from the body into the branch tap entrance.

F. Duct shall meet the following load specifications:

<table>
<thead>
<tr>
<th>Diameter (inches)</th>
<th>Maximum Loading (pounds per linear foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 9-1/2 uncorrugated</td>
<td>400</td>
</tr>
<tr>
<td>10 to 13-1/2 uncorrugated</td>
<td>600</td>
</tr>
<tr>
<td>14 to 36 corrugated</td>
<td>1,800</td>
</tr>
</tbody>
</table>

2.3 BURIED UNDERGROUND DUCT FABRICATION

A. Construct buried ducts using the following: concrete encased sheet metal or concrete encased PVC coated spiral round ducts as indicated on Drawings.

B. Fabricate metal ductwork in accordance with SMACNA Low Pressure Duct Construction Standards. Fabricate using two gages heavier material than indicated for 2 inch wg pressure class.

END OF SECTION 23 60 50