SECTION 230000 - MECHANICAL GENERAL REQUIREMENTS

PART 1 GENERAL

1.1 DESCRIPTION

A. All work under this Section shall comply with the requirements of General Conditions, Supplemental Conditions, Special Conditions and Division 1 - General Requirements, and shall include all Sections of Division 230000 and shall apply to all Work specified, indicated in the Drawings, and as required to furnish a complete installation of mechanical systems for the Project. Review all Sections of the Specifications for related work and coordinate the work of this Section with all other Sections.

B. Furnish all labor, services, materials, tools, equipment, appliances, facilities, transportation and incidental work and appurtenances required to furnish a complete and properly operating system.

C. The Contractor shall refer to the architectural interior details, floor plans, elevations, and the structural and other Contract Drawings and shall coordinate the work with that of the other trades to avoid interference. The plans are diagrammatic and show the general arrangement of the fixtures, equipment, piping and ductwork. All dimensions and existing conditions shall be the responsibility the Contractor. Before proceeding with work check and verify all dimensions.

D. The Contractor shall assume all responsibility for fitting of materials and equipment to other parts of equipment and structure. Make adjustments that may be necessary or as requested, in order to resolve space problems, preserve headroom, and avoid architectural openings, structural members and work of other trades. Where existing pipes, conduits and/or ducts prevent installation of new work as indicated, relocate, or arrange for relocation, of existing pipes, conduits and/or ducts.

E. Where the project involves interface with existing building and site systems, the Consultant has used reasonable care to identify existing utilities and services. The Contractor is responsible to thoroughly familiarize themselves with existing conditions and be aware that in some cases information is not available i.e. concealed conditions, which exist in the existing building affected by this work.

F. Drawings are diagrammatic and do not represent to show or list every item to be provided and specifications may include performance language. When an item not shown or listed, is necessary for proper operation of the system and/or equipment in accordance with the diagrammatic and performance based nature of areas of the documents, the Contractor shall provide the item which will allow the system to function properly at no increase in Contract Sum.

G. Work shall include, but shall not be limited to, the following:

1. Tie-ins to existing water piping.
2. Relocation of existing systems which interfere with new construction.
3. Removal of existing ductwork, piping and equipment to be abandoned.
4. Coordinate maintenance of existing services during construction with Owner.
5. Special coordination of chases and plenums.
6. Hoisting and rigging required to complete work of this section.

7. Sleeves, inserts and hangers.
8. Flexible connections for pumps and other vibrating and rotating equipment.
9. Equipment bases and supports.
10. Vibration isolators, seismic restraints and inertia blocks.
11. Motors.
12. Complete hot water system including pumps, expansion tanks, piping, valves, fittings and other hardware.
13. Complete chilled water system including pumps, expansion tanks, piping, valves, fittings and other hardware.
14. Complete refrigerant system including piping, valves, fittings and other hardware.
15. Expansion joints, anchors and guides.
16. Pressure gauges and thermometers.
17. Water treatment equipment and chemicals, and testing.
18. Radiant systems such chilled beams, radiant ceilings and radiant floors.
19. Sheet metal work.
20. Complete air distribution system including low and medium pressure ductwork, diffusers, registers, grilles, dampers, etc.
21. Insulation for duct, piping, equipment and tanks.
22. Air handling units, including fans, filters, motors, and mixing boxes.
23. Air volume terminal boxes.
24. Sound Attenuators.
25. Exhaust and ventilating air fans.
26. Rooftop supply and exhaust fans.
27. Condensate piping from chilled water coil drain pans.
28. Unit heaters.
29. Cabinet heaters.
30. Prime painting.
31. Pipe, duct, valve and equipment identification.
32. Instruction manual and start up instructions.
33. Testing and balancing.
34. Commissioning.
35. Cleaning.
36. Automatic temperature controls, air volume controls and other controls.
37. Power wiring to all DDC control panels and controls.

H. Related work specified elsewhere: The following work, unless otherwise noted is not included in this section shall be performed in other sections:

1. Electric power wiring for all equipment. See division 260000.
2. Provision of circuit breakers testing and connections for DDC control power wiring.
3. Gypsum drywall enclosures of supply and return ductwork on all rooftop air handlers, supply and return shafts, as shown on drawings.
4. Excavation and backfill.
5. Concrete work, including concrete housekeeping pads and other pads and blocks for vibrating and rotating equipment, duct bank envelopes and cast in place manholes and handholes, except as part of an inertia base. See Division 3
6. Cutting and patching of masonry, concrete, tile and other parts of structure, with the exception of drilling for hangers and providing holes and openings in metal deck.
7. Flashing of wall and roof penetrations.
8. Installation of access panels in floors, walls, furred spaces or above ceilings
9. Outdoor air intake and exhaust louvers.
10. Undercutting of doors and door louvers
11. Partitions and Painting (except as specifically indicated) See Division.
12. Structural supports necessary to distribute loading from equipment to roof or floor, except as specified herein.

13. Foundation drainage systems and site drainage structures.
14. Paving
15. Thermal and sound insulation in partitions and ceilings.

1.2 QUALITY ASSURANCE

A. General:

1. All equipment and accessories shall be the product of a manufacturer regularly engaged in its manufacturer.
2. All equipment and accessories shall be new and free from defects.
3. Supply all equipment and accessories in compliance with the applicable standards listed in this Section and with all applicable National, State and Local Codes.
4. All items of a given type shall be the product of the same manufacturer.
5. Install work by craftsmen skilled in trade involved and by apprentices as indicated in the general conditions. Rough work will be rejected.
6. The subcontractor must, within the last five years, prior to the bid opening, have successfully completed in a timely fashion at least three projects similar in scope and type to the required work.

B. Requirement of regulatory agencies:

1. In accordance with requirements of Division 1 and as specified herein.
2. Nothing in the Drawings or Specifications shall be construed to permit Work not conforming to applicable laws, ordinances, rules or regulations.
3. When Drawings or Specifications exceed requirements of applicable laws, ordinances, rules or regulations, Drawings and Specifications take precedence.
4. It is not the intent of Drawings and Specifications to repeat requirements of codes except where necessary for completeness or clarity.
5. If any of the requirements of the above are in conflict with one another, or with the requirements of these specifications, the most stringent requirements shall govern.
6. Local codes as required by the Town of Cornwall, NY.

C. Green Building Performance Requirements

1. The Contractor shall implement practices and procedures to meet the Project’s Green Building requirements. The Contractor shall ensure that the requirements related to these goals, as defined in Section 018113: “Sustainable Design Requirements”, and as specified in this Section, are implemented to the fullest extent. Substitutions or other changes to the work shall not be proposed by the Contractor or their sub-contractors if such changes compromise the stated Green Building Performance Criteria.
2. VOC Limits: All field-applied adhesives, sealants, primers, paints and coatings used on the interior of the building shall meet the volatile organic compound (VOC) and chemical component limitations as defined in Section 018115 "Volatile Organic Compound Limits", VOC contents shall be identified and documented.
3. Insulation:

a. Fiberglass Insulation: Fiberglass insulation will contain no formaldehyde-based binders or will be third-party certified for conformance with Greenguard or Indoor Advantage Gold. (Many fiberglass insulation products are bonded with a formaldehyde resin, which can contribute to unwanted indoor emissions.) Unfaced fiberglass batt insulation shall not be used above suspended ceilings. Fiberglass board products used in plenums and shafts or for insulating ductwork must be wrapped or enclosed.
b. Duct Acoustical Insulation: Insulation shall only be installed in duct where needed for sound attenuation, not solely for thermal insulation or condensation control. Insulation shall be installed only in clean and dry areas. Mechanical sound insulation materials within duct will consist of an impervious, non-porous coating that prevents dust from accumulating in the insulating materials and resists damage and wear.
c. Mineral Fiber Firestopping: Materials exposed to supply or return air plenums, or located above suspended ceilings, must be encapsulated or fully sealed to prevent direct exposure of the mineral or glass fibers to the plenum. Where sealants are used to encapsulate the fibrous materials (e.g., smoke sealants used at firestopping joints), the sealants shall meet the VOC requirements of Section 018115 “Volatile Organic Compound (VOC) Limits For Adhesives, Sealants, Paints & Coatings.

4. Elimination of CFCs and HCFCs:

a. Ozone Protection: Building cooling equipment shall contain no refrigerants other than the following: HCFC-123, HFC-134a, HFC-245fa, HFC-407c, or HFC 410a.
b. Fire suppression systems may not contain ozone-depleting substances such as halons, CFCs or HCFCs. Any extruded polystyrene insulation (XPS) and closed-cell spray foam polyurethane insulation shall not be manufactured with hydrochlorofluorocarbon (HCFC) blowing agents.

1.3 APPLICABLE PUBLICATION

A. Materials and equipment shall be manufactured, installed and tested as specified in latest editions of applicable publications, standards, rulings and determinations of:

1. Local and state building, plumbing, mechanical, electrical, fire and health department codes.
2. American Gas Association (AGA).
3. National Fire Protection Association (NFPA).
4. American Insurance Association (AIA) (formerly National Board of Fire Underwriters).
5. Occupational Safety and Health Act (OSHA)
6. Underwriter’s Laboratories (UL).
7. Factory Mutual Association (FM).
8. National Electric Code (NEC)
9. Environmental Protection Agency (EPA)
10. National Bureau of Standards (NBS)
11. Owner’s Insurance Underwriter.

B. All materials and equipment shall be listed by Underwriters” Laboratories (UL), and approved by ASME, ANSI, ASTM, AGA, and NEC for intended service.

C. Most recent editions of applicable specifications and publications of the following organizations form part of these Contract Documents.

1. American National Standards Institute (ANSI)
2. American Society of Mechanical Engineers (ASME)
3. National Electrical Manufacturers' Association (NEMA)
4. American Society for Testing and Materials (ASTM)
5. American Water Works Association (AWWA)
6. Plumbing and Drainage Institute (PDI)
7. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
8. Air Moving and Conditioning Association (AMCA)
9. Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
10. Air Conditioning and Refrigeration Institute (ARI)
11. Hydraulic Institute (HI)
12. Associated Air Balance Council (AABC)
13. Manufacturers Standardization Society of the Valves & Fittings Industry (MSS)
14. Adhesive and Sealant Council (ASC)
15. American Society of Sanitary Engineering (ASSE)
16. American Welding Society (AWS)
17. Institute of Electrical and Electronic Engineers (IEEE)
18. Insulated Cable Engineers Association (ICEA)
19. Certified Ballast Manufacturers (CMB)
20. Illuminating Engineering Society (IES)
21. National Environmental Balancing Bureau (NEBB)
22. Tubular Exchanger Manufacturer's Association (TEMA)
23. Thermal Insulation Manufacturers Association (TIMA)

D. Specific reference is made to following NFPA codes which contain an exceptionally high quantity of mechanical, electrical, and fire protection requirements.

1. No. 13- Installation of sprinkler systems
2. No. 14- Installation of standpipe and hose systems
3. No. 20- Installation of centrifugal fire pumps.
4. No. 30- Combustible Liquids
5. No. 45- Fire Protection for Laboratories
6. No. 70- National Electric Code
7. No. 72D- Proprietary Protective Signaling Systems
8. No. 72E- Automatic Fire Detectors

1.4 DEFINITIONS

A. “Provide” means “furnish and install”, complete, the specified material, equipment or other item and perform all required labor to make a finished and properly operational installation.

B. “Furnish” means to purchase and deliver to project site complete with all appurtenance and support. “Install” means to unload at the delivery point at the site and perform every operation necessary to establish secure mounting and correct operation at the proper location in the project

C. “Consultant” means “Prime Design Consultant”. An individual or organization engaged by the owner or the architect to render professional engineering consulting services complementing or supplementing the architect’s services concerning the content of the Mechanical, Electrical, Plumbing & Fire Protection sections of specifications.

D. “Owner” means the individual or entity with whom Contractor has entered into the Agreement for whom the Work is to be performed

E. “Construction Manager Advisor” or “CMA” means the Construction Manager that provides services to advise the Owner and Architect on design and materials decisions during the design and document development process. The CMA coordinates the entire design process using his skills and knowledge of construction to clarify cost and time considerations of design decisions, to advise on feasibility of single, multiple-contract or fast-track delivery systems, recommend the construction process, and to handle the bidding and award, as well as to manage the construction of the Project.

F. “Construction Manager Constructor” or “CMC” means the Construction Manager that in addition to acting as an advisor to the Owner during a design period, assumes responsibility for the construction of the Project. The CMC become contractually bound to provide the labor and material for the Project. The CMC may also serve as administrator of multiple prime contract construction; however, some states prohibit that practice.

G. General Contractor/ Prime Contractor means the contractor who contracts with a property owner and, in turn, employs a subcontractor or subcontractors to perform some of all of the work.

H. “Contractor” or “Subcontractor” means the trade contractor responsible for the work in this Division of the specification.

I. “Owner’s Representative” means the Consultant, Engineer, or other Specialty Consultant retained by the Owner.

J. “RFI” means “Contractor’s Request for Information”.

K. "Above Grade": Not buried in the ground and not embedded in concrete slab on ground.

L. “Accessible”: Ability to perform recommended maintenance without removal of services or equipment and requiring no special platforms.

M. "Actuating" or "Control" Devices: Automatic sensing and switching devices such as thermostats, pressure, float, electro-pneumatic switches and electrodes controlling operation of equipment.

N. "Below Grade": Buried in the ground or embedded in concrete slab on ground.

O. "Concealed": Embedded in masonry or other construction, installed in furred spaces, within double partitions or hung ceilings, in trenches, in crawl spaces, or in enclosures. In general, any item not visible or directly accessible.

P. "Connect": Complete hook-up of item with required service.

Q. "Exposed": Not installed underground or "concealed."

R. "Indicated," "Shown" or " "Noted": As indicated, shown or noted on Drawings or Specifications.

S. "Install": To erect, mount and connect complete with related accessories.

T. "Piping": Pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation, and related items.

U. "Reviewed," "Satisfactory" or "Directed": As reviewed, satisfactory, or directed by or to Architect/Engineer/Owner.

V. "Rough-In": Provide all indicated services in the necessary arrangement suitable for making final connections to fixture or equipment.

W. "Shall": An exhortation or command to complete the specified task.

X. "Similar" or "Equal": Of base bid manufacture, equal in materials, weight, size, design, and efficiency of specified products.

Y. "Supply": To purchase, procure, acquire and deliver complete with related accessories.

Z. “Typical” or “Typ”: Exhibiting the qualities, traits, or characteristics that identify a kind, class, number, group or category. Of or relating to a representative specimen. Application shall apply to all other similarly identified on plan or detail.

AA. "Will": A desire to complete the specified task. Allows some flexibility in application as opposed to "Shall."

BB. "Wiring": Raceway, fittings, wire, boxes and related items.

CC. "Work": Labor, materials, equipment, apparatus, controls, accessories, and other items required for proper and complete installation.

DD. Reference by abbreviation may be made in the specifications and the Contract Drawings for Mechanical and Electrical Work in accordance with the following list:

1.	HVAC	Heating, Ventilating and Air Conditioning
2.	GC	General Contractor
3.	AC	Air Conditioning
4.	H&V	Heating and Ventilating
5.	AWG	American Wire Gauge
6.	BWG	Birmingham Wire Gauge
7.	USS	United States Standards
8.	B&S	Brown and Sharpe
9.	OS&Y	Outside Screw and Yoke
10.	IBBM	Iron Body Brass Mounted
11.	WSP	Working Steam Pressure
12.	PSIG	Pounds Per Square Inch
13.	PRV	Pressure Reducing Valve
14.	GPM	Gallons Per Minute
15.	MBH	Thousand BTU per Hour
16.	BTU	British Thermal Units
17.	WG	Water Gage
18.	LB	Pound (Also shown as: #)

19. ASME American Society of Mechanical Engineers
20. ASTM American Society of Testing Materials
21. ABMA American Boiler Manufacturer's Association
22. ASA American Standards Association

1.5 SCOPE

A. Perform work and provide material and equipment as shown on the drawings and/or as specified and/or as indicated in this section of the specifications. Completely coordinate all work of this section with work of other trades and provide a complete and fully functional installation

B. Drawings and Specifications form complimentary requirements; provide work specified and not shown, and work shown and not specified as though explicitly require by both. Although work is not specifically shown or specified, provide supplementary or miscellaneous items, appurtenances, devices and materials obviously necessary for sound, secure and complete installation.

C. Give notices, file plans, obtain permits and licenses, pay fees and back-charges, and obtain necessary approvals from authorities that have jurisdiction as required to perform work in accordance with all legal requirements and with Specifications, Drawings, Addenda and Change Orders, all of which are part of Contract Documents.

D. Contractor shall be responsible with obtaining all the final inspection as required by Local Code and ordinances.

1.6 CONTRACT DOCUMENTS

A. Listing of Documents does not limit responsibility of determining full extent of work required by these Contract Documents. Refer to the Consultant's, HVAC, Plumbing and Fire Protection, Electrical, Structural, Site Utility and all other drawings and other sections that types of and work of other trades with which work of this section must be coordinated

B. Except where modified by a specific notation to the contrary; it shall be understood that the indication and/or description of any item, in the drawings or specifications or both, carries with it the instruction to furnish and install the item, regardless of whether or not this instruction is explicitly stated as part of the indication or description.

C. Items referred to in singular number in Contract Documents shall be provided in quantities necessary to complete work.

D. Drawings are diagrammatic. They are not intended to be absolutely precise; they are not intended to specify every offset, fitting and component. The purpose of the document is to indicate systems concept, the main components of the systems, and the approximate geometric relationships. Based on the systems concept, the main components and the approximate geometrical relationships, the contractor shall provide all other components and materials necessary to make the systems fully complete and operational

E. Information and components shown on riser diagrams, but not shown on plans, and vice versa, shall apply and be provided as if expressly required on both

F. Data that may be furnished electronically by the Consultant (on compact disk, diskette, or otherwise) is diagrammatic. Such electronically furnished information is subject to the same limitation of precision as heretofore described. If furnished, such data is for convenience and generalized reference, and shall not be substitute for Consultant's sealed or stamped construction documents.

1.7 ELECTRIONIC MEDIA FILES

A. Construction drawings for this project have been prepared utilizing Autodesk software to produce two dimensional drawings.

B. Contractors and Subcontractors may request electronic media files of the contract drawings and/or copies of the specifications. All drawings and specifications will be provided in vector PDF format. Plans may be requested in AutoCAD DWG format. Under no circumstances will risers, details, diagrams or notes be released in DWG format. Release of three dimension/BIM electronic design information will be at Engineer's sole discretion unless Engineer's contract with Owner provides for specific conditions of such release.

C. Upon request for electronic media, the Contractor shall complete and return a signed "Electronic File Release" form provided by Buro Happold.

D. The electronic contract documents can be used to assist in the preparation of shop drawings and as-built drawings however the electronic media files obtained from Buro Happold are for reference only. The information may not be used in whole or in part for any other project. They may not be relied upon for contractual purpose.

E. The drawings prepared for bidding purposes may not be used directly for ductwork layout drawings or coordination drawings.

F. The use of these CAD or BIM documents by the Contractor does not relieve them from their responsibility for coordination of work with other trades, other prime contractors, and verification of space available for the installation.

G. The information is provided to expedite the project and assist the Contractor with no guarantee by Buro Happold as to the accuracy or correctness of the information provided. Buro Happold accepts no responsibility or liability for the Contractor's use of these documents.

1.8 REVIEW OF CONTRACT DOCUMENTS AND SITE

A. With the submission of his bid, Contractor shall give written notice to the Owner of any materials or apparatus believed inadequate or unsuitable, in violation of laws, ordinances, rules or regulations of Authorities having jurisdiction, and any necessary items of work omitted. In the absence of such written notice it is mutually agreed that the Contractor has included the cost of all required items in his proposal for a complete project.

B. Contractor shall acknowledge that he has examined the Plans, Specifications and Site, and from his own investigations he has satisfied himself as to the nature and location of the work; the general and local conditions, particularly those bearing upon transportation, disposal, handling and storage of materials; availability of labor, water, electric power, roads and uncertainties of weather; the conformation and condition of the ground; the character, quality and quantity of surface and subsurface materials to be encountered; the character of equipment and facilities needed preliminary to and during the execution of the work; all federal, state, county, township and municipal laws, ordinances and regulations particularly those relating to employment of labor, rates of wages, and construction methods; and all other matters which can in any way affect work or the cost thereof under this Contract. Any failure by the Contractor to acquaint himself with the available information concerning these conditions will not relieve him from the responsibility for estimating properly the difficulty or cost of successfully performing the work.

C. The location and elevation of the underground utilities, such as sewers, electrical power, water piping, steam and steam condensate return piping, conduit, etc., is as exact as can be determined from available information and its accuracy cannot be guaranteed. Exact location and elevation of these services shall be verified prior to excavation or installation of any portion of the work indicated. Exercise special care when excavating at or near the general location of underground utilities to avoid damage to the utility services. The Contractors is responsible to insure worker safety.

D. The contractor shall also acknowledge having been to the site and examined conditions under which work must be performed including preparatory work done under other Sections or other Contracts or by the Owner. Report conditions to the Consultant. Do not proceed until defects have been corrected and conditions are satisfactory. Commencement of work shall be construed as complete acceptance of existing conditions and preparatory work.

E. Owner assumes no responsibility for any understanding or representation made during or prior to the negotiation and execution of this Contract unless such understanding or representations are expressly stated in the Contract, and the Contract expressly provides that the responsibility, therefore, is assumed by the Owner.

1.9 DISCREPANCIES IN DOCUMENTS

A. Where Drawings or Specifications conflict or are unclear, advise the Consultant in writing before award of Contract. Otherwise, Consultant’s interpretation of the Contract documents shall be final, and no additional compensation shall be permitted due to discrepancies or ambiguousness thus resolved.

B. Where Drawings or Specifications do not coincide with manufacturer’s recommendations, or with applicable codes and standards, alert the Consultant in writing before installation. Otherwise, make changes in installed work as the Consultant requires within Contract Price.

C. If the required material, installation, or work can be interpreted differently from drawing to drawing, or between drawings and specification, this contractor shall provide material, installation, or work which is of the higher standard and price.

D. It is the requirement of these documents to have contractor provide systems and components that are fully complete and fully operational and fully suitable for intended use. There may be situations in the documents where insufficient information exists to precisely describe a certain component or subsystem, or the routing of the component or its coordination with other building elements. In cases such as this, where the contractor has failed to notify the Consultant of the situation in accordance with paragraph (A) above, the contractor shall provide specific component or subsystem with all parts necessary for the intended use, fully complete and operational, and installed in workmanlike manner either concealed or exposed per the design intent.

E. In cases covered by paragraph (D) above, where the contractor believes he needs the engineering guidance, he shall submit a sketch identifying his proposed solution and the Consultant shall review, note if necessary, and approve the sketch.

1.10 MODIFICATION IN LAYOUT

A. HVAC, Plumbing, Fire Protection, and Electrical Drawings are diagrammatic. They indicate general arrangements of mechanical and electrical systems and other work. They do not show all offsets required for coordination nor do they show exact routings and locations needed to coordinate with structure and other trades to meet the Consultant's requirements

B. In order to obtain the Consultant's desired aesthetics in spaces used by building occupants, in all such spaces, prior to installation of visible materials, finishes and equipment (including access panels, review Consultant's Drawings for desired locations and where not definitely indicated, request information from the Consultant.

C. Check Contract Drawings, as well as Shop Drawings, of all subcontractors to verify and coordinate spaces in which work of this section will be installed

D. Maintain maximum headroom at all locations. All piping, duct conduit, and associated components to be as tight to underside of structure as possible.

E. Make reasonable modifications in layout and components to prevent conflict with work of other trades and to coordinate according to Paragraphs A,B,C,and D above. Systems shall be run in an organized and rectilinear fashion.

F. Where conflicts or potential conflict exists and engineering guidance is desired, submit sketch of proposed resolution to the Consultant for review and approval

1.11 RFI'S

A. If the RFI is a request to resolve a conflict or an un-clarity, or a request for additional detail, Contractor's RFI shall include a sketch or equivalent description of Contractor's proposed solution, in accordance with paragraph 1.9(E) above

1.12 PROJECT COMMUNICATION

A. Communication and Submittals:

B. The specification references communication and submittal of information and documents by the Contractor to the Engineers of Record and CM or vice versa. In all cases such communication shall be submitted to the CM who will review it before forwarding to the relevant party for review and response.

C. If the information provided is not in conformance with the specification the CM shall return it to the relevant Contractor for re-submission.

D. The time taken for this process shall be factored into all work schedules and submissions.

1.13 MEASUREMENTS

A. Contractor shall base all his measurements, both horizontal and vertical from established benchmark. All work shall agree with these established lines and levels. He shall verify all measurements at site; and check the correctness of same as related to the work.

1.14 MATERIALS AND WORKMANSHIP

A. Materials shall be new, meet detailed requirements of the Contract Documents and be identifiable as being specified or substitute products.

B. Materials which do not conform to the requirements of the Contract Documents, are not equal to approved samples or are unsatisfactory or unsuited to the purpose for which they are intended, will be rejected.

C. All work shall be performed in the best and most workmanlike manner by tradesmen skilled in their respective trades and properly licensed.

D. All equipment shall be installed in accordance with the recommendation of the manufacturer.

E. Defective work, whether the result of poor workmanship, use of defective materials, damage through carelessness, or other cause shall be removed within ten (10) days after written notice is given by the Owner’s Representative and the work shall be re-executed by the Contractor. The fact that the Owner’s Representative may have previously overlooked such defective work shall not constitute total or partial acceptance of it.

F. In no case shall a Bidder base his bid on a class of material or workmanship less than that required by the contract documents nor the governing codes and ordinances.

1.15 CHECKING AND TESTING EQUIPMENT BY CONTRACTORS AND MANUFACTURER'S REPRESENTATIVE

A. All equipment shall be installed in strict accordance with manufacturer's instructions. During construction request supervisory assistance from equipment manufacturer's representatives so the equipment will be correctly installed. After installation, request the Owner’s Representative to inspect and see the equipment is in proper working order.

B. Manufacturer's representative shall review the overall system design relative to the proper application of his equipment in the particular system. He shall note conduit, wiring, control, location, and other relevant relationships, and furnish appurtenances necessary for satisfactory operation.

C. Before final payment is issued the following shall be complete:

D. The Contractor’s representative shall submit to the CM a signed statement certifying:

1. The equipment is properly installed and ready for operation
2. The owners maintenance representatives have been thoroughly trained
3. Maintenance and operation manuals issued and accepted by the Owner’s Representative.

1.16 TEMPORARY FACILITIES

A. Temporary Heating: Temporary heating shall be as specified in construction manager’s bid package. Contractor shall provide all means of temporary heating of the construction site and area impacted by the shutdown of the heating during the construction.

B. Temporary Light and Power: Provided under Division 26000.

C. All temporary facilities shall be removed at completion of project.

D. Temporary Water: Temporary water outlets shall be as listed in construction manager’s bid package.

1.17 SUBMITTALS

A. This paragraph supplements the requirements of Division 1 and any other general conditions.

B. Definitions:

1. Shop Drawings are information prepared by the Contractor to illustrate portions of the work in more detail than shown in Contract Documents.
2. Coordination Drawings are detailed, large scale layout Shop Drawings showing HVAC, Electrical, Plumbing and Fire protection work superimposed in order to identify conflicts and ensure inter-coordination of Mechanical, Electrical, Plumbing, Fire Protection, Structural and other work.

C. Submittal Cover Sheet

1. Shop drawing submittal for each product shall include the copy of following cover sheet completely filled out. Incomplete or incorrect cover sheet submittal shall constitute reason for rejection.
2. Shop drawings shall be submitted according to specification section with a separate cover sheet completed for each product, rather than one cover sheet for multiple products, whether or not supplied by one manufacturer or vendor.
3. In order to maintain the shop drawing review schedule described hereafter, it is important that all submittals include a completed submittal cover sheet for each type of equipment submitted. This requirement will be enforced by the engineer.

SHOP DRAWING COVER SHEET		
PROJECT	CONTRACTOR	
DIVISION NO:	SECTION NO:	
DESCRIPTION:		
CONTRACT DRAWING REFERENCE NO:		
EQUIPMENT TAG:		
SUBMISSION (CIRCLE ONE): I II III IV		
DATE:		
INFORMATION AND CHECKLIST	REPLY	COMMENTS
1. Contractor's Log # ID		
2. Name, address, and phone number of supplier		
3. Are all specified or scheduled items included and exactly match scheduled/specified items.	Yes No	
4. Is this item a substitution?	Yes No	
5. Are deviations clearly identified?	Yes No	
6. Does this equipment fit space shown on construction documents, coordination drawings, and actual field conditions?	Yes No	
7. Has support, erection, weights, and installation been coordinated with all trades?	Yes No	
8. Does the proposed installation void warranties and/or violate UL or code requirements?	Yes No	
9. Does this material/equipment add expense to any other trade or project costs?	Yes No	
10. Does equipment require interface with other trades? Lists divisions and specifics requiring coordination?	Yes No	
11. Is control interface coordinated?	Yes No	
12. List electrical characteristics (V/Ph/A)	Yes No	

Submittals procedure and format

4. Review submittal packages for compliance with Contract Documents and then submit to the Consultant for review. Submit legible vector PDF format drawings and product submittal information. Paper submittals and raster PDFs (information that is printed and then scanned) will be rejected. All shop drawings will be returned by electronic means.
5. Shop Drawings showing layouts of systems shall contain sufficient plans, elevations, sections, details and schematics to describe work clearly. They shall be ¼”=1’-0” scale unless otherwise specified. Sheet metal shop drawings shall be 3/8”=1’-0” and shall indicate work of other sections where physical clearances are critical and where interferences are possible. Provide larger scale details as necessary. Shop drawings shall show elements of Consultant’s reflected ceiling plan, exposed ductwork, walls, partitions, diffusers, registers, grilles, fire dampers, sleeves and other aspects of construction as necessary coordination.
6. ALL RATED WALLS AND ASSEMBLIES AS DEPICTED ON ARCHITECTURAL DRAWINGS SHALL BE HIGHLIGHTED ON THE SHEET METAL DRAWINGS FOR APPROPRIATE COORDINATION.
7. Shop Drawings showing manufacturer’s product data shall contain detailed dimensional drawings, accurate and complete description of materials of construction, manufacturer’s published performance characteristics and capacity ratings (performance data alone, is not acceptable), electrical requirements, wiring diagrams, field installation diagrams and manufacturer’s performance test on equipment. Drawings shall clearly indicate location (terminal block or wire number), voltage and function for all field terminations, and other information necessary to demonstrate compliance with all requirements of Contract Documents.
8. Provide shop drawings submittals showing details of piping and ductwork connections to all equipment. If connection details are not submitted, and the connections are found installed incorrectly in the field, this contractor shall reinstall them within the original contract price.
9. Shop drawings shall clearly indicate compliance with each and every requirement of specifications and drawings.

    a. Contractor shall list all specification paragraphs that have been complied with
    b. Contractor shall also list all specification paragraphs that are not being complied with but address the features or installation of the submitted product together with a reason compliance with the requirement is not possible or not within the scope of their contract.
    c. To document compliance with this submission requirement contractor may simply submit the contract specification with each paragraph marked with compliance, non-compliance together with a reason compliance is not possible, and non-applicability to submitted product.
    d. Engineer reserves the right to summarily reject any submittal omitting this summary of compliance.

10. Consultant's review of shop drawing information presented in plan will generally exclude review of piping and ductwork sizes of risers passing through or heading to or from other floors.
11. Consultant's review of Contractor's riser diagrams is primarily for vertical distribution sizes and distribution topology. Consultant shall not be estopped from giving direction and binding feedback to contractor for horizontal distribution, offsets, location of risers in plan, equipment sizes, equipment quantities, and equipment locations when such items are reviewed within the context of other submissions.

D. Acceptable Manufacturers: The Consultant's mechanical/electrical design for each product is based on the single manufacturer listed in the schedule or shown on the drawings. In Part 2 of the specifications certain Alternate Manufacturers are listed as being acceptable. These are acceptable only if, as a minimum, they:

1. Meet all performance criteria listed in the schedules and outlined in the specifications. For example, to be acceptable, an air handling unit must deliver equal CFM against equal external static pressure using equal or less horsepower, equal or better coil thermal performance, equal or better acoustic performance as the air handler listed in schedules.
2. Have identical operating characteristics to those called for in the specifications. For example, a two stroke diesel generator will not be acceptable if a four stroke is specified.
3. Fit within the available space it was designed for, including space for maintenance and component removal, with no modification to either space or product. Clearances to walls, ceilings and other equipment will be least equal to those shown on the design drawings. The fact that a manufacturer's name appears as acceptable shall not be taken to mean that the Consultants has determined that the manufacturer's products will fit within the available space. This determination is solely the responsibility of the contractor.
4. For rooftop mounted equipment and for equipment mounted where structural matters are a consideration, the products must have a weight no greater than listed in the schedule or specifications.
5. Products must adhere to all Consultant's considerations including, but not limited to: being of same color as the product scheduled or specified, fitting within Consultant's enclosures and details, and for diffusers, lighting and plumbing fixtures – being the same size and physical appearance as scheduled or specified products.
6. The proposed substitution shall meet performance and quality of scheduled equipment, whether it requires additional accessories or not.
7. There is no increase in Contract Sum and this Contractor shall pay for any additional work required by other trades as a result of the substitution.
8. Submit all equipment sound power and pressure level for review and compliance.

E. Required Use of Acceptable Manufacturers on his Project: Substitution of products other than those of the Acceptable Manufacturers specified herein shall not be made. Only the specified items or the comparable product by one of the specified Alternate Manufacturers shall be submitted. Products by other manufacturers shall not be used on this project.

F. Deviations:

1. Concerning deviations other than substitutions, proposed deviations from Contract Documents shall be requested individually in writing whether deviations result from field conditions, standard shop practice or other cause. Submit letter with transmittal of shop drawings, which flags deviation to the attention of the Consultants.
2. Without letters flagging the deviation to the Consultants, it is possible that the Consultants may not notice such deviation or may not realize its ramifications. Therefore, if such letters are not submitted to the Consultants, the contractor shall hold the Consultants and his consultants harmless for any adverse consequences resulting from the deviations being implemented. This shall apply regardless of whether the Consultants has reviewed or approved shop drawings containing the deviation, and will be strictly enforced.
3. Approval of proposed deviations, if any, will be made at discretion of Consultants.
4. Any of the approved deviations shall be deemed acceptable to this Contractor with no change in contract sum, unless the Consultant also receives a written notice to the contrary.

G. Submittal Notations: Submittals will be returned from the Consultants marked as illustrated below:

1. In no case do any actions relieve the contractor from compliance with the contract documents, authorize changes in price or schedule, or otherwise mitigate the contractor's responsibilities as outlined in the contract documents or in the submittal review stamp.
2. No exceptions taken: "Reviewed and found generally acceptable. No further submittal required if notations are complied with."
3. Make corrections noted: "Reviewed and found generally acceptable. Minor deviations may be noted. No further submittal required if notations are complied with."
4. Revise and resubmit: "Submittal contains deviations which must be corrected and confirmed by a new submittal."
5. Rejected: "Submittal is incorrect to such an extent that the material is unacceptable, or in incomplete to such an extent that a review cannot be made. Resubmit in accordance with requirements of the Contract Documents."

H. Responsibility:

1. Intent of Submittal review is to check for capacity, rating, and certain construction features. Contractor shall ensure that the work meets the requirements of Contract Documents regarding information that pertains to fabrication processes or means, methods, techniques, sequences and procedures of construction; and for coordination of work of this or other Sections. Work shall comply with submittals marked "REVIEWED" to the extent they agree with the Contract Documents. Submittal review shall not diminish responsibility under this Contract for dimensional coordination, quantities, installation, wiring, supports and access for service, nor shop drawing errors or deviations from requirements of Contract Documents. The Consultant's noting of some errors while overlooking the others will not excuse the contractor from proceeding in error. Contract Documents are not limited, waived nor superseded in any way by review.
2. INFORM SUBCONTRACTORS, MANUFACTURERS, SUPPLIERS, ETC. OF SCOPE AND LIMITED NATURE OF REVIEW PROCESS AND ENFORCE COMPLIANCE WITH CONTRACT DOCUMENTS.

I. Schedule: Incorporate shop drawing review period into construction schedule so that Work is not delayed. Contractor shall assume full responsibility for delays caused by not incorporating the following review time requirements into his project schedule. Working days listed reference the time in Engineer's office. It does not include transmittal time or review time of Contractor or the Consultant. Allow at least 10 working days, exclusive of transmittal time, for review each time shop drawing is submitted or resubmitted with the exception that 20 working days, exclusive of transmittal time, are required for the following:

1. HVAC temperature control submittals.
2. HVAC balancing report.
3. Coordination Drawings.
4. If more than five shop drawings of a single trade are received in one calendar week.

J. List of Proposed Equipment and Materials:

1. Within four weeks of Award of Contract and before ordering materials or equipment, submit complete list of materials and equipment and indicate manufacturer's name, addresses and telephone numbers. No consideration will be given to partial lists submitted out of sequence.

2. If the List of Materials and Equipment is not received within the prescribed time limit, provide the first-named manufacturer for all material and equipment on this project.

1.18 EQUIPMENT SUPPLIER'S INSPECTION

A. The following equipment shall not be placed in operation until a competent installation and service representative of the manufacturer has inspected the installation and certified that the equipment is properly installed, adjusted and lubricated; that preliminary operating instructions have been given; and that the equipment is ready for operation:

1. Base Mounted Pumps
2. Heat Rejection Equipment, including but not limited to:

    a. Dry coolers

    b. Condensing units.

3. Fire Seal Systems
4. Seismic Restraints and Equipment Bracing
5. Air Handling Units
6. Dedicated Outdoor Air Units

B. Contractor shall arrange for and obtain supplier's on-site inspection(s) at proper time(s) to assure each phase of equipment installation and/or connection is in accordance with the manufacturer's instructions.

C. Submit copies of start-up reports to the Engineer and include copies IN THE Project Close-Out and Owner's Operation and Maintenance Manuals.

1.19 COORDINATION DRAWINGS:

A. A single set of coordination drawings shall be mutually prepared by all mechanical and electrical trades.

B. The initiation of these drawings begins with Sheet Metal Subcontractor.

C. The Sheet Metal Subcontractor shall prepare a complete set of electronic background drawings at scale not less than 3/8" equals 1'-0", showing structure and other information as needed for coordination. He shall show sheet metal layout thereon. These will be Coordination Drawings.

D. Each of the mechanical, electrical and other specialty trade shall add its work to these background drawings with appropriate elevations and grid dimensions. Specialty trade information is require for fan rooms and mechanical rooms, horizontal exits from duct shafts, crossovers, and for spaces in and above ceilings where congestion of work may occur such as corridors, and even entire floors. Drawings shall indicate horizontal and vertical dimensions, to avoid interference with structural framing, ceilings, partitions, and other services.

E. Each specialty trade shall sign and date each coordination drawing. Return drawing to the Sheet Metal Subcontractor, who shall route them sequentially to all specialty trades.

F. Where conflicts occur with placement of materials of various trades, the Sheet Metal Subcontractor will be responsible to coordinate the available space to accommodate all trades. Any resulting adjustments shall be initialed and dated by specialty trade. The Sheet Metal Subcontractor shall then final date and sign each drawing. If he cannot resolve conflicts, the decision of the General Contractor/Construction Manager shall be final.

G. A Subcontractor who fails to promptly review and incorporate his work on the drawings shall assume full responsibility of any installation conflicts affecting his work and of any schedule ramifications.

H. Sheet Metal Subcontractor shall make prints of all coordination drawings. Fabrication shall not start until such transparencies of completed coordination drawings are received by the Consultant/Engineer and have been reviewed and approved.

I. The review of coordination drawings shall not diminish responsibility under this Contract for final coordination of installation and maintenance clearances of all systems and equipment with the other trades, structural and other work.

J. After review:

1. After review of coordination drawings, the method used to resolve interferences not previously identified shall be as in “MODIFICATIONS IN LAYOUT” above.
2. All changes to reviewed coordination drawings shall be in writing by the Consultants/Engineer prior to start of work in affected area.

K. Distribution of Coordination Drawings:

1. The Sheet Metal Subcontractor shall provide the following distribution of documents:

    a. One sepia (reproducible) of each Coordination Drawing to each specialty trade and affected Contractor for their use.
    b. One reproducible of each Coordination drawing to Owner.
    c. One sepia (reproducible) of each coordination drawing to the General Contractor/Construction Manager.
    d. The above documents can be submitted as electronic media upon agreement of all parties.

L. ALL FIREWALLS AND SMOKE PARTITIONS SHALL BE HIGHLIGHTED ON COORDINATION DRAWINGS FOR APPROPRIATE COORDINATION.

M. The main paths of egress and for equipment removal from main mechanical and electrical rooms must be clearly shown on coordination drawings.

N. Coordination Drawings shall include, but not limited to:

1. Plumbing systems, piping and equipment.
2. HVAC piping, systems and equipment.
3. Control systems.
4. Electrical distribution, systems and equipment.
5. Lighting systems and fixtures.
6. Sheet metal work, components and accessories, costs and boxes in terminals, etc.
7. Fire protection and sprinkler system, piping and heads.
8. Structural.

9. Electrical Equipment Room layouts.
10. Environmental Rooms and associated refrigeration/heating systems.
11. Partition/room layout.
12. Ceiling tile and grid.
13. Access panels.
14. Smoke and fire dampers.
15. Roof drain piping.
16. Major electrical conduit runs, panel-boards, feeder conduit and racks of branch conduit.
17. Above ceiling miscellaneous metal.
18. Heat tracing of piping.
19. Minimum access space requirements for all equipment for both installation and maintenance.

1.20 COORDINATION BUILDING INFORMATION MODEL (BIM)

A. General Requirements:

1. The General Contractor shall appoint a BIM Coordination Manager to prepare a BIM Execution Plan developed specifically for the project, and based on the Computer Integrated Construction (CIC) Research Program's BIM Planning procedures. The BIM Execution Plan will establish the protocols, expected levels of development, and authorized uses of Building Information Models on this Project and assigns specific responsibility for the development of each Model Element to a defined Level.

B. Services to be modelled:

1. All piping (above ½") and all equipment shall be modelled based on the proposed submitted products. The model may be used for production of shop drawings.

C. Clash Detection:

1. Perform three-dimensional component conflict analysis as part of coordination process with all other trades, including but not limited for Mechanical, Plumbing, Fire Protection and Fire Alarm. Resolve component conflicts prior to submittal of shop drawings. Indicate where conflict resolution requires modification of design requirements by Construction Manager.

D. 3D Assets:

1. The contractor shall hand over all digital data files related to the BIM execution plan at the end of the construction process, including all, but not limited to the shop drawings and as built conditions.

1.21 REGULATIONS, CODES, PERMITS, AND FEES

A. Conform to all rules, regulations, standards, ordinances and laws of local, state, and Federal governments and other authorities that have legal jurisdiction over the site.

B. Prior to commencement of work, notify State and applicable authorities as required and submit all of the applicable notifications for construction, operation and demolition. Secure required permits and inspections from any of the authorities having jurisdiction, for this work and pay for all fees required for permits, inspections and review, including special agency construction.

C. Include all utility and local building department charges for providing temporary and permanent water, sewer, and gas services to buildings.

D. Provide Owner, Owner's Representative and Inspectors from any of the authorities / agencies having jurisdiction access to work at all times.

E. Contractor shall be responsible for all law violations caused by the work under this Division. Notify Construction Manager in writing when a discrepancy occurs between code requirements and work shown on drawings and resolve matter before proceeding with work.

F. When requirements cited in this specification conflict with each other or with Contract Documents, most stringent shall govern work. Consultants may relax this requirement when such relaxation does not violate ruling of authorities that have jurisdiction. Approval for such relaxation shall be obtained in writing.

G. Make corrections in the work as required by the Owner's Representative or Inspector to pass local regulations.

H. Contractor shall deliver to the Construction Manager any and all certificates of inspections, permits, and approvals. Contractor shall submit final inspection certificates signed by governing authorities to the Owner.

I. Make all necessary submissions to the Department of Environmental Protection, Bureau of Air Resources and Management, Department of Labor and Industry and other agencies having jurisdiction. Pay all required fees for review, registration and sign off.

1.22 ACOUSTICAL COMPLIANCE FOR AIR HANDLING EQUIPMENT, PUMPS, FANS, COOLING TOWERS, AND EXHAUST SYSTEMS

A. Contractor shall provide provision to bring on board, at contractor cost and no cost to the owner, the service of an Acoustical consultant for evaluation of submitted units (outdoor equipment or indoor equipment) and system exposed to ambient surrounding and noise level criteria set forth by the local code and law.

B. Contractor shall certify noise level compliance and provide potential alteration(s) in the submissions of the equipment for noise level compliance installation.

C. Contractor confirm that the installation of any equipment in communication with outdoor shall comply with Local Law and regulations.

D. Contractor shall provide ambient noise level testing and report to establish the existing noise level at the site prior to new construction. Contractor shall also provide noise level testing upon completion of the installation to warranty the level pre code compliance.

E. LEED for Schools noise requirements shall be complied with on school projects.

1.23 OPERATING AND MAINTENANCE MANUALS

A. Obtain at time of purchase of equipment, three copies of operation and maintenance manuals for all items. Assemble literature in coordinated "D" ring notebooks. All information shall also be provided in electronic PDF format. Divide the manuals into three sections or books as follows:

B. System General Description and Information. Section shall include a general description of the systems used and contain names and addresses of manufacturers and local representatives who stock or furnish or repair parts for items or equipment. List of all major equipment as installed and include model number, capacities, nameplate data and manufacturer's location and purchase order information. Include in the manuals, parts catalogs for each item of equipment furnished with the components identified by number for replacement ordering. This section shall also include:

1. Letters from manufacturers certifying their supervision of equipment installation and startup procedures as required.
2. Machinery vibration test reports.
3. Certificates of piping system cleaning and chemical treatment.
4. Equipment test certificates.

C. Operation, Start-up and Shutdown Procedures. Section shall include directions for and sequence of operation for each item of the Mechanical and Electrical systems; e.g., air handling units, boilers, chillers, domestic water pump, generator, etc. Sequence list shall list valves, switches, and other devices used to start, stop and control system. Include detailed approved control diagrams and flow diagrams of each air and hydronic system. Include approved valve directory showing each valve number, location of each valve, and equipment or fixture controlled by valve. Provide a motorized and manual damper charts organized on a room and by system basis, detailing and damper number.

D. Provide a step-by-step write-up and video of the operation, start-up and shut down procedures for all major equipment.

E. Problems, Solutions and Troubleshooting. Section shall include detailed procedures to be followed in case of equipment or system malfunctions. Include manufacturer's printed troubleshooting procedures into the operating manual for reference.

F. Preventative Maintenance. Section shall include preventative maintenance requirements and schedule for each piece of equipment. This shall include lubrication instructions detailing type of lubricant, amount and intervals recommended by manufacturer for each item of equipment. A lubrication chart listing each item of equipment, all points of lubrication, lubrication type and lubrication schedule.. Include additional instructions necessary for implementation of preventative lubrication program. In addition provide additional preventative maintenance procedures concerning routine maintenance, draining of coils, belt sizes, types and adjustment tension etc. required in order to properly operate equipment.

G. Diagrams and Charts.

1. One copy of each valve chart, damper chart, and lubrication chart shall be mounted under glass and installed at locations to be selected by the Owner.
2. Provide control diagrams, for each air and hydronic system, suitably framed, with glass front. Diagrams shall show complete equipment, controls, model numbers, etc., marked to correspond to identification on equipment. Locate as directed by Owner.
3. Air and water flow diagrams.

H. In addition to the above provide all information in electronic media.

I. Furnish three copies of manuals to the Consultant for approval and distribution to Owner. Deliver manuals no less than 30 days prior to project close-out or 10 days prior to commissioning whichever is sooner.

1.24 FIELD ADJUSTMENT TO AIR HANDLING EQUIPMENT, PUMPS, AND FANS

A. Contractor shall be responsible for changing or adjusting belts, drives, pulleys, motors, impellers, etc., as required, by adjustment for acoustic performance, and by balancing company to achieve the desired air and water delivery by all air handling equipment and pumps.

1.25 RECORD DRAWINGS (AS-BUILTS)

A. As work progresses and for duration of Contract, maintain current complete and separate sets of prints of Contract drawings at job site. Record work completed and all changes from original Contract Drawings clearly and accurately including work installed as a modification or addition to original design. Include actual location of existing utilities if they differ from design documents. Record valve tags as they are installed. In addition, take photographs of concealed work to include, but not limited to:

1. All concealed equipment in gypsum board ceilings.
2. All shafts.
3. All concealed piping routes in walls, floors, underground, or above inaccessible ceilings.
4. Ducting concealed in walls, underground, or above inaccessible ceilings.
5. Volume dampers, fire and smoke dampers, and access panels; both exposed and concealed.
6. All underground waste and soil lines inside the building.

B. Underground utility services, both inside and outside of buildings, shall be dimensioned from permanent structures or benchmark. Utility services outside of buildings shall also show depth of burial with reference to the finished ground floor elevation.

C. All “main air” pneumatic control piping routing locations shall be shown on record drawings.

D. Drawings shall show record condition of details, sections, riser diagrams, control changes and correction to schedules. Schedules shall show actual manufacturer and make and model numbers of final equipment installation. All elements shall be dimensioned from grid lines or benchmarks and all elevations shall be noted. Construction notes (such as component numbers, conflict notes, etc.) shall be removed and the drawings shall clearly be noted in the title block as being as-built drawings.

E. At the completion of the project, prepare a complete set of record drawings, showing all systems actually installed, as well as electronic files on latest CAD version.

F. The design tracings will be made available for Contractor’s copying, at his expense, into reproducible to serve as background drawings. The quantity of design tracings, which are made available shall in no way be interpreted as setting a limit to the number of drawings necessary to show required information. Contractor’s professional draftsperson shall transfer changes to record files and then submit the electronic files and three sets of prints to the Consultant for comments as to compliance with this section.

G. The record set reproducible, as corrected and recorded by the Contractor, shall be submitted to the Owner's Representative for approval prior to authorization for final payment. Record drawings shall be certified as to their correctness by the signature of the Contractor, and shall be stamped or otherwise identified as record drawings. THE CONSULTANT WILL NOT CERTIFY THE ACCURACY OF THE RECORD DRAWINGS – THIS IS THE SOLE RESPONSIBILITY OF THE CONTRACTOR.

H. Each trade shall submit record set for approval by the building department in a form acceptable to the department, when required by the jurisdiction. Such drawing format size changes, and supplemental information required for the submittal are the requirement of the contractor.

1.26 COOPERATION BETWEEN TRADES

A. Cooperate with all other Divisions performing work on this project as necessary to achieve a complete neatly fitted installation for each condition. Consult the Drawings and Specifications to determine nature and extent of work specified in other Divisions that adjoins or attaches to the work of this Division. Confer with other Divisions at the site to coordinate this work with theirs in view of job conditions to the end that interferences may be eliminated and that maximum head room and clearance may be obtained. In the event that interferences develop, the Owner's Representative's decision will be final as to which Division shall relocate its work, and no additional compensation will be allowed for the moving of piping, ductwork, conduit, or equipment, to clear such interferences. Provide templates, information, and instructions to other divisions to properly locate holes and openings to be cut or provided

B. For Testing and Balancing of the system, ensure full co-ordination between the Testing and Balancing subcontractor and all other Trades to achieve access to all system components, including leaving wall/ceiling sections down for access. HVAC Contractor shall be responsible for pre-balancing checks and check sheet and responsibilities outlined in Section 15990.

C. Ensure full co-ordination between controls subcontractor and Testing and Balancing subcontractor to ensure the system is commissioned in accordance with the complete requirements of the complete contract documents.

1.27 HOIST, RIGGING, TRANSPORTATION AND SCAFFOLDING

A. Provide all scaffolding, staging, cribbing, tackle hoist and rigging necessary for placing all materials and equipment in their proper places in the Project. All temporary work shall be removed from the premises when its use is no longer required.

1.28 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver equipment in its original package to prevent damage or entrance of foreign matter. Perform all handling and shipping in accordance with manufacturer's recommendations. Provide protective coverings during construction.

B. Identify materials and equipment delivered to Site to permit check against approved materials list, reviewed Shop Drawings.

C. Completely cover motors and other moving machinery to protect from dirt and water during construction.

D. Cap all openings in pipe and ductwork daily to protect against entry by foreign matter.

E. Protect premises and Work of other Divisions from damage arising out of installation of Work of this Division.

F. Perform Work in manner precluding unnecessary fire hazard.

G. All ductwork shall be delivered to site with all ends and openings capped with minimum of heavy gauge polyethylene sheeting taped all around to prevent ingress of moisture, dust, debris, etc.

H. Protect from loss or damage. Replace lost or damaged materials and equipment with new at no increase in Contract Sum. Protect from damage, water, dust, etc., material, equipment and apparatus provided under this Division, both in storage and installed, until Notice of Completion has been filed. Provide temporary storage facilities for material and equipment. Material, equipment or apparatus damaged because of improper storage or protection will be rejected. Remove from Site and provide new, duplicate material, equipment or apparatus in replacement of that rejected.

I. All stock piled conduit and piping shall be placed on dunnage, and protected from weather and from entry of foreign material. All stored materials and equipment shall be carefully inspected prior to installation and replaced with new material or equipment if found to be damaged, corroded, etc.

1.29 GUARANTEE AND 24 HOUR SERVICE

A. Guarantee the Work of this section for one year following the date of Substantial Completion. If the equipment is used for ventilation, temporary heat, etc. prior to initial beneficial occupancy by the Owner, the bid price shall include an extended period of warranty covering the one year of occupancy starting from the initial date of beneficial occupancy by the Owner. The guarantee shall repair or replace defective materials, equipment, workmanship and installation that develop within this period, promptly and to the Consultant’s satisfaction and correct damage caused in making necessary repairs and replacements under guarantee within Contract Price.

B. In addition to guarantee requirements of Division 1 and of Paragraph A above, obtain written equipment and material warranties offered in manufacturer’s published data without exclusion or limitation, in Owner’s name.

C. Replace material and equipment that require excessive service during guarantee period as defined and as directed by the Consultant.

D. Provide 24 hour service beginning on the date of substantial completion and lasting until the termination of guarantee period. Service shall be at no cost to Owner. Service can be provided by this Contractor or a separate service organization. Choice of service organization shall be subject to the Consultant and Owner approval. Submit name and phone number that will be answered on a 24 hour basis each day of the week, for the duration of the service.

E. Submit copies of equipment and material warranties to Consultants before final payment.

F. At end of guarantee period, transfer manufacturer’s equipment and warranties still in force to Owner.

G. This paragraph shall not be interpreted to limit Owner's rights under applicable codes and laws under this Contract.

H. Part 2 Paragraphs of the Specification sections may specify warranty requirements that exceed those of this Paragraph.

I. Use of systems provided under this Section for temporary services and facilities shall not constitute Final Acceptance of work nor beneficial use by Owner, and shall not institute guarantee period.

J. Provide manufacturer's engineering and technical staff at site to analyze and rectify problems that develop during guarantee period immediately. If problems cannot be rectified immediately to Owner's satisfaction, advise the Consultant in writing, describe efforts to rectify situation, and provide analysis of cause of problem. Consultants will suggest course of action.

PART 2 PRODUCTS

2.1 GENERAL

A. Equipment and materials shall be as described in the respective Sections of Division 230000 and Division 260000 and as shown.

2.2 MATERIALS

A. Equipment specified by manufacturer's number shall include all accessories, controls, etc., listed in catalog as standard with equipment. Furnish optional or additional accessories as specified. And or/as required to provide a fully operational installation.

B. Equipment, material damaged during transportation, installation, operation is considered as totally damaged. Replace with new. Payment for this equipment shall not be approved. Variance from this permitted only with written acceptance.

C. All items of materials in each category of equipment shall be of one manufacturer.

D. Material and Equipment–General Requirements:

1. New.
2. Testing agency labeled or with other identification wherever standards have been established.
3. Owner's Representative reserves right to reject items not in accordance with Specification either before or after installation.
4. Comprised to render complete and operable systems; provide additional items needed to complete installation to realized design.
5. Compatible with space allocated. Modifications necessary to adjust items to space limitations at Contractor's expense.
6. Installed fully operating and without objectionable noise or vibration.

2.3 FLAME-SPREAD AND SMOKE-DEVELOPED PROPERTIES OF MATERIALS

A. All materials and adhesives used throughout the mechanical systems shall have a flame spread rating not over 25 without evidence of continued combustion and with a smoke-developed rating not higher than 50. Materials include but not limited to are insulation, acoustical lining, filter, ducts, flexible connections, jackets or coverings regardless of kind, etc. If such materials are to be applied with adhesives and the adhesives used shall have a flame-spread rating not over 25 and a smoke developed rating not higher than 50.

B. "Flame Spread Rating" and "Smoke Developed Rating" shall be as determined by the "method of test of surface burning characteristics of building materials, NFPA no. 244, ASTM E84, Underwriters' Laboratories, Inc., Standard." Such materials are listed in the Underwriters' Laboratories, Inc., "Building Materials List" under the heading "Hazard Classification (Fire)."

PART 3 EXECUTION

3.1 COMMISSIONING OF EQUIPMENT AND SYSTEMS

A. General

1. Completion of startup and commissioning shall be accomplished as a prerequisite for substantial completion and shall be completed for each phase of construction.
2. Operate and maintain systems and equipment until final acceptance by Owner.
3. All guarantees and warranties shall not begin until final acceptance of the systems and equipment by the Owner. Acceptance requires, at a minimum complete systems and commissioning.
4. The Owner maintains the right to have access to the entire project site to develop his own operational procedures.

B. Comprehensive Work Plan and Reporting

1. Provide detailed, methodical, scheduled, start up and commissioning procedures and execution of same and every system and piece of equipment provided.
2. Attend start up and commissioning meetings on a regular basis, as directed by the General Contractor or Construction Manager.
3. Develop and provide a written work plan with detailed procedures for this work and submit, using shop drawing submittal procedure, within 6 weeks of the contract award. The work plan shall include provisions for an integrated start up plan and schedule. The plan and schedule shall identify tasks, start and completion dates, critical path items, interface requirements with other trades and major equipment start up, as minimum requirements of the plan. The plan and schedule shall clearly identify work in each construction phase, as well.
4. The purpose of this work plan is to provide for smooth, quick, and efficient start up and commissioning of systems and equipment and for a smooth transition to turn the complete, correctly operating building over to the Owner, at each phase of construction.
5. The Owner and the Consultant will have input to and be part of approval process for startup and commissioning plan.
6. Develop and submit for approval a specific start up, check out and sign off form for every piece of major equipment.

7. Develop and submit for approval a specific start up, check out and sign off form for every piece of major system.
8. Systems shall be operated under actual or simulated full load conditions. Identify the operating conditions in the work plan.
9. Work plan shall incorporate the below specified “Demonstration of Successful Operation”
10. The Consultant/Owner may check the completed and commissioned installation either sequentially as different parts are completed, and/or when the entire installation is complete, at sole option of the Consultant/Owner.
11. Each contractor shall arrange that an officer of his contracting company shall certify that each and every system has been tested. At the conclusion of the tests, this contractor shall submit a letter and enclosed commissioning forms signed by the officer stating:
12. That he is the officer of the company.
13. That he certifies that the specified testing of the systems has been performed by the company (give the name and dates of system testing).
14. The results of testing as compared to specified performance, listing the name, title, and company affiliation of all those witnessing and performing these tests.

C. Commissioning

1. Commission equipment and systems in accordance with the approved work plan, completing the startup, check out and sign off forms for each piece of equipment and each system.
2. Provide qualified personnel, equipment, apparatus and services for startup and testing of equipment and systems, to obtain the performance shown in schedules, as specified or on commissioning forms, and as required by codes, standards, regulations and authorities having jurisdiction including Municipal Inspectors, Owners and Consultants.
3. Start up and testing procedures as may be outlined in various mechanical and electrical sections of the specifications are the minimum effort required for the project. Contractor shall use any additional procedures he feels will be necessary to properly start up and test the systems and equipment actually installed on the job at no additional cost to the Owner.
4. Provide capacity and performance of equipment by field testing. Install thermowells and gauge connections and, at no additional cost to Owner, equipment and instruments required for testing.
5. Qualified representative of equipment manufacturer shall be present at test.
6. For each piece of equipment, copy nameplate data and include with the letter and start up, check out and sign off forms referred to above.
7. Do not cover or conceal work before testing and inspection and obtaining approval.
8. Leaks, damage and defects discovered or resulting from startup and testing shall be repaired or replaced by this contract to like-new condition with acceptable materials. Tests shall be continued until system operates without adjustments or repairs.

D. Demonstration of Successful Operation: After all components and every system has been completely commissioned, provide a two week, 24 hour per day fully functional automatic operation period of all systems simultaneously. This shall be successfully concluded before systems are accepted by the Owner.

3.2 SPECIAL RESPONSIBILITIES:

A. Cooperate and coordinate with work of other Sections in executing work of this Section.

1. Perform work such that progress of entire project including work of other Sections shall not be interfered with or delayed.

2. Provide information as requested on items furnished under this Section which shall be installed under other Sections.
3. Obtain detailed installation information from manufacturers of equipment provided under this section.
4. Obtain final roughing dimensions or other information needed for complete installation of items furnished under other Sections or by Owner.
5. Keep fully informed as to shape, size and position of openings required for material or equipment to be provided under this and other Sections. Give full information so that openings required by work of this Section may be coordinated with other work and other openings and may be provided for in advance. In case of failure to provide sufficient information on proper time, provide cutting and patching or have same done, at own expense and to full satisfaction of Consultants.
6. Provide information as requested as to sizes, number and locations of housekeeping pads necessary for floor mounted vibrating and rotating equipment provided under this Section.
7. Notify Consultants of location and extent of existing piping, conduit, ductwork and equipment that interferes with new construction. In coordination with and with approval of Consultants, relocate piping, ductwork and equipment to permit new work to be provided as required by Contract Documents. Remove non-functioning and abandoned piping, ductwork and equipment as directed by Consultants. Dispose of or store items as requested by Consultants.

B. Installation Only Items

1. Where this contractor is required to install items which it does not purchase, it shall coordinate delivery and be responsible for their unloading from delivery vehicles and for their safe handling and field storage up to time of installation. This trade shall be responsible for:
2. Any necessary field assembly and internal connections, as well as mounting in place of the items, including the purchase and installation of all dunnage supporting members and fastenings necessary to adapt to Consultant’s and structural conditions.
3. Their connection to building systems including the purchase and installation of all terminating fittings necessary to adapt and connect them to the building systems.
4. This contractor shall carefully examine such items upon delivery. Claims that any of these items have been received in such condition that their installation will require procedures beyond the reasonable scope of work of this contractor will be considered only if presented in writing within one week of their date of delivery. Unless such claims have been submitted this contractor shall be fully responsible for the complete reconditioning or replacement of the damaged items.

C. Maintenance of equipment and systems: Maintain equipment and systems until Final Acceptance. Ensure adequate protection of equipment and material during delivery, storage, installation and shutdown and during delays pending final test of systems and equipment because of seasonal conditions.

D. Use of premises: Use of premises shall be restricted as directed by the Consultant and as required below:

1. Remove and dispose of dirt and debris, and keep premises clean. During progress of work, remove equipment and unused material. Put building and premises in neat and clean condition, and do cleaning and washing required to provide acceptable appearance and operation of equipment, to satisfaction of the Consultant.

2. Store materials in a manner that will maintain an orderly clean appearance. If stored on-site in open or unprotected areas, all equipment and material shall be kept off the ground by means of pallets of racks and covered with tarpaulins.
3. Do not interfere with function of existing sewers and water and gas mains, electrical or mechanical systems and services. Extreme care shall be observed to prevent debris from entering pipe, ductwork and equipment. Confer with the Consultant as to the disruption of services or other utilities due to testing, connection of new work to existing. Interruption of services shall be performed at time of day or night deemed by Owner to provide minimal interference with normal operation. Obtain Owner's approval of the method proposed for minimizing service interruption.

E. Surveys and Measurements:

1. Base measurements, both horizontal and vertical, on reference points established by Contractor and be responsible for correct laying out of work.
2. In event of discrepancy between actual measurements and those indicated, notify the Consultant in writing and do not proceed with work until written instructions have been issued by the Consultant.

F. Fireproofing:

1. Clip, hangers, clamps, supports and other attachments to surfaces to be fireproofed shall be installed, insofar as possible prior to start of spray fiber work.
2. Ducts, piping and other items which would interfere with proper application of fireproofing shall be installed after completion of spray fiber work.
3. Patching and repairing of fireproofing due to cutting or damaging to fireproofing during course of work specified under this section shall be shall be performed by installer of fireproofing and paid for by the trade responsible for damage and shall not constitute grounds for an extra to Owner.

G. Temporary Utilities:

H. Refer to Division 1 regarding requirements.

1. Coordinate work under this Section with progress of construction so that permanent heating system will be ready for temporary heating if permitted by the Consultant as soon as the building is closed in.
2. Provide and direct labor required for attendance, operation and final restoration of permanent heating system if used for temporary heating purposes. Continuous direct attendance shall be provided whenever permanent system is in operation prior to acceptance of permanent heating system by Owner.

I. Air bound Systems: If, after the plant is in operation, any piping systems, coils or other apparatus are stratified or air bound (by vacuum or pressure), they shall be re-piped with new approved and necessary fittings, air vents, or vacuum breakers at no extra cost. If connections are concealed in furring, floors or ceilings, this trade shall bear the cost of tearing up and refinishing construction and finish, leaving same in as good condition as before it was disturbed.

J. Miscellaneous: Unload materials and equipment delivered to site. Pay cost for rigging, hoisting, lowering and moving electrical equipment on and around site, in building or on roof.

3.3 MATERIAL AND WORKMANSHIP

A. Work shall be neat and rectilinear. Ductwork, piping, conduit, etc. shall run concealed except in mechanical rooms and areas where no hung ceiling exists. Install material and equipment to comply with manufacturers. Recommended Requirements. Rough Work will be rejected. Installation shall operate safely and without leakage, undue wear, noise, vibration, corrosion or water hammer. Work shall be properly and effectively protected, and pipe and duct openings shall be temporarily closed to prevent obstruction and damage before completion.

B. Except as specified otherwise, material and equipment shall be new. Provide supplies, appliances and connections necessary for complete and operational installation. Provide components required or recommended by OSHA and applicable NFPA documents.

C. Finish of materials, components and equipment shall be as approved by the Consultant and shall be resistant to corrosion and weather as necessary.

D. Owner will not be responsible for material and equipment before testing, commissioning, and acceptance.

3.4 CONTINUITY OF SERVICES

A. Do not interrupt existing services without Owner's approval.

B. Schedule interruptions in advance, according to Owner's instructions. Submit, in writing, with request for interruption, methods proposed to minimize length of interruption.

C. Interruptions shall be scheduled at such times of day and work so that they have minimal impact to Owner's operations.

D. Subcontractor shall coordinate any shutdowns of existing systems as follows:

1. Give proper notice to Owner when making shutdowns; a minimum of fourteen full days are required.
2. Minimize shutdowns of any system.
3. Provide temporary services where required and perform shutdown and tie-ins at a time convenient to Owner.
4. Subcontractor shall be responsible for completing and filing Owner's shutdown notice questionnaire.
5. Perform required survey and inspection work required by the notice for shutdown.

E. Include premium time work associated with interruption of services and/or shutdown as necessary to avoid disruption to Owner's operations.

3.5 ANCHORS AND INSERTS:

A. Inserts shall be iron or steel of type to receive machine bolt head or nut after installation. Insert shall permit adjustment of bolt in one horizontal direction and shall develop strength of bolt when installed in properly cured concrete.

B. Provide anchors as necessary for attachment of equipment support and hangers.

3.6 ESCUTCHEONS

A. Install escutcheons around exposed pipe passing through finished floor, floor, wall, or ceiling. Escutcheons shall be heavy cast brass, chromium plated, adjustable, and of sufficient outside diameter to cover sleeve opening and shall fit snugly around pipe and flush against floor or wall surface. Escutcheon plates shall be provided on pipes at fixtures and shall be polished chrome plated. Plated steel escutcheon plates are not acceptable. Sample escutcheon plates shall be submitted to the Consultant for approval prior to installation.

3.7 CORE DRILLING

A. Core drilling is to be avoided.

B. Set sleeves prior to installation of structure for passage of pipes, conduits, ducts, etc.

C. Where core drilling is unavoidable, or required by renovation projects, locate all required openings prior to coring and submit to the Consultant for review.

D. Coordinate openings with General Contractor/Construction Manager and all other trades.

E. Responsibility for core drilling shall be as per the scope boundaries identified in Division 1.

F. Do not disturb existing systems.

G. Thoroughly investigate existing conditions in vicinity of required opening prior to coring.

3.8 CUTTING AND PATCHING:

A. Complete cutting and patching in accordance with Division 1, Cutting and Patching Article, and as follows.

B. Provide all sleeves, core drilling, carpentry, cutting and patching required for proper installation of material and equipment specified in this Division.

C. Do not cut or drill structural members without written approval of Owner’s Representative and structural engineer.

D. No cutting or patching should be done without first receiving the Consultant’s and Structural Engineer’s written approval.

E. Any damage caused by cutting and patching shall be restored to the original condition as required by the Consultant.

3.9 VIBRATION CONTROL:

A. Coordinate with Division 1.

B. Design criteria for all the Work of Division 230000 shall be as specified in 230548.

3.10 WATERPROOF CONSTRUCTION:

A. Maintain waterproof integrity of penetrations of materials intended to be waterproof. Provide flashing at exterior wall and roof penetrations. Caulk watertight penetrations of foundation walls and floors. Provide membrane clamps at penetrations of waterproof membranes.

B. Provide galvanized sheet metal weather protection canopies, hoods or enclosures over all out-of-doors equipment, the operation or maintenance of which would be impaired by rainwater. This requirement applies to damper operators and bearing, damper motors, controls, and instruments. See other paragraphs in this Division for application of this requirement to motors, drive, ducts, and fans.

3.11 RESTORATION OF DAMAGE:

A. Repair or replace, as directed by the Consultant and/or Owner's Representative, materials and parts of premises which become damaged as result of installation of Work of this Division. Remove replaced parts from premises.

3.12 LINTELS

A. Where openings break into an already completed wall as a result of a failure to set sleeves or provide openings during erection of the wall, the Contractor shall provide lintels as required for the support of building construction above the inserted item.

B. Lintels shall be structural steel angles, channels or tees of proper size and sections for the supported load; submit to the Consultant with supporting calculations for approval prior to the installation.

C. Where new openings are required in an existing wall; coordinate opening size, location and lintel type with structural engineer.

3.13 ROOF OPENINGS AND CURBS

A. Roof openings where required shall be coordinated with the other affected trades and all flashing and patching shall be as per details indicated on the Consultant's plans.

B. TOOLS AND EQUIPMENT

1. Furnish all tools and equipment necessary for the proper installation, protection and upkeep of the Work.

3.14 ADJUSTMENTS

A. Preliminary Operation:

1. Operate any portion of installation for Owner's convenience if so requested by Construction Manager. Such operation does not constitute acceptance of Work as complete. Cost of utilities, such as gas and electrical power, will be borne by Owner if Owner requests operation.

B. Startup Service:

1. Prior to startup, ensure that systems are ready, including checking the following: proper equipment rotation, proper wiring, auxiliary connections, lubrications, venting fan balance, controls and installed and properly set relief and safety valves.

C. Start and operate all systems. Provide services of factory trained technicians for startup of major equipment and systems including chillers, boilers, pumps, air handling units, etc.

D. Adjusting:

1. Adjust all equipment and system components as shown or as otherwise required to result in intended system operation.
2. Thereafter, as a result of system operation or as directed by Owner’s Representative, make readjustments as necessary to refine performance and to effect complete system "tune-up".
3. After completion of testing and adjustment, operate the different systems and equipment under normal working conditions for 72 hours continuously and show specified performance.
4. If, in the opinion of the Consultant, performance of equipment or systems is not in accordance with specifications or submitted data, alter or replace equipment at no increase in Contract Sum. The Contractor, at his option, may order tests from an independent approved laboratory to prove compliance. All such tests shall be at no increase in Contract Sum. Repeat process as often as required. If the reason for unsatisfactory operation is design errors all additional cost for corrective measures will be reimbursed to the contractor.
5. At completion of Work, provide written certification that all systems are functioning properly without defects.

E. Noise:

1. Cooperate in reducing any objectionable noise or vibration caused by mechanical systems to the extent of adjustments to specified and installed equipment and appurtenances.
2. Cooperate in adjustment of mechanical systems and terminal devices, as directed by Owner’s Representative, to obtain specified acoustic properties.
3. Completely correct noise problems caused by failure to make installation in accordance with Contract Documents, including labor and materials required as a result of such failure, at no increase in Contract Sum. Includes refinish walls, floors etc.

3.15 INSTALLATION OF EQUIPMENT

A. Use printed descriptions, specifications and recommendations of manufacturers as a guide for installation of Work.

B. Assemble equipment required to be field assembled under the direct supervision of the manufacturers' agent. Prior to the final acceptance submit letters from the manufacturers that this has been done.

C. Avoid interference with structure and with work of other trades, preserving adequate headroom and clearing doors and passageways, to the satisfaction of the Consultant and in accordance with code requirements. Installation shall permit clearance for access to equipment for repair, servicing and replacement.

D. Install equipment so as to properly distribute equipment loads on building structural members provided for equipment support under other Sections. Roof mounted equipment shall be installed and supported on structural steel provided under other Sections.

E. Provide suspended platforms, strap hangers, brackets, shelves, stands or legs as necessary for floor, wall of ceiling mounting of equipment as required.

F. Provide steel supports and hardware for proper installation of hangers, anchors, guides, etc.

G. Provide cuts, weights, and other pertinent data required for proper coordination of equipment support provisions and installations.

H. Structural steel and hardware shall conform to Standard specifications of ASTM; use of steel and hardware shall conform to requirements of Section V of Code of Practice of American Institute of Steel Construction.

I. Verify site conditions and dimensions of equipment to ensure access for proper installation of equipment without disassembly, which will void warrantee. Report in writing to the Consultant, prior to purchase or shipment of equipment involved, on conditions which may prevent proper installation.

3.16 PAINTING

A. Equipment installed shall have shop coat of non-lead gray paint. Hangers and supports shall have one coat of non-lead primer. Machinery such as pumps, fans, etc., shall be stenciled with equipment name. Stencil shall be at least 6” high for large equipment, 2” high for small equipment. Finish painting, including painting of various piping and duct systems, shall be done under other Sections.

B. Paint all outside exposed equipment and equipment supports with two coats of weather resistant enamel.

C. Provide heat resistant paint for hot piping, equipment and materials.

D. Properly prepare Work under this Division to be finish painted under Division 9.

E. Refer to standard paint colors for all Mechanical, Electrical equipment inside the Building.

3.17 LUBRICATION

A. Lubricate all equipment at completion of Work. Furnish Owner with a written lubrication schedule for all equipment as specified in Division 1 and Division 23000.

3.18 SELECTIVE DEMOLITION

A. Refer to all drawings for general description of areas requiring demolition.

B. Refer to General Contractor's/Construction Manager's Instructions for all existing equipment and materials that shall remain the property of the Owner.

C. Items of value which are not directed to be returned to the Owner shall become the property of the Contractor. Storage or sale of items on the project site is prohibited.

D. Protection: Ensure the safe passage of persons in and around building during demolition. Prevent injury to persons and damage to property. Provide adequate shoring and bracing to prevent collapse. Immediately repair damaged property to the condition before being damaged. Take effective measures to prevent windblown dust.

E. Utilities: Maintain all utilities except those requiring removal or relocation. Keep utilities in service and protect from damage. Do not interrupt utilities serving used areas without first obtaining permission from the utility company and the Owner. Provide temporary services as required.

3.19 FINAL JOBSITE OBSERVATION

A. As the work nears completion, the Contractor is to review the requirements of the Contract Documents, inspect the work and inform all parties involved of the work to be corrected or completed before the project can be deemed substantially complete.

B. When the Project is substantially complete, In order to prevent the Final Jobsite Observation from occurring too early, the Contractor is required to review the completion status of the project and certify that the job is ready for the final jobsite observation. Notify the Owner's Representative in writing of this fact, listing any items of Work remaining incomplete, the reason therefore, and the anticipated date that all remaining work will be completed. The Contractor shall inform the certification that the project is complete and ready for a final punch, the Contractor shall sign the attached certification and return it to the Architect/Engineer so that the final observation can be scheduled.

C. It is understood that if the Engineer finds the job not ready for the final observation and that additional trips and observations are required to bring the project to completion, the costs incurred by the Engineers additional time and expenses will be deducted from the Contractor's contract retainage prior to final payment at the completion of the job.

D. The Contractor shall carry out their own final inspection and satisfy the Work.

E. The Owner's Representative reserves the right to cancel and reschedule the inspection in the event considerable more work remains to be completed or corrected than indicated in the written request for inspection.

F. All items not completed or found not complying with drawings or specifications by the Owner's Representative will be identified in their inspection report.

G. Correct all items on inspection report. Make the correction and initial and date each item on the report after corrections have been completed.

H. Include the fee for all local inspections.

3.20 INSTRUCTING THE OWNER'S REPRESENTATIVES

A. Adequately instruct the Owner's designated representatives in the maintenance, care, and operation of all systems installed under this contract.

B. Provide verbal and written instructions to the Owner's representatives by FACTORY PERSONNEL in the care, maintenance, and operation of the equipment and systems.

C. The Owner has the option to video tape all instructions. Coordinate schedule of instructions to facilitate this recording.

D. The instructions shall include:

1. Explanation of all system flow diagrams.
2. Explanation of all air handling systems.
3. Temperature control system operation including calibration, adjustment and proper operating conditions of all sensors.
4. Maintenance of equipment.
5. Smoke control systems.
6. Start-up procedures for all major equipment.
7. Explanation of seasonal system changes.
8. Description of emergency system operation.

3.21 PROJECT CLOSE-OUT PROCEDURE

A. General

1. The requirements of this section are in addition to and supplement the requirements outlined in Division 1.
2. It shall be each contractor's responsibility to personally hand-deliver all of the required project close-out checklist items and to obtain Owner's authorized representative(s) signed receipt on all items requiring Owner sign-off.

B. Project Close-Out Checklist

1. Review requirements of each section of the specifications and submit for approval to Consultants the sign-off forms which shall become the project close-out checklist. These, at a minimum, shall include the following information shown in attached Project Closeout Checklist Example. The Consultants and/or Owner may incorporate additional specific items to the following checklist which shall become part of project requirements.

C. Close-Out Checklist Example:

PROJECT CLOSE-OUT			
PROJECT:			
DIVISION NO:			
CONTRACTOR:			
ITEM1	DATES		OWNER'S
	COMPLETED	RECEIVED BY	SIGN-OFF

		OWNER	
Permits			
City and County Inspection			
Manufacturer's Warranties			
State Fire Rating Data			
Copy of Final Shop Drawings			
List and Possession of Spare Parts			
Pressure Tests			
Equipment Tests Required by Specs			
O&M Manuals			
Record Documents			
Coordination Drawings			
Sanitization Reports			
Commissioning Reports/Letters/Forms			
On Site Training Complete			
Protective Device Settings			
Valve Tags and Charts			
Final ATC Installation Drawings			
Insurance Underwriters Approvals			
Final Punch List (Initialed by contractor that items are complete)			
Building Certificate of Occupancy			
24 Hr Phone No. for Service During Guarantee Period.			
1 Provide separate line item for each specified item (do not group items).			

READINESS CERTIFICATION PRIOR TO FINAL JOBSITE OBSERVATION

In order to prevent the final job observation from occurring too early, we require that the Contractor review the completion status of the project and, by copy of this document, certify that the job is indeed ready for the final job observation. The following is a typical list of items that represent the degree of job completeness expected prior to your requesting a final job observation.

Penetrations fire sealed and labeled in accordance with specifications.

All air handling units operating and balanced.

All fans shall be operating and balanced.

All pumps and chillers operating and balanced.

All miscellaneous mechanical systems (unit heaters, fan coil units, cabinet heaters, etc.) operating.

All temperature control systems operating, programmed and calibrated.

Pipe insulation complete, pipes labeled and valves tagged.

Fire damper and fire/smoke damper access doors labeled in accordance with specifications.

Accepted by:

Contractor _____

By _____ Date _____

Upon Contractor certification that the project is complete and ready for a final job observation, we require the Contractor to sign this agreement and return it to the Engineer so that the final observation can be scheduled.

It is understood that if the Engineer finds the job not ready for the final observation and that additional trips and observations are required to bring the project to completion, the costs incurred by the Engineers for additional time and expenses will be deducted from the Contractor's contract retainage prior to final payment at the completion of the job.

END OF SECTION 230500

SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

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

1.3 COORDINATION

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

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

PART 2 PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

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

2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Rotor: Random-wound, squirrel cage.

F. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

G. Temperature Rise: Match insulation rating.

H. Insulation: Class F.

I. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

J. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

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

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

2.5 SINGLE-PHASE MOTORS

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

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

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

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

PART 3 EXECUTION (Not Applicable)

END OF SECTION 230513

SECTION 230516 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Pipe loops and swing connections.

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.

B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

PART 3 EXECUTION

3.1 PIPE LOOP AND SWING CONNECTION INSTALLATION

A. Install pipe loops cold-sprung in tension or compression as required to partly absorb tension or compression produced during anticipated change in temperature.

B. Connect risers and branch connections to mains with at least five pipe fittings, including tee in main.

C. Connect mains and branch connections to terminal units with at least four pipe fittings, including tee in main.

END OF SECTION 230516

SECTION 230517 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

1.1 SLEEVES

A. Cast-Iron Pipe Sleeves: Cast iron or ductile iron, with plain ends and integral waterstop collar.

B. Steel Pipe Sleeves: Anti-corrosion coated, with plain ends and integral waterstop collar.

C. Galvanized-Steel Sheet Pipe Sleeves: Round tube closed with welded longitudinal joint.

1.2 SLEEVE-SEAL SYSTEMS

A. Field-assembled, modular sealing-element unit for filling annular space between piping and sleeve.

1.3 SLEEVE-SEAL FITTINGS

A. Manufactured plastic, sleeve-type, plastic or rubber waterstop assembly, made for imbedding in concrete slab or wall.

1.4 GROUT

A. Nonshrink, factory packaged.

1.5 SILICONE SEALANTS

A. Silicone, S, NS, 25, NT: Single-component, non-sag, plus 25 percent and minus 25 percent movement capability, non-traffic-use, neutral-curing silicone joint sealant.

1.6 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Leak Test: After allowing for a full cure, test sleeves and sleeve seals for leaks. Repair leaks and retest until no leaks exist.

1.7 SLEEVE AND SLEEVE-SEAL SCHEDULE

A. Concrete Slabs above Grade:

1. Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves .
2. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves.

B. Interior Partitions:

1. Piping Smaller Than NPS 6: PVC-pipe sleeves.
2. Piping NPS 6 and Larger: Galvanized-steel-sheet sleeves.

END OF SECTION 230517

SECTION 230518 - ESCUTCHEONS FOR HVAC PIPING

1.1 SUMMARY

A. Section includes:

1. Escutcheons.
2. Floor plates.

1.2 PRODUCTS

A. Escutcheons for New Piping:

1. Piping with Fitting or Sleeve Protruding from Wall: One-piece deep pattern.
2. Insulated Piping: One-piece steel with polished chrome-plated finish.
3. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece steel with polished chrome-plated finish.
4. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece steel with polished, chrome-plated finish.
5. Bare Piping in Unfinished Service Spaces: One-piece steel with polished, chrome-plated finish.
6. Bare Piping in Equipment Rooms: One-piece steel with polished, chrome-plated finish.

B. Floor Plates: Split-plate stamped steel with concealed hinge.

END OF SECTION 230518

SECTION 230519 - METERS AND GAGES FOR HVAC PIPING

1.1 PRODUCTS

A. Filled-System Thermometers:

1. Direct-Mounted, Metal-Case, Vapor-Actuated Thermometers:

B. Liquid-in-Glass Thermometers:

1. Metal-Case, Compact-Style, Liquid-in-Glass Thermometers:

C. Duct-Thermometer Mounting Brackets: Flanged bracket, for attachment to air duct.

D. Thermowells:

1. Material for Use with Copper Tubing: CNR or CUNI.
2. Material for Use with Steel Piping: CRES.

E. Pressure Gages:

1. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

F. Test Plugs: Test-station fitting made for insertion in piping tee fitting.

G. Test-Plug Kits: Furnish one test-plug kit(s) containing two thermometer(s), one pressure gage and adapter, and carrying case.

H. Sight Flow Indicators:

1. Construction: Bronze or stainless-steel body, with sight glass and ball, flapper, or paddle wheel indicator.

I. Flowmeters:

1. Orifice Flowmeters:

J. Thermal-Energy Meters:

1. Ultrasonic, Thermal-Energy Meters:

END OF SECTION 230519

SECTION 230529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Thermal-hanger shield inserts.
3. Equipment supports.

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design trapeze pipe hangers and equipment supports.

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

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

2.2 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Galvanized Metallic Coatings: Pregalvanized, hot-dip galvanized, or electro-galvanized.
3. Nonmetallic Coatings: Plastic coated, or epoxy powder-coated.
4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel.

2.3 THERMAL-HANGER SHIELD INSERTS

A. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with 100-psiminimum compressive strength and vapor barrier.

B. Insulation-Insert Material for Hot Piping: ASTM C 552, Type II cellular glass with 100-psiminimum compressive strength.

C. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

D. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

E. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.4 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.5 MATERIALS

A. Aluminum: ASTM B 221.

B. Carbon Steel: ASTM A 1011/A 1011M.

C. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; galvanized.

D. Stainless Steel: ASTM A 240/A 240M.

E. Threaded Rods: Continuously threaded. Zinc-plated or galvanized steel for indoor applications and stainless steel for outdoor applications. Mating nuts and washers of similar materials as rods.

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

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

PART 3 EXECUTION

3.1 APPLICATION

A. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping materials and installation for penetrations through fire-rated walls, ceilings, and assemblies.

B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.

3.2 HANGER AND SUPPORT INSTALLATION

A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

B. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

C. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.

D. Equipment Support Installation: Fabricate from welded-structural-steel shapes.

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

F. Install lateral bracing with pipe hangers and supports to prevent swaying.

G. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

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

I. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

J. Insulated Piping:

1. Attach clamps and spacers to piping.

    a. Use thermal-hanger shield insert with clamp sized to match OD of insert.
    b. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.

2. Shield Dimensions for Pipe: Not less than the following:

    a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
    b. NPS 4: 12 inches long and 0.06 inch thick.
    c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
    d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
    e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.

3. Pipes NPS 8 and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
4. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.3 EQUIPMENT SUPPORTS

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

B. Grouting: Place grout under supports for equipment and make bearing surface smooth.

C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.4 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for equipment supports.

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

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

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

3.5 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

3.6 HANGER AND SUPPORT SCHEDULE

A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.

B. Comply with MSS SP-58 for pipe-hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon-steel pipe hangers and supports and attachments for general service applications.

F. Use copper-plated pipe hangers and copper attachments for copper piping and tubing.

G. Use padded hangers for piping that is subject to scratching.

H. Use thermal-hanger shield inserts for insulated piping and tubing.

END OF SECTION 230529

SECTION 230548.13 - VIBRATION CONTROLS FOR HVAC

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Elastomeric isolation pads.
2. Restrained-spring isolators.
3. Elastomeric hangers.
4. Spring hangers.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device type required.

1.4 QUALITY ASSURANCE

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

PART 2 PRODUCTS

2.1 ELASTOMERIC ISOLATION PADS

A. Elastomeric Isolation Pads: .

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

a. Mason Industries, Inc.

2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
3. Size: Factory or field cut to match requirements of supported equipment.

4. Pad Material: Oil and water resistant with elastomeric properties.
5. Surface Pattern: Waffle pattern.

2.2 RESTRAINED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint:

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

    a. Mason Industries, Inc.

2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.

    a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
    b. Top plate with threaded mounting holes.
    c. Internal leveling bolt that acts as blocking during installation.

3. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.3 ELASTOMERIC HANGERS

A. Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods:

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

    a. Mason Industries, Inc. Type HD

2. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.
3. Dampening Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing steel to steel contact.

2.4 SPRING HANGERS

A. Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression:
.

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

   a. Mason Industries, Inc. Type 30N

2. Minimum Static Deflection: 1in

3. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
8. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
9. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

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

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

3.2 VIBRATION CONTROL DEVICE INSTALLATION

A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."

B. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.

C. Device Schedule:

1. Dedicated Outside Air Unit Fans to be internally individually isolated with Mason Industries Type 30N, rated for a minimum 1" static deflection.
2. VRF Condensing units to be provided with mixed spring and neoprene vibration isolation similar to Mason Industries Type 30N, rated for a minimum 1" static deflection.
3. VRF Fan Coil Units to be provided with mixed spring and neoprene vibration isolation similar to Mason Industries Type 30N, rated for a minimum 1" static deflection.

4. Exhaust fans to be provided with mixed spring and neoprene vibration isolation similar to Mason Industries Type 30N, rated for a minimum 1" static deflection.
5. Electric Unit Heaters to be provided with double deflection neoprene hangars similar to Mason Industries Type HD.

END OF SECTION 230548.13

SECTION 230553 **-** IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

1.1 QUALITY ASSURANCE

A. Quality Standard for Piping Identification: ASME A13.1.

1.2 PRODUCTS

A. Equipment Labels: Metal.

B. Warning Signs and Labels: 1/8 inch thick with .

C. Pipe Labels: Self-adhesive.

D. Duct Labels: thick with adhesive.

E. Stencils: Brass.

F. Valve Tags: stainless steel, 0.025-inch minimum thickness.

G. Warning Tags: ; brass grommet and wire fasteners.

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

a. Constant-volume air systems.
b. Variable-air-volume systems.
c. Multizone systems.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TABB: Testing, Adjusting, and Balancing Bureau.

E. TAB Specialist: An entity engaged to perform TAB Work.

1.4 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity certified by NEBB.
1. TAB Field Supervisor: Employee of the TAB contractor and certified by NEBB.
2. TAB Technician: Employee of the TAB contractor and who is certified by NEBB as a TAB technician.

B. TAB Report Forms: Use standard TAB contractor's forms approved by Construction Manager.

C. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

E. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.5 PROJECT CONDITIONS

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.6 COORDINATION

A. Notice: Provide [seven] <Insert number> days' advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on [air] [and] [water] distribution systems have been satisfactorily completed.

PART 2 PRODUCTS (Not Applicable)

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in [Section 233113 "Metal Ducts"] [Section 233116 "Nonmetal Ducts"] and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

F. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

K. Examine system pumps to ensure absence of entrained air in the suction piping.

L. Examine operating safety interlocks and controls on HVAC equipment.

M. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Automatic temperature-control systems are operational.
3. Equipment and duct access doors are securely closed.
4. Balance, smoke, and fire dampers are open.
5. Isolating and balancing valves are open and control valves are operational.
6. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
7. Windows and doors can be closed so indicated conditions for system operations can be met.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in and in this Section.

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

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."

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

D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed as specified in Section 233113 "Metal Ducts."

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
b. Measure static pressure directly at the fan outlet or through the flexible connection.
c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

    a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.

6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

    a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record final fan-performance data.

3.7 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.

2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.8 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor data.

3.9 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

B. Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Measure, adjust, and record the following data for each steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Air pressure drop.
4. Inlet steam pressure.

D. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.

3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.10 TOLERANCES

A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent.
2. Air Outlets and Inlets: Plus or minus 10 percent.
3. Heating-Water Flow Rate: Plus or minus 10 percent.
4. Cooling-Water Flow Rate: Plus or minus 10 percent.

3.11 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare [weekly] [biweekly] [monthly] <Insert time interval> progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.12 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Fan curves.
2. Manufacturers' test data.
3. Field test reports prepared by system and equipment installers.
4. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Architect's name and address.

6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Inlet vane settings for variable-air-volume systems.
    g. Settings for supply-air, static-pressure controller.
    h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement and class.
    g. Discharge arrangement.
    h. Sheave make, size in inches, and bore.
    i. Center-to-center dimensions of sheave, and amount of adjustments in inches.
    j. Number, make, and size of belts.
    k. Number, type, and size of filters.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

a. Total air flow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Preheat-coil static-pressure differential in inches wg.
g. Cooling-coil static-pressure differential in inches wg.
h. Heating-coil static-pressure differential in inches wg.
i. Outdoor airflow in cfm.
j. Return airflow in cfm.
k. Outdoor-air damper position.
l. Return-air damper position.
m. Vortex damper position.

F. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Coil identification.
d. Capacity in Btu/h.
e. Number of stages.
f. Connected volts, phase, and hertz.
g. Rated amperage.
h. Air flow rate in cfm.
i. Face area in sq. ft..
j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):

a. Heat output in Btu/h.
b. Air flow rate in cfm.
c. Air velocity in fpm.
d. Entering-air temperature in deg F.
e. Leaving-air temperature in deg F.
f. Voltage at each connection.
g. Amperage for each phase.

G. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

    a. System identification.
    b. Location.
    c. Make and type.
    d. Model number and size.
    e. Manufacturer's serial number.
    f. Arrangement and class.
    g. Sheave make, size in inches, and bore.
    h. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Motor Data:

    a. Motor make, and frame type and size.
    b. Horsepower and rpm.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches, and bore.
    f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
    g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

    a. Total airflow rate in cfm.
    b. Total system static pressure in inches wg.
    c. Fan rpm.
    d. Discharge static pressure in inches wg.
    e. Suction static pressure in inches wg.

H. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

    a. System and air-handling-unit number.
    b. Location and zone.
    c. Traverse air temperature in deg F.
    d. Duct static pressure in inches wg.
    e. Duct size in inches.
    f. Duct area in sq. ft..
    g. Indicated air flow rate in cfm.
    h. Indicated velocity in fpm.
    i. Actual air flow rate in cfm.
    j. Actual average velocity in fpm.
    k. Barometric pressure in psig.

I. Air-Terminal-Device Reports:

1. Unit Data:

    a. System and air-handling unit identification.

b. Location and zone.
c. Apparatus used for test.
d. Area served.
e. Make.
f. Number from system diagram.
g. Type and model number.
h. Size.
i. Effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Air velocity in fpm.
c. Preliminary air flow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final air flow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

J. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

a. System and air-handling-unit identification.
b. Location and zone.
c. Room or riser served.
d. Coil make and size.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Entering-air temperature in deg F.
c. Leaving-air temperature in deg F.

3.13 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
2. Check the following for each system:

a. Measure airflow of at least [10] <Insert number> percent of air outlets.
b. Measure water flow of at least [5] <Insert number> percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
d. Verify that balancing devices are marked with final balance position.
e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Construction Manager.
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Construction Manager.
3. Construction Manager shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

END OF SECTION 230593

SECTION 230713 - DUCT INSULATION

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes insulating the following duct services:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

B. LEED Submittals:

1. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
2. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail insulation application at elbows, fittings, dampers, specialties and flanges for each type of insulation.

1.4 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Ductwork Mockups:

a. One 10-foot section each of rectangular and round straight duct.
b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
d. One rectangular and round transition fitting.
e. Four support hangers for round and rectangular ductwork.
f. Each type of damper and specialty.

2. Notify Design Teamseven days in advance of dates and times when mockups will be constructed.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, . Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of the following:

    a. Johns Manville; Microlite.
    b. Knauf Insulation; Friendly Feel Duct Wrap.
    c. Manson Insulation Inc.; Alley Wrap.
    d. Owens Corning; SOFTR All-Service Duct Wrap.

2.2 FIELD-APPLIED JACKETS

A. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

2.3 TAPES

A. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Width: 2 inches.
2. Thickness: 3.7 mils.
3. Adhesion: 100 ounces force/inch in width.
4. Elongation: 5 percent.
5. Tensile Strength: 34 lbf/inch in width.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

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

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.

B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Provide vapor barrier on all insulation for outdoor air, and supply air duct. Seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic or tape.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [2 inches] [4 inches] o.c.

    a. For below ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 PENETRATIONS

A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

1. Comply with requirements in Section 078413 "Penetration Firestopping"irestopping and fire-resistive joint sealers.

C. Insulation Installation at Floor Penetrations:

1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.

2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 INSTALLATION OF MINERAL-FIBER INSULATION

A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
    b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    d. Do not overcompress insulation during installation.
    e. Impale insulation over pins and attach speed washers.
    f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

    a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
    b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.
6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
    b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    d. Do not overcompress insulation during installation.
    e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

    a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
    b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.6 FINISHES

A. Insulation with Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

    a. Finish Coat Material: Interior, flat, latex-emulsion size.

B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

3.7 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.

3.8 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Supply-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.

B. Outdoor-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.

END OF SECTION 230713

SECTION 230719 - HVAC PIPING INSULATION

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes insulating the following HVAC piping systems:

1. Condensate drain piping, indoors.
2. Chilled-water piping, indoors.
3. Condenser-water piping, indoors when used for water-side economizer or for condensate control.
4. Heating hot-water piping, indoors.
5. Refrigerant suction and hot-gas piping, indoors.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).

B. LEED Submittals:

1. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.
2. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
2. Detail removable insulation at piping specialties.

1.4 QUALITY ASSURANCE

A. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Piping Mockups:

a. One 10-foot section of NPS 2 straight pipe.
b. One each of a 90-degree threaded, welded, and flanged elbow.
c. One each of a threaded, welded, and flanged tee fitting.
d. Four support hangers including hanger shield and insert.

2. Notify Design Team seven days in advance of dates and times when mockups will be constructed.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule," and "Outdoor, Underground Piping Insulation Schedule" articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.

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

a. Aeroflex USA, Inc.; Aerocel.
b. Armacell LLC; AP Armaflex.
c. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.

2.2 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Flexible Elastomeric Adhesive: Comply with MIL-A-24179A, Type II, Class I.

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

a. Aeroflex USA, Inc.; Aeroseal.
b. Armacell LLC; Armaflex 520 Adhesive.
c. K-Flex USA; R-373 Contact Adhesive.

2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

EXECUTION

2.3 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

2.4 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
2. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

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

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

2.5 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during application and finishing.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Vapor barrier is required on all pipes containing chilled water, condensate, or refrigerant, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [2 inches] [4 inches] o.c.

    a. For below-ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

P. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.
4. Manholes.
5. Handholes.
6. Cleanouts.

2.6 PENETRATIONS

A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.

1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

C. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

2.7 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

2.8 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

2.9 FINISHES

A. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

C. Do not field paint aluminum or stainless-steel jackets.

2.10 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water:

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible Elastomeric: 1 inch thick.

B. Refrigerant Suction and Hot-Gas Piping:

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible Elastomeric: 1-1/2 inch thick.
b. Provide rigid external jacket on all refrigerant piping visible from occupied spaces.

END OF SECTION 230719

SECTION 230800 - COMMISSIONING OF HVAC

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes commissioning process requirements for the following HVAC&R systems, assemblies, and equipment:

1. Energy supply systems, including generator oil supply.
2. Cooling generation systems, including direct-expansion systems.
3. Distribution systems, including air distribution (heating and cooling) systems exhaust systems air-handling units.
4. Terminal and packaged units, including energy recovery units, unit ventilators unit heaters fan-coil units electric heating packaged units.
5. Vibration and sound systems, including sound attenuation vibration isolation devices.
6. Controls and instrumentation, including BAS energy monitoring and control system.
7. Systems testing and balancing verification, including domestic hot-water circulating systems supply-air systems return-air systems exhaust-air systems.
8. Specialty Industrial Process Exhaust Systems

B. Related Requirements:

1. Section 019113 "General Commissioning Requirements" for general commissioning process requirements and Commissioning Coordinator responsibilities.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. DDC: Direct digital controls.

C. HVAC&R: Heating, Ventilating, Air Conditioning, and Refrigeration.

D. "Systems," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.

E. TAB: Testing, adjusting, and balancing.

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data: For [BAS] [and] [HVAC&R] Testing Technician.

B. Construction Checklists: See related Sections for technical requirements for the following construction checklists:

1. Vibration and seismic controls for HVAC&R piping and equipment.
2. Instrumentation and control for HVAC&R.
3. Refrigerant piping.
4. Metal ducts and accessories.
5. Fans.
6. Particulate air filtration.
7. Air-handling units.
8. Computer-room air conditioners.
9. Air Handling Units
10. Variable Refrigerant Flow (VRF) Systems
11. Specialty Industrial Process Exhaust Systems

1.5 QUALITY ASSURANCE

A. BAS Testing Technician Qualifications: Technicians to perform BAS construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:

1. Journey-level or equivalent skill level with knowledge of BAS, HVAC&R, electrical concepts, and building operations.
2. Minimum [three years'] <Insert time> experience installing, servicing, and operating systems manufactured by approved manufacturer.
3. International Society of Automation (ISA) Certified Control Systems Technician (CCST) Level I.

B. HVAC&R Testing Technician Qualifications: Technicians to perform HVAC&R construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:

1. Journey-level or equivalent skill level. Vocational School four-year program graduate or an Associates degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC&R systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC&R equipment, assemblies, and systems.
2. Minimum [three years'] <Insert time> experience installing, servicing, and operating systems manufactured by approved manufacturer.
3. One of the following:

    a. National Environmental Balancing Bureau (NEBB) Certified Testing, Adjusting, and Balancing Technician.
    b. Associated Air Balance Council (AABC) Certified Test and Balance Technician.
    c. Owner retains the right to waive NEBB or AABC Certification.

C. Testing Equipment and Instrumentation Quality and Calibration: For test equipment and instrumentation required to perform HVAC&R commissioning work, perform the following:

1. Submit test equipment and instrumentation list. For each equipment or instrument, identify the following:

    a. Equipment/instrument identification number.
    b. Planned commissioning application or use.
    c. Manufacturer, make, model, and serial number.
    d. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.

2. Test equipment and instrumentation shall meet the following criteria:

    a. Capable of testing and measuring performance within the specified acceptance criteria.
    b. Be calibrated at the manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
    c. Be maintained in good repair and operating condition throughout the duration of use on this Project.
    d. Be recalibrated/repaired if dropped or damaged in any way since last calibrated.

D. Proprietary Test Instrumentation and Tools:

1. Equipment Manufacturer's Proprietary Instrumentation and Tools: For installed equipment included in the commissioning process, test instrumentation and tools manufactured or prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, perform the following:

    a. Submit proprietary instrumentation and tools list. For each instrument or tool, identify the following:

        1) Instrument or tool identification number.
        2) Equipment schedule designation of equipment for which the instrument or tool is required.
        3) Manufacturer, make, model, and serial number.
        4) Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

    b. Include a separate list of proprietary test instrumentation and tools in the operation and maintenance manuals.
    c. HVAC&R proprietary test instrumentation and tools become the property of Owner at the time of Substantial Completion.

PART 2 PRODUCTS (Not Used)

PART 3 EXECUTION

3.1 GENERAL TESTING REQUIREMENTS

A. Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents and approved Shop Drawings and submittals.

B. Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents and approved Shop Drawings and submittals, and that pretest set points have been recorded.

C. Certify that TAB procedures have been completed and that TAB reports have been submitted, discrepancies corrected, and corrective work approved.

D. Set systems, subsystems, and equipment into operating mode to be tested according to approved test procedures (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

E. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions to verify compliance with acceptance criteria.

F. Test systems, assemblies, subsystems, equipment, and components operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and response according to acceptance criteria.

G. Construction Checklists: Prepare and submit detailed construction checklists for HVAC&R systems, subsystems, equipment, and components.

1. Contributors to the development of construction checklists shall include, but are not limited to, the following:

    a. HVAC&R systems and equipment installers.
    b. TAB technicians.
    c. HVAC&R instrumentation and controls installers.

H. Perform tests using design conditions, whenever possible.

1. Simulated conditions may, with approval of Architect, be imposed using an artificial load when it is impractical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by Commissioning Coordinator and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
2. Commissioning test procedures may direct that set points be altered when simulating conditions is impractical.

3. Commissioning test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.

I. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to Owner. After deficiencies are resolved, reschedule tests.

J. If seasonal testing is specified, complete appropriate initial performance tests and documentation and schedule seasonal tests.

K. Coordinate schedule with, and perform the following activities at the direction of, Commissioning Coordinator.

L. Comply with construction checklist requirements, including material verification, installation checks, start-up, and performance tests requirements specified in Sections specifying HVAC systems and equipment.

M. Provide technicians, instrumentation, tools, and equipment to complete and document the following:

1. Performance tests.
2. Demonstration of a sample of performance tests.
3. Commissioning tests.
4. Commissioning test demonstrations.

3.2 TAB COMMISSIONING TESTS

A. TAB Verification:

1. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
2. Completion of "Preparation" Article requirements for preparation of a TAB plan that includes strategies and step-by-step procedures, and system-readiness checks and reports, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
3. Scope: HVAC&R air systems and hydronic piping systems.
4. Purpose: Differential flow relationships intended to maintain air pressurization differentials between the various areas of Project.
5. Conditions of the Test:

    a. Commissioning Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
    b. Systems operating in full heating mode[with minimum outside-air volume].
    c. Systems operating in full cooling mode[with minimum outside-air volume].
    d. For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.

6. Acceptance Criteria:

    a. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
    b. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than two times the tolerances allowed.

c. Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

3.3 HEATING CONTROL SYSTEM COMMISSIONING TESTS

A. Heating-Water Supply Temperature Control:

1. Prerequisites: Installation verification of the following:

   a. Startup of [boiler] <Insert boiler designations> [steam to hot-water converter] <Insert converter designations> <Insert prime heating-water equipment>.
   b. Startup of heating-water pump(s) <Insert pump designations>.
   c. TAB of heating-water flow and pressure.
   d. Input Device: Heating-water supply temperature; [thermostat] [thermistor temperature sensor] [resistance temperature sensor] <Insert device designations>.
   e. Output Device: Control valve <Insert device designation>.
   f. Display the following at the operator's workstation:

      1) Heating-water supply temperature.
      2) Heating-water supply temperature set point.
      3) Control-valve position.

2. Scope: Heating-water system.
3. Purpose: Control of heating-water supply temperature at input device <Insert device designation>.
4. Conditions of the Test:

   a. Minimum heating-water flow.
   b. Midrange Heating-Water Flow: [50 to 60] <Insert number(s)> percent of maximum.
   c. Maximum heating-water flow.

5. Acceptance Criteria: Under all conditions, heating-water supply temperature is within plus or minus [2.0 deg F] <Insert temperature> of set point.

B. Heating-Water Supply Temperature Reset:

1. Prerequisites: Installation verification of the following:

   a. Startup of [boiler] <Insert boiler designations> [steam to hot-water converter] <Insert converter designations> <Insert prime heating-water equipment>.
   b. Startup of heating-water pump(s) <Insert pump designations>.
   c. TAB of heating-water flow and pressure.
   d. Input Device: Heating-water supply temperature; [thermostat] [thermistor temperature sensor] [resistance temperature sensor] <Insert device designations>.
   e. Input Device: Outdoor-air temperature; [electric, outdoor-air-reset controller] [outdoor-air sensor].
   f. Output Device: Control valve <Insert device designations>.
   g. Display the following at the operator's workstation:

      1) Outdoor-air temperature.
      2) Heating-water supply temperature.
      3) Heating-water supply temperature set point.

4) Control-valve position.

2. Scope: Heating-water system.
3. Purpose: Control of heating-water supply temperature at heating-water supply temperature input device <Insert device designation> in response to variable outdoor-air temperature input; [electric, outdoor-air-reset controller] [outdoor-air sensor].
4. Conditions of the Test: Outdoor-air temperature input value may be overridden for this test.

   a. Low Temperature: Outdoor-air temperature between [minus 30 and 0 deg F] <Insert temperature range>.
   b. Midrange Temperature: Outdoor-air temperature between [30 and 45 deg F] <Insert temperature range>.
   c. High Temperature: Outdoor-air temperature above [65 deg F] <Insert temperature>.

5. Acceptance Criteria: Heating-water supply temperature resets in straight-line relationship with outdoor-air temperature for the following reset schedule. Under all conditions, heating-water supply temperature is within [2.0 deg F] <Insert temperature> of set point.

   a. [195 deg F] <Insert temperature> heating water when outdoor-air temperature is [minus 30 deg F] <Insert temperature>.
   b. [130 deg F] <Insert temperature> heating water when outdoor-air temperature is [65 deg F] <Insert temperature>.
   c. Under all conditions, heating-water supply temperature is within plus or minus [2.0 deg F] <Insert temperature> of set point.

C. Control Primary Circulating Pump(s):

1. Prerequisites: Installation verification of the following:

   a. Startup of heating-water pump(s) <Insert pump designations>.
   b. Input Device: Outdoor-air temperature; [electric, outdoor-air-reset controller] [outdoor-air sensor].
   c. Output Device: Heating-water pump; [starter] [DDC system command to starter] relay.
   d. Display the following at the operator's workstation:

      1) Outdoor-air temperature.
      2) Operating status of primary circulating pump(s).

2. Scope: Heating-water pump(s) <Insert pump designations> and associated controls.
3. Purpose: On-off control of heating-water pump(s) in response to variable outdoor-air temperature input; [electric, outdoor-air-reset controller] [outdoor-air sensor].
4. Conditions of the Test:

   a. High Temperature: Outdoor-air temperature above [65 deg F] <Insert temperature>.
   b. Low Temperature: Outdoor-air temperature below [65 deg F] <Insert temperature>.

5. Acceptance Criteria:

a. High Temperature: Pump(s) are off when outside-air temperature is above [65 deg F] <Insert temperature>.
b. Low Temperature: Pump(s) are on when outside-air temperature is below [65 deg F] <Insert temperature>.

3.4 CENTRAL REFRIGERATION SYSTEM COMMISSIONING TESTS

A. Start and Stop Condenser-Water Pump(s):

1. Prerequisites: Installation verification of the following:

a. Startup of condenser-water pump(s) <Insert pump designations>.
b. Startup of cooling tower <Insert cooling tower designations>.
c. Input Device: Water pressure transducer <Insert device designation>.
d. Input Device: [Space thermostat] [DDC system outdoor-air temperature] <Insert device designation>.
e. Input Device: [Time clock] [DDC system time schedule] <Insert device designation>.
f. Output Device: Hard wired through motor starter; [DDC system binary output] <Insert device designation>.
g. Output Device: [Time clock] [Binary output] <Insert device designation>.
h. Display the following at the operator's workstation:

1) Low-level cooling-tower sump alarm.
2) Outdoor-air temperature.
3) Cooling (software) demand indication.
4) Time and time schedule.
5) Condenser-water pump(s) on-off status.
6) Condenser-water pump(s) on-off indication.
7) Condenser-water flow indication.

2. Scope:

a. Condenser-water system, including condenser-water pump(s), cooling towers, and associated controls.

3. Purpose:

a. Condenser-water pump(s) lockout.
b. Condenser-water pump(s) start.
c. Condenser-water pump(s) shutdown.
d. Low-level cooling-tower sump alarm.
e. Condenser-water pump(s) time-of-day schedule.

4. Conditions of the Test:

a. Verify Lockout: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One-by-one, place the enable-input devices in the "enable" state, and then return each to the "disable" state before placing the next enable-input device to the "enable" state.

b. Verify Start: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One-by-one, place the enable-input devices in the "enable" state.
c. Verify Shutdown: Place all enable-input devices in the "enable" state to allow the pump(s) to start. One-by-one, place the enable-input devices to their "disable" state, and then return each to the "enable" state before placing the next enable-input device to the "disable" state.
d. Verify Schedule: Compare condenser-water pump start and stop schedule times with Owner-approved time-of-day schedule.

5. Acceptance Criteria:

a. Lockout: No single enable-input device starts the pump(s) when released to the enable state.
b. Start: Condenser-water pump(s) start when and only when all enable-input devices are in the "enable" state.
c. Shutdown: Each enable-input device stops the condenser-water pump(s) when placed in the "disable" state, regardless of the state of other enable-input devices.
d. Schedule: Condenser-water pump start and stop schedule times agree with Owner-approved time-of-day schedule.

B. Start and Stop Chilled-Water Pump(s):

1. Prerequisites: Installation verification of the following:

a. Startup of chilled-water pump(s) <Insert pump designations>.
b. Startup of condenser-water pump(s) <Insert pump designations>.
c. Startup of cooling tower <Insert cooling tower designations>.
d. Input Device: Flow switch in condenser-water circuit<Insert device designation>.
e. Output Device: [Starter] [DDC system command to starter] relay.
f. Display of the following at the operator's workstation:

1) Chilled-water flow indication.
2) Condenser-water flow indication.
3) Chilled-water pump(s) on-off status.
4) Chilled-water pump(s) on-off indication.

2. Scope: Chilled-water system, including chilled-water pump(s), associated controls, and condenser-water system controls.
3. Purpose:

a. Chilled-water pump(s) start.
b. Chilled-water pump(s) shutdown.

4. Conditions of the Test:

a. Verify Start: Start with chilled-water pump enable-input device in the "disable" state to prevent pump start. Place the enable-input device in the "enable" state.
b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the pump(s) to run. Then place the enable-input device to the "disable" state.

5. Acceptance Criteria:

a. Start: Chilled-water pump(s) start when and only when the enable-input device is in the "enable" state.
b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

C. Start and Stop Cooling-Tower Fans(s):

1. Prerequisites: Installation verification of the following:

a. Input Device: Flow switch in condenser-water circuit <Insert device designation>.
b. Output Device: [Starter] [DDC system command to starter] relay.
c. Display:

1) Condenser-water flow indication.
2) Cooling-tower fan(s) on-off indication.

2. Scope: Condenser-water system, including cooling tower, condenser-water pump(s), and associated controls.
3. Purpose:

a. Cooling-tower fan(s) start.
b. Cooling-tower fan(s) shutdown.

4. Conditions of the Test:

a. Verify Start: Start with cooling-tower fan enable-input device in the "disable" state to prevent fan(s) start. Place the enable-input device in the "enable" state.
b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the fan(s) to run. Then place the enable-input device to the "disable" state.

5. Acceptance Criteria:

a. Start: Chilled-water pump(s) start when and only when the enable-input device is in the "enable" state.
b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

D. Alternative Chiller(s):

1. Prerequisites: Installation verification of the following:

a. Input Device: [Electric alternator] [DDC system software] <Insert device designation>.
b. Output Device: [Chiller] [DDC system command to chiller] <Insert device designation> terminal strip.
c. Display:

1) Chiller(s) on-off indication.
2) Chiller failure alarm.

2. Scope:

a. Chilled-water system and associated controls.

b. Condenser-water system and associated controls.

3. Purpose:

a. Lead-lag rotation of chillers.
b. Replacement of failed chiller in rotation.
c. Adding and dropping chillers as follows: <Insert sequence and parameters>.
d. Replacement of failed chiller in add/drop sequence.
e. Chiller failure alarm initiation.

4. Conditions of the Test:

a. Lead-Lag Rotation - Chiller Start: Create a number of chilled-water system start-stop cycles equal to the number of chillers plus one.
b. Lead-Lag Rotation - Lead Chiller Fail: Disable the lead chiller while it is running.
c. Lead-Lag Rotation - Lag Chiller Fail: Disable a lag chiller while it is running.
d. Lead-Lag Rotation - Chiller Start Fail: Disable a chiller while it is in standby mode. Initiate a lead-lag rotation call for the disabled chiller to start.
e. Add/Drop Sequence - Increasing Demand: Increase chilled-water demand incrementally to observe the corresponding addition of chillers. Increase demand gradually as the load approached the set point for adding the next chiller to permit observation of the actual load at the time the next chiller is enabled.
f. Add/Drop Sequence - Decreasing Demand: Decrease chilled-water demand incrementally to observe the corresponding dropping of chillers. Decrease demand gradually as the load approached the set point for dropping the next chiller to permit observation of the actual load at the time the next chiller is disabled.
g. Add/Drop Sequence - Operating Chiller Fail:
h. Add/Drop Sequence - Chiller Start Fail:

5. Acceptance Criteria:

a. Lead-Lag Rotation - Chiller Start: On each chilled-water system start event, the [other] [next] chiller in rotation starts as the lead chiller, and the previous lead chiller is designated as the [last]lag chiller.
b. Lead-Lag Rotation - Lead Chiller Fail: When the lead chiller fails, the [other] [next] chiller in rotation starts as the lead chiller, and a chiller failure alarm is initiated for the failed chiller.
c. Lead-Lag Rotation - Lag Chiller Fail: When the lag chiller fails, [the next chiller in rotation starts as the lead chiller, and]a chiller failure alarm is initiated for the failed chiller.
d. Lead-Lag Rotation - Chiller Start Fail: When a chiller fails to start, [the next chiller in rotation starts in its place, and]a chiller failure alarm is initiated for the failed chiller.
e. Add/Drop Sequence - Increasing Demand: Chillers are added at the specified load set point, plus or minus [5] <Insert number> percent. Chilled-water supply temperature remains stable within plus or minus [2.0 deg F] <Insert temperature> of set point.
f. Add/Drop Sequence - Decreasing Demand: Chillers are dropped at the specified load set point, plus or minus [5] <Insert number> percent. Chilled-water supply temperature remains stable within plus or minus [2.0 deg F] <Insert temperature> of set point.
g. Add/Drop Sequence - Operating Chiller Fail: When an operating chiller fails, the next chiller in sequence starts and a chiller failure alarm is initiated for the failed chiller.

h. Add/Drop Sequence - Chiller Start Fail: When a chiller fails to start, the next chiller in sequence starts in its place, and a chiller failure alarm is initiated for the failed chiller.

3.5 TERMINAL UNIT EQUIPMENT COMMISSIONING TESTS

A. Variable-Air-Volume Terminal Air Units with Coils:

1. Prerequisites: Installation verification of the following:

a. Occupancy Input Device: Occupancy sensor.
b. Occupancy Output Device: DDC system binary output.
c. Room Temperature Input Device: [Room thermostat] [Electronic temperature sensor].
d. Room Temperature Output Device: [Pneumatic] [Electronic] damper actuators and control-valve operators.
e. Display the following at the operator's workstation:

1) Room/area served.
2) Room occupied/unoccupied.
3) Room temperature indication.
4) Room temperature set point.
5) Room temperature set point, occupied.
6) Room temperature set point, unoccupied.
7) Air-damper position as percentage open.
8) Control-valve position as percentage open.

2. Scope: Variable-air-volume terminal air units with [hydronic] [steam] coils in supply-air systems, and associated controls.
3. Purpose:

a. Occupancy-dependent room temperature set-point reset.
b. Room temperature control.

4. Conditions of the Test:

a. Commissioning Test Demonstration Sampling Rate: [10] <Insert number> percent of each model/size unit.
b. Temperature Control - Occupied: Start with the room unoccupied. Occupy the room and observe the change to occupied status. Observe temperature control until room temperature is stable at occupied set point plus or minus [1.0 deg F] <Insert temperature>.
c. Temperature Control - Unoccupied: Start with the room occupied. Vacate the room and observe the change to unoccupied status. Observe temperature control until room temperature is stable at unoccupied set point plus or minus [1.0 deg F] <Insert temperature>.

5. Acceptance Criteria:

a. Temperature Control - Occupied:

1) Control system status changes from "occupied" to "unoccupied" after the specified time.

2) Room temperature is stable at occupied set point plus or minus [1.0 deg F] <Insert temperature> within [10] <Insert number> minutes of occupancy. Room temperature does not overshoot or undershoot set point by more than [2.0 deg F] <Insert temperature> during transition.

b. Temperature Control - Unoccupied:

1) Control system status changes from "unoccupied" to "occupied" [immediately] [after five minutes of continuous occupancy].
2) Room temperature is stable at unoccupied set point plus or minus [1.0 deg F] <Insert temperature> within [30] <Insert number> minutes of occupancy.

3.6 AIR-HANDLING SYSTEM COMMISSIONING TESTS

A. Supply Fan(s) Variable-Volume Control:

1. Prerequisites: Installation verification of the following:

a. Volume Control Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing supply-duct static pressure referenced to conditioned-space static pressure.
b. Volume Control Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator. Set inlet guide vanes to [minimum] [closed] position when fan is stopped.
c. Volume Control Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing supply-duct static pressure referenced to conditioned-space static pressure.
d. Volume Control Output Device: [Receiver controller] [DDC system analog output] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
e. High-Pressure Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
f. High-Pressure Output Device: [Receiver controller] [DDC system binary output] to [alarm panel] [motor starter].
g. Display the following at the operator's workstation:

1) Supply-fan-discharge static-pressure indication.
2) Supply-fan-discharge static-pressure set point.
3) Supply-fan airflow rate.
4) Supply-fan [inlet vane position] [speed].

2. Scope: Variable-air-volume supply fan units and associated controls.
3. Purpose:

a. Supply-air discharge static pressure control.
b. Response to excess supply-air discharge static pressure condition.

4. Conditions of the Test:

a. Minimum supply-air flow.
b. Midrange Supply-Air Flow: [50 to 60] <Insert number(s)> percent of maximum.
c. Maximum supply-air flow.

d. Excess supply-air discharge static pressure.

5. Acceptance Criteria:

a. At all supply-air flow rates, and during changes in supply-air flow, discharge air static pressure is at set point plus or minus [2] <Insert number> percent.
b. Fan stops and an alarm is initiated at the operator's workstation when supply-air discharge static pressure is at the excess static pressure plus or minus [2] <Insert number> percent.

B. Air-Handler Mixed-Air Control:

1. Prerequisites: Installation verification of the following:

a. Minimum Position Input Device: [Time clock] [DDC system time schedule].
b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator(s).
c. Heating Reset Input Device: [Room thermostat] [DDC system software].
d. [Supply] [Mixed]-Air Temperature Input Device: [Duct-mounted thermostat] [Electronic temperature sensor].
e. Cooling Reset Input Device: Outdoor- and return-air, duct-mounted [thermostats] [electronic temperature sensors].
f. Display the following at the operator's workstation:

1) Mixed-air-temperature indication.
2) Mixed-air-temperature set point.
3) Mixed-air damper position.

2. Scope: Air handler with mixed-air control and associated controls.
3. Purpose:

a. Occupied time control.
b. Minimum damper position control.
c. Heating reset control.
d. [Supply] [Mixed]-air temperature control.
e. Cooling reset control.
f. Unoccupied time control.

4. Conditions of the Test:

a. Occupied Time Control: Start in unoccupied schedule. Advance to occupied schedule time.
b. Minimum Damper Position Control: Command system to mode in which minimum damper position is required.
c. Heating Reset Control: Create a call for heating.
d. [Supply] [Mixed]-Air Temperature Control: Override [supply] [mixed]-air temperature set point to a value [2.0 deg F] <Insert temperature> above current [supply] [mixed]-air temperature.
e. Cooling Reset Control: Override outdoor-air [temperature to a value that exceeds return-air temperature] [enthalpy to a value that exceeds return-air enthalpy].
f. Unoccupied Time Control: Advance to unoccupied schedule time.

g. Control Data Trend Log: Set up a data trend log of the following input device values and output device commands. Record data at [hourly] <Insert alternative recording frequency> intervals. Submit trend data for [24-hour] <Insert time> periods in which natural conditions require heating reset control, [supply] [mixed]-air temperature control, and cooling reset control.

1) Minimum position input device.
2) Heating reset input device.
3) [Supply] [Mixed]-air temperature input device.
4) Cooling reset input device.

5. Acceptance Criteria:

a. Occupied Time Control: Mixed-air control is active in occupied mode.
b. Minimum Damper Position Control: Controller [opens minimum outdoor-air dampers] [positions outdoor-air dampers to minimum position].
c. Heating Reset Control: Controller [closes minimum outdoor-air dampers] [sets outdoor-air dampers to minimum position].
d. [Supply] [Mixed]-Air Temperature Control: Controller modulates outdoor-, return-, and relief-air dampers to maintain temporary [supply] [mixed]-air temperature set point plus or minus [1.0 deg F] <Insert temperature>.
e. Cooling Reset Control: Controller sets outdoor-air dampers to minimum position when outdoor-air [temperature exceeds return-air temperature] [enthalpy exceeds return-air enthalpy].
f. Unoccupied Time Control: Controller positions outdoor- and relief-air dampers closed and return-air dampers open.
g. Control Data Trend Log: Data verifies control according to sequence of control.

END OF SECTION 230800

SECTION 230900 - INSTRUMENTATION AND CONTROLS FOR HVAC

PART 1 GENERAL

1.1 SUMMARY

A. Furnish and install a new state of art Direct Digital Control System with all the latest hardware and software application necessary to perform the control sequence of operations.

B. Provide a totally BACnet based system with MS/TP and IP networks, including a server with the DDC operating software for unlimited amount of data managers and unitary controllers. All controllers as well as all input/outputs devices shall communicate using the protocols and network standards as defined by Ashrae standards. It is not acceptable to use gateways for communication to controllers. The use of proprietary protocols on any part of the DDC system is prohibited.

C. The control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to applications & system controllers operating in multiuser, multitasking environment on an IP Ethernet network independent from the building IT infrastructure. A browser based solution compliant with the Integration and Architecture Guidelines will interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.

D. Furnish a rack server with the DDC operating building management system software including all the necessary accessories for mounting and connecting to the IT owner¢s rack for remote access or to act as a virtual server accessible at any given point of the owner¢s IT infrastructure. Additionally, an user interface station with a 27• monitor, keyboard and printer shall be provided in the level (s) or floor (s) where main HVAC equipment is located.

E. DDC Software

1. Shall adhere to all requirements as established by the building owner.
2. Shall be integrated into the Centralized Automation Platform
3. Shall be delivered via a 19 inch rack mountable server, server will be provided by the contractor and meet the minimum hardware requirements of the provided solution.
4. Must be on the latest Windows 7 or Windows Server operating system.
5. Shall provide role based portals that will display customized view based on secure access. Authorized users will be able to both monitor and command systems based on their function
6. Shall provide both 2D and 3D graphics.
7. Will support touch screens.
8. Provide 24x7 proactive self-monitoring of all systems and forward all alarms via the requirements as established by the building owner.
9. Shall provide a self-contained reporting tool and be able to view, print and export reports.

F. All mechanical equipment controllers will support TCP/IP, BACnet IP, and BACnet Ethernet communications. Controllers will connect directly to the Ócore & shell• Ethernet network for communications

G. Provide and install all interconnecting cables between all operator terminals and peripheral devices, such as printers as well as connectivity to end user IT network for remote access supplied under this section.

H. The DDC contractor shall get familiarize with all related specification sections associated with HVAC equipment or any system monitor or control by the DDC system including commissioning planning, power requirements, low voltage wiring guidelines.

I. Provide integration capabilities with the ownerȼs Centralized Automation Platform (CAP). The intent of the integration is to form a cohesive Enterprise Information System for data acquisition and management with the ability to have a single seat access to all integrated systems. The Building Management System (BMS) shall have management level monitoring and control capabilities of multiple integrated building systems.

J. Items of work included are as follows:

1. Provide submittals that meet the requirements below for approval.
2. Coordinate installation schedule with the mechanical contractor and general contractor.
3. Provide installation of all panels and devices unless otherwise stated.
4. Provide miscellaneous control wiring for HVAC and related systems regardless of voltage.
5. Provide engineering and field technician labor to program and commission software for each system and operator interface. Submit commissioning reports for approval.
6. Provide project management labor to manage all aspects of the installation process, including but not limited to, coordination with contracting parties, project administration and scheduling, labor management and field supervision of BMS contractor and subcontractor staff.
7. Provide testing, demonstration and training as specified below.
8. Provide electrical products which have been tested, listed and labeled by Underwriters Laboratories, and comply with NEMA standards and the National Electric Code.
9. Provide a comprehensive detailed operator and technical training program.
10. DDC vendor shall appoint experience project manager and technicians to manage the project and assist in all phases of the system installation, start-up and commissioning as well as balancing.
11. Maintain a journal of all DDC field installation activities, this journal shall describe the daily progress made on project from starting date to the last day of the DDC installation scope of work. A copy of this journal shall be submitted with the as-built drawings.
12. An icon shall be included in the server as a Óshortcut• which will allow quick access to all as-built control drawings, associated mark-up mechanical drawings, end devices datasheets and control sequence of operations. This file will be accessed as a batch of pdf files easily accessible and readable at the server. This will allow the local user, a third party service company or the DDC contractor to access and look up the technical information regarding any controlled system.
13. Provide installation of control panels

1.2 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.

2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
7. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:

    a. Water Temperature: Plus or minus 1 deg F.
    b. Water Flow: Plus or minus 5 percent of full scale.
    c. Water Pressure: Plus or minus 2 percent of full scale.
    d. Space Temperature: Plus or minus 1 deg F.
    e. Ducted Air Temperature: Plus or minus 1 deg F.
    f. Outside Air Temperature: Plus or minus 2 deg F.
    g. Dew Point Temperature: Plus or minus 3 deg F.
    h. Temperature Differential: Plus or minus 0.25 deg F.
    i. Relative Humidity: Plus or minus 5 percent.
    j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
    k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
    l. Airflow (Terminal):Plus or minus 10 percent of full scale.
    m. Air Pressure (Space): Plus or minus 0.01-inch wg.
    n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
    o. Carbon Monoxide: Plus or minus 5 percent of reading.
    p. Carbon Dioxide: Plus or minus 50 ppm.
    q. Electrical:Plus or minus 5 percent of reading.

1.3 SEQUENCE OF OPERATION

A. Refer to sequence of operation section of mechanical specifications (section 230993).

B. Contractor shall read and interpret these sequences and prepare for Engineer's review a more detailed sequence corresponding to the exact parameters of the program to be entered into controllers. Where self-tuning or canned or preprogramed blocks are used, reference may be made to these blocks of code or programs together with a submission clearly documenting the features and operation of the code block/program and the standard sequence of operation for that program.

C. The level of detail of all sequences submitted shall exceed the engineer's sequence and shall be sufficient for the commissioning agent to fully field verify the correct operation of all factory and custom programming in the controller.

D. Submissions of sequences for review that are or are verbatim or nearly verbatim reproductions of engineer's sequences may be rejected at Engineer's discretion as being unacceptable for review.

E. Incomplete documentation of the sequence of operation to be programmed, including withholding adequate documentation of the behavior of canned or vendor standard programs on the basis of that information being Óproprietary• shall be sufficient grounds for Engineer to withhold approval.

F. A text sequence shall be presented for review. The entire text sequence shall exist within the commented code. A copy of the commented code or graphical programming language with the relevant portions of the sequence of operation identified to each block of code shall be submitted for record following approval of text sequences and shall form part of the as built submission.

G. The algorithms must be approved by the Engineer and the building Facilities Systems Engineer.

1.4 ACTION SUBMITTALS

A. The DDC contractor is responsible to request and receive all third party equipment submittal as well as wiring diagram indicating point to point terminations related to DDC control to develop control submittal drawings. In the event there is a delay in obtaining specific information the DDC contractor shall add notes in the control submittal indicating the control intent design and add related notes explaining the coordination efforts made to obtain necessary details. Holding submittal for not obtaining this information is not acceptable.

B. If project requires DDC interface between the DDC system and third party packaged equipment, the DDC contractor shall be responsible to request and received any require mapping tables from the third party equipment manufacturer. This information shall be provided accordingly to accomplish proper integration into the DDC system and to avoid delays.

C. Partial Submittal for controls and end devices are not acceptable. Control Submittal as well as end devices data-sheets shall be provide together as one package submission to engineer for approval.

D. Control Submittal drawings are NOT only for DDC contractor use but it shall become an important piece of information for building operators and owners and it shall be organize in such way to follow a logical and easy pattern therefore the control submittal shall follow the same flow of information as the mechanical drawings from lower level floor HVAC equipment to upper level floor equipment and it shall include separate and dedicate sections including but not limited to the following page types:

E. Network Riser: This diagram shall indicate how the DDC contractor plans to interconnect all data manager controllers via an independent communication riser in a multi-level facility and within an ownerȼs IT network for remote access. This diagram shall be separate from the BACnet MS/TP riser. Proving a table schedule is not acceptable and submittal will be rejected as this type of submission has limited and not enough detail. Avoid placing non-network devices on this diagram, if there is a need to indicate distance relationship from a non-network device to a network device indicate such a detail on a separate page.

F. BACnet Riser: This diagram should indicate the BACnet communication bus connection between specific application unitary controllers and the associated data manager within each multi-level facility. Typical diagrams for similar system is not acceptable. This diagram shall include only communication devices. If a distance between a hardwire device and its associated control panel needs to be indicate then use a separate page. Providing a table schedule and combining BACnet Riser and Network into one page is not acceptable and submittal will be rejected as this type of submission has limited and not enough detail. Avoid placing non-ms/tp devices such as valves, DPT on this diagram, if there is a need to indicate distance relationship from an end device to a MS/TP device indicate such a detail on a separate page. Each MS/TP communication loop shall have a return loop at the associated Data-manager controller.

G. BACnet Communication Layout: this diagram shall indicate hot the DDC vendor contractor plans to run the communication network on a specific floor. Using the pertained mechanical drawing floor layout as a reference to mark and illustrate such a communication run is acceptable.

H. Flow Diagrams per system: This diagram shall indicate a representation of airflow or water flow on a HVAC system and it shall be compose of all associated end devices with their respective tagging or designed name. Typical diagrams for similar systems is not acceptable.

I. System Control Panel Point List per system: This diagram shall contain a full point list of hardwire inputs and outputs per system to each controller.

J. Wire Pull diagrams: This diagram shall indicate each control point wire gauge and amount of conductor per point pull to a dedicated control panel. Typical diagrams for similar system is not acceptable. Providing table schedule is not acceptable and submittal will be rejected as this type of submission has limited and not enough detail.

K. Point to Point wiring diagrams for each control panel: This diagram shall include each control point wire connection from field and inside a control panel, This diagram shall include any relay interlock diagram accompanied by a written explanation of the interlock intent. Each wire shall be label including color code. Providing a table schedule format for control panels is not acceptable and submittal will be rejected as this type of submission is not specific and detail enough. Typical diagrams for similar system is not acceptable.

L. Control Panel layout: This diagram indicate the position of each controllers, wires, wire duct, terminal blocks, relays, power supplies, transformers. Each of this components shall be labeled to ease identify each part. Submittal will be reject if this information is missing from submission package.

M. Valve Schedule: this schedule indicate all the valve selection made by the DDC contractor. It shall include flow characteristics, gpm, design pressure drops, actual pressure drop, design cv, calculated cv, valve body pressure rating and close-off pressure rating as well as safe fail position.

N. In the event 24vac power distribution loops are part of the DDC scope of work then the DDC contractor need to supplied as part of the submittal a detailed breakdown of how the low voltage power wiring is distributed among unitary controllers. Indicating location of panel, type of wire gauge and amount of conductors use as well as power loads on controllers and end devices assigned to an individual power loop transformer.

O. The DDC contractor shall provide as part of the control submittal the label system intended to be used to identify each control panel for each control system.

P. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.

1. IP System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator rack server equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.
2. Control System Software: Include technical data for operating system software, operator interface, color graphics, and other third-party applications.
3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

Q. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
3. Wiring Diagrams: Power, signal, and control wiring.
4. Details of control panel faces, including controls, instruments, and labeling.
5. Written description of sequence of operation.
6. Schedule of dampers including size, leakage, and flow characteristics.
7. Schedule of valves including flow characteristics.
8. IP System Hardware:

    a. Wiring diagrams for control units with termination numbers.
    b. Schematic diagrams and floor plans for field sensors and control hardware.
    c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.

9. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
10. Controlled Systems:

    a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
    b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
    c. Written description of sequence of operation including schematic diagram.
    d. Points list.

R. Samples for Initial Selection: For each color required, of each type of thermostat [or sensor] cover with factory-applied color finishes.

S. Samples for Verification: For each color required, of each type of thermostat [or sensor] cover.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. The following shall be included:

1. Maintenance instructions and lists of spare parts for each type of control device and compressed-air station.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

B. Contractor shall not order material or begin fabrication or field installation until receiving authorization to proceed in the form of an approved submittal.

C. Submit to Facilities Systems Engineering prior to software generation:

1. Approved submittals
2. Tree outline of color graphics
3. Samples of trends and history report
4. List of alarm points limits, classification, message interlocks with devices, and other relevant alarm information.
5. Initial setpoint values
6. List of advisories for operators for manual control.

D. Software and Firmware Operational Documentation: Include the following:

1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
3. Device address list.
4. Printout of software application and graphic screens.
5. Software license required by and installed for BAS Software and control systems.

1.6 QUALITY ASSURANCE

A. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this Project.

B. Engineering, drafting, programming, and graphics generation shall be performed by the local branch engineers and technicians directly employed by the Building Management System Contractor.

C. Supervision, checkout and commissioning of the system shall be by the manufacturer's authorized branch engineers and technicians directly employed by the Building Management System contractor. They shall perform commissioning and complete testing of the BMS system.

D. DDC System contractor shall convene a pre-submittal meeting with the engineer, commissioning agent and owner within one month of the notice to proceed. The purpose of this meeting is to review the sequences of operation, outline where the proposed system deviates from the specified sequence of operation, and identify potential problems with the specified sequence. Once the sequences of operation are agreed to by all parties, the contractor shall proceed with the formal controls submittal process. DDC System contractor shall submit a print out of all graphics proposed for the project within one month following submittal approval for review jointly by the owner, engineer, and commissioning agent. DDC System Contractor will be required to demonstrate the prescribed operations while in the Owners office. The Owner, Engineer, Construction Manager, Commissioning Agent and Mechanical Contractor may be present to observe and evaluate the demonstration.

E. The following items will be reviewed during demonstration:

1. Access to the system through a standard web browser, internet explorer.

2. Ease-of use of the system relating to:

a. Changing Schedule
b. Changing Set Points
c. Modifying Program Logic
d. Modifying Graphics
e. Reviewing Historical Trends
f. Downloading Controllers
g. Review Activity Log
h. Review/Edit/Acknowledge Alarms
i. Programming remote alarms to cellphones and email.

F. Project Sequence - The control system work for this project shall proceed in the following order:

1. Submit and receive approval on the Shop Drawings, Product Data as describe in the section "ACTION SUBMITTALS."

2. Perform the control system installation work, including all field check-outs and tuning.

3. Provide support to TAB personnel as specified under the paragraph "TEST AND BALANCE SUPPORT."

4. Provide support to Commissioning Agent

5. Submit and receive approval of the Controls System Operators Manual specified under the paragraph "CONTROLS SYSTEM OPERATORS MANUALS."

6. Submit and receive approval of the Performance Verification Testing Plan and the Pre-PVT Checklist specified under the paragraph "PERFORMANCE VERIFICATION TESTING."

7. Perform the Performance Verification Testing.

8. Submit and receive approval on the PVT Report.

9. Provide one year trend data

10. Submit and receive approval on the Training Documentation at least 30 days before training.

11. Deliver the final Controls System Operators Manuals.

12. Conduct the Phase I Training.

13. Conduct the Phase II Training.

14. Conduct the Phase III Training.

15. Submit and receive approval of Closeout Submittals.

1.7 TECHNICAL PROPOSAL

A. Provide a detailed technical proposal describing all elements of the system. A schematic system layout shall be provided, showing relation of these elements and a description of how they operationally interrelate. Technical specification data sheets shall be provided for all proposed system components and devices.

B. Provide a paragraph-by-paragraph statement of conformance with the specifications. This statement shall consist of a list of all numbered paragraphs. Where the proposed system complies fully, such shall be indicated by placing the word "comply" opposite the paragraph number. Where the proposed system does not comply, or accomplishes the stated function in a manner different from that described, a full description of the deviation shall be provided.

C. Where a full description of a deviation is not provided, it shall be assumed that the proposed system does not comply with the paragraph in question.

D. Provide a total System Architecture drawing showing typical IP controller part numbers for the types of systems used on this project. Detail the types of networks, speeds and protocols used by each network segment.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Handle, store and protect equipment and materials to prevent damage before and during installation according to manufacturer's recommendations.

B. Replace damaged or defective items.

C. System Software: Update to latest version of software at Project completion.

D. Protect components from humidity and temperature variation, dust and contaminants.

E. If components are stored before installation, keep them within the manufacturer's limit.

1.9 COORDINATION

A. Coordinate location of thermostat and heights as well as control panel and other exposed control sensors in the field prior installation.

B. If thermostat locations are not shown on contract drawings then DDC contractor shall propose and coordinate proper and final locations prior installation following the approval protocol channels. Otherwise, the possible relocation of thermostat shall be at the DDC contractor expense.

C. If thermostat heights are not shown on contract drawings then DDC contractor shall proposed or coordinate final proper locations prior installation following the approval protocol channels. Otherwise, the possible relocation of thermostat heights shall be at the DDC contractor expense.

D. If panel locations are not shown on contract drawings, DDC contractor shall proposed or coordinate final locations prior installation following the approval protocol channels. Otherwise, the possible relocation of control panels shall be at the DDC contractor expense.

E. If location of temperature wells, flow meters, differential pressure transmitters, airflow stations are not indicated on contract drawings then DDC contractor shall proposed or coordinate final proper locations that work in conjunction to meet the design sequence of operations.

F. If DDC contractor requires power wiring for the control panels and it is not part of the DDC scope of work then the DDC contractor shall provide a detailed list of all the control panels requiring power at once following the proper communication channels. This information should be provided prior submitting an official control submittal to avoid delays and to document selected power circuitry and loads.

G. If DDC contractor requires power for any HVAC equipment under the DDC system control then the DDC contractor should notify the GC and mechanical contractor at once.

H. Whenever a valve schedule or damper schedule is approved or release by mechanical contractor, DDC contractor should coordinate the proper delivery of all these materials in order to be install by the pipefitter in a timely manner and avoid delays.

I. Upon approval of control submittal and upon release notification from GC and mechanical contractor, the DDC contractor should advise of any long lead material items for critical operation to avoid delays. This in not limited to control valves, isolation valves, dampers, airflow stations and the DDC contractor should provide an alternate solution to avoid delays to the project schedule.

J. The DDC contractor shall provide a plan for the activation of all DDC controllers as well as a plan for all point to point checkout procedure to the GC and mechanical to work in a synergy manner to start up HVAC equipment within project schedule deadlines.

K. The DDC contractor programming shall be completed offsite and tested offline prior the implementing into the DDC controllers and fine tune programming during the point to point checkout process.

L. The DDC contractor shall provide any necessary tool for the balancer to perform modification on their controller.

M. The DDC contractor technician shall assist during the balancing process as require.

N. The DDC contractor standard graphic layout for typical repeated HVAC equipment such as VAV, FCU, package RTU shall be submitted with the initial control submittal for approval and it shall be ready to download prior commissioning agent testing.

O. The DDC contractor shall submit to facilities systems engineering prior software generation:

1. Approved submittals
2. Tree outline of color graphics
3. Samples of trends and history reports
4. List of alarm point limits, classification, message interlocks with devices, and other relevant alarm notification.
5. Initial setpoint values
6. List of advisories for operators for manual control
7. Software operating and upgrade manuals
8. Program software backup complete with data files.
9. Device address list
10. Print out of software application and graphics screens
11. Software license require by and installed for DDC software and control systems.

1.10 TRAINING

A. Training manuals: the standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the operation and maintenance manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the operation and maintenance manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals and in all software displays.

B. Conduct trainings that are tailored to the needs and skill-level of the trainees.

C. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The owner shall approve the instructor prior to scheduling the training.

D. During any demonstration, should the system fail to perform in accordance with the requirements of the Operation and Maintenance manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.

E. The DDC contractor shall discuss the interaction of the controls system as it relates to each HVAC equipment being under control of the building management system (DDC), the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure shall be illustrated.

F. Training shall be break up into three training sessions as follow:

1. Training I (40 hours) Control systems overview: this training may be held on-site or in the supplier¢s facility. If held off-site, the training may occur prior to completion of the final system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the DDC system.
2. Training II (40 hours): Building systems: the second session shall be held on-site and will consist of actual hands-on training after the completion of system commissioning. the session shall include instruction on:

a. Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems applicable to the actual scope owe by the DDC contractor.
b. Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing set points and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
c. All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
d. Every screen shall be completely discussed, allowing time for questions.
e. Use of keypad or plug-in laptop computer at the zone level.
f. Use of remote access to the system via phone lines or networks.
g. Setting up and changing an air terminal unit controller.
h. Graphics generation or modification.
i. Point database entry and modifications
j. Understanding DDC field panel operating programming (when applicable)

3. Training III (20 hours): Follow-up training: the third and final session will be conducted on-site six months after occupancy. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

G. Since the owner may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the contractor. If the owner requires such training, it will be contracted at a later date. Provide description of available local and factory customer training. Provide costs associated with performing training at an off-site classroom facility and detail what is included in the manufacturer¢s standard pricing such as transportation, meals, etc.

1.11 DDC SYSTEM ARCHITECTURE NETWORK

A. GENERAL

1. The DDC system architecture shall be completely separate from owner¢s IT infrastructure and it shall interact between each other only for remote access purposes and to set up the DDC rack server into the owner¢s IT network.
2. IT infrastructure owner shall provide static IP addresses as require by the ddc contractor¢s equipment.
3. The DDC contractor should comply with all owner it infrastructure security policies for remote access.
4. All data communications protocol shall be Bacnet MS/TP or Bacnet IP.
5. The DDC contractor shall furnish an Ethernet riser communication on a small scale multilevel facility (maximum 15 floor or levels) it shall provide for the primary network an individual cat6 homeruns from DDC server switch/hub to each data manager or primary controller as long as Ethernet maximum distance limitation are maintained.

6. If applicable, the DDC contractor on a medium scale multilevel facility (more than 15 floor or levels up to 30 floors) shall utilize the first initial 15 floor a Ethernet riser then furnish a separate primary network via a multimode fiber optic vertical communication backbone from DDC server to a fiber to Ethernet converter hub to create an extended Ethernet separate riser for the next 15th floors.
7. If applicable, the DDC contractor on a large scale multilevel facility (more than 30 floors) shall furnish an additional fiber multimode run to further extend an Ethernet riser for the next 15th floor. This shall be repeated every additional 15 floors.
8. The DDC vendor is responsible for cat6 horizontal homeruns from the floor level fiber/ethernet converter switch/hub to the individual data manager or primary controllers.
9. All Ethernet switches or fiber to Ethernet converters and associated accessories to be provided by the DDC contractor.
10. The DDC contractor shall follow all the technical requirements in the DDC system architecture design for distance limitations on Ethernet and fiber network.
11. All Ethernet switches or fiber converters should be mounted on a panel enclosure
12. All Ethernet switches or fiber panel enclosure locations should be coordinate with GC.
13. Power wiring require for any DDC contractor¢s Ethernet or fiber switches/hubs shall be provided by division 26 electrical subcontractor.
14. The DDC system shall allow the distribution of system functions such as monitoring and control and graphical user interface etc. across the network to achieve maximum flexibility, accessibility and performance.
15. It is not acceptable to utilize the network to send critical data required by a control algorithm from one controller to another. Critical data shall be a direct hardwire input to the controller containing the control algorithm. If multiple controllers require the same piece of data for a control algorithm, the data shall be a direct hardwire input to each controller.
16. It is not acceptable to restricted access to DDC system data by the hardware configuration of the DDC. Hardware configuration of the DDC network shall be totally open and transparent to the user when accessing data or developing control programs.
17. The DDC contractor design shall be made to allow the co-existence of current and future expansion of data manager controllers and personal computer operator workstations on the same primary network.

B. Primary Peer-to-Peer Network

1. All operator workstations and primary controllers shall directly reside on a network such that communications (i.e., ability to access, edit, modify, add, delete, back up, report, trend, restore all system point database and all programs) may be executed directly between servers, primary control panels, and operator workstations on a peer-to-peer basis.
2. All operator devices either network resident or connected via intranet and internet, shall have the ability to access all point status and application report data or execute control functions for any and all other devices via the primary network or the secondary network.
3. Access to data shall be based upon logical identification of building equipment.
4. It is not acceptable to imposed a hardware or software limits on the number of devices with global access to the network data.
5. The primary network shall provide a high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall insure that an alarm occurring at any control panel is displayed at any pc workstation, standalone alarm printer and/or control panel within 5 seconds.
6. The primary network shall support of any combination of primary control panels and operator workstations directly connected to the primary network. A minimum of 64 devices and a maximum of 100 devices shall be supported per data manager or primary network controller.

7. The primary network shall provide message and alarm buffering to prevent information from being lost, error detection, correction and re-transmission to guarantee data integrity.
8. The primary network should be capable to do synchronization of real-time clocks between server, primary control panels, and operator workstations, including automatic daylight savings time corrections.
9. The DDC contractor shall provide network wiring as required to ensure total system operation and communication without interruption, even if the network wiring is open in one (1) location.
10. The primary network shall allow the primary control panels to access any data from, or send control commands and alarm reports directly to, any other primary control panel or combination of controllers on the network without dependence upon a central or intermediate processing device.
11. The primary control panel shall send alarm reports to multiple operator workstations without dependence upon a central or intermediate processing device.
12. The peer-to-peer network shall also allow any primary control panel to access, edit, modify, add, delete, back up, restore all system point database and all programs, assign password access and control priorities to each system individually. The logon password (at any pc workstation or portable operator terminal) shall enable the operator to monitor, adjust and control only the system that the operator is authorized for.

C. Secondary Network

1. This network shall connect and support stand-alone secondary control panels and shall communicate bi-directionally with the primary network through primary control panels for transmission of global data. A sufficient number of primary control panels shall be provided for connection of secondary networks based on quantity of secondary controls panels and distance limitations.
2. Secondary control panels shall be arranged on the secondary network in a functional relationship manner with the primary control panels. For example, a VAV secondary control panel on a secondary network of a primary control panel that is controlling the VAV¢s corresponding AHU.
3. A maximum of 60 secondary control panels may be configured on an individual secondary network to insure adequate global data and alarm response times and future space capacity.
4. The secondary network shall be connected to and communicate with the primary control independently.

D. Primary Control Panel Hardwire (Data Manager)

1. Provide one (1) data manager or primary control panel at each floor or level to monitor and sequencing equipment within associated floor.
2. Unless it is noted in the contract documents or drawings, it is not acceptable to have (1) data manager or primary controller serving several floors unless the mechanical equipment is interacting with each other for example: an ahu unit is located on the first floor and all associated VAV boxes are on a second floor if this is the case then it is acceptable.
3. HVAC equipment that interact with each other shall be within the same data manager or primary controller.
4. Spare capacity

a. All primary control panels shall be installed with 30% spare memory capacity for future connections. provide all hardware modules, software modules, processors, power supplies, repeaters etc. required to ensure adding a controller to the spare memory
b. Provide all processors, power supplies and communication controllers so that the implementation of adding a controller to the spare memory only requires the addition of the appropriate: end devices and field wiring.
c. Provide all necessary hardware for a complete operating system as required. All hardware shall reside in each primary control panel and associated server. Primary control panels shall not be dependent upon any higher level computer or another controller for operation.

5. The data manager or primary network controller shall be provided all communication cards needed for project including cards for spare port left on controller.
6. Memory to accommodate all data manager or primary control panel software requirements, including but not limited to, its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, operator i/o, dial-up communications. Controller shall have a minimum of 32 mb ram, 1 mb of flash and 16k eprom or eeprom. controller shall be provided with battery backup capable of supporting all ram, clock functions, ddc database and operating programs within the controller for a minimum of 72 hours in the event of power failure or power interruption (if information is not stored in non-volatile memory).
7. The data manager or primary network controller shall be provided with data collection/ data trend module sized for 10,000 data samples.
8. The data manager or primary network controller shall be provided with power supplies as required for all associated modules, sensors, actuators, etc.
9. The data manager or primary network controller shall be provided with any software modules for all sequences of operation, logic sequences and energy management routines.
10. The data manager or primary network controller shall be provided with a portable operator terminal connection port to allow the temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals.
11. Monitoring of all industry standard types of interface protocols without the addition of equipment to the primary control panel or additional drives.
12. The operator shall have the ability to manually override automatic or centrally executed commands at the data manager or primary control panels via a display mounted on the front door (for example: Distech controls' horyzon-c displays)
13. Each data manager primary control panel shall continuously perform self-diagnostics on all hardware modules and network communications. The primary control panel shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication with any system.
14. All data manager or primary controller databases and programs shall be stored in non-volatile memory.
15. Each data manager or primary control panel shall support firmware upgrades without the need to replace hardware.
16. Data manager or primary control panels shall provide at least two (2) eia-232c serial data communication ports for operation of operator i/o devices such as industry standard printers, operator terminals, modems and portable laptop operator's terminals. Primary control panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals.
17. Immunity to power and noise.

18. Controller shall be able to operate at 90% Ó 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
19. Operation shall be protected against electrical noise of 5 Ó 120 hz and from keyed radios up to 5w at 1m (3¢).

E. Primary Control Panel Software (Data Manager)

1. Furnish software to form complete operating system for building and energy management
2. DDC software shall be capable to host an unlimited amount of data manager or primary controller for expandability (e.g., EC-net 4 supervisor UNL)
3. Provide all necessary software for a complete operating system as required. All software shall reside in each data manager or primary control panel. Primary control panels shall not be dependent upon any higher level computer or another controller for operation.
4. All programs points shall be identified by a 30 character name and a 16 character point descriptor. The same names shall be displayed at both the data manager or primary control panel(s) (via portable terminal, printer or modem) and the pc operator workstation(s). If there is similar multi-system consistency on point name should be maintained.
5. All digital points shall have a user-defined, 2-state status indication with 8 characters minimum (e.g., summer/winter, enabled/disabled, abnormal/normal).
6. System security

    a. User access shall be secured using individual security passwords and user names.
    b. Passwords shall restrict the user to the objects, applications and system functions as assigned by the system manager.
    c. Data manager or primary controllers shall be able to assign a minimum of 50 passwords access and control priorities to each point individually. the logon password (at any operator interface or portable operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. all other points shall not be displayed at the operator interface or portable terminal. passwords and priorities for every point shall be fully programmable and adjustable.
    d. User log on / log off attempts shall be recorded.
    e. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. the delay time shall be user-definable.

7. Each data manager or primary control panel shall, at a minimum, be provided with software for:

    a. 2-position control, proportional control, proportional plus integral control, proportional, integral, plus derivative control algorithms, all with automatic control loop tuning.
    b. Limiting the number of times each piece of equipment may be cycled within any 1-hour period.
    c. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads. upon the resumption of power, each ddc controller shall analyse the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.
    d. Priority load shedding.

e. Energy management routines including time of day scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides, start-stop time optimization, automatic daylight savings time switch over, night setback control, enthalpy switch over, peak demand limiting, temperature-compensated duty cycling, heating/cooling interlock, supply temperature reset, priority load shedding and power failure restart.
f. Custom, job-specific processes defined by the user, to automatically perform calculations and special control routines and sequences of operations.

8. Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.
9. It shall be possible to use any system measured point data or status, any system calculated data, a result from any process or any user-defined constant in any controller in the system.
10. Any process shall be able to issue commands to points in any and all other controllers in the system.
11. Processes shall be able to generate operator messages and advisories to other operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or pager.
12. The custom control programming feature shall be documented via English language descriptors.
13. Each controller shall support text comment lines in the operating program to allow for quick troubleshooting, documentation and historical summaries of program development.
14. Controller shall provide a help function key, providing enhanced context sensitive on-line help with task orientated information from the user manual.
15. Generate and receive automatic and manual operator messages and advisories.
16. Comment lines for all programs.
17. Distributed independent alarm analysis and filtering. Reporting of selected alarms during system shutdown and start-up shall be automatically inhibited. a minimum of 6 priority levels shall be provided for each point.
18. Automatically accumulate and store run-time hours for all digital points.
19. Automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for all analog and pulse input type points.
20. Trend data shall be stored at the primary control panels and automatically uploaded to the pc workstation.
21. Uploads shall occur based on user-defined intervals, manual commands, or automatically when the trend buffer is 80% full. All trend data shall be available for use in any 3rd party personal computer applications located in the DDC system.
22. Primary control panels shall be able to assign password access and control priorities to each system individually. the logon password (at any pc workstation(s) or pot) shall enable the operator to monitor, adjust and/or control only the systems, programs, primary control panel and/or secondary control panels that the operator is authorized for. All other systems, programs, primary and secondary control panels shall not be displayed at the pc workstation, pot or modem. Passwords and priority levels for each system, program, primary control panel and secondary control panel shall be fully programmable and adjustable.
23. Primary control panels shall be able to access any data from, or send control commands and alarm reports directly to, any other primary control panel or combination of controllers on the network without dependence upon a central or intermediate processing device. Primary control panels shall also be able to send alarm reports to multiple operator workstations without dependence upon a central or intermediate processing device.

24. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each DDC controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the DDC controllers ability to report alarms be affected by either operator or activity at a pc workstation, local i/o device or communications with other panels on the network.
25. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
26. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of 6 priority levels shall be provided for each point.
27. Point priority levels shall be combined with user definable destination categories (pc, printer, DDC controller, etc.) to provide full flexibility in defining the handling of system alarms. Each DDC controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.
28. Alarm reports and messages shall be routed to user-defined list of operator workstations or other devices based on time and other conditions. an alarm shall be able to start programs, print, be logged in the event log, generate custom messages and display graphics.
29. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.
30. Each DDC controller shall be capable of storing a library of at least 50 alarm messages. Each message may be assignable to any number of points in the controller.
31. Operator-selected alarms shall be capable of initiating a call to a remote operator device.
32. Scheduling:

    a. Provide a comprehensive menu driven program to automatically start and stop designated object or group of objects in the system according to a stored time.
    b. It shall be possible to define a group of objects as a custom event (i.e., meeting, athletic activity, etc.). Events can then be scheduled to operate all necessary equipment automatically.
    c. For points assigned to one (1) common load group, it shall be possible to assign variable time delays between each successive start and stop within that group

33. The operator shall be able to define the following information:

    a. Time, day.
    b. Commands such as on, off, auto and so forth.
    c. Time delays between successive commands.
    d. There shall be provisions for manual overriding of each schedule by an appropriate operator.

34. It shall be possible to schedule calendar-based events up to 1 year in advance based on the following:

    a. Weekly schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop and night economizer.
    b. When a group of objects are scheduled together as an
    c. Event, provide the capability to adjust the start and stop times for each member.

d. Exception schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by the standard schedule for that day of the week.
e. Holiday schedules. Provide the capability for the operator to define up to 99 special or holiday schedules. These schedules may be placed on the scheduling calendar and will be repeated each year. The operator shall be able to define the length of each holiday period.

35. Peak demand limiting (PDL)

    a. The peak demand limiting (PDL) program shall limit the consumption of electricity to prevent electrical peak demand charges.
    b. PDL shall continuously track the amount of electricity being consumed, by monitoring one (1) or more electrical kilowatt-hour/demand meters. These meters may measure the electrical consumption (kwh), electrical demand (kw) or both.
    c. PDL shall sample the meter data to continuously forecast the demand likely to be used during successive time intervals.
    d. if the PDL forecasted demand indicates that electricity usage is likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads
    e. Once the demand peak has passed, loads that have been shed shall be restored and returned to normal control.

36. Temperature-compensated duty cycling.

    a. The dccp (duty cycle control program) shall periodically stop and start loads according to various patterns.
    b. The loads shall be cycled such that there is a net reduction in both the electrical demands and the energy consumed.

37. Automatic daylight savings time switchover: the system shall provide automatic time adjustment for switching to/from daylight savings time.
38. Night setback control. The system shall provide the ability to automatically adjust setpoints for night control.
39. Enthalpy switchover (economizer). The primary controller software shall control the position of the air handler relief, return and outside air dampers. If the outside air enthalpy is below the return air enthalpy, the software will modulate the dampers to provide 100% outside air. The user will be able to quickly changeover to an economizer system based on enthalpy and will be able to override the economizer cycle and return to minimum outside air operation at any time.
40. PID control. A PID (proportional-integral-derivative) algorithm with direct or reverse action and anti-windup shall be supplied. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, set point and PID gains shall be user-selectable.
41. Provide application software based upon the sequences of operation specified to properly sequence equipment.
42. Staggered start:

    a. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order, in which equipment (or groups of equipment) is started, along with the time delay between starts, shall be user definable.

b. Upon the resumption of power, each primary controller shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.

43. Totalization

a. Run-time totalization. Primary controllers shall automatically accumulate and store runtime hours for all digital input and output points. A high runtime alarm shall be assigned, if required, by the operator.
b. Consumption totalization. Primary controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for all analog and digital pulse input type points.
c. Event totalization. Primary controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for all points. The event totalization feature shall be able to store the records associated with events before reset.

44. A variety of historical data collection utilities shall be provided to manually or automatically sample, store and display system data for all points.
45. DDC controllers shall store point history data for selected analog and digital inputs and outputs:

a. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each DDC controllers point group. Two (2) methods of collection shall be allowed: either by a pre-defined time interval or upon a pre-defined change of value. Sample intervals of l minute to 7 days shall be provided. Each DDC controller shall have a dedicated ram-based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.
b. Trend data shall be stored at the DDC controllers and automatically uploaded to the workstation. Uploads shall occur based upon user-defined interval, manual command or automatically when the trend buffers are 80% full.
c. DDC controllers shall also provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for a minimum of 36 operator-selected PID control loops.
d. Provide capability to view or print trend and tuning reports.
e. the controller shall perform a step response test with a minimum 1-second resolution, evaluate the trend data, calculate the new PID gains and input. These values into the selected loop statement.
f. Loop tuning shall be capable of being initiated either locally at the DDC controller, from a network workstation, or remotely using dial-in modems.
g. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

46. DDC controllers shall automatically accumulate and store run-time hours for all digital input and output points.
47. DDC controllers shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for all analog and digital pulse input type points.
48. DDC controllers shall count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly and monthly basis for all points. The event totalization feature shall be able to store the records associated with a minimum of 9,999.9 events before reset.

F. Secondary Control Panel Hardware (unitary controller)

1. Each secondary control panel shall operate as a stand-alone controller capable of performing its user selectable control routines independently of any other controller in the system. Each secondary control panel shall be a microprocessor-based, multi-tasking, real-time digital control processor.
2. Each primary controller shall be able to communicate with secondary controllers over the secondary network to control terminal equipment only.
3. Each secondary controller shall include all point inputs and outputs necessary to perform the specified control sequences. The secondary controller shall accept input and provide output signals that comply with industry standards. Controllers utilizing proprietary control signals shall not be acceptable. Outputs may be utilized either for 2-state, modulating, floating or proportional control, allowing for additional system flexibility.

4. Each secondary control panel shall, at a minimum, be provided with:

    a. Appropriate NEMA rated enclosure for its application.
    b. A stand-alone real-time digital control microprocessor module.
    c. built-in display (with the exception of VAV controllers)
    d. Secondary network communications ability.
    e. Power supplies as required for all associated modules, sensors, actuators, etc.

5. Input/output points as required.
6. Software as required for all sequences of operation, logic sequences and energy management routines.
7. A portable operator terminal connection port.
8. Auxiliary enclosure for analog output transducers, isolation relays, etc. auxiliary enclosure shall be part of secondary enclosure or mounted adjacent enclosure.
9. Each controller measuring air volume shall include provisions for manual and automatic calibration of the differential pressure transducer in order to maintain stable control and insuring against drift over time.
10. Each controller measuring air volume shall include a differential pressure transducer.
11. SCR control of electric heaters.
12. Fan speed controller for fan powered VAV boxes.
13. Fan relay for fan powered VAV boxes and fan coil units.
14. Communication: each controller shall perform its primary control function independent of other secondary network communication or if secondary network communication is interrupted.
15. Reversion to a fail-safe mode of operation during secondary network interruption is not acceptable.
16. Control algorithms. The controller shall receive its real-time data from the primary controller time clock to insure secondary network continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) gains for all applications. All PID gains and biases shall be field-adjustable by the user via room sensor LCD or the portable operator¢s terminal as specified herein.
17. Control applications. Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of all applications are not acceptable.
18. Each controller shall include provisions for manual and automatic calibration of the differential pressure transducer in order to maintain stable control and insuring against drift overtime.

19. Manual calibration may be accomplished by either commanding the actuator to 0% via the pot or by depressing the room sensor override switch. Calibration of the transducer at the controller location shall not be necessary.
20. Each secondary control panel shall continuously perform self-diagnostics on all hardware and secondary network communications. the secondary control panel shall provide both local and remote annunciation of any detected component failures or repeated failure to establish communication to the system
21. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. As a minimum, 50% of the point outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. In lieu of universal outputs, provide a minimum of 50% spare outputs of each type via additional point termination boards or controllers. Analog outputs shall be industry standard signals such as 24 vac floating control, allowing for interface to a variety of modulating actuators. Terminal equipment controllers utilizing proprietary control signals and actuators shall not be acceptable.
22. Provide each secondary control panel with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile memory. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration.
23. Provide uninterruptible power supplies (UPS) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility.
24. Controller shall have a minimum of 16k eprom or eeprom.
25. The secondary control panels shall be powered from a 24 vac source provided by this contractor and shall function normally under an operating range of 18 Ó 28 VAC(-25% Ó 17%), allowing for power source fluctuations and voltage drops. install plenum data line and sensor cable in accordance with local code and NEC. the DDC contractor shall provide a dedicated power source and separate isolation transformer for each controller to function normally under the specified operating range. the controllers shall also function normally under ambient conditions of 32º Ó 122ºf (0º Ó 50ºc) and 10% Ó 95% RH (non-condensing).
26. Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly. Power supply must be rated at a minimum of 125% of power consumption and shall be of the fused or current limiting type. the DDC contractor shall provide 24VAC power to the terminal units by utilizing:

    a. The existing line voltage power trunk and installing separate isolation transformers for each controller.
    b. Dedicated line voltage power source and isolation transformers at a central location and installing 24 vac power trunk to supply multiple controllers in the area.

27. Environment. The controllers shall function normally under ambient conditions of 32º Ó 122ºf (0º Ó 50ºc) and 10% Ó 95% rh (non-condensing). Provide each controller with a suitable cover or enclosure to protect the circuit board assembly.
28. Immunity to noise. Operation shall be protected against electrical noise of 5 Ó 120hz and from keyed radios up to 5w at 1m (3¢).

G. Secondary Control Panel Software (Unitary Controller)

1. Provide all necessary software for a complete operating system as required. All software shall reside in each secondary control panel. Secondary control panels shall not be dependent upon any higher level computer or another controller for operation.

2. Secondary control panel software configured for CAV or VAV control algorithms shall include provisions for manual and automatic calibration of attached differential pressure transducer in order to maintain stable control and insuring against drift over time. Calibration shall be accomplished by stroking the terminal unit damper actuator to a 0% position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa. Manual calibration may be accomplished by either commanding the actuator to 0% via the pot or by depressing the room sensor override switch. Calibration of the transducer at the controller location shall not be necessary.
3. Each secondary controller shall perform its primary control function independent of primary controller LAN communication, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the primary control panel time clock to insure LAN continuity.
4. Controllers that require factory application changes are not acceptable.

1.12 Input and Outputs

A. Hardwire input and output points shall connect to the network programmable application and application-specific controller.

B. Input and output points shall be protect so shorting of point to itself, to another point, or to ground will not damage controller.

C. Input and output points shall be protect from voltage up to 24 V of any duration so that contact will not damage controller.

D. There shall be 15% control point spare capacity per system.

E. Analog Inputs: It shall include monitoring of low voltage (zero to 10Vdc), Current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.

1. It shall be compatible with, and field configurable to sensors and transmitters installed.
2. Signal conditioning including transient rejection shall be provided for each AI.
3. Capable of being individually calibrate for zero and span.
4. Incorporate common-mode noise rejection of at least 40dB from zero to 100 HZ for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 1000 ohms.

F. Analog Outputs: Output signals shall have a range of 4-20mA dc or 0-10Vdc as required to include proper control of output device.

1. Capable of being individually calibrate for zero and span.

2. AOs shall not exhibit a drift of greater than 0.4 percent of range per year

G. Binary Outputs: Controller binary inputs shall accept contact closure and shall ignore transients of less than 5-ms duration.

1. Isolation and protection against applied steady-state voltage of up to 180-V ac peak.
2. Binary inputs shall include a wetting current of at least 12mA to be compatible with commonly available control devices and shall be protect against effects of contact bounce and noise.

3. Binary inputs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
4. Binary Outputs: Controller binary outputs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.
5. Relay contact closures shall have a minimum duration of 0.1 seconds. Relays shall include at least 180 V of isolation.
6. Electromagnetic interference suppression shall be provide on all output lines to limit transients to non-damaging levels.
7. Triac outputs shall include at least 180 V of isolation.
8. Minimum contact rating shall be 1 A at 24VAC.
9. Binary Outputs shall include two-state operation control.
10. Floating or Pulse with Modulation are NOT ACCEPTABLE.
11. Binary Output shall be selectable for either open or normally close operation and it shall be capable to have verification of operator tracking.

1.13 GRAPHICS

A. GENERAL

1. Provide system graphics as required.
2. Graphic displays shall have full-screen resolution when viewed on the workstation and notebook computers.
3. Dynamic data on graphics pages shall refresh within 10 seconds using an Internet connection
4. The graphics shall show the present value and object name for each of the project's I/O points on at least one graphic page.
5. Arrange point values and names on the graphic displays in their appropriate physical locations with respect to the floor plan or equipment graphic displayed. Graphics shall allow the operator to monitor current status, view zone and equipment summaries, use point-and-click navigation between graphic pages, and edit setpoints and parameters directly from the screens. Items in alarm shall be displayed using a different color or other obvious visual indicator.
6. Provide graphics with the following:

B. Graphic Types

1. Provide at least one graphic display for each piece of HVAC equipment, building floor, and controlled zone.
2. Indicate dynamic point values, operating statuses, alarm conditions, and control setpoints on each display. Provide summary pages where appropriate.

C. Building Floor Plans

1. Provide a overview plan graphic that allow user to navigate between levels, site, floors.

2. Provide a floor plan graphic for each of the building's floors with dynamic display of space temperature and other important data.
3. If used, indicate and provide links to sub-plan areas.
4. If possible, use the project's electronic drawing files for the graphic backgrounds.
5. Provide clear names for important areas. Include room names and numbers where applicable.
6. Include features such as stairwells, elevators, and main entrances.

7. Where applicable, include the mechanical room, HVAC equipment, and control component locations, with corresponding links to the equipment graphics.

D. Sub-plan Areas

1. Where a building's floor plan is too large to adequately display on the screen, sub-divide the plan into distinct areas, and provide a separate graphic display for each area. Provide same level of detail requested in building floor plan section above.

E. HVAC Equipment

1. Provide a graphic display for each piece of HVAC equipment, such as a fan coil unit, VAV terminal, or air handling unit. Equipment shall be represented by a two or three-dimensional drawing.
2. Where multiple pieces of equipment combine to form a system, such as a central chiller plant or central heating plant, provide one graphic to depict the entire plant.
3. Indicate the equipment, piping, ductwork, dampers, and control valves in the installed location. Include labels for equipment, piping, ductwork, dampers, and control valves.
4. Show the direction of air and water flow. Include dynamic display of applicable object data with clear names in appropriate locations.

F. Sequence of Operation:

1. Provide a graphic screen displaying the written out full sequence of operation for each piece of HVAC equipment. Provide a link to the sequence of operation displays on their respective equipment graphics.
2. Include dynamic real-time data within the text for setpoints and variables.

G. Graphic Title:

1. Provide a prominent, descriptive title on each graphic page.

H. Dynamic Update:

1. When the workstation is on-line, all graphic I/O object values shall update with change-of-value services, or by operator selected discrete intervals.

I. Graphic Linking:

1. Provide forward and backward linking between floor plans, sub-plans, and equipment.

J. Graphic Editing

1. Provide installed software to create, modify, and delete the DDC graphics.

1.14 WARRANTY

A. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one (1) year from completion of system demonstration.

B. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours.

C. This warranty shall apply equally to both hardware and software..

PART 2 INSTALLATION

2.1 GENERAL

A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices in accordance with ADA requirements above the floor.

D. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

E. Install guards on thermostats in the following locations:

1. Entrances.
2. Public areas.
3. Where indicated.

2.2 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Furnish only new material and equipment manufactured by reputable companies regularly engaged in manufacturing the material or equipment for a minimum of three years.

B. The DDC contractor is required to participate in any required inspections and validations by GC, project inspectors, owners, agents, consultant or any other party requiring inspection and validation.

C. It is the responsibility of the DDC contractor to provide any necessary on-site facilities or equipment to execute their work including trenching, scaffolding, lifts, hoists, storage, site offices, communication equipment, etc.

D. The DDC contractor is required to attend all project progress meetings.

E. Install, connect and wire the items included under this section and all other sections of HVAC work. This work includes providing required conduit, wire, fittings, back boxes, transformers and related wiring accessories. All conduit, wiring and accessories shall be installed in accordance with div.26 specifications.

F. Provide, install and terminate all cable, wiring, raceways, control tubing, junction boxes, pull boxes, wire trough, cable tray, Óunistrut• mounting segments/surfaces and required hangers, and supports, sized and typed as required and specified, anchored and adhered as required and specified, etc., to provide a complete job, in accordance with all contract documents.

G. All raceway tubing or conduit is to be 1 inch minimum.

H. All exposed wiring and wiring in mechanical equipment rooms shall be installed in conduit

I. All wiring located outside shall be installed in rigid conduit, seal tide or EMT with compression fittings.

J. Provide conduit and wiring between thermostats and unit heater motors, all control and alarm wiring for all control and alarm devices for all sections of specifications.

K. All 120 volt, single phase, 60 hertz power to every DDC controller panel, HVAC/mechanical equipment controllers, pc console, power supply, transformer, annunciator, modems, printers and to other devices should be provided by div. 26.

L. Control for HVAC intent that the entire building management system except terminal equipment shall be operative under emergency power conditions in the building (if applicable).

M. Provide conduit and wiring between the DDC panels and the temperature, or pressure sensing elements, including low voltage control wiring in conduit.

N. Provide conduit and control wiring for devices specified in this section.

O. Provide conduit and signal wiring between motor starters/disconnect switches in motor control centers and high and/or low temperature relay contacts and remote relays in DDC panels located in the vicinity of motor control centers.

P. Provide conduit and wiring between the pc workstation, electrical panels, metering instrumentation, indicating devices, miscellaneous alarm points, remotely operated contractors, and DDC panels, as shown on the drawings or as specified.

Q. All wiring to be compliant to local building code and the NEC.

R. Provide all conduit wiring for chillers, ac units, etc. as required for a complete and operational system.

S. Stub-ups for all wall space sensors shall be provided by DDC Contractor.

T. The DDC contractor electrical installer shall avoid connection to devices with Óflying leads• , twisting and taping is not acceptable.

U. Cables to end devices shall be uninterrupted. splices in any of the wiring associated with the system installation not acceptable

V. The DDC contractor electrical installer shall mount and wire all loose-shipped controls and panels provided by other mechanical equipment manufacturers as required and associated with low voltage for the entire project mechanical specifications.

W. All wire and cable labels must be installed within 8• (eight inches) of its termination point.

X. The DDC contractor shall furnish appropriate anchors for the surface (wall, ceiling, floor, etc.) and support requirements shall be used. Anchors, used in drywall applications, must provide support to the back side of the wall surface. Plastic, screw-in or any other anchor type that do not provide such support shall be replaced at the DDC contractor¢s expense.

Y. Critical DDC control devices and panels are typically shown in approximate locations on mechanical drawings and are subject to final field validation. Actual field installation of panels, thermostats, sensors, etc. must be validated through the appropriate job site channels prior to installation. Otherwise, the possible relocation of panels or devices shall be at the DDC contractor's expense.

Z. It is the responsibility of the DDC contractor to turn over a trouble-free communication bus free of all ground faults, open lines, and shorts prior to power up. each bus segment shall be tested by the subcontractor to ensure it is: (a) continuous end to end for each wire (b) only one shield ground exists per segment and (c) bus voltages (+ to -, - to com and + to com) are within documented tolerances of the appropriate communications bus.

AA. The DDC contractor is required to be present and immediately address any issues discovered.

BB. The DDC contractor shall not pull any exposed cable on or near sources of excessive heat (hot water, steam pipes, etc.), moisture (un-insulated piping, valves, pumps, etc.), high voltage equipment (light fixtures, MCC¢s switch gear, panel boards, etc) or any other location which could damage or cause interference with the cable.

CC. All communications wiring routing shall be documented on the mechanical or electrical plans. Device addressing and the location of bus end-of-lines, repeaters, routers, coordinators, power supplies and similar equipment shall be documented on the mechanical or electrical plans. These plans shall be kept current and made available, on as progress basis, upon request by the GC or mechanical contractor and it shall be turned over as part of the as-built documentation.

DD. Furnish all penetrations necessary to install the equipment, raceways and piping associated with project documents.

EE. The DDC contractor shall be responsible for all damper and valve actuator mounting, wiring, linkage setup, alignment, end switches, positioners, and other components required to meet sequence of operations.

FF. Provide and install all fire stopping and sealing of the electrical/mechanical penetrations applicable to DDC work. This includes all areas associated with electrical/mechanical penetrations including the area around and inside sleeves and raceways that may provide a path for air infiltration. All fire stopping and sealing must be installed to meet the applicable project specifications and/or other requirements.

GG. Demolishing all wire, raceways, and hangers associated with inactivated control systems.

HH. Once the DDC contractor employee responsible for supervision for a project has commenced work they shall not be removed or replaced from a project without prior written notice and approval from the GC or mechanical contractor. Such notice and request is required to have a minimum of 5 days advance written notice. Any additional costs incurred by the GC or mechanical contractor due to such changes will be back charged to the DDC contractor. Such charges shall include, but be limited to, on or off the project site training, errors or omissions in installation or any other costs, as determined by contract documents to be caused by said change.

II. Prior to installation the DDC contractor electrical installer shall size all wiring to ensure that (a) 24 volt power voltage drop does not exceed 2 volts from source to farthest device under maximum load conditions and (b) inputs used for analog readings shall not exceed 3 ohms of resistance for the entire circuit.

JJ. The DDC contractor electrical installer is required to complete their work in a timely manner in order for the other trades contractors and the owner to have a reasonable amount of time to complete their work and commission the systems prior to the contract completion date. The DDC contractor will be required to provide the specified materials and manpower in accordance with this scope of work during all phases of the project to avoid impacting any contractual milestone finish dates.

KK. For all installed wiring ensure no stray voltages or ground faults are present.

LL. To the extent that DDC subcontractor has failed to comply with any specification, or that the DDC contractor has failed to request written clarification or any specification that is ambiguous, or that the DDC subcontractor has assumed design responsibility for any portion of the work, DDC contractor shall be fully responsible for all costs necessary to provide a complete and operable system capable of meeting the intent of the contract documents.

MM. If it is the DDC contractor to test all Ühardwire interlocks¢ to ensure operation. Ühardwire interlocks¢ are considered any wiring that is not dependent on system input or outputs for functionality. Examples include: 120v circuits, dedicated or shared 24 vac circuits, low limits, high limits, static pressure safety switches, etc.

NN. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

OO. Plenum rated cable shall be acceptable in hung ceilings, walls and raised floors.

PP. Cables for 120 vac wiring and low level signal wiring (i.e., 24vac, 24vdc, 4 Ó 20 ma analog) shall always be run in separate raceways.

2.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
2. Test and adjust controls and safeties.
3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
4. Pressure test control air piping at 30 psig or 1.5 times the operating pressure for 24 hours, with maximum 5-psig loss.
5. Pressure test high-pressure control air piping at 150 psig and low-pressure control air piping at 30 psig for 2 hours, with maximum 1-psig loss.
6. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.

7. Test each point through its full operating range to verify that safety and operating control set points are as required.
8. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
9. Test each system for compliance with sequence of operation.
10. Test software and hardware interlocks.

C. IP Controller Verification:

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check instrument tubing for proper fittings, slope, material, and support.
5. Check installation of air supply for each instrument.
6. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
8. Check temperature instruments and material and length of sensing elements.
9. Check control valves. Verify that they are in correct direction.
10. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
11. Check IP Controller system as follows:

    a. Verify that IP controller power supply is from emergency power supply, if applicable. (NOTE all POE Switches providing power are already on emergency Power)
    b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
    c. Verify that spare I/O capacity has been provided.
    d. Verify that IP controllers are protected from power supply surges. (Note: all IP controllers PoE powered are grounded via the TCGB outlined in section 27)

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

2.4 ADJUSTING

A. Calibrating and Adjusting:

1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analog instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:

    a. Check analog inputs at 0, 50, and 100 percent of span.
    b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
    c. Check digital inputs using jumper wire.
    d. Check digital outputs using ohmmeter to test for contact making or breaking.

e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.

5. Flow:

a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
b. Manually operate flow switches to verify that they make or break contact.

6. Pressure:

a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

7. Temperature:

a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
b. Calibrate temperature switches to make or break contacts.

8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.
11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to Project during other than normal occupancy hours for this purpose.

2.5 RECORD DOCUMENTATION

A. Operation and maintenance manuals

1. Three (3) copies of the operation and maintenance manuals shall be provided to the owner's representative upon completion of the project. the entire operation and maintenance manual shall be furnished on compact disc media and include the following for the DDC contractor shall provide:

a. Table of contents.
b. As-built system record drawings. Record drawings shall represent the as-built condition of the system and incorporate all information supplied with the approved submittal.
c. DDC network riser diagram
d. Wiring diagrams
e. Electrical drawings
f. Flow diagrams and device locations

g. Hardware and software points list
h. Bill of materials
i. Sequence of operations.
j. I/O point lists
k. Cut sheets of all equipment installed
l. Manufacturer¢s product data sheets or catalog pages for all products including software.
m. System operator¢s manuals.
n. Archive copy of all site-specific databases and sequences.
o. Interfaces to all third-party products and work by other trades.
p. Training course list.

2.6 BALANCING ASSISTANCE

A. The DDC vendor shall give field support to the Balancer to balance the system by adjusting as necessary the DDC system during the balancing process.

B. This field support shall include:

1. On-site operation and manipulation of control systems during the testing and balancing.
2. Control Setpoint adjustments for balancing all relevant mechanical systems, including VAV systems.
3. Tuning control loops with setpoints and adjustments determined by TAB personnel.

2.7 COMMISSIONING

A. Prior to full operation, the contractor in the presence of the owner¢s representative and facility engineer shall perform a complete demonstration and testing of the system operating functions and alarms. this testing shall take place after having satisfactorily met the requirements of shop drawing acceptance. upon successful completion of system operation, the contractor shall submit a statement in writing stating that the full operation of all systems, functions and alarms has been demonstrated and are operational as well as a listing of all systems, alarms and functions that have been commissioned. all items shall be submitted for review and acceptance to the owner, owner¢s representative and engineer before final acceptance can take place.

B. The DDC vendor contractor shall coordinate with the commissioning agent and provide on-site support to the commissioning agent.

C. The DDC vendor contractor shall review the commissioning specifications and commissioning plan and include all stated and implied DDC system contractor requiremnets in bid.

2.8 PERFORMANCE VERIFICATION TESTING (PVT)

A. General:

1. The PVT shall demostrate compliance of the control system work with the contract requirements. The PVT shall be performed by the contractor and witnessed and approved by Engineer.

2. If the project is phased, provide separate testing for each phase. A Pre-PVT meeting to review the Pre-PVT Checklist is required to coordinate all aspects of the PVT and shall include the Contractor's QA representative, the Contractor's PVT administrator, and the Owner.

B. Performance Verification Testing Plan

1. Submit a detailed PVT Plan of the proposed testing for Engineer approval. Develop the PVT Plan specifically for the control system in this contract. The PVT Plan shall be a clear list of test items arranged in a logical sequence.
2. Include the intended test procedure, the expected response, and the pass/fail criteria for every component tested.
3. The plan shall clearly describe how each item is tested, indicate where assisting personnel are required (like the mechanical contractor), and include what procedures are used to simulate conditions.

C. PVT Sample Size

1. Test all central plant equipment and primary air handling unit controllers unless otherwise directed.
2. Twenty percent sample testing is allowed for identical controllers typical of terminal control like VAV boxes and fan coil units.
3. The Engineer may require testing of like controllers beyond a statistical sample if sample controllers require retesting or do not have consistent results.
4. The Engineer may witness all testing, or random samples of PVT items. When only random samples are witnessed, the Engineer may choose which ones.

D. Pre-Performance Verification Testing Checklist

1. Submit the following as a list with items checked off once verified. Provide a detailed explanation for any items that are not completed or verified.
2. Verify all required mechanical installation work is successfully completed, and all HVAC equipment is working correctly (or will be by the time the PVT is conducted).
3. Verify all required control system components, wiring, and accessories are installed.
4. Verify the installed control system architecture matches approved drawings.
5. Verify all control circuits operate at the proper voltage and are free from grounds or faults.
6. Verify all require surge protection is installed. Verify all DDC network communications function properly, including uploading and downloading programming changes.
7. Using the BACnet protocol analyzer, verify communications are error free.
8. Verify each digital controller¢s programming is backed up.
9. Verify all wiring, components, and panels are properly labeled.
10. Verify all required points are programmed into devices.
11. Verify all TAB work affecting controls is complete.
12. Verify all valve and actuator zero and span adjustments are set properly.
13. Verify all sensor readings are accurate and calibrated.
14. Verify each control valve and actuator goes to normal position upon loss of power.
15. Verify all control loops are tuned for smooth and stable operation. View trend data where applicable.
16. Verify each controller works properly in stand-alone mode.
17. Verify all safety controls and devices function properly, including freeze protection and interfaces with building fire alarm systems.
18. Verify all electrical interlocks work properly.

19. Verify all workstations, notebooks and maintenance personnel interface tools are delivered, all system and database software is installed, and graphic pages are created for each workstation and notebook.
20. Verify the as-built (shop) control drawings are completed.

E. Conducting Performance Verification Testing

1. Conduct Engineer-witnessed PVT after approval of the PVT Plan and the completed Pre-PVT Checklist.
2. Notify the engineer of the planned PVT at least 15 days prior to testing. Provide an estimated time table required to perform the testing. Furnish personnel, equipment, instrumentation, and supplies necessary to perform all aspects of the PVT. Ensure that testing personnel are regularly employed in the testing and calibration of DDC systems. Using the project's as-built control system drawings, the project's mechanical design drawings, the approved Pre-PVT Checklist, and the approved PVT Plan, conduct the PVT.
3. During testing, identify any items that do not meet the contract requirements and if time permits, conduct immediate repairs and re-test. Otherwise, deficiencies shall be investigated, corrected, and re-tested later.
4. Document each deficiency and corrective action taken.
5. If re-testing is required, follow the procedures for the initial PVT.
6. The Engineer may require re-testing of any control system components affected by the original failed test.

F. Controller Capability and Labeling

1. Test the following for each controller:
2. Memory:
3. Demonstrate that programmed data, parameters, and trend/ alarm history collected during normal operation is not lost during power failure.

G. Direct Connect Interface:

1. 1) Demonstrate the ability to connect directly to each type of digital controller with a portable electronic device like a notebook computer.
2. Show that maintenance personnel interface tools perform as specified in the manufacturer's technical literature.

H. Stand Alone Ability:

1. Demonstrate controllers provide stable and reliable stand-alone operation using default values or other method for values normally read over the network.

I. Wiring and AC Power:

1. Demonstrate the ability to disconnect any controller safely from its power source using the AC Power Table. Demonstrate the ability to match wiring labels easily with the control drawings. Demonstrate the ability to locate a controller's location using the BACnet Communication Architecture Schematic and floor plans.

J. Nameplates and Tags:

1. Show the nameplates and tags are accurate and permanently attached to control panel doors, devices, sensors, and actuators.

K. Workstation and Software Operation

1. For every user workstation or notebook provided:
2. Show points lists agree with naming conventions.
3. Show that graphics are complete.

L. BACnet Communications and Interoperability Areas

1. Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management.
2. If available or required in this specification, use a BACnet protocol analyzer to assist with identifying devices, viewing network traffic, and verifying interoperability. These requirements must be met even if there is only one manufacturer of equipment installed. Testing includes the following:

    a. Data Presentation: On each BACnet Operator Workstation, demonstrate graphic display capabilities.
    b. Reading of Any Property: Demonstrate the ability to read and display any used readable object property of any device on the network.
    c. Setpoint and Parameter Modifications: Show the ability to modify all setpoints and tuning parameters in the sequence of control or listed on project schedules. Modifications are made with BACnet messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.
    d. Peer-to-Peer Data Exchange: Show all BACnet devices are installed and configured to perform BACnet read/write services directly (without the need for operator or workstation intervention), to implement the project sequence of operation, and to share global data.
    e. Alarm and Event Management: Show that alarms/events are installed and prioritized according to the DDC SYSTEM Owner.

PART 3 PRODUCTS

3.1 CONTROL SYSTEM

A. Manufacturers:

1.

3.2 BMS NETWORK

A. The BMS shall use the high speed Ethernet backbone independent from the ownerȼs IT infrastructure. The BMS contractor shall provide all the necessary accessories on each floor level to interconnect entire facility for the DDC system including rack server and UI stations.

B. All control products provided for this project shall comprise an industry standard open protocol internetwork. Using protocols on any part of the DDC network that is proprietary to one company or distributed by one company are prohibited.

C. The system and its controllers must be fully TCP/IP or BACnet/IP compliant at the time of installation. This means that the system must use TCP/IP or BACnet/IP as the native communications protocol between distributed controllers communicating on the controller network, and must at a minimum support the BACnet Interoperability Building Blocks (BIBBs) for each IP application as specified herein.

D. The system shall meet IP communication services such that the connection of any operator interface via nay device to any one controller shall allow the operator to interface with all other controllers. The software shall provide transparent viewing and editing of all data, control programs, schedules, trends, alarms from any one controller through connection to any other controller via the IP network.

E. It shall network to all of the BACnet Application Specific Controllers (B-ASC) controlling the terminal equipment on a floor or in a system. All ASCs shall connect via a TCP/IP or BACnet/IP to the Ócore & shell• network

F. The primary BMS network shall be BACnet/IP over Ethernet. It shall network all primary IP controllers (B-BC, B-AAC), the BMS server, operator workstations (B-AWS), routers and switches.

G. The BMS server and Operator Interface shall use BACnet/IP over Ethernet and Web Technology applications over TCP/IP.

H. Systems that use variations of BACnet using PTP or MSTP between controllers, gateways, bridges or networks that are not peer-to-peer are not allowed.

I. The BMS design shall allow the co-existence of current and future primary control panels and personal computer operator workstations on the same primary network.

J. Remote Communications: Provide a TCP/IP compatible communication port for connection to the Ownerȼs network for remote communications. Provide coordination with the Owner for addressing and router configuration on both ends of the remote network.

3.3 OPERATOR INTERFACE

A. BMS server: Furnish rack server to host the main software for the system. The rack server shall reside on the core & shell network.

1. Server Hardware. Windows, Linux, or purpose built appliance latest version.

    a. 19 inch rack mountable monitor.
    b. All system functionality will be available via standard web browser, Internet Explorer, Mozilla, Safari, and Chrome are to be supported at a minimum.
    c. All hardware will meet the minimum requirements of the server being provided per manufacture specifications
    d. Provide PowerEdge Dell R230 Rack Server or approved equal.

e. The rack server shall made of : Chassis with up to 2, 3.5 Cabled Hard Drives, Intel Xeon E3-1240 v6 3.7GHz, 8M cache, 4C/8T, turbo (72W), 16GB (1x16GB) 2400MT/s DDR4 ECC UDIMM, PERC H330 Integrated RAID Controller for Cabled Chassis, 2TB 7.2K RPM SATA 6Gbps 3.5in Cabled Hard Drive, On-Board LOM 1GBE Dual Port (BCM5720 GbE LOM), DVD ROM, SATA, Internal, for Cabled Chassis, 2/4 -Static Post Static Rails, NEMA 5-15P to C13 Wall Plug, 125 Volt, 15 AMP, 10 Feet, Power Cord, North America
f. Windows Server® 2016,Standard,16CORE,Factory Inst,No MED,NO CAL
g. Server and UI station must include latest version of all Microsoft Windows Office applications as well as Adobe Acrobat Standard.

2. The DDC server shall be located in the owner¢s IT rack.

B. Mobile Operator Interface: Furnish one (1) touch screen tablet computer as mobile operator interface for BMS monitoring and control. The tablet shall provide full functionality for system access, including but not limited to, animated dynamic color graphics. Provide IPad PRO with electronic pointer or pencil and heavy duty protection casing or equal.

3.4 WEB SERVER and GRAPHICAL USER INTERFACE

A. The BMS contractor shall provide system software based upon a architecture, designed around the open standards of web technology. The BMS server shall communicate using ASHRAE¢s BACnet/IP protocol, as well as all other IP protocols. Protocols not using TCP/IP are specifically excluded. Server shall be accessed using a web browser over The Owner¢s intranet and remotely over the Internet.

B. The intent of the web based architecture is to provide the operator(s) complete and secure access to the BMS system via a web browser. No special software, (active-x components or fat java clients) shall be required to be installed on the PC¢s or hand held mobile devices (e.g. smart phones, tablets) used to access the BMS via a web browser. No special server hardware shall be required.

C. The BMS server software must support at least the following server platforms (Windows and Linux). The BMS server software shall be developed and tested by the manufacturer of the system standalone controllers and network controllers/routers. Third party manufactured and developed BMS software is not acceptable.

3.5 ELECTRONIC DOCUMENTATION

A. Provide software applications and files to view documentation through the Web based interface.

B. Provide a CAD viewer to view all project AutoCAD documents that are made available by the Architect and Owner.

C. Provide all controls cut sheets in PDF format. Make them available to any user accessing the system over the Internet.

D. Provide a text version of the sequence of operation. Make the written sequence available from the graphic that represents each system. The sequence shall pop up in a printable format such as HTML or PDF.

3.6 IP EQUIPMENT

A. IP System Controllers

1. Must support TCP/IP, BACnet IP and BACnet Ethernet communications
2. Must connect directly to the provided Ethernet network via Twisted-Pair (CAT 6) cabling without the use of any external getaway or transceiver
3. Application Database can be flash loaded over the network
4. Must include all mounting hardware
5. The controller firmware must be able to be flash loaded over the network
6. Must coordinate with the owner who is providing the base building Ethernet network to to bring all system controllers onto the facilities Virtual LAN
7. Minimum 32 Bit Processor
8. Minimum 2 MB Flash Memory
9. Minimum 319 KB SRAM for Database
10. IP PoE Application Controllers
11. Must support Ethernet (10/100), BACnet IP and BACnet Ethernet communications
12. Must connect directly to the provided Ethernet network via Twisted-Pair (CAT 6) cabling without the use of any external getaway or transceiver
13. Must be Power over Ethernet (PoE IEEE 802.af-2003 or IEEE 802.at-2009)
14. Minimum 32 Bit Processor
15. Minimum 2 MB Flash Memory
16. Minimum 319 KB SRAM for Database
17. Supports firmware upgrades and database load/save over the network
18. Management will review both wired and wireless solutions (Zigby or sub gigahertz) for thermostats and sensors.
19. Must coordinate with the owner who is providing the base building Ethernet network to to bring all system controllers onto the facilities Virtual LAN

3.7 SYSTEM APPLICATION SOFTWARE

A. Provide a copy of the software (or all software if there are multiple) used to program and download sequences to controllers. Provide a backup of the all of the programs used in the system for storage by the Owner.

B. Software generation shall follow standard sequences for heat exchanger control, condensate alarming, psychometric chart control of DX systems, and reset schedules.

C. Software alarms shall be provided for analog deviation, run-time, utility services failure, space comfort range deviation, and additional alarms as directed by the Facilities Systems Engineering team.

D. Alarms shall report device location, software name, description, criticality of alarm, and the appropriate corrective action to be taken. Alarms shall report to the designated Work Stations and be logged on the alarm printer showing date and time of alarm.

E. All control software programs shall be loaded onto the hard disk drive of the Engineering Work Station. All programs shall be down loaded from this terminal to insure that the control programs in the field are identical to those on record in the Engineering Work Station.

F. The PMI (Person Machine Interface) programs, such as color graphics, summaries, reports, etc., shall be developed by the contractor, approved by Facilities team and loaded to the Engineering Work Station and controllers prior to the initial job walk-through.

G. Alarm Management

1. All alarm or point change reports shall include the point¢s English language description, and the time and date of occurrence.
2. The installer shall set up all system analog points with high and low alarm limits. All digital system points shall be associated with a status feedback point and all exceptions shall be reported as alarms. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized and filtered to minimize nuisance reporting and to speed operator response to critical alarms.
3. The user shall also be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.
4. Critical alarms shall be displayed at the designated workstations, printed at the alarm printer, and paged to the on-duty maintenance person over the owner¢s or vendor¢s paging system, as requested by the owner. Alpha pages shall provide sufficient information to identify the equipment and the point in alarm and the time and date of occurrence.
5. All other alarms shall be considered non-critical and shall be displayed and acknowledged before being sent to the alarm log.
6. Alarm reports, messages, and files shall be directed to a owner-defined list of operator devices, or devices used for archiving alarm information or reports. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.
7. In Dial-up applications, only critical alarms shall initiate a call to a remote operator device. In all other cases, call activity shall be minimized by time-stamping and saving reports until an operator scheduled time, a manual request is made, or until the buffer space is full. The alarm buffer must store a minimum of 50 alarms.

H. Color Graphics

1. Provide animated 3D graphics in .gif or other graphical format suitable for display in a web browser. Graphics shall include aerial building/campus views, color building floor-plans, equipment drawings, active graphic setpoint controls, web content, and other valid HTML, XML, SVG elements. The data on each graphic page shall automatically refresh at a rate defined by the operator.
2. Floor plan graphics shall show heating and cooling zones throughout the buildings in a range of colors, which provide a visual display of temperature relative to their respective setpoints.
3. Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. Selected I/O points being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units. Animation shall be used for rotation or moving mechanical components to enhance usability. Each piece of equipment being monitored or controlled shall be depicted including: Each piece of equipment including each terminal unit, each building, each floor and each zone.

I. Scheduling

1. Scheduling shall be accomplished by using the system geographic navigation tree. The viewer shall be able to define a Time of Day, Holiday or Event schedule for an individual piece of equipment, room, area, floor, tenant, building, campus, site, etc. For example, a new time schedule for every level in the system would be created by clicking at the top of the geographic hierarchy defined in the Navigation Tree.
2. Schedules shall comply with the BACnet standard, (Schedule Object, Calendar Object, Weekly Schedule property and Exception Schedule property) and shall allow events to be scheduled. Schedules shall have the ability to be created in the following manner: a specific date, a range of dates, any combination of month of year (1-12, any), day of week, wildcard (example, allow combinations like second Tuesday of every month).

J. Security

1. Each operator shall be required to log on to the system with a user name and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system supervisor shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the functions accessible to viewing and/or changing each system application.

K. Historical Trending and Data Collection

1. Trends shall conform to the BACnet Trend Log Object specification. The system shall be able to trend and display graphically any analog, digital or calculated points.
2. Trend Logs. The operator shall be able to define a custom trend log for any data object in the system. This definition shall include change-of-value digital, change-of-value analog, time interval, start time, and stop time. Trend data shall be sampled and stored on the DDC controller, and be uploaded and archived on the hard disk and be retrievable for use in spreadsheets and standard database programs.
3. Dynamic Data Exchange (DDE). Software shall support dynamic data sharing with other Windows-based programs for third party add-on functionality e.g. preventative maintenance, tenant billing, etc.

L. Reporting

1. The system shall have the capability to generate pre-configured or customized reports automatically or upon manual command.

M. Diagnostics

1. Provide software which allows efficient identification of unfavorable trends from the operator workstation. Provide tuning screens which shall aid the operator in tuning individual PID loops.

3.8 CONTROL PANELS

A. Select the proper panel type depending of application as follow:

1. NEMA 1 applications: general purpose for indoor protection, where conditions are not unusually severe.
2. NEMA 2 applications: drip-tight for indoor protection, designed to exclude falling moisture or dirt. Particularly applicable to cooling room, laundries etc.., where condensation is prevalent.

3. NEMA 3 applications: weather resistant (weatherproof) for outdoor use; designed to withstand all normal exposure to natural elements
4. NEMA 3R applications: rain-proof and sleet (ice) resistant for outdoor use; intended to protect enclosed equipment against rain and meet the requirements of UL 506, applying to Órain-proof enclosures• .
5. NEMA 4 applications: watertight withstands water pressure from 1 inch hose nozzle, 65 gallons per minute, from distance of not less than 10 feet for five minutes. Suitable for maritime applications, breweries, etc.
6. NEMA 4X applications: corrosion-resistant, same provisions as NEMA 4 and, in addition is corrosion-resistant.
7. NEMA 5 applications: dust-tight, equipped with dust-tight gaskets. Suitable for mills and other high-dust atmospheres.
8. NEMA 6 applications: submersible, for submerged operation under specified pressure & time.
9. NEMA 7 applications: hazardous locations, NEC class 1 (circuit breaks in air)
10. NEMA 8 applications: hazardous locations, NEC code class 1 (circuit breaks in oil)
11. NEMA 9 applications: hazardous locations, national electrical code class 2
12. NEMA 10 applications: explosion-proof meet US bureau of mines requirements for explosive atmospheres.
13. NEMA 11 applications: acid or fume resistant provides for immersion of enclosed equipment in oil
14. NEMA 12 applications: industrial use, excludes oils, dust, and moisture, to satisfy individual requirements.

B. Recommended manufacturer:

1. Unity manufacturer
2. Hoffman enclosures

C. The DDC contractor shall use double terminal blocks within a control panel for control panels, with a cognizant sequential numbering system, use different terminal block color for type of use in order to user ease identification. The control panel shall consist of (3) dedicated transformer for controllers, end devices and (1) 24v power supply for DC power devices as follow:

1. 120v power (black Ó hot, black Ó neutral, green Ó ground)

    a. Recommended Terminal block manufacturer:

        1) Automation Direct or Approved equal

2. Panel switch and receptacle assembly.
3. Transformer#1 (To be use to power all DDC controllers within control panel Ó use red double terminals top terminal - 24vac, bottom terminal Ó common)

    a. Recommended Terminal Block manufacturer: A

        1) Automation Direct or Approved equal

    b. Recommended Transformer Manufacturer:

        1) Functional devices model# TR100VA-001 with circuit breaker.

4. Transformer #2 (To be use to power valves and actuators from associated control panel, use yellow top terminal for 24vac and bottom terminal for common).

a. Recommended Terminal Block manufacturer:

1) Automation Direct or Approved equal

b. Recommended Transformer Manufacturer:

1) Functional devices model# TR100VA-001 with circuit breaker.

5. Transformer #3 (To be use for additional power for valves and actuators from associated control panel, use orange top terminal for 24vac and bottom terminal for common)

a. Recommended Terminal Block manufacturer:

1) Automation Direct or Approved equal

b. Recommended Transformer Manufacturer:

1) Functional devices model# TR100VA-001 with circuit breaker.

6. Power supply (To be use to power DC end devices Ó use blue top terminal for 24vdc and bottom terminal for common or negative)

a. Recommended Terminal Block manufacturer:

1) Automation Direct or Approved equal

b. Recommended Power Supply Manufacturer:

1) Automation Direct model# PSP24-024C with circuit breaker.

7. For End devices inputs or outputs use gray terminal top terminal for universal input signal (analog or digital) bottom terminal - universal input common (analog or digital)

a. Recommended Terminal Block manufacturer:

1) Automation Direct or Approved equal

8. Use terminal block accessories such as jumpers and terminal block number tagging.

a. Recommended jumper and tag manufacturer:

1) Automation Direct or Approved equal.

D. The DDC contractor shall submit as part of the control submittal the labelling system intended to be used in order to identify control panel per system. This labelling system shall be describe throughout the control submittal to ease identification.

E. The DDC contractor shall submit as part of the control submittal a control panel layout.

F. The DDC contractor shall labelled each control panel using engraved phenolic labels as follow:

1. Use black background, white letters.
2. Label text should be situated in the middle of the label.

3. Each word should have first letter capitalized and rest lower case.
4. Use a 5• wide x 5• high label as minimum.
5. Text size should be in commensurate with label size.

G. Each DDC control panel shall have a copy of the control submittal delineating the panel internal control wiring

H. Power wiring and communication wiring shall be provided in separate conduits with separate hot, neutral, and ground wire runs and separate breakers.

I. Coordinate installation of the control panels with the owner.

J. Coordinate power for the panels with the electrical contractor.

K. Unless otherwise noted, mounting any control devices on the back of the control panel enclosure door is not acceptable.

L. All panel wirings shall in be installed in panduit and wiring duct. This shall include but not be limited to wiring from the DDC controller to the terminal block, between DDC controller and relays (and other panel mounted control devices), power wiring for the controller and communication.

M. Only one controller shall be allowed in a control panel with expansion modules if extra points are needed then the DDC contractor shall utilize the largest controller and control panels available and if maxed out, only then can a second controller to be installed within the panel.

N. Each DDC control panel shall have a label located in the back door containing the following information:

1. Controller designated name or number
2. Building management system mac address
3. Network segment that belongs and the associated data manager or primary controller name assigned to.
4. It is not acceptable to have hand-written notes on control panel back door.

O. Each DDC control panel shall be equipped with:

1. A Perforated back panel.
2. 3/8 flange nut.
3. cylinder key lock, std 751coin lock cam
4. Metal back door pocket.

3.9 ELECTRONIC SENSORS

A. Manufactured, brand labelled or distributed by Belimo.

B. Description: Vibration and corrosion resistant with SI Protection; for wall, immersion, or duct mounting as required.

C. Enclosure shall be a color contrasting NEMA Type 4X/IP65 including a NEMA 4X/IP65 cable gland, a 1/2 NPT conduit adapter fitting a tool-free access.

D. Thermistor Temperature Sensors and Transmitters:

1. Accuracy: Plus or minus 0.3 deg F at 77 degF (25 degC).
2. Cable: Single pair shielded, plenum rated to 300 DegF (150 degC) 22AWG, tinned copper, green jacket, 300V.
3. Insertion Elements for Liquids: Single piece stainless steel thermowell pocket.

E. RTDs and Transmitters:

1. Accuracy: +/- 0.5 degF (0.3 degC) at 32 DegF (zero DegC).
2. Cable: Single pair shielded, plenum rated to 300 DegF (150 degC) 22AWG, tinned copper, green jacket, 300V.
3. PT1000 Averaging element shall incorporate a true averaging continuous sensing element throughout the length of the probe.
4. Insertion Elements for Liquids: Single piece stainless steel thermowell pocket.

F. Humidity Sensors: Capacitor sensor element.

1. Accuracy: ±2% between 10 to 90% RH at calibration point.
2. Duct Sensor: 0 to 100% relative humidity range with stainless steel wire mesh filter and adjustable rubber mounting flange.
3. Outside Air Sensor: 0 to 100% relative humidity range with mounting enclosure and detachable mounting plate suitable for operation at outdoor temperatures [Ó30 to 160 deg F (-30 to 70 deg C)]
4. Duct/Outside Air Sensor shall have selectable output for relative humidity, enthalpy, dew point or absolute humidity.
5. Duct/Outside Air Sensor shall have temperature integration with dual outputs of 0-5/10 Vdc or 4 to 20 mA.

G. Pressure Transmitters/Transducers:

1. Air Differential-Pressure Transmitter: 8 field selectable ranges.

a. Range: 0- to 1-inch wc (0 to 250 Pa)

1) Accuracy: [+/- 0.004 inch wc (1 Pa)]
2) Outputs: 0 to 5/10 VDC and 4 to 20 mA integrated into one unit.
3) Auto zero calibration.

b. Duct Air Differential-Pressure Range: 0- to 10-inch wc (0 to 2500 Pa)

1) Accuracy: 2 inch wc (498 Pa) or less [+/- 0.02 inch wc (5 Pa)]
2) Accuracy: 2 inch wc (498 Pa) to 12 inch wc (2500 Pa) [+/- 0.04 inch wc (10 Pa)]
3) Outputs: 0 to 5/10 Vdc and 4 to 20 mA integrated into one unit.

c. Duct Air Differential-Pressure Range: 0- to 28-inch wc (0 to 7000 Pa)

1) Accuracy: 8 inch wc (1991 Pa) or less [+/- 0.04 inch wc (10 Pa)]
2) Accuracy: 9 inch wc (2240 Pa) to 29 inch wc (7000 Pa) [+/- 0.1 inch wc (25 Pa)]
3) Outputs: 0 to 5/10 Vdc and 4 to 20 mA integrated into one unit.

2. Liquid Gauge Pressure Transducers: NEMA Type 4/IP65, stainless steel housing, stainless steel diaphragm construction, suitable for service; minimum double the nominal operating pressure; linear output 0 to 10 Vdc or 4 to 20 mA.
3. Liquid Differential-Pressure Transducers: NEMA Type 4/IP65 stainless steel housing, ceramic/stainless steel diaphragm construction, suitable for service; measurement range 0-15/30 psig, single sided 85 psig operating pressure and tested to 300 psig; suitable for service; measurement range 0-50-/100 psig, single sided 230 psig operating pressure and tested to 300 psig; linear output 0 to 10 vdc or 4 to 20 mA.

3.10 STATUS SENSORS

A. Status Inputs for Fans and Pumps: Current sensor measuring Amperage.

B. Status of flow Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig, piped across pump. Pumps Statuses shall include current sensing as well prove of flow.

C. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.

D. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.

E. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.

F. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.

G. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

H. Water-Flow Switches: Bellows-actuated mercury or snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.

I. Manufacturers:

1. Veris Industries
2. Functional Devices

3.11 GAS DETECTION EQUIPMENT

A. Manufacturers:

1. Honeywell Analytics.

B. Carbon Monoxide Detectors: Single or multichannel, dual-level detectors using solid-state plug-in sensors with a 3-year minimum life; suitable over a temperature range of 32 to 104 deg F; with 2 factory-calibrated alarm levels at 50 and 100 ppm.

C. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of 23 to 130 deg F (minus 5 to plus 55 deg C) and calibrated for 0 to 2 percent, with continuous or averaged reading, 4- to 20-mA output;, for wall mounting.

3.12 Accessories:

3.13 FLOW MEASURING STATIONS

A. Duct Airflow Station: It shall include probes and transmitter .

B. Fan Inlet Airflow Station: It shall include probes and transmitter

C. The DDC vendor shall be responsible to submit proper and applicable size for each application through an airflow station schedule along with the selected model number of all associated components.

1. Manufacturers:

a. EBTRON.

3.14 STATUS AND SAFETY SWITCHES

A. All safety switches shall have 2 contacts, one for interlock to device, one for DDC input.

3.15 THERMOSTATS

A. Manufacturers:

1. Johnson Controls.
2. Approved equal

B. Combination Thermostat and Fan Switches: Line-voltage thermostat with push-button or lever-operated fan switch.

1. Label switches "FAN ON-OFF" or as required.
2. Mount on single electric switch box.

C. Electric, solid-state, microcomputer-based room thermostat with remote sensor.

1. Automatic switching from heating to cooling.
2. Preferential rate control to minimize overshoot and deviation from set point.
3. Set up for four separate temperatures per day.
4. Instant override of set point for continuous or timed period from 1 hour to 31 days.
5. Short-cycle protection.
6. Programming based on weekday, Saturday, and Sunday.

7. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable, remote sensor, and fan on-auto.
8. Battery replacement without program loss.
9. Thermostat display features include the following:

    a. Time of day.
    b. Actual room temperature.
    c. Programmed temperature.
    d. Programmed time.
    e. Duration of timed override.
    f. Day of week.
    g. System mode indications include "heating," "off," "fan auto," and "fan on."

D. Low-Voltage, On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.

E. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.

1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.
2. Selector Switch: Integral, manual on-off-auto.

F. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.

1. Bulbs in water lines with separate wells of same material as bulb.
2. Bulbs in air ducts with flanges and shields.
3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit; adequately supported.
4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
6. Modulating Thermostats: Construct so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.

G. Fire-Protection Thermostats: Listed and labeled by an NRTL acceptable to authorities having jurisdiction; with fixed or adjustable settings to operate at not less than 75 deg F above normal maximum operating temperature, and the following:

1. Reset: Manual.
2. Reset: Automatic, with control circuit arranged to require manual reset at central control panel; with pilot light and reset switch on panel labeled to indicate operation.

H. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.

I. Airstream Thermostats: Two-pipe, fully proportional, single-temperature type; with adjustable set point in middle of range, adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.

J. Electric, Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic- reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or below set point.

1. Bulb Length: Minimum 20 feet.
2. Quantity: One thermostat for every 20 sq. ft. of coil surface.

K. Electric, High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic- reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or above set point.

1. Bulb Length: Minimum 20 feet.
2. Quantity: One thermostat for every 20 sq. ft. of coil surface.

L. Heating/Cooling Valve-Top Thermostats: Proportional acting for proportional flow, with molded-rubber diaphragm, remote-bulb liquid-filled element, direct and reverse acting at minimum shutoff pressure of 25 psig, and cast housing with position indicator and adjusting knob.

3.16 HUMIDISTATS

A. Manufacturers:

1. MAMAC Systems, Inc.
2. Veris Industries.
3. ACI

B. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.

3.17 VARIABLE FREQUENCY DRIVES

A. Refer to VFD section of the performance specification for VFD performance.

B. Serial Interface: RS-485 Communications interface to DDC Systems:

1. The VFD shall interface to the DDC system through a serial communications port, which shall allow the DDC system to control speed, start/stop, set PID parameters, limit current, and accel, decal time adjustments. DDC shall monitor through the interface: output speed, current, % torque, power, kWh, operating hours, alarms

C. All VFDs to be wired over BACnet/MSTP for monitoring purposes only, no control.

D. All VFDs to be controlled via hard-wired inputs and outputs.

3.18 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.

1. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
3. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
4. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
5. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
6. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.

B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.

1. Manufacturers:

    a. Belimo Aircontrols (USA), Inc.

2. The position of actuators serving some systems must be monitored with analog points. Monitor the position of all actuators with analog points. Waiver of this requirement may be allowed by the facility Systems Engineer when the device is in close proximity to the controlled device, ie a coil discharge temperature sensor.

    a. Actuators used on the following equipment and systems require monitoring with analog points:
    b. Air Handling Units
    c. Dampers serving Air Handling Units
    d. VAVs with reheat
    e. Heat exchangers
    f. Actuators used on the following equipment and systems do not require monitoring with analog points:
    g. Fan Coil Units
    h. Dampers not serving Air Handling Units

3. Valves: Size for torque required for valve close off at maximum pump differential pressure.
4. Dampers: Size for running torque calculated as follows:

    a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. (86.8 kg-cm/sq. m) of damper.
    b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. (62 kg-cm/sq. m) of damper.
    c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft (49.6 kg-cm/sq. m) of damper.
    d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. (37.2 kg-cm/sq. m) of damper.
    e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.

f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.

5. Coupling: V-bolt and V-shaped, toothed cradle.
6. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
7. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on non-spring-return actuators.
8. Power Requirements (Two-Position Spring Return): 24-V ac.
9. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
10. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
11. Temperature Rating: Minus 22 to plus 122 deg F (Minus 30 to plus 50 deg C).
12. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F (Minus 30 to plus 121 deg C).
13. Run Time: 12 seconds open, 5 seconds closed.

3.19 CONTROL VALVES

A. Manufacturers:

1. Belimo.

B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

C. Hydronic system globe valves shall have the following characteristics:

1. NPS 2 and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. NPS 2-1/2 and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. Internal Construction: Replaceable plugs and stainless-steel or brass seats.

   a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
   b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.

4. Sizing: 3-psig maximum pressure drop at design flow rate or the following:

   a. Two Position: Line size.
   b. Two-Way Modulating: Either the value specified above or twice the load pressure drop, whichever is more.
   c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.

5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

D. Butterfly Valves: 200-psig, 150-psig maximum pressure differential, ASTM A 126 cast-iron or ASTM A 536 ductile-iron body and bonnet, extended neck, stainless-steel stem, field-replaceable EPDM or Buna N sleeve and stem seals.

1. Body Style: Wafer.
2. Disc Type: Aluminum bronze.
3. Sizing: 1-psig maximum pressure drop at design flow rate.

E. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.

1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
2. Sizing: 3-psig maximum pressure drop at design flow rate, to close against pump shutoff head.
3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.

F. Self-Contained Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.

1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
2. Thermostatic Operator: Liquid-filled remote sensor with remote adjustable dial.

3.20 24VAC POWER DISTRIBUTION PANELS

A. There shall be 24VAC power distribution panels to feed VAV boxes and associated end devices low voltage power load.

B. The 24VAC power distribution panels not to exceed from 5 24VAC power loops.

C. Each power loop shall feed a maximum of 4 control devices only or 80% power consumption load from each transformer maximum capacity.

D. Use Proper gauge wire for each low voltage power loop.

E. Follow local and natioanl standard electrical codes.

F. Manufacturers:

1. Functional Devices: PSH500A - 480/277/240/120 VAC to 24VAC, five 100VA outputs with enclosure.

END OF SECTION 230900

SECTION 230993.11 - SEQUENCE OF OPERATIONS FOR HVAC DDC

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes control sequences for DDC for HVAC systems, subsystems, and equipment.

1.3 DEFINITIONS

A. Analog Output: Proportional output signal (zero- to 10-V dc, 4 to 20 mA).

B. Binary Output: On/off output signal or contact closure.

C. DDC: Direct digital control.

D. Digital Output: Data output that must be interpreted digitally.

PRODUCTS (Not Applicable)

PART 2 EXECUTION (Not Applicable)

END OF SECTION 230993.11

SECTION 232300 - REFRIGERANT PIPING

1.1 PERFORMANCE REQUIREMENTS

A. Quality Standards: ASHRAE 15 and ASME B31.5.

1.2 PRODUCTS

A. Copper Tube and Fittings: Type K or L.

B. Valves and Specialties:

1. Diaphragm packless valves.
2. Packed-angle valves.
3. Check valves.
4. Service valves.
5. Solenoid Valves: 24 -V ac.
6. Safety relief valves.
7. Thermostatic expansion valves for 40 deg F suction temperature; adjustable superheat.
8. Angle-type strainers.
9. Moisture/liquid indicators.

1.3 REFRIGERANTS

A. R-410A.

1.4 PIPING APPLICATION SCHEDULES

A. Piping Applications for Refrigerant R-410A: Maximum NPS 4.

1. Suction Lines for Conventional Air-Conditioning Applications: Copper.
2. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications:

    a. NPS 2 and Smaller: Copper with brazed joints.
    b. NPS 2-1/2 and Larger: Schedule 40, black steel with welded joints.

3. Safety-Relief-Valve Discharge Piping:

    a. NPS 2 and Smaller: Copper with brazed joints.

END OF SECTION 232300

SECTION 233113 - METAL DUCTS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

B. No part of the Contract Documents exists in isolation. Recitations of requirements relevant to one vendor, prime contractor, subcontractor or trade may exist in multiple sections. Failure to reference or review the relevant information within the complete Contract Documents shall not grant relief from any provision of the Contract Documents.

C. If these Contract Documents are incompletely delivered, immediately request a complete set. If a complete set is not delivered upon request, the contract holder that failed to provide the complete set as requested (that is the Owner, General Contractor, and Construction Manager as applicable) shall remain responsible for providing scope that was not priced because the scope was noted on an element of the Contract Documents not made available as requested.

D. Technical standards and codes are referenced within this document. Where a standard is referenced, all work and products described within this section that are covered within the scope of the referenced standard shall comply with the applicable requirements of the referenced standard. The applicable requirements of referenced standards are incorporated into this document by reference.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round and flat-oval ducts and fittings.
4. Double-wall round and flat-oval ducts and fittings.
5. Sheet metal materials.
6. Duct liner.
7. Sealants and gaskets.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.
3. Seismic-restraint devices.

B. Sustainable Design Submittals:

1. Product Data: For ventilation equipment, indicating compliance with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data: For adhesives, indicating VOC content.
3. Laboratory Test Reports: For adhesives, indicating compliance with requirements for low-emitting materials.
4. Product Data: For sealants, indicating VOC content.
5. Laboratory Test Reports: For sealants, indicating compliance with requirements for low-emitting materials.

C. Delegated-Design Submittal:

1. Schedule of sheet metal thicknesses for use on the project. Designations used in shop standards shall be used in shop drawings.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Attachments of linings including nosings.
5. Details of fitting construction.
6. Materials, fabrication, assembly, and spacing of hangers and supports.

D. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Shop drawings shall clearly show locations of all fire and smoke rated assemblies, security perimeters, EMI/RFI shielding (nuclear magnetic resonance, magnetic resonance imaging, sensitive electronics rooms), and xray shielding.
3. Factory- and shop-fabricated ducts and fittings.
4. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
5. Elevation of bottom and tops of ducts.
6. Dimensions of main duct runs from building grid lines.
7. Fittings.
8. Reinforcement and spacing.
9. Seam and joint construction type.
10. Penetrations through fire-rated and other partitions.
11. Equipment installation based on equipment being used on Project.
12. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
13. Hangers and supports, including methods for duct and building attachment and vibration isolation.
14. Note static pressure loss for any unapproved fitting type. See Delegated Design submittal requirements.
15. Note duct velocity between each connection, for each duct size

16. Note duct flow between each connection, for each duct size

E. Quality Control Submittals

1. Duct leakage testing protocol.
2. Duct leakage testing reports.

    a. Test results
    b. Remediation undertaken to resolve unacceptable test results.
    c. Retest results.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.
3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items penetrating finished ceiling including the following:

    a. Lighting fixtures.
    b. Air outlets and inlets.
    c. Speakers.
    d. Sprinklers.
    e. Access panels.
    f. Perimeter moldings.
    g. Suspended artwork, sculpture or structures.

7. Documented sign off by all trades and construction manager prior to fabrication of each area.

B. Welding certificates.

C. Field quality-control reports other than leakage testing.

1.6 QUALITY ASSURANCE

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

PART 2 PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Only a subset of the constructions described within these standards are permissible on this project. Please reference the schedules within the execution part of this section for applicability.

2.2 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.

B. Outer Duct: Comply with requirements for single walled duct.

C. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

D. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch- diameter perforations, with overall open area of 23 percent.

E. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Traverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

F. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SINGLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

C. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than 30 inch in Diameter: Flanged.

D. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.4 DOUBLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.

B. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

1. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

3. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch- diameter perforations, with overall open area of 23 percent.

D. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

2.5 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

2.6 DUCT LINER

A. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Aeroflex USA, Inc.
b. Armacell LLC.

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

a. Adhesive shall have a VOC content of 80 g/L or less.

B. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm.
7. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

    a. Fan discharges.
    b. Intervals of lined duct preceding unlined duct.
    c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

9. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.

    a. Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

10. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.7 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.

9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

C. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. Sealant shall have a VOC content of 420 g/L or less.
7. Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

D. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

2.8 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 , "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

C. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

D. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

E. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

F. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

G. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

1. Drawings show the general layout of ductwork and accessories but do not show all required fittings and offsets that may be necessary to connect ducts to equipment, boxes, diffusers, grilles, etc., and to coordinate with other trades. Fabricate ductwork based on field measurements. Provide all necessary fittings and offsets at no additional cost. Coordinate with other trades for space available and relative location of HVAC equipment and accessories. Duct sizes on the drawings are inside dimensions which shall be altered by Contractor to other dimensions with the same air handling characteristics where necessary to avoid interferences and clearance difficulties.
2. Provide duct transitions, offsets and connections to dampers, coils, and other equipment in accordance with SMACNA Standards, Section II. Provide streamliner, when an obstruction cannot be avoided and must be taken in by a duct. Repair galvanized areas with galvanizing repair compound.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round and flat-oval ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through elevator machine rooms, transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Where ducts pass through rated interior partitions, floor slabs, roofs, and exterior walls, install fire dampers, smoke dampers, and combination fire-smoke dampers as required. Comply with requirements in Section 233300 "Air Duct Accessories" for dampers.

L. Where ducts are located within a rated ceiling/floor or ceiling/roof assembly, provide ceiling radiation dampers at ceiling penetrations for air outlets. Provide fire dampers, smoke dampers, and combination fire-smoke dampers as required when passing from within a rated ceiling/floor or ceiling/roof assembly into a shaft enclosure or exiting the rated horizontal assembly other than through a ceiling mounted air outlet.

M. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Spiral lock seams shall be oriented the same way and aligned from one section to the next for round ductwork.

F. Pieces within a single room shall be fabricated from material of the same manufacturing batch.

G. Cross beading is not permitted. Cross breaking shall be used.

H. All longitudinal and transverse joints shall be constructed using the same system for all exposed ducts. Do not mix transverse joint types. For example, if some ducts require flanged, all ducts shall be flanged.

I. Flanged connection types shall be required for ducts which pass through to other spaces. The presence of such exposed ducts shall require all ducts within the space to be flanged for visual consistency.

J. Only ductwork which terminates in the space is permitted to use connection types T-1, T-5, and T-6.

K. Ductwork pieces shall be of consistent length. No more than one piece per straight run of each size may have a different length than all other pieces.

L. Elbows and tees shall have identical straight lengths leading into and out of the fitting.

M. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Unless more stringent standards are indicated elsewhere in this section, seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2. Outdoor, Supply-Air Ducts: Seal Class A.
3. Outdoor, Exhaust Ducts: Seal Class C.
4. Outdoor, Return-Air Ducts: Seal Class C.
5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wgand Lower: Seal Class B.
6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
7. Unconditioned Space, Exhaust Ducts: Seal Class C.
8. Unconditioned Space, Return-Air Ducts: Seal Class B.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wgand Lower: Seal Class C.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class B.
11. Conditioned Space, Exhaust Ducts: Seal Class B.
12. Conditioned Space, Return-Air Ducts: Seal Class C.
13. Exhaust ducts conveying Class 2 or more contaminated air under more than 0.5-Inch wgpositive pressure located indoors: Seal Class A
14. Exhaust ducts conveying Class 3 or more contaminated air under positive, negative or neutral pressure: Seal Class A.

C. Schedule of sealing required according to SMACNA Seal classes:

1. Transverse joints, splits, pants, nests, and taps: Seal classes A, B and C. All ducts on this project
2. Longitudinal joints: Seal classes A and B.
3. Penetrations of duct wall such as those for sensors, sensor cable, probes, balancing taps, and fasteners which penetrate the duct wall: Seal class A only.
4. Seal class A shall apply to all systems constructed 4-Inch wgand higher and any lower pressure class systems noted elsewhere
5. Seal class B shall apply to all systems constructed 3-Inch wgand higher and any lower pressure class systems noted elsewhere
6. Seal class C shall apply to all systems where a higher seal class is not specified elsewhere.
7. Unsealed ducts are not permitted.

3.4 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inchesthick.
4. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inchesof each elbow and within 48 inchesof each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

1. Space hangers at equal distances within a single room. Reduce spacing from SMACNA maximums to maintain equal spacing and alignment with other visual features.
2. Note location of all hangers exposed to view on shop drawings.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer.

B. Paint internal pin-type fasteners for any internal linings for linear diffusers, sidewall grilles and other air outlets which allow sight lines into connected ductwork.

C. Paint materials and application requirements are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Where tests fail on the first area required to be tested (if less than 100% of the system), an additional 25% of duct area shall be tested. If the additional area tested fails, the entire duct system shall be tested.

3. Use portable high pressure blower and necessary, calibrated airflow measuring instruments to indicate amount of leakage. Measurement instruments for flow shall have less than 3% error for the values measured. Reference testing and balancing specification.
4. Test the following systems where they are constructed to the noted pressure class or a higher class. Where multiple descriptions within this schedule are applicable, the most stringent of the conflicting provisions shall be applicable.

    a. Code minimum : all ducts 3-Inch wgor greater initially test 25% of duct area.
    b. Supply ducts (conditioned air): 2-Inch wg or greater initially test 25% of duct area.
    c. Return ducts: 2-Inch wg or greater initially test 25% of duct area.
    d. Negatively pressurized exhaust ducts (Class 1 or Class 2 air): 2-Inch wg or greater initially test50 % of duct area.
    e. Negatively pressurized outside air intake ducts: 2-Inch wg or greater initially test 25 % of duct area.
    f. Positively pressurized outside air intake ducts: 2-Inch wg or greater initially test 50% of duct area.
    g. Duct systems in excess of 150 feet in critical branch length: all pressure classes initially test 100% of duct area.

5. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
6. Ducts may not be concealed by insulation, lagging, other construction or services until they pass leakage tests.

    a. Contractor need not wait for approval of leakage testing reports which indicate passing results to conceal ductwork, which has passed the required tests.
    b. Contractor may not conceal any ductwork for which test results indicate non-compliance.
    c. Constructions which conceal ducts that do not pass tests shall be removed and replaced at contractor’s sole cost to facilitate retesting and remediation of non-conforming ductwork.

7. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test entire duct system at the appropriate pressure for the equipment design external static pressure or duct pressure class. Do not pressurize systems above the maximum allowable for the duct construction.
8. Give seven days' advance notice for testing.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

    a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.8 DUCT CLEANING

A. Clean new and existing duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clearly mark the positions of balancing dampers and concealed pattern controllers before cleaning, photograph the position of pattern controllers exposed to view. Positions of exposed balancing dampers shall be marked on paper taped to the damper quadrant which can be cleanly removed. Restore to their marked position following completion. Following cleaning the system shall operate as it was prior to cleaning but for the lack of foreign matter removed.

E. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

F. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.

4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.9 START UP

A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.10 DUCT SCHEDULE

A. Notes:

1. Where conflicting provisions exist, the most stringent provisions from each category applicable to the project condition shall be the requirement.
2. The leakage class numbers refer to the maximum permitted leakage in cfm per 100 square feet.
3. The seal class refers to the sealing requirements of the Duct Sealing article within this section.
4. The pressure class refers to the minimum positive or negative (as applicable) pressure class for the system type and duct service. No ducts may be constructed to a pressure class less than the design external static pressure for the associated equipment even if a lower minimum pressure class is noted for the application.

B. Duct construction schedule.

1. Minimum requirements for all ducts per code:

    a. Comply with the duct construction and testing requirements of chapters 5 and 6 of mechanical code and ASHRAE 62.1.
    b. Comply with ASHRAE 90.1-2010

2. Any duct constructed to a pressure class of class of 3 inch wgor higher

    a. Minimum SMACNA Seal Class: B.
    b. Maximum SMACNA Leakage Class for Rectangular: 12.
    c. Maximum SMACNA Leakage Class for Round and Flat Oval: 12.

3. Ducts designed to operate at more than 2000 FPM

    a. Pressure Class: 4 inch wg
    b. Minimum SMACNA Seal Class: A
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.

4. Ducts conveying more than 10000 CFM

    a. Pressure Class: 3 inch wg
    b. Minimum SMACNA Seal Class: B
    c. SMACNA Leakage Class for Rectangular: 12.
    d. SMACNA Leakage Class for Round and Flat Oval: 12.

5. Supply and return air ducts connected between fan coil units, furnaces, heat pumps and air terminal units and supply and return grilles.

    a. Pressure Class: 1-inch wg.
    b. Minimum SMACNA Seal Class: C.
    c. SMACNA Leakage Class for Rectangular: 24.
    d. SMACNA Leakage Class for Round and Flat Oval: 24.
    e. Galvanized steel.

6. Ducts connected to VAV and pressure controlled CAV air handling systems between air flow control devices and fans or air handlers.

    a. Pressure Class: 2 inch wg.
    b. Minimum SMACNA Seal Class: B.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 6.
    e. Galvanized steel.

7. Ducts connected between spaces and constant speed fan systems.

    a. Pressure Class: 2 inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 6.
    e. Galvanized steel.

8. Negatively pressurized exhaust ducts (Class 1 or Class 2 air and car parks)

    a. Pressure Class: 2 inch wg
    b. Minimum SMACNA Seal Class: A
    c. SMACNA Leakage Class for Rectangular: 12.
    d. SMACNA Leakage Class for Round and Flat Oval: 12.
    e. Galvanized steel

9. Negatively pressurized outside air intake ducts. (Unconditioned.)

    a. Pressure Class: 2 inch wg
    b. Minimum SMACNA Seal Class: [A] [B] [C]
    c. SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
    d. SMACNA Leakage Class for Round and Flat Oval: [12] [24] <Insert value>.
    e. Galvanized Steel

10. Positively pressurized outside air intake ducts. (Unconditioned.)

    a. Pressure Class: [2 inch wg] [3 inch wg][4 inch wg]

b. Minimum SMACNA Seal Class: A
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.
e. Galvanized Steel

C. Transverse Joints

1. The following flanged transverse joints are permitted. All others noted within the SMACNA standard are prohibited from use on this project.

a. Type T-22 companion flanges and gaskets.

2. At fire dampers, fire smoke dampers and smoke dampers

a. T-24, T-25 shall use plastic clips and bolts unless otherwise approved by the listing of the damper
b. T-5 and T-6 shall not exceed the quantity of screws per side and total permitted by the listing of the damper.
c. The following are prohibited

1) T-1 is prohibited.
2) T-24a is prohibited

D. Longitudinal Joints

1. The following longitudinal seams are permitted. All others noted within the SMACNA standard are prohibited from use on this project.

a. L-1 “Pittsburgh Lock” with sealant, minimum $3/8$ in pocket depth
b. L-3 “Pipe Lock” with sealant, minimum $1/2$ inpocket depth
c. L-4 “Standing Seam” with sealant.

E. Cross Breaking or Beading

1. Cross break or cross bead duct sides 20 inchesand larger and 0.036 inchthick or less, with more than 10 sq. ft.of nonbraced panel area.
2. Exposed ducts and fittings shall be cross broken only. Cross beading is unacceptable due to visually unappealing patterns on fittings and ducts running in different directions.

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel or carbon steel coated with zinc-chromate primer.
2. PVC-Coated Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Match duct material.

3. Stainless-Steel Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Match duct material.

4. Aluminum Ducts: Aluminum.

G. Liner:

1. Install liner in all exposed single wall duct conveying heated or cooled air accordance with the insulation requirements of 230713 and

   a. In return ducts within [5 ft] [10 ft] [15 ft] [20 ft] [33 ft] of equipment or fan inlets.
   b. In supply ducts within [5 ft] [10 ft] [15 ft] [20 ft] [33 ft] of equipment or fan discharges.
   c. In supply ducts within [5 ft] [10 ft] [15 ft] of VAV box discharges.
   d. In branch ductwork from risers operating in excess of [1500 FPM] [2000 FPM] within [5 ft] [10 ft] [15 ft] of the branch connection.
   e. In all transfer ductwork.
   f. In all diffuser plenums.

2. Install liner with the following thicknesses. Thicknesses may be increased to achieve insulation performance required per 230713 entirely with liner.

   a. Ducts supplying or exhausting wet air (shower/toilet exhausts, dishwasher exhausts, pools, humidification systems) shall not be lined.
   b. Supply Air Ducts: [Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber], [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.
   c. Return Air Ducts: [Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber], [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.
   d. Exhaust Air Ducts: [Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber], [1 inch] <Insert thickness> thick.
   e. Supply Fan Plenums: [Fibrous glass, Type II] [Flexible elastomeric] [Natural fiber], [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.
   f. Return- and Exhaust-Fan Plenums: [Fibrous glass, Type II] [Flexible elastomeric] [Natural fiber], [2 inches] <Insert thickness> thick.
   g. Transfer Ducts: [Fibrous glass, Type I] [Flexible elastomeric] [Natural fiber], [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.

H. Double-Wall Duct Interstitial Insulation. Thicknesses shall be the larger of the value noted below and the insulation performance required per 230713 entirely with liner. .

1. Supply Air Ducts: [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.
2. Return Air Ducts: [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.
3. Exhaust Air Ducts: [1 inch] [1-1/2 inches] [2 inches] <Insert thickness> thick.

I. Permissible Fittings for Rectangular Ducts

1. The following fittings are permitted with reference to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible,".

   a. Type RE-3 according to Figure 4-2, radiused elbow with splitter vanes according to chart 4-1.
   b. 45° lead in round taps according to Figure 4-6
   c. Concentric, eccentric and bellmouthed transitions according to Figure 4-7

2. The following fittings are permitted with applicability limits as noted

a. Type RE-2 according to Figure 4-2, 90° mitered elbow with double thickness vanes according to Figures 4-3 and 4-4 may be used when all of the following conditions are met

1) A minimum duct width of [8 in] [10 in] [12 in] and minimum height of [6 in] [8 in]. The intent is to avoid relying on the theoretical benefits of turning vanes where the duct is too small to correctly install a sufficient number of vanes.
2) Maximum vane height shall be 36 in. Use intermediate baffles to support multiple tiers of vanes for taller elbows.
3) Elbows less than 18 in wide shall use smaller vane sizes.
4) The velocity is less than 2000 FPM
5) In acoustically lined ducts turning vanes shall be formed from perforated metal 2 gages lower (thicker metal) filled with acoustically absorbent material.

b. 45° boot taps according to Figure 4-6 may be used when all of the following conditions are met

1) The diverging flow is less than 30% of the main flow
2) The main velocity is less than 1500 FPM,
3) The branch is not the critical branch
4) The boot depth must be at least 25% of the branch duct width according to the figure.
5) The intent is to limit boot taps to lower velocity systems where using a lower resistance, but more difficult to fabricate fitting will not impact the static pressure requirements for the fan.

c. Obstruction avoidance Figure C according to Figure 4-8 may be used where all of the following conditions are met

1) Velocity is less than 1200 FPM
2) No fittings are within three (3) times the duct height H downstream,
3) The height reduction to clear the obstruction is no more than 20% of the duct height H

d. Angled offset Type 1 according to Figure 4-7 may be used when all of the following conditions are met

1) Velocity is less than 1200 FPM
2) The offset distance is less than 20% of the duct width
3) The offset angle is less than 15°
4) There are no fittings within three times the duct width downstream of the offset.

e. Where velocity is less than 1200 FPMconical and bellmouth round taps according to Figure 4-6 are permitted.

3. No other fittings may be used without clearly annotating the pressure drop associated with the fitting and any system effects due to the configuration of nearby fittings and ductwork on sheetmetal shop drawings and submitting backup calculations with sheetmetal shop drawings.

J. Permissible Fittings for Round and Flat Oval

1. The following fittings are permitted with reference to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible,". A minimum of 1.5 diameter to radius ratio shall be used.

   a. Stamped elbow according Figure 3-4
   b. Up to 12 in [welded] [standing seam or welded according to duct construction requirements] segmented elbows according to Figure 3-4 with minimum 5 segments for 90° turn, 3 segments for 45° turn and minimum 1.5 radius to diameter ratio
   c. Larger than 12 in [welded] [standing seam or welded according to duct construction requirements] segmented elbows according to Figure 3-4 with minimum 5 segments and minimum 1.5 radius to diameter ratio
   d. Adjustable segmented elbows for round ducts up to [6 in] [8 in] diameter and less than 1500 fpm.

2. Taps: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

   a. Velocity 1500 fpm or Lower: Conical tap.
   b. Velocity 1500 fpm or Higher: 45-degree lateral.
   c. Conical wye.

K. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

   a. Rectangular Main to Rectangular Branch: 45-degree entry.
   b. Rectangular Main to Round Branch: Spin in.

2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

   a. Velocity 1000 fpm or Lower: 90-degree tap.
   b. Velocity 1000 to 1500 fpm: Conical tap.
   c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 233113

SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Manual volume dampers.
2. Fire dampers.
3. Combination fire and smoke dampers.
4. Duct-mounted access doors.
5. Flexible connectors.
6. Duct accessory hardware.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

1.4 MAINTENANCE MATERIAL SUBMITTALS

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

1. Fusible Links: Furnish quantity equal to 10 percent of amount installed.

PART 2 PRODUCTS

2.1 ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: [G60] [G90].

2.3 MANUAL VOLUME DAMPERS

A. Low-Leakage, Steel, Manual Volume Dampers:

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

a. Nailor Industries Inc.
b. Ruskin Company.

2. Comply with AMCA 500-D testing for damper rating.
3. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
4. Suitable for horizontal or vertical applications.
5. Frames:

a. Hat shaped.
b. 0.094-inch- thick, galvanized sheet steel.
c. Mitered and welded corners.
d. Flanges for attaching to walls and flangeless frames for installing in ducts.

6. Blades:

a. Multiple or single blade.
b. Parallel- or opposed-blade design.
c. Stiffen damper blades for stability.
d. Galvanized, roll-formed steel, 0.064 inch thick.

7. Blade Axles: Galvanized steel.
8. Bearings:

a. Oil-impregnated bronze.
b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

9. Blade Seals: Neoprene.
10. Jamb Seals: Cambered stainless steel.
11. Tie Bars and Brackets: Galvanized steel.
12. Accessories:

a. Include locking device to hold single-blade dampers in a fixed position without vibration.

B. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting.

2.4 FIRE DAMPERS

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

1. Greenheck Fan Corporation.
2. Ruskin Company.

B. Type: Dynamic; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Curtain type with blades inside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

I. Heat-Responsive Device: , replaceable link and switch package, factory installed, rated.

2.5 COMBINATION FIRE AND SMOKE DAMPERS

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

1. Greenheck Fan Corporation.
2. Ruskin Company.

B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Heat-Responsive Device: Electric resettable and switch package, factory installed, rated.

F. Smoke Detector: Integral, factory wired for single-point connection.

G. Rated pressure and velocity to exceed design airflow conditions.

H. Mounting Sleeve: Factory-installed, 0.05-inch- thick, galvanized sheet steel; length to suit wall or floor application.

I. Master control panel for use in dynamic smoke-management systems.

J. Damper Motors: two-position action.

K. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: 115 V, single phase, 60 Hz.

L. Accessories:

1. Auxiliary switches for signaling or position indication.
2. Test and reset switches, remote mounted.

2.6 DUCT-MOUNTED ACCESS DOORS

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

1. Greenheck Fan Corporation.
2. Nailor Industries Inc.

B. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: Double wall with insulation fill with metal thickness applicable for duct pressure class.
3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.

4. Factory set at 3.0- to 8.0-inch wg.
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.
7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
9. Insulation Fill: 1-inch- thick, fibrous-glass or polystyrene-foam board.

2.7 FLEXIBLE CONNECTORS

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

1. Duro Dyne Inc.

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd..
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.

2.8 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Compliance with ASHRAE/IESNA 90.1-2004 includes Section 6.4.3.3.3 - "Shutoff Damper Controls," restricts the use of backdraft dampers, and requires control dampers for certain applications. Install control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

1. Install steel volume dampers in steel ducts.
2. Install aluminum volume dampers in aluminum ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire and smoke dampers according to UL listing.

H. Connect ducts to duct silencers with flexible duct connectors.

I. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream and downstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. At each change in direction and at maximum 50-foot spacing.
8. Upstream and downstream from turning vanes.
9. Upstream or downstream from duct silencers.
10. Control devices requiring inspection.
11. Elsewhere as indicated.

J. Install access doors with swing against duct static pressure.

K. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
3. Head and Hand Access: 18 by 10 inches.
4. Head and Shoulders Access: 21 by 14 inches.
5. Body Access: 25 by 14 inches.
6. Body plus Ladder Access: 25 by 17 inches.

L. Label access doors according to Section 230553 "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

M. Install flexible connectors to connect ducts to equipment.

N. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

O. Connect terminal units to supply ducts directly or with maximum 2-inch lengths of flexible duct. Do not use flexible ducts to change directions.

P. Connect diffusers or light troffer boots to ducts[directly or] with maximum 60-inch lengths of flexible duct clamped or strapped in place.

Q. Connect flexible ducts to metal ducts with adhesive plus sheet metal screws.

R. Install duct test holes where required for testing and balancing purposes.

S. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

END OF SECTION 233300

SECTION 233423 - HVAC POWER VENTILATORS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. In-line centrifugal fans.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.

1.4 COORDINATION

A. Coordinate size and location of structural-steel support members.

PART 2 PRODUCTS

2.1 IN-LINE CENTRIFUGAL FANS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:

1. Greenheck Fan Corporation.
2. Loren Cook Company.
3. PennBarry.

B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

C. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing; with wheel, inlet cone, and motor on swing-out service door.

D. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

E. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Companion Flanges: For inlet and outlet duct connections.

2.2 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

B. Enclosure Type: Totally enclosed, fan cooled.

2.3 SOURCE QUALITY CONTROL

A. Certify sound-power level ratings according to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Certify fan performance ratings, including flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating." Label fans with the AMCA-Certified Ratings Seal.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.

B. Equipment Mounting:

1. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

C. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch.

D. Install units with clearances for service and maintenance.

E. Label units according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."

B. Install ducts adjacent to power ventilators to allow service and maintenance.

C. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

3.4 ADJUSTING

A. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

B. Replace fan and motor pulleys as required to achieve design airflow.

C. Lubricate bearings.

END OF SECTION 233423

SECTION 233600 - AIR TERMINAL UNITS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Modulating, single-duct air terminal units.
2. Balancing terminal units.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of air terminal unit.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for air terminal units.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Sustainable Design Submittals:

1. Product Data: For adhesives, indicating VOC content.
2. Laboratory Test Reports: For adhesives, indicating compliance with requirements for low-emitting materials.
3. Product data showing compliance with ASHRAE 62.1.

C. Shop Drawings: For air terminal units.

1. Include plans, elevations, sections, and mounting details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Ceiling suspension assembly members.
2. Size and location of initial access modules for acoustic tile.
3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

a. Instructions for resetting minimum and maximum air volumes.
b. Instructions for adjusting software set points.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

C. ASHRAE Compliance: Applicable requirements in ASHRAE/IES 90.1, "Section 6 - Heating, Ventilating, and Air Conditioning."

2.2 MODULATING, SINGLE-DUCT AIR TERMINAL UNITS

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Titus.
2. Trane.
3. Price

B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: 0.040-inch- thick galvanized steel, single wall.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [fibrous-glass] [flexible elastomeric] duct liner.
2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections[, size matching inlet size].
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from zero to 140 deg F, shall be impervious to moisture and fungus, shall be suitable for 10-inch wg static pressure, and shall be factory tested for leaks.

E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: AHRI 880 rated, [2] percent of nominal airflow at 3-inch wg inlet static pressure.
2. Damper Position: Normally closed.

F. Attenuator Section: [0.034-inch steel] [0.032-inch aluminum] sheet.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for flexible elastomeric duct liner.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

1. SCR controlled.
2. Access door interlocked disconnect switch.
3. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).
4. Nickel chrome 80/20 heating elements.
5. Airflow switch for proof of airflow.
6. Fan interlock contacts.
7. Fuses in terminal box for overcurrent protection (for coils more than 48 A).

H. Controls:

1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg inlet static pressure.

2.3 CASING LINER

A. Casing Liner: Flexible elastomeric duct liner fabricated of preformed, cellular, closed-cell, sheet materials complying with ASTM C534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. Minimum Thickness: 3/4 inch.
2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

a. Adhesive shall have a VOC content of 80 g/L or less.

2.4 SOURCE QUALITY CONTROL

A. Factory Tests: Test assembled air terminal units according to AHRI 880.

1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, [coil type,]and AHRI certification seal.

PART 3 EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 5, "Hangers and Supports" and with Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.2 TERMINAL UNIT INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.

C. Install wall-mounted thermostats.

3.3 DUCTWORK CONNECTIONS

A. Comply with requirements in [Section 233113 "Metal Ducts"] [Section 233116 "Nonmetal Ducts"] for connecting ducts to air terminal units.

B. Make connections to air terminal units with flexible connectors complying with requirements in Section 233300 "Air Duct Accessories."

3.4 ELECTRICAL CONNECTIONS

A. Install field power to each air terminal unit electrical power connection. Coordinate with air terminal unit manufacturer and installers.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least $1/2$ inch high.

3.5 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.6 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

3.7 FIELD QUALITY CONTROL

A. Perform the following tests and inspections[with the assistance of a factory-authorized service representative]:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
2. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

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

B. Air terminal unit will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.8 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
3. Verify that controls and control enclosure are accessible.
4. Verify that control connections are complete.
5. Verify that nameplate and identification tag are visible.
6. Verify that controls respond to inputs as specified.
7. .

3.9 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 233600

SECTION 233713.13 - AIR DIFFUSERS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Rectangular and square ceiling diffusers.
2. Linear bar diffusers.
3. Linear slot diffusers.
4. Ceiling-integral continuous slot diffusers.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

PART 2 PRODUCTS

2.1 RECTANGULAR AND SQUARE CEILING DIFFUSERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:

1. Titus

2. Price

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: Steel.

D. Finish: Baked enamel, color selected by Architect.

2.2 LINEAR BAR DIFFUSERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:

1. Titus

2. Price

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: Steel.

D. Finish: Baked enamel, color selected by Architect.

E. Two-Way Deflection Vanes: Extruded construction louvers with removable core.

F. Accessories: Directional vanes Blank-off strips.

2.3 LINEAR SLOT DIFFUSERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:

1. Titus

2. Price

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material - Shell: Steel, insulated.

D. Finish - Face and Shell: Insert finish.

E. Finish - Pattern Controller: Baked enamel, black.

2.4 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

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

3.2 INSTALLATION

A. Install diffusers level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust diffusers to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713.13

SECTION 237219 - FIXED PLATE AIR-TO-AIR ENERGY RECOVERY UNITS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Fixed-plate total heat exchangers.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product. Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Shop Drawings: For air-to-air energy recovery equipment.

1. Include plans, elevations, sections, and [mounting] [attachment] details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
2. Support location, type, and weight.
3. Field measurements.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

1.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver and store products in a clean, dry place.

B. Comply with manufacturer's written rigging and installation instructions for unloading and moving to final installed location.

C. Handle products carefully to prevent damage, breakage, denting, and scoring. Do not install damaged products.

D. Protect products from weather, dirt, dust, water, construction debris, and physical damage.

1. Retain factory-applied coverings on equipment to protect finishes during construction and remove just prior to operating unit.
2. Cover unit openings before installation to prevent dirt and dust from entering inside of units. If required to remover coverings during unit installation, reapply coverings over openings after unit installation and remove just prior to operating unit.
3. Replace installed products damaged during construction.

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of unit components.

C. ASHRAE Compliance:

1. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
2. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat/Energy Exchangers."

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. Comply with ASTM E84 or UL 723.

1. Insert requirements for Component Amplification Factor and Component Response Modification Factor.

2.2 FIXED-PLATE TOTAL HEAT EXCHANGERS

A. Casing: Galvanized steel.

B. Drain Pan: Same material as casing, with drain connections on exhaust and supply side .

1. Comply with requirements in ASHRAE 62.1.

C. Plates: Evenly spaced, sealed, and arranged for counter airflow.

D. Bypass Plenum: Within casing, with gasketed face-and-bypass dampers having operating rods extended outside casing.

E. Maximum Differential Pressure: Suitable for maximum 6-inch wg.

F. Maximum Temperature: Suitable for maximum 194 deg F.

2.3 SOURCE QUALITY CONTROL

A. AHRI 1060 Certification: Certified according to AHRI 1060.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for electrical services to verify actual locations of connections before installation.

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

3.2 INSTALLATION

A. Install fixed-plate heat exchangers so supply and exhaust airstreams flow in opposite directions.

1. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to heat exchanger. Access doors and panels are specified in Section 233300 "Air Duct Accessories."

B. Install floor-mounted units on 4-inch- high, concrete base[designed to withstand, without damage to equipment, seismic force required by code].

C. Equipment Mounting:

1. Install air-to-air energy recovery equipment on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

D. Install seismic restraints according to manufacturers' written instructions.

E. Install units with clearances for service and maintenance.

F. Comply with requirements for ductwork specified in Section 233113 "Metal Ducts."

3.3 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260529 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 250526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.4 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.5 FIELD QUALITY CONTROL

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

D. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper water wash control and unit operation.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

E. Air-to-air energy recovery equipment will be considered defective if it does not pass tests and inspections.

F. Prepare test and inspection reports.

3.6 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to electrical systems are complete. Verify that proper thermal-overload protection is installed.
4. Verify water wash mechanism operation.

B. Starting procedures for air-handling units include the following:

1. Energize water wash motor and verify proper operation of motor and water wash system.
2. Measure and record motor electrical values for voltage and amperage.

3.7 ADJUSTING

A. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.8 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-to-air heat recovery unit,[and after completing startup service,] clean unit to remove foreign material and construction dirt and dust.

END OF SECTION 237219

SECTION 237313.19 - INDOOR, CUSTOM AIR-HANDLING UNITS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes indoor, custom air-handling units with capacities, characteristics, and configurations indicated on Drawings.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit.

1. Product information organized to show compliance with each performance requirement of "Performance Requirements" Article.
2. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
3. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
4. Include unit dimensions and weight.
5. Include cabinet material, metal thickness, finishes, insulation, and accessories.
6. Fans:

    a. Include certified fan-performance curves with system operating conditions indicated. For fans operating at variable speeds include curves in [10] <Insert number> percent speed increments starting at design speed down to minimum speed.
    b. Include fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
    c. Include fan construction and accessories. Submit sufficient information to show product compliance with requirements indicated.
    d. Include dimensions and weight.
    e. Include motor ratings, electrical characteristics, and motor accessories.

7. Vibration isolation product data with performance ratings. Uniquely identify and include information for each different isolator type and indicate for each air-handling unit where each isolator type is being used.
8. Include certified coil-performance ratings with system operating conditions indicated. Product data to include dimensions, dry and operating weight, volume of fluid contained, materials of construction, and performance ratings with system operating conditions indicated.
9. Casing insulation product data and performance ratings.
10. Access door and access panel product data and performance ratings.
11. Paint product data and performance ratings.

12. Electrical product data and performance ratings.
13. Metal grating product data and performance ratings.
14. Electric heater product data with performance ratings.
15. Steam humidifier product data with performance ratings.
16. Dampers product data, including housings, linkages, and operators with performance ratings.
17. Filters product data with performance characteristics.
18. Heat wheels product data with performance ratings.
19. Fixed plate heat exchangers product data with performance ratings.
20. Heat pipe heat exchangers product data with performance ratings.
21. Duct silencers product data with performance ratings.
22. Air blender product data with dimensions, weights, materials of construction, performance ratings, and installation requirements.
23. UV-C lamp systems product data with performance ratings.
24. <Insert requirements>.

B. Shop Drawings: For each type and configuration of indoor, custom air-handling unit.

1. Prepared by manufacturer's factory employees with review and sign-off by those individuals responsible for manufacturing the air-handling units.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, sections, and other details, or BIM model, drawn to scale, showing the items described in this Section and coordinated with all building trades.

B. Startup service reports.

C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.7 DELIVERY, STORAGE, HANDLING

A. Deliver air-handling units with factory-installed shipping skids and lifting lugs; pack small components in factory-fabricated protective containers. Cover units with heat-shrinkable plastic sheeting suitable for shipping from point of manufacture to Project.

B. Handle air-handling units carefully to avoid damage to components, casing, and finish. Do not install damaged components; replace and return damaged components to air-handling unit manufacturer.

C. Store air-handling units in a clean dry place and protect them from weather and construction activities.

D. Keep air-handling units fully covered and protected during construction. Remove dirt and debris and clean units to a factory-cleaned condition.

E. Comply with manufacturer's written rigging and installation instructions for unloading air-handling units and moving them to their final locations.

F. For air-handling units equipped with key locks on access doors, keep doors locked during construction.

1. If access is required within air-handling units, only open the doors to sections that require access and lock doors at the end of each [workday] [work shift] <Insert requirement>.
2. Protect inside of air-handling units from damage and keep inside of units as clean as the factory-cleaned condition.
3. Report observed abuse to <Insert entity> for immediate corrective action.

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handing units and components.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. Delegated Design: Engage a qualified professional [specialist] [engineer], as defined in Section 014000 "Quality Requirements," to design air-handling units, [vibration isolation,] [and seismic restraints] including comprehensive engineering analysis, using performance requirements and design criteria indicated.

F. Casing Structural Performance:

1. Floor: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a deflection of [L/300] [L/360] <Insert deflection> of span.
2. Walls and Roof: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a midpoint deflection of [L/200] [L/240] <Insert deflection> of span.

G. Casing Leakage Performance, ASHRAE 111: Class 3 leakage or better at plus or minus 8 inches wg.

H. Casing Leakage Performance: Comply with more stringent of the following requirements:

1. ASHRAE 111, Class 3 leakage or better at plus or minus 8 inches wg.
2. Not more than 0.5 percent of the total unit airflow at 8 inches wg.

I. Casing Thermal Performance:

1. Surface Condensation: Air-handling manufacturer shall evaluate potential for condensation and design and manufacture entire unit casing to prevent condensation at most extreme operating conditions encountered.
2. Thermal Break: Incorporate a thermal break at each through metal path to prevent condensation from occurring on interior and exterior of casing.
3. U-Value: Overall U-value or equivalent R-value of casing shall not exceed governing codes and ASHRAE/IES 90.1, while considering the effects of metal-to-metal contact and thermal bridging in calculations.

J. Air Tunnel Aerodynamic Performance: Position air-handling unit internal components and transition between internal components to maintain uniform airflow; minimize sound levels and energy consumption. Use methods indicated and other means to ensure compliance.

1. Use turning vanes if necessary to direct the air path.

    a. Design, manufacture, and install vanes in accordance with applicable requirements in ASHRAE and SMACNA guidelines, handbooks, and standards.
    b. Install vanes firmly in place so that no vane movement occurs at worst-case airflow capacity possible.

2. Use fan inlet and discharge transitions and other devices to maximize system regain and minimize airborne sound levels.
3. Center system components such as coils, fans, and filters, vertically and horizontally, in airstream.
4. Maintain spacing between components such that airflow patterns to adjacent components are as uniform as possible and that component "dead spots" or "jetted areas" are avoided.
5. Design and install internal structural supports, piping, and conduit that do not block airflow and impede performance of coils, fans, filters, and other unit components, and service space clearances.

K. Air-Handling Unit Acoustical Performance:

1. Radiated Noise: Noise radiated from air-handling unit casing[and openings not ducted] shall not exceed following sound pressure levels when measured [3 feet] <Insert distance> away from any exterior surface of unit. Sound pressure levels indicated in each octave band are in decibels (dB) (reference 20 µPa).

    a. 63 Hz: <Insert value> dB.
    b. 125 Hz: <Insert value> dB.
    c. 250 Hz: <Insert value> dB.
    d. 500 Hz: <Insert value> dB.
    e. 1000 Hz: <Insert value> dB.

f. 2000 Hz: <Insert value> dB.
g. 4000 Hz: <Insert value> dB.

L. Casing Acoustical Performance:

1. Sound Absorption: Minimum acceptable sound absorption coefficient and noise reduction coefficient (NRC) of perforated inside casing assemblies when tested by an independent testing laboratory in accordance with ASTM C423 and ASTM E795.

a. 125 Hz: <Insert value> dB.
b. 250 Hz: <Insert value> dB.
c. 500 Hz: <Insert value> dB.
d. 1000 Hz: <Insert value> dB.
e. 2000 Hz: <Insert value> dB.
f. 4000 Hz: <Insert value> dB.
g. NRC: <Insert value>.

2. Sound Transmission: Minimum acceptable sound transmission loss and STC of proposed cabinet construction when tested by an independent testing laboratory in accordance with ASTM E90 and ASTM E413.

a. 125 Hz: <Insert value> dB.
b. 250 Hz: <Insert value> dB.
c. 500 Hz: <Insert value> dB.
d. 1000 Hz: <Insert value> dB.
e. 2000 Hz: <Insert value> dB.
f. 4000 Hz: <Insert value> dB.
g. STC: <Insert value>.

M. Durability Performance: Design and manufacture air-handling units with underlying requirement to provide a highly durable piece of equipment.

1. Unit Life Expectancy: [25] <Insert number> years.
2. Supporting Documentation: Submit documentation showing proposed products to consider and include design features, components, and materials to satisfy requirement.

N. Extreme Operating Conditions:

1. Corrosive Environments: Air-handling unit manufacturer shall evaluate the quality and potential corrosiveness of air passing through air-handling units and propose additional protective finishes and better-quality materials of a heavier thickness if required to comply with requirements indicated.

a. Unless otherwise indicated, air-handling units for HVAC applications may use up to 100 percent of outdoor air or a mix of outdoor air with return air from habitable areas served.[Projects located in coastal and industrial areas may require added protection.]
b. Air-handling units circulating [Class 3] [and] [Class 4] exhaust air in accordance with ASHRAE 62.1 could potentially be hot, humid, and corrosive and may require added protection.

2. Humidity and Temperatures: Materials and components of air-handling units shall be suitable for use in low and high humidity and temperature extremes when operating under normal and abnormal conditions without permanent degradation or loss in material performance.

O. Safety:

1. Comply with OSHA regulations.
2. Exposed sharp edges and corners of metal shall be protected or rounded to prevent injury to personnel not wearing gloves.
3. Cover exposed ends of screws with plastic or metal covers to prevent injury to personnel coming in contact with screws.

P. Serviceability:

1. Hoisting Provisions: Fans and motors weighing more than [200 lb] <Insert weight> to have full-length hoist rails mounted over the equipment to facilitate service, removal, and replacement.
2. Mounting Location: Install internal components in readily accessible locations to facilitate ease of service and replacement.
3. Service Access:

    a. Internal components shall be serviceable through access sections with doors indicated on Drawings.
    b. Internal components shall be removable and replaceable through access doors or panels.
    c. Review requirements for access doors and panels indicated and recommend additional access doors and panels if required for uninhabited service, removal, and replacement of components.

4. Tripping Hazards: Floors in accessible sections of air-handling unit shall be free of standing seams, reinforcing, supports, or section splits located in the walking path that is capable of causing a tripping hazard. Locate section splits immediately adjacent to internal walls.

Q. Quality: Type and thickness of materials indicated are the minimum acceptable. Provide better-quality materials of a heavier thickness if required to comply with performance requirements indicated.

1. If manufacturer's standard construction exceeds requirements indicated, use manufacturer's standard construction.
2. If manufacturer's standard construction does not comply with requirements indicated, modify manufacturer's standard construction to comply with requirements.

R. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined in accordance with [ASCE/SEI 7] <Insert requirement>.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[and the unit will be fully operational after the seismic event]."
2. Component Importance Factor: [1.5] [1.0].
3. <Insert requirements for Component Amplification Factor and Component Response Modification Factor>.

S. Vibration Performance: Air-handling unit manufacturer shall evaluate vibration of internal components installed inside of air-handling units and include internal vibration isolation required to limit the vibration transmitted to the building at a low enough level that vibration is not perceived by building occupants.

2.2 CAPACITIES AND CHARACTERISTICS

A. See equipment schedules on Drawings.

2.3 SOURCE LIMITATIONS

A. Source all indoor [and outdoor]custom air-handling units from same manufacturer.

B. Like components furnished with air-handling units shall be from same manufacturer.

C. Air-handling units shall be manufactured in [United States] [United States or Canada] [North America] <Insert requirement>.

D. <Insert requirements>.

2.4 MANUFACTURERS

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

1. Haakon Industries.
2. Trane; An Ingersoll Rand Company.
3. VenMar

EXECUTION

2.5 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine air-handling units before installation. Reject units with physical damage, and air-handling unit components that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for the following before installation of air-handling units:

1. Structural substrate mounting and anchorage to verify actual sizes, types, and locations.
2. Piping systems to verify actual sizes, types, and locations of connections.
3. Ductwork and plenums to verify actual sizes, types, and locations of connections.

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

2.6 PROTECTION DURING CONSTRUCTION

A. Exterior Covers: Cover air-handling units during construction with sealed covers to protect air-handling unit casing and externally mounted components from physical damage, dirt, dust and debris, paint splatter, and any other construction materials.

1. Minor physical damage, as determined by Owner, shall be repaired by air-handling unit factory service personnel to factory-finished condition.
2. Replace air-handling units with damage that in any way compromises the performance indicated.

2.7 PIPING CONNECTIONS

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

B. Where installing piping adjacent to air-handling unit, provide unobstructed access to inside of air-handling units for service and maintenance.

C. Connect piping to air-handling units with flexible connectors.

D. Air-Handling Unit Floor Drains: Do not require installation of permanent drain piping.

E. Air-Handling Unit Floor Drain Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with [flanges or]unions.
2. Extend [dedicated]drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.
5. Secure drain piping to structure.

F. Chilled-[and Hot-]Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a [flange] [or] [union].
3. Connect to each coil inlet with shutoff valve, test plug, [pressure gauge] [and] [thermometer].
4. Connect to each coil outlet with balancing valve, test plug, [pressure gauge] [thermometer] [flow meter] [and] [shutoff valve].
5. Connect each coil drain connection with a drain valve, which is full size of drain connection.[Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.]
6. Connect each coil vent connection with [automatic] [or] [manual] vent, which is full size of vent connection.

G. Refrigerant Coil Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve at each supply and return connection.

2.8 STARTUP SERVICE

A. Engage an air-handling unit factory[-authorized] service representative to perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, controls, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that face-and-bypass dampers provide full face flow.
7. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
8. Comb coil fins for parallel orientation.
9. Verify that proper thermal-overload protection is installed for electric heaters.
10. Install new, clean filters.
11. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.
12. <Insert requirement>.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.[Replace fan and motor pulleys as required to achieve design conditions.]
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.
4. <Insert requirement>.

C. Heat Wheel Startup Service:

1. After field installation is complete, a final checkout and startup shall be completed to ensure proper purge adjustment, seal adjustment, control settings, and other key operational functions.
2. Service shall be completed by trained factory service personnel employed by heat wheel manufacturer.
3. Submit a report summarizing findings, adjustments made, and final settings.

2.9 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

C. Before turning equipment over to Owner for use, adjust air-handling unit components that require further adjustment for proper operation. Consult air-handling unit manufacturer for instruction.

D. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to visits to Project during other-than-normal occupancy hours for this purpose.

E. Seasonal Adjustments: Make seasonal visits during warranty period to inspect and review operation of equipment. Make necessary adjustments for components observed to require adjustments for proper operation. Prepare and submit a report to Owner documenting each visit, observations, and any adjustments made.

2.10 CLEANING

A. Cleaning Schedule: After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems, and after completing startup service, and immediately before Owner use, clean air-handling units to remove foreign material and construction dirt and dust.

B. Unit Interior: Clean air-handling units internally to factory clean condition. Remove foreign material and construction debris, dirt, and dust.

1. Vacuum clean with HEPA-filtered vacuum and then wipe down with cleaning solution.
2. Clean casing floors, roofs, wall surfaces, access doors, and panels.
3. Clean all internal components, such as, coils, dampers, filter frames, fans, and motors.
4. Clean light fixtures and control devices.

C. Unit Exterior: Clean external surfaces of air-handling units to factory clean condition. Remove foreign material and construction debris, dirt, and dust. Vacuum clean with HEPA-filtered vacuum and then wipe down all surfaces with cleaning solution.

D. Cleaning Materials: Use cleaning materials and products recommended in writing by air-handling unit manufacturer.

E. Acceptance: Following unit cleaning, submit a written request for review and [Owner]acceptance. Acceptance for cleaning of air-handling units [with absolute filters]must pass a white glove test.

2.11 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform the following tests and inspections[with the assistance of a factory-authorized service representative].

1. After field piping connections are complete, test [hydronic] [and] [steam] coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Field-Assembly Supervision: Instruct Installer and supervise field installation of [first] <Insert quantity> air-handling unit(s) shipped in multiple pieces for field assembly.
4. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Field Casing Leakage Test:

1. Perform leak testing of air-handling units that include field assembly of multiple sections. Air-handling units that are shipped and installed as a single piece do not require field testing.
2. Leak test [one] <Insert value> air-handling unit(s) of each unique size and arrangement randomly selected by [Architect] [Commissioning Agent] [Owner].
3. Follow procedures complying with ASHRAE 111.
4. Assembled air-handling units shall satisfy leakage criteria indicated. Modify air-handling units that fail to satisfy criteria and retest. For every air-handling unit that fails test, another air-handling unit shall be tested until all air-handling units tested pass leakage criteria on first attempt.
5. Submit a test report for each test indicating test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Test report shall be in accordance with ASHRAE 111.
7. Witness Testing:

    a. Provide written notification at least [30] [20] <Insert number> business days in advance of testing.
    b. Testing shall be conducted in presence of testing and balancing agent.
    c. Other parties such as Architect, Commissioning Agent, and Owner shall be invited to witness testing with attendance being optional.

E. Field Fan Vibration Test:

1. Perform fan vibration testing for every one out of [10] <Insert number> air-handling unit fans randomly selected by [Architect] [Commissioning Agent] [Owner].
2. Test after air-handling unit installation is complete.
3. Three vibration readings shall be taken for each bearing in horizontal, vertical, and axial directions. Record each reading including vibration amplitude verses frequency.
4. Modify fans that fail to satisfy performance criteria and retest. For every fan that fails test, another fan shall be tested until all fans tested pass criteria on first attempt.
5. Submit a report for each fan tested indicating air-handling unit designation, fan designation, test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Witness Testing:

    a. Provide written notification at least [30] [20] <Insert number> business days in advance of testing.
    b. Testing shall be conducted in presence of testing and balancing agent.

c. Other parties such as Commissioning Agent, Architect, and Owner shall be invited to witness testing with attendance being optional.

F. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

G. Prepare test and inspection reports.

2.12 OPERATION DURING CONSTRUCTION

A. Operation of air-handling units for temporary cooling, heating, and ventilation is not allowed without Owner authorization.

1. Submit written request for Owner approval by signature with detailed description of operating procedures to be followed including, but not limited to, the following:

a. Operation:

1) Beginning and ending calendar dates.
2) List each day during week.
3) List start and stop time and hours for each day.

b. Startup procedures and shut-down procedures.
c. Provisions for routine monitoring of unit operation.
d. Provisions to prevent and protect against damage to equipment due to adverse operation such as, low temperature, high temperature, over pressure, fire, smoke, electrical over- and undervoltage, and current and electrical fault.
e. Provisions and safeguards for filtration to keep inside of units from getting dirty.
f. Record keeping.

2. If approved by Owner, units used for temporary cooling, heating, and ventilation during and before interior finish work is complete shall include an unconditional complete unit labor and parts warranty to extend at least years after the warranty indicated expires.
3. Interior and exterior of air-handling units shall be cleaned to a factory-cleaned condition and clean condition must be accepted by Owner.

B. Filtration during Temporary Use:

1. Protect air-handling system ducts (exhaust air, outdoor air, and return air) with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV [8] [11] [13] <Insert MERV> in accordance with ASHRAE 52.2.
2. Protect air-handling units with open inlets that are not ducted with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV [8] [11] [13] <Insert MERV> in accordance with ASHRAE 52.2.
3. Do not operate air-handling units until both temporary and scheduled permanent air-handling unit particulate filters are in place. Temporary filters must be installed upstream of permanent filters while units are operating.
4. Replace temporary and permanent filters used during construction when dirty. After end of temporary use, replace permanent filters with new, clean filters before beginning testing, adjusting, and balancing.

C. Comply with SMACNA 008, "IAQ Guidelines for Occupied Buildings under Construction," for procedures to protect HVAC system.

2.13 DEMONSTRATION

A. Engage air-handling unit manufacturer [employed training instructor] [or] [factory-authorized service representative] to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

B. Training shall include, but not be limited to, procedures and schedules related to performance, safety, startup and shut down, troubleshooting, servicing, preventive maintenance, and how to obtain replacement parts.

1. Damper Assemblies: Cleaning, operation, service, removal and replacement, and spare parts.
2. Fan and Motor Assemblies: Cleaning, operation, removal and replacement, service, and spare parts.
3. Humidifiers: Cleaning, operation, service, removal and replacement, and spare parts.
4. UV-C Lamp Systems: Cleaning, operation, service, removal and replacement, and spare parts.
5. Lights, Receptacles, and Switches: Cleaning, operation, service, removal and replacement, and spare parts.
6. <Insert requirement>.

C. Instructor:

1. Instructor shall be factory trained and certified by air-handling unit manufacturer with current training on equipment installed.
2. Instructor's credentials shall be submitted for review by [Architect] [Commissioning Agent] [Owner] before scheduling training.
3. Instructor(s) [primary] [sole] job responsibility shall be Owner training.
4. Instructor(s) shall have not less than [three] <Insert number> years of training experience with air-handling unit manufacturer and past training experience on at least [three] <Insert number> projects of comparable size and complexity.

D. Schedule and Duration:

1. Schedule training with Owner at least [20] <Insert number> business days before first training session.
2. Training shall occur before Owner occupancy.
3. Training shall be held at mutually agreed date and time during normal business hours.
4. Each training day shall not exceed [eight] <Insert number> hours of training. Daily training schedule shall allow time for a [one] <Insert number>-hour lunch period and [15] <Insert number>-minute break after every [two] <Insert number> hours of training.
5. Perform not less than [eight] [16] [24] <Insert number> hours of training.

E. Training Attendees: Assume [three] <Insert number> people.

F. Training Attendance Records: For record purposes, document training attendees at start of each new training session. Record date, time, brief description of training covered during the session, attendee's name, signature, phone number, and e-mail address. Submit scanned copy of sign-in sheet to Owner for each training session.

G. Training Format: Individual training modules toinclude classroom training followed by hands-on field demonstration and training.

H. Training Materials: Provide training materials in electronic format to each attendee.

1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.

I. Training Video Recording: Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.

J. Written Acceptance: Obtain [Architect] [Commissioning Agent] [or] [Owner] written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION 237313.19

SECTION 238129 - VARIABLE REFRIGERANT FLOW HVAC SYSTEMS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes complete VRF HVAC system(s) including, but not limited to, delegated design and the following components to make a complete operating system(s) according to requirements indicated:

1. Indoor, concealed, ceiling-mounted units for ducting.
2. Indoor, exposed, wall-mounted units.
3. Indoor, hydronic heat recovery units.
4. Outdoor, air-source, heat-pump units.
5. Heat recovery control units.
6. System refrigerant and oil.
7. System condensate drain piping.
8. Miscellaneous support materials.
9. Piping and tubing insulation.
10. System control cable and raceways.

1.3 DEFINITIONS

A. Air-Conditioning System Operation: System capable of operation with all zones in cooling only.

B. Heat-Pump System Operation: System capable of operation with all zones in either heating or cooling, but not with simultaneous heating and cooling zones that transfer heat between zones.

C. Heat Recovery System Operation: System capable of operation with simultaneous heating and cooling zones that transfer heat between zones.

D. HRCU: Heat Recovery Control Unit. HRCUs are used in heat recovery VRF HVAC systems to manage and control refrigerant between indoor units to provide simultaneous heating and cooling zones. "Heat Recovery Control Unit" is the term used by ASHRAE for what different manufacturers term as branch circuit controller, branch selector box, changeover box, flow selector unit, mode change unit, and other such terms.

E. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

F. Plenum: A space forming part of the air distribution system to which one or more air ducts are connected. An air duct is a passageway, other than a plenum, for transporting air to or from heating, ventilating, or air-conditioning equipment.

G. Three-Pipe System Design: One high pressure refrigerant vapor line, one low pressure refrigerant vapor line, and one refrigerant liquid line connect a single outdoor unit or multiple manifold outdoor units in a single system to associated system HRCUs. One liquid line and refrigerant vapor line connect HRCUs to associated indoor units.

H. Two-Pipe System Design: One refrigerant vapor line and one refrigerant liquid line connect a single outdoor unit or multiple manifold outdoor units in a single system to associated system HRCUs. One refrigerant liquid line and refrigerant vapor line connect HRCUs to associated indoor units. HRCUs used in two pipe systems act as an intermediate heat exchanger and include diverting valves and gas/liquid separators to move high and low pressure refrigerant between indoor units.

I. VRF: Variable refrigerant flow.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for indoor and outdoor units and for HRCUs.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
3. Include operating performance at design conditions and at extreme maximum and minimum outdoor ambient conditions.
4. Include description of system controllers, dimensions, features, control interfaces and connections, power requirements, and connections.
5. Include system operating sequence of operation in narrative form for each unique indoor- and outdoor-unit and HRCU control.
6. Include description of control software features.
7. Include total refrigerant required and a comprehensive breakdown of refrigerant required by each system installed.
8. Include refrigerant type and data sheets showing compliance with requirements indicated.
9. For system design software.
10. Indicate location and type of service access.

B. Shop Drawings: For VRF HVAC systems.

1. Include plans, elevations, sections, and mounting details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
4. Include diagrams and details of refrigerant piping and tubing showing installation requirements for manufacturer-furnished divided flow fittings.
5. Include diagrams for power, signal, and control wiring.

1.5 QUALITY ASSURANCE

A. Mockups: Build mockups to set quality standards for materials and execution.

1. Build mockups to show a finished installation for each of the following applications:

a. Horizontal Fan Coil Unit. Full mockup shall include:

1) 5 ft of connected supply ductwork
2) Return Plenum
3) 5 feet of connected refrigerant piping
4) 5 feet of connected condensate drain
5) Outside air volume flow controller
6) Modulating outside air damper
7) Vibration isolation
8) All accessories required by manufacturer's install guidelines

2. Mockups shall be operational.
3. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
4. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver and store products in a clean and dry place.

B. Comply with manufacturer's written rigging and installation instructions for unloading and moving to final installed location.

C. Handle products carefully to prevent damage, breaking, denting, and scoring. Do not install damaged products.

D. Protect products from weather, dirt, dust, water, construction debris, and physical damage.

1. Retain factory-applied coverings on equipment to protect finishes during construction and remove just prior to operating unit.
2. Cover unit openings before installation to prevent dirt and dust from entering inside of units. If required to remover coverings during unit installation, reapply coverings over openings after unit installation and remove just prior to operating unit.

E. Replace installed products damaged during construction.

1.7 WARRANTY

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace equipment and components that fail(s) in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

a. Structural failures.
b. Faulty operation.
c. Deterioration of metals, metal finishes, and other materials beyond normal weathering and use.

2. Warranty Period:

a. For Compressor: Five year(s) from date of Substantial Completion.
b. For Parts, Including Controls: Five year(s) from date of Substantial Completion.
c. For Labor: Five year(s) from date of Substantial Completion.

PART 2 PRODUCTS

2.1 MANUFACTURERS

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

1. Mitsubishi

2. Samsung
3. Daikin

B. Source Limitations: Obtain products from single source from single manufacturer including, but not limited to, the following:

1. Indoor and outdoor units, including accessories.
2. Controls and software.
3. HRCUs.
4. Refrigerant isolation valves.
5. Specialty refrigerant pipe fittings.

2.2 SYSTEM DESCRIPTION

A. Direct-expansion (DX) VRF HVAC system(s) with variable capacity in response to varying cooling and heating loads. System shall consist of multiple indoor units, HRCUs, outdoor unit(s), piping, controls, and electrical power to make complete operating system(s) complying with requirements indicated.

1. Two-pipe or three-pipe system design.
2. System(s) operation, heat recovery as indicated on Drawings.
3. Each system with one refrigerant circuit shared by all indoor units connected to system.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. AHRI Compliance: System and equipment performance certified according to AHRI 1230 and products listed in AHRI directory.

D. ASHRAE Compliance:

1. ASHRAE 15: For safety code for mechanical refrigeration.
2. ASHRAE 62.1: For indoor air quality.
3. ASHRAE 135: For control network protocol with remote communication.
4. ASHRAE/IES 90.1 Compliance: For system and component energy efficiency.

E. UL Compliance: Comply with UL 1995.

2.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional specialist, as defined in Section 014000 "Quality Requirements," to design complete and operational VRF HVAC system(s) complying with requirements indicated.

1. Provide system refrigerant calculations.

    a. Refrigerant concentration limits shall be within allowable limits of ASHRAE 15 and governing codes.
    b. Indicate compliance with manufacturer's maximum vertical and horizontal travel distances. Prepare a comparison table for each system showing calculated distances compared to manufacturer's maximum allowed distances.

2. Include a mechanical ventilation system and gas detection system as required to comply with ASHRAE 15 and governing codes.
3. System Refrigerant Piping and Tubing:

    a. Arrangement: Arrange piping to interconnect indoor units, HRCUs, and outdoor unit(s) in compliance with manufacturer requirements and requirements indicated.
    b. Routing: Conceal piping above ceilings and behind walls to maximum extent possible.
    c. Sizing: Size piping system, using a software program acceptable to manufacturer, to provide performance requirements indicated. Consider requirements to accommodate future change requirements.

4. System Controls:

    a. Network arrangement.
    b. Network interface with other building systems.
    c. Product selection.
    d. Sizing.

B. Service Access:

1. Provide and document service access requirements.
2. Locate equipment, system isolation valves, and other system components that require service and inspection in easily accessible locations. Avoid locations that are difficult to access if possible.
3. Where serviceable components are installed behind walls and above inaccessible ceilings, provide finished assembly with access doors or panels to gain access. Properly size the openings to allow for service, removal, and replacement.
4. If less than full and unrestricted access is provided, locate components within an 18-inch reach of the finished assembly.

5. Where ladder access is required to service elevated components, provide an installation that provides for sufficient access within ladder manufacturer's written instructions for use.
6. Comply with OSHA regulations.

C. System Design and Installation Requirements:

1. Design and install systems indicated according to manufacturer's recommendations and written instructions.
2. Where manufacturer's requirements differ from requirements indicated, contact Architect for direction. The most stringent requirements should apply unless otherwise directed in writing by Architect.

D. System Adaptability to Future Changes: Arrange and size system refrigerant piping to accommodate future changes to system without having to resize and replace existing refrigerant piping.

1. Future changes to system(s) indicated on Drawings.
2. Each branch circuit shall accommodate addition of two indoor unit(s) with unit capacity equal to average indoor unit connected to the branch circuit.
3. Each branch circuit shall accommodate deletion of two indoor unit(s) with unit capacity equal to average indoor unit connected to the branch circuit.

E. Isolation of Equipment: Provide isolation valves to isolate each HRCU, indoor unit and outdoor unit for service, removal, and replacement without interrupting system operation.

F. System Capacity Ratio: The sum of connected capacity of all indoor units shall be within the following range of outdoor-unit rated capacity:

1. Range acceptable to manufacturer.

G. System Turndown: Stable operation down to 20 percent of outdoor-unit capacity.

H. Sound Performance: Sound levels generated by operating HVAC equipment shall be within requirements indicated.

1. Indoor: Within design guidelines of "2015 ASHRAE HANDBOOK- HVAC Applications."

I. Thermal Movements: Allow for controlled thermal movements from ambient, surface, and system temperature changes.

J. Capacities and Characteristics: As indicated on Drawings.

2.4 INDOOR, CONCEALED, CEILING-MOUNTED UNITS FOR DUCTING

A. Description: Factory-assembled and -tested complete unit with components, piping, wiring, and controls required for mating to ductwork, piping, power, and controls field connections.

B. Cabinet:

1. Material: Galvanized steel.
2. Insulation: Manufacturer's standard internal insulation, complying with ASHRAE 62.1, to provide thermal resistance and prevent condensation.

3. Duct Connections: Extended collar or flange, or designated exterior cabinet surface, designed for attaching field-installed ductwork.
4. Mounting: Manufacturer-designed provisions for field installation.
5. Internal Access: Removable panels or hinged doors of adequate size for field access to internal components for inspection, cleaning, service, and replacement.

C. DX Coil Assembly:

1. Coil Casing: Aluminum, galvanized, or stainless steel.
2. Coil Fins: Aluminum, mechanically bonded to tubes, with arrangement required by performance.
3. Coil Tubes: Copper, of diameter and thickness required by performance.
4. Expansion Valve: Electronic modulating type with linear or proportional characteristics.
5. Unit Internal Tubing: Copper tubing with brazed joints.
6. Unit Internal Tubing Insulation: Manufacturer's standard insulation, of thickness to prevent condensation.
7. Field Piping Connections: Manufacturer's standard.
8. Factory Charge: Dehydrated air or nitrogen.
9. Testing: Factory pressure tested and verified to be without leaks.

D. Drain Assembly:

1. Pan: Non-ferrous material, with bottom sloped to low point drain connection.
2. Condensate Removal: Unit-mounted pump or other integral lifting mechanism, capable of lifting drain water to an elevation above top of cabinet.
3. Field Piping Connection: Non-ferrous material with threaded NPT.

E. Fan and Motor Assembly:

1. Fan(s):

    a. Direct-drive arrangement.
    b. Single or multiple fans connected to a common motor shaft and driven by a single motor.
    c. Fabricated from non-ferrous components or ferrous components with corrosion-resistant finish.
    d. Wheels statically and dynamically balanced.

2. Motor: Brushless dc or electronically commutated with permanently lubricated bearings.
3. Motor Protection: Integral protection against thermal, overload, and voltage fluctuations.
4. Speed Settings and Control: Two (low, high), three (low, medium, high), or more than three speed settings or variable speed with a speed range of least 50 percent.
5. Vibration Control: Integral isolation to dampen vibration transmission.

F. Filter Assembly:

1. Access: Bottom, side, or rear to accommodate field installation without removing ductwork and to accommodate filter replacement without need for tools.
2. Efficiency: ASHRAE 52.2, MERV 13.
3. Media:

    a. Replaceable: Extended surface, panel, or cartridge with antimicrobial treatment fiber media.

G. Unit Controls:

1. Enclosure: Metal, suitable for indoor locations.
2. Factory-Installed Controller: Configurable digital control.
3. Factory-Installed Sensors:

   a. Unit inlet air temperature.
   b. Coil entering refrigerant temperature.
   c. Coil leaving refrigerant temperature.

4. Communication: Network communication with other indoor and outdoor units.
5. Cable and Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Field Connection: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.

H. Unit Electrical:

1. Enclosure: Metal, suitable for indoor locations.
2. Field Connection: Single point connection to power unit and integral controls.
3. Disconnecting Means: Factory-mounted circuit breaker or switch.
4. Control Transformer: Manufacturer's standard. Coordinate requirements with field power supply.
5. Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Raceways: Enclose line voltage wiring in metal raceways.

2.5 INDOOR, EXPOSED, WALL-MOUNTED UNITS

A. Description: Factory-assembled and -tested complete unit with components, piping, wiring, and controls required for mating to piping, power, and controls field connections.

B. Cabinet:

1. Material: Painted steel, or coated steel frame covered by a plastic cabinet, with an architectural acceptable finish suitable for tenant occupancy on exposed surfaces.
2. Insulation: Manufacturer's standard internal insulation, complying with ASHRAE 62.1, to provide thermal resistance and prevent condensation.
3. Mounting: Manufacturer-designed provisions for field installation.

C. DX Coil Assembly:

1. Coil Casing: Aluminum, galvanized, or stainless steel.
2. Coil Fins: Aluminum, mechanically bonded to tubes, with arrangement required by performance.
3. Coil Tubes: Copper, of diameter and thickness required by performance.
4. Expansion Valve: Electronic modulating type with linear or proportional characteristics.
5. Unit Internal Tubing: Copper tubing with brazed joints.
6. Unit Internal Tubing Insulation: Manufacturer's standard insulation, of thickness to prevent condensation.
7. Field Piping Connections: Manufacturer's standard.
8. Factory Charge: Dehydrated air or nitrogen.

9. Testing: Factory pressure tested and verified to be without leaks.

D. Drain Assembly:

1. Pan: Non-ferrous material, with bottom sloped to low point drain connection.
2. Condensate Removal: Gravity.

    a. If a floor drain is not available at unit, provide unit with field-installed condensate pump accessory.

3. Field Piping Connection: Non-ferrous material with threaded NPT.

E. Fan and Motor Assembly:

1. Fan(s):

    a. Direct-drive arrangement.
    b. Single or multiple fans connected to a common motor shaft and driven by a single motor.
    c. Fabricated from non-ferrous components or ferrous components with corrosion protection finish.
    d. Wheels statically and dynamically balanced.

2. Motor: Brushless dc or electronically commutated with permanently lubricated bearings.
3. Motor Protection: Integral protection against thermal, overload, and voltage fluctuations.
4. Speed Settings and Control: Two (low, high), three (low, medium, high), or more than three speed settings or variable speed with a speed range of least 50 percent.
5. Vibration Control: Integral isolation to dampen vibration transmission.

F. Unit Accessories:

1. Remote Room Temperature Sensor Kit: Wall-mounted, hardwired room temperature sensor kit for use in rooms that do not have room temperature measurement.
2. Condensate Pump: Integral reservoir and control with electrical power connection through unit power.

G. Unit Controls:

1. Enclosure: Manufacturer's standard, and suitable for indoor locations.
2. Factory-Installed Controller: Configurable digital control.
3. Communication: Network communication with other indoor units and outdoor unit(s).
4. Cable and Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
5. Field Connection: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.

H. Unit Electrical:

1. Enclosure: Manufacturer's standard, and suitable for indoor locations.
2. Field Connection: Single point connection to power entire unit and integral controls.
3. Disconnecting Means: Factory-mounted circuit breaker or switch, complying with NFPA 70.
4. Control Transformer: Manufacturer's standard. Coordinate requirements with field power supply.

5. Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Raceways: Enclose line voltage wiring in metal raceways to comply with NFPA 70.

2.6 AIR COOLED HEAT RECOVERY UNITS

A. Description: Factory-assembled and -tested complete unit with components, piping, wiring, and controls required for mating to piping, power, and controls field connections.

1. Specially designed for use in systems with simultaneous heating and cooling.
2. Systems shall consist of one unit, or multiple unit modules that are designed by variable refrigerant system manufacturer for field interconnection to make a single refrigeration circuit that connects multiple indoor units.
3. All units installed shall be from the same product development generation.

B. Compressor and Motor Assembly:

1. One or more positive-displacement, direct-drive and hermetically sealed scroll compressor(s) with inverter drive and turndown to 15 percent of rated capacity.
2. Protection: Integral protection against the following:

    a. High and low refrigerant pressure.
    b. Low oil level.
    c. High oil temperature.
    d. Thermal and overload.
    e. Voltage fluctuations.
    f. Phase failure and phase reversal.
    g. Short cycling.

3. Speed Control: Variable to automatically maintain refrigerant suction and condensing pressures while varying refrigerant flow to satisfy system cooling and heating loads.
4. Vibration Control: Integral isolation to dampen vibration transmission.
5. Oil management system to ensure safe and proper lubrication over entire operating range.
6. Crankcase heaters with integral control to maintain safe operating temperature.
7. Fusible plug.

C. Drain Pan: If required by manufacturer's design, provide unit with non-ferrous drain pan with bottom sloped to a low point drain connection.

D. Unit Controls:

1. Enclosure: Manufacturer's standard, and suitable for unprotected outdoor locations.
2. Factory-Installed Controller: Configurable digital control.
3. Factory-Installed Sensors:

    a. Entering-air temperature.
    b. Leaving-air temperature.
    c. Refrigerant suction temperature.
    d. Refrigerant discharge temperature.
    e. Refrigerant high pressure.
    f. Refrigerant low pressure.
    g. Oil level.

4. Features and Functions: Self-diagnostics, time delay, auto-restart, fuse protection, not less than 15 steps of capacity control, freeze protection sensor, proof of water flowautomatic control through a remote signal.
5. Communication: Network communication with indoor units and other outdoor unit(s).
6. Cable and Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
7. Field Connection: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.

E. Unit Electrical:

1. Enclosure: Metal, similar to enclosure, and suitable for unprotected outdoor locations.
2. Field Connection: Single point connection to power entire unit and integral controls.
3. Disconnecting Means: Factory-mounted circuit breaker or switch, complying with NFPA 70.
4. Control Transformer: Manufacturer's standard. Coordinate requirements with field power supply.
5. Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Raceways: Enclose line voltage wiring in metal raceways to comply with NFPA 70.

F. Unit Hardware: Zinc-plated steel, or stainless steel.

G. Unit Piping:

1. Unit Tubing: Copper tubing with brazed joints.
2. Unit Tubing Insulation: Manufacturer's standard insulation, of thickness to prevent condensation.
3. Field Piping Connections: Manufacturer's standard.
4. Factory Charge: Dehydrated air or nitrogen.
5. Testing: Factory pressure tested and verified to be without leaks.

2.7 HEAT RECOVERY CONTROL UNITS (HRCUs)

A. Description: Factory-assembled and -tested complete unit with components, piping, wiring, and controls required for mating to piping, power, and controls field connections.

1. Specially designed for use in systems with simultaneous heating and cooling.
2. Systems shall consist of one unit, or multiple unit that are designed by variable refrigerant system manufacturer for field interconnection to make a single refrigeration circuit that connects multiple indoor units.

B. Cabinet:

1. Galvanized-steel construction.
2. Insulation: Manufacturer's standard internal insulation to provide thermal resistance and prevent condensation.
3. Mounting: Manufacturer-designed provisions for field installation.
4. Internal Access: Removable panels or hinged doors of adequate size for field access to internal components for inspection, cleaning, service, and replacement.

C. Drain Pan: If required by manufacturer's design, provide unit with non-ferrous drain pan with bottom sloped to a low point drain connection.

D. Refrigeration Assemblies and Specialties:

1. Specially designed by manufacturer for type of VRF HVAC system being installed, either two or three pipe.
2. Each refrigerant branch circuit shall have refrigerant control valve(s) to control refrigerant flow.
3. Spares: Each heat recovery control unit shall include at least two branch circuit port(s) for future use.
4. Each system piping connection upstream of heat recovery unit shall be fitted with an isolation valve to allow for service to any heat recovery control unit in the system without interrupting operation of the system.
5. Each branch circuit connection shall be fitted with an isolation valve and capped service port to allow for service to any individual branch circuit without interrupting operation of the system.

    a. If not available as an integral part of the heat recovery control unit, isolation valves shall be field installed adjacent to the unit pipe connection.

E. Unit Controls:

1. Enclosure: Manufacturer's standard, and suitable for indoor locations.
2. Factory-Installed Controller: Configurable digital control.
3. Factory-Installed Sensors: .
4. Communication: Network communication with indoor units and outdoor unit(s).
5. Cable and Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Field Connection: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.

F. Unit Electrical:

1. Enclosure: Metal, similar to enclosure, and suitable for indoor locations.
2. Field Connection: Single point connection to power entire unit and integral controls.
3. Disconnecting Means: Factory-mounted circuit breaker or switch, complying with NFPA 70.
4. Control Transformer: Manufacturer's standard. Coordinate requirements with field power supply.
5. Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Raceways: Enclose line voltage wiring in [metal]raceways to comply with NFPA 70.

G. Unit Piping:

1. Unit Tubing: Copper tubing with brazed joints.
2. Unit Tubing Insulation: Manufacturer's standard insulation, of thickness to prevent condensation.
3. Field Piping Connections: Manufacturer's standard.
4. Factory Charge: Dehydrated air or nitrogen.
5. Testing: Factory pressure tested and verified to be without leaks.

2.8 SYSTEM REFRIGERANT AND OIL

A. Refrigerant:

1. As required by VRF HVAC system manufacturer for system to comply with performance requirements indicated.
2. ASHRAE 34, Class A1 refrigerant classification.
3. R-410a.

B. Oil:

1. As required by VRF HVAC system manufacturer and to comply with performance requirements indicated.

2.9 SYSTEM CONDENSATE DRAIN PIPING

A. If more than one material is listed, material selection is Contractor's option.

B. Copper Tubing:

2.10 SYSTEM HYDRONIC PIPING

A. Comply with requirements in Section 232113 "Hydronic Piping" for system piping requirements.

2.11 SYSTEM REFRIGERANT PIPING

A. Comply with requirements in Section 232300 "Refrigerant Piping" for system piping requirements.

B. Refrigerant Piping:

1. Copper Tube: [ASTM B 280, Type ACR] <Insert material>.
2. Wrought-Copper Fittings: ASME B16.22.
3. Brazing Filler Metals: AWS A5.8/A5.8M.

C. Refrigerant Isolation Ball Valves:

1. Description: Uni-body full port design, rated for maximum system temperature and pressure, and factory tested under pressure to ensure tight shutoff. Designed for valve operation without removing seal cap.
2. Seals: Compatible with system refrigerant and oil. Seal service life of at least 20 years.
3. Valve Connections: Flare or sweat depending on size.

2.12 METAL HANGERS AND SUPPORTS

A. Copper Tube Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
2. Hanger Rods: Continuous-thread rod, nuts, and washer made of [galvanized or copper-coated steel] [stainless steel] <Insert material>.

2.13 PIPING AND TUBING INSULATION

A. Comply with requirements in Section 230719 "HVAC Piping Insulation" for system piping insulation requirements.

2.14 SOURCE QUALITY CONTROL

A. Factory Tests: Test and inspect factory-assembled equipment.

B. Equipment will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports for historical record. Submit reports only if requested.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine products before installation. Reject products that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for piping and tubing to verify actual locations of connections before equipment installation.

D. Examine roughing-in for ductwork to verify actual locations of connections before equipment installation.

E. Examine roughing-in for wiring and conduit to verify actual locations of connections before equipment installation.

F. Examine walls, floors, roofs, and outdoor pads for suitable conditions where equipment will be installed.

G. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

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

3.2 EQUIPMENT INSTALLATION, GENERAL

A. Clearance:

1. Maintain manufacturer's recommended clearances for service and maintenance.
2. Maintain clearances required by governing code.

B. Loose Components: Install components, devices, and accessories furnished by manufacturer, with equipment, that are not factory mounted.

1. Loose components shall be installed by system Installer under supervision of manufacturer's service representative.

C. Equipment Restraint Installation: Install equipment with seismic-restraint device. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

3.3 INSTALLATION OF INDOOR UNITS

A. Install units to be level and plumb while providing a neat and finished appearance.

B. Unless otherwise required by VRF HVAC system manufacturer, support ceiling-mounted units from structure above using threaded rods; minimum rod size of 3/8 inch.

C. Adjust supports of exposed and recessed units to draw units tight to adjoining surfaces.

D. Protect finished surfaces of ceilings, floors, and walls that come in direct contact with units. Refinish or replaced damaged areas after units are installed.

E. In rooms with ceilings, conceal piping and tubing, controls, and electrical power serving units above ceilings.

F. In rooms without ceiling, arrange piping and tubing, controls, and electrical power serving units to provide a neat and finished appearance.

G. Provide lateral bracing if needed to limit movement of suspended units to not more than 0.25 inch.

H. For floor- and wall-mounted units that are exposed, conceal piping and tubing, controls, and electrical power serving units within walls.

I. Attachment: Install hardware for proper attachment to supported equipment.

J. Grouting: Place grout under equipment supports and make bearing surface smooth.

K. Install outdoor units on support structures indicated on Drawings.

3.4 GENERAL REQUIREMENTS FOR PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping and tubing systems. Install piping and tubing as indicated unless deviations to layout are approved on coordination drawings.

B. Install piping and tubing in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping and tubing at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping and tubing above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping and tubing to permit valve servicing.

F. Install piping and tubing at indicated slopes.

G. Install piping and tubing free of sags.

H. Install fittings for changes in direction and branch connections.

I. Install piping and tubing to allow application of insulation.

J. Install groups of pipes and tubing parallel to each other, spaced to permit applying insulation with service access between insulated piping and tubing.

K. Install sleeves for piping and tubing penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

L. Install escutcheons for piping and tubing penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.5 INSTALLATION OF SYSTEM CONDENSATE DRAIN PIPING

A. General Requirements for Drain Piping and Tubing:

1. Install a union in piping at each threaded unit connection.
2. Install an adjustable stainless-steel hose clamp with adjustable gear operator on unit hose connections. Tighten clamp to provide a leak-free installation.
3. If required for unit installation, provide a trap assembly in drain piping to prevent air circulated through unit from passing through drain piping. Comply with more stringent of the following:

    a. Details indicated on Drawings.
    b. Manufacturer's requirements.
    c. Governing codes.
    d. In the absence of requirements, comply with requirements of ASHRAE handbooks.

4. Extend drain piping from units with drain connections to drain receptors as indicated on Drawings. If not indicated on Drawings, terminate drain connection at nearest accessible location that is not exposed to view by occupants.
5. Provide each 90-degree change in direction with a Y- or T-fitting. Install a threaded plug connection in the dormant side of fitting or future use as a service cleanout.

B. Gravity Drains:

1. Slope piping from unit connection toward drain termination at a constant slope of not less than one percent.

C. Pumped Drains:

1. If unit condensate pump or lift mechanism is not included with an integral check valve, install a full-size check valve in each branch pipe near unit connection to prevent backflow into unit.

3.6 INSTALLATION OF REFRIGERANT PIPING

A. Install refrigerant piping according to ASHRAE 15 and governing codes.

B. Select system components with pressure rating equal to or greater than system operating pressure.

C. Install piping as short and direct as possible, with a minimum number of joints and fittings.

D. Arrange piping to allow inspection and service of equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Section 083113 "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.

E. Unless otherwise required by VRF HVAC system manufacturer, slope refrigerant piping and tubing as follows:

1. Install horizontal hot-gas discharge piping and tubing with a uniform slope downward away from compressor.
2. Install horizontal suction lines with a uniform slope downward to compressor.
3. Install traps to entrain oil in vertical runs.
4. Liquid lines may be installed level.

F. When brazing, remove or protect components that could be damaged by heat.

G. Before installation, clean piping, tubing, and fittings to cleanliness level required by VRF HVAC system manufacturer.

H. Joint Construction:

1. Ream ends of tubes and remove burrs.
2. Remove scale, slag, dirt, and debris from inside and outside of tube and fittings before assembly.
3. Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.

a. Use Type BCuP (copper-phosphorus) alloy for joining copper fittings with copper tubing.
b. Use Type BAg (cadmium-free silver) alloy for joining copper with bronze.

3.7 INSTALLATION OF PIPING AND TUBING INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated. Installation to maintain a continuous vapor barrier.

B. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are unavailable, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

3.8 ELECTRICAL INSTALLATION

A. Comply with requirements indicated on Drawings and in applicable Division 26 Sections.

B. To extent electrical power is required for system equipment, components, and controls, and is not indicated on Drawings and addressed in the Specifications, the design for such electrical power shall be delegated to VRF HVAC system provider.

1. Delegated design of electrical power to equipment, components and controls, and associated installation shall be included at no additional cost to Owner.

C. Connect field electrical power source to each separate electrical device requiring field electrical power. Coordinate termination point and connection type with Installer.

D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for wiring connections.

E. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding connections.

F. Install nameplate or acrylic label with self-adhesive back for each electrical connection indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated phenolic layers of black with engraved white letters. Letters at least 1/2 inch high.
2. Locate nameplate or label where easily visible.

G. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for raceway selection and installation requirements for boxes, conduits, and wireways as supplemented or revised in this Section.

1. Outlet boxes shall be no smaller than 2 inches wide, 3 inches high, and 2-1/2 inches deep.
2. Outlet boxes for cables shall be no smaller than 4 inches square by [1-1/2 inches] [2-1/8 inches] deep with extension ring sized to bring edge of ring to within 1/8 inch of the finished wall surface.
3. Flexible metal conduit shall not be used.

H. Comply with TIA-569-D for pull-box sizing and length of conduit and number of bends between pull points.

I. Install manufactured conduit sweeps and long-radius elbows if possible.

J. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.

3.9 FIRESTOPPING

A. Comply with requirements in Section 078413 "Penetration Firestopping."

B. Comply with TIA-569-D, Annex A, "Firestopping."

C. Comply with BICSI TDMM, "Firestopping" Chapter.

3.10 GROUNDING INSTALLATION

A. For data communication wiring, comply with TIA-607-B and with BICSI TDMM, "Bonding and Grounding (Earthing)" Chapter.

B. For low-voltage control cabling, comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.11 IDENTIFICATION

A. Identify system equipment, piping, tubing, and valves. Comply with requirements for identification specified in Section 230553 "Identification for HVAC Piping and Equipment."

B. Identify system electrical and controls components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

1. Identify each control cable on each end and at each terminal with a number-coded identification tag. Each cable shall have a unique tag.

3.12 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage VRF HVAC system manufacturer's service representative to advise and assist installers; witness testing; and observe and inspect components, assemblies, and equipment installations, including controls and connections.

1. Field service shall be performed by a factory-trained and -authorized service representative of VRF HVAC system manufacturer whose primary job responsibilities are to provide direct technical support of its products.

a. Additional factory-authorized representatives may assist with completion of certain activities only if supervised by manufacturer's employee. A factory-authorized representative shall not provide assistance without manufacturer's employee supervision.

2. Manufacturer shall provide on-site visits during the course of construction at installation milestones indicated. System Installer shall coordinate each visit in advance to give manufacturer sufficient notice to plan the visit.

   a. First Visit: Kick-off meeting.
   b. Second Visit: At approximately 50 percent completion of system(s).
   c. Third Visit: Final inspection before system startup.

3. Kick-off Meeting:

   a. Meeting shall include system Installer and other related trades with sole purpose of reviewing VRF HVAC system installation requirements and close coordination required to make a successful installation.
   b. Meeting shall be held at Project site and scheduled at a mutually agreed to time that occurs before the start of any part of system installation.
   c. Meeting shall cover the following as a minimum requirement:

      1) Review of latest issue of Contract Documents, Drawings, and Specifications, relevant to VRF HVAC systems.
      2) Manufacturer's installation requirements specific to systems being installed.
      3) Review of all relevant VRF HVAC system submittals, including delegated-design submittals.
      4) Required field activities related installation of VRF HVAC system.
      5) Project team communication protocol, contact information, and exchange of responsibilities for each party involved, including manufacturer, supplier, system Installer, and other related trades.

4. Site Visits: Activities for each site visit shall include the following:

   a. Meet with VRF HVAC system Installer to discuss field activities, issues, and suggested methods to result in a successful installation.
   b. Offer technical support to Installer and related trades as related to VRF system(s) being installed.
   c. Review progress of VRF HVAC system(s) installation for strict compliance with manufacturer's requirements.
   d. Advise and if necessary assist Installer with updating related refrigerant calculations and system documentation.
   e. Issue a report for each visit, documenting the visit.

      1) Report to include name and contact information of individual making the visit.
      2) Date(s) and time frames while on-site.
      3) Names and contact information of people meeting with while on-site.
      4) Clearly identify and list each separate issue that requires resolution. For each issue, provide a unique identification number, relevant importance, specific location or equipment identification, description of issue, recommended corrective action, and follow-up requirements needed. Include a digital photo for clarification if deemed to be beneficial.

5. Final Inspection before Startup:

   a. Before inspection, Installer to provide written request to manufacturer stating the system is fully installed according manufacturer's requirements and ready for final inspection.
   b. All system equipment and operating components shall be inspected. If components are inaccessible for inspection, they shall be made accessible before the final inspection can be completed.
   c. Manufacturer shall provide a comprehensive inspection of all equipment and each operating component that comprise the complete system(s). Inspection shall follow a detailed checklist specific to each equipment and operating component.
   d. Inspection reports for indoor units shall include, but not be limited to, the following:

      1) Unit designation on Drawings.
      2) Manufacturer model number.
      3) Serial number.
      4) Network address, if applicable.
      5) Each equipment setting.
      6) Mounting, supports, and restraints properly installed.
      7) Proper service clearance provided.
      8) Wiring and power connections correct.
      9) Line-voltage reading(s) within acceptable range.
      10) Wiring and controls connections correct.
      11) Low-voltage reading(s) within an acceptable range.
      12) Controller type and model controlling unit.
      13) Controller location.
      14) Temperature settings and readings within an acceptable range.
      15) Humidity settings and readings within an acceptable range.
      16) Condensate removal acceptable.
      17) Fan settings and readings within an acceptable range.
      18) Unit airflow direction within an acceptable range.
      19) If applicable, fan external static pressure setting.
      20) Filter type and condition acceptable.
      21) Noise level within an acceptable range.
      22) Refrigerant piping properly connected and insulated.
      23) Condensate drain piping properly connected and insulated.
      24) If applicable, ductwork properly connected.
      25) If applicable, external interlocks properly connected.
      26) Remarks.

   e. Inspection reports for outdoor units shall include, but not be limited to, the following:

      1) Unit designation on Drawings.
      2) Manufacturer model number.
      3) Serial number.
      4) Network address, if applicable.
      5) Each equipment setting.
      6) Mounting, supports, and restraints properly installed.
      7) Proper service clearance provided.
      8) Wiring and power connections correct.
      9) Line-voltage reading(s) within acceptable range.
      10) Wiring and controls connections correct.

11) Low-voltage reading(s) within an acceptable range.
12) Condensate removal acceptable.
13) Noise level within an acceptable range.
14) Refrigerant piping properly connected and insulated.
15) Condensate drain piping properly connected and insulated.
16) Remarks.

f. Inspection reports for indoor, dedicated outdoor air ventilation units shall include, but not be limited to, the following:

1) Unit designation on Drawings.
2) Manufacturer model number.
3) Serial number.
4) Network address, if applicable.
5) Each equipment setting.
6) Mounting, supports, and restraints properly installed.
7) Proper service clearance provided.
8) Wiring and power connections correct.
9) Line-voltage reading(s) within acceptable range.
10) Wiring and controls connections correct.
11) Low-voltage reading(s) within an acceptable range.
12) Controller type and model controlling unit.
13) Controller location.
14) Temperature settings and readings within an acceptable range.
15) Humidity settings and readings within an acceptable range.
16) Condensate removal acceptable.
17) Fan settings and readings within an acceptable range.
18) Fan external static pressure setting.
19) Filter type and condition acceptable.
20) Noise level within an acceptable range.
21) Refrigerant piping properly connected and insulated.
22) Condensate drain piping properly connected and insulated.
23) Automatic dampers properly installed and operating.
24) Ductwork properly connected.
25) If applicable, external interlocks properly connected.
26) Remarks.

g. Inspection reports for energy recovery ventilators shall include, but not be limited to, the following:

1) Unit designation on Drawings.
2) Manufacturer model number.
3) Serial number.
4) Network address, if applicable.
5) Each equipment setting.
6) Mounting, supports, and restraints properly installed.
7) Proper service clearance provided.
8) Wiring and power connections correct.
9) Line-voltage reading(s) within acceptable range.
10) Wiring and controls connections correct.
11) Low-voltage reading(s) within an acceptable range.
12) Controller type and model controlling unit.
13) Controller location.
14) Temperature settings and readings within an acceptable range.
15) Humidity readings.

16) Condensate removal acceptable.
17) Fan settings and readings within an acceptable range.
18) Fan external static pressure setting.
19) Filter type and condition acceptable.
20) Noise level within an acceptable range.
21) Automatic dampers properly installed and operating.
22) Ductwork properly connected.
23) If applicable, external interlocks properly connected.
24) Remarks.

h. Inspection reports for hydronic units shall include, but not be limited to, the following:

1) Unit designation on Drawings.
2) Manufacturer model number.
3) Serial number.
4) Network address, if applicable.
5) Each equipment setting.
6) Mounting, supports, and restraints properly installed.
7) Proper service clearance provided.
8) Wiring and power connections correct.
9) Line-voltage reading(s) within acceptable range.
10) Wiring and controls connections correct.
11) Low-voltage reading(s) within an acceptable range.
12) Controller type and model controlling unit.
13) Controller location.
14) Temperature settings and readings within an acceptable range.
15) Condensate removal acceptable.
16) Noise level within an acceptable range.
17) Refrigerant piping properly connected and insulated.
18) Hydronic piping properly connected and insulated.
19) Proof of water flow checked for proper operation.
20) Condensate drain piping properly connected and insulated.
21) If applicable, external interlocks properly connected.
22) Remarks.

i. Installer shall provide manufacturer with the requested documentation and technical support during inspection.
j. Installer shall correct observed deficiencies found by the inspection.
k. Upon completing the on-site inspection, manufacturer shall provide a written report with complete documentation describing each inspection step, the result, and any corrective action required.
l. If corrective action is required by Installer that cannot be completed during the same visit, provide additional visits, as required, until deficiencies are resolved and systems are deemed ready for startup.
m. Final report shall indicate the system(s) inspected are installed according to manufacturer's requirements and are ready for startup.

B. Perform the following tests and inspections with the assistance of manufacturer's service representative:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Refrigerant Tubing Positive Pressure Testing:

1. Comply with more stringent of VRF HVAC system manufacturer's requirements and requirements indicated.
2. After completion of tubing installation, pressurize tubing systems to a test pressure of not less than 1.5 times VRF HVAC system operating pressure, but not less than 600 psig, using dry nitrogen.
3. Successful testing shall maintain a test pressure for a continuous and uninterrupted period of 24 hours. Allowance for pressure changes attributed to changes in ambient temperature are acceptable.
4. Prepare test report to record the following information for each test:

    a. Name of person starting test, company name, phone number, and e-mail address.
    b. Name of manufacturer's service representative witnessing test, company name, phone number, and e-mail address.
    c. Detailed description of extent of tubing tested.
    d. Date and time at start of test.
    e. Test pressure at start of test.
    f. Outdoor temperature at start of test.
    g. Name of person ending test, company name, phone number, and e-mail address.
    h. Date and time at end of test.
    i. Test pressure at end of test.
    j. Outdoor temperature at end of test.
    k. Remarks:

5. Submit test reports for Project record.

D. Refrigerant Tubing Evacuation Testing:

1. Comply with more stringent of VRF HVAC system manufacturer's requirements and requirements indicated.
2. After completion of tubing positive-pressure testing, evacuate tubing systems to a pressure of [500] <Insert value> microns.
3. Successful testing shall maintain a test pressure for a continuous and uninterrupted period of [one] <Insert number> hour(s) with no change.
4. Prepare test report to record the following information for each test:

    a. Name of person starting test, company name, phone number, and e-mail address.
    b. Name of manufacturer's service representative witnessing test, company name, phone number, and e-mail address.
    c. Detailed description of extent of tubing tested.
    d. Date and time at start of test.
    e. Test pressure at start of test.
    f. Outdoor temperature at start of test.
    g. Name of person ending test, company name, phone number, and e-mail address.
    h. Date and time at end of test.
    i. Test pressure at end of test.

j. Outdoor temperature at end of test.
k. Remarks:

5. Submit test reports for Project record.
6. Upon successful completion of evacuation testing, system shall be charged with refrigerant.

E. System Refrigerant Charge:

1. Using information collected from the refrigerant tubing evacuation testing, system Installer shall consult variable refrigerant system manufacturer to determine the correct system refrigerant charge.
2. Installer shall charge system following VRF HVAC system manufacturer's written instructions.
3. System refrigerant charging shall be witnessed by system manufacturer's representative.
4. Total refrigerant charge shall be recorded and permanently displayed at the system's outdoor unit.

F. Products will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports.

3.13 STARTUP SERVICE

A. Engage a VRF HVAC system manufacturer's service representative to perform system(s) startup service.

1. Service representative shall be a factory-trained and -authorized service representative of VRF HVAC system manufacturer.
2. Complete startup service of each separate system.
3. Complete system startup service according to manufacturer's written instructions.

B. Startup checks shall include, but not be limited to, the following:

1. Check control communications of equipment and each operating component in system(s).
2. Check each indoor unit's response to demand for cooling and heating.
3. Check each indoor unit's response to changes in airflow settings.
4. Check each indoor unit, HRCU, and outdoor unit for proper condensate removal.
5. Check sound levels of each indoor and outdoor unit.

C. Installer shall accompany manufacturer's service representative during startup service and provide manufacturer's service representative with requested documentation and technical support during startup service.

1. Installer shall correct deficiencies found during startup service for reverification.

D. System Operation Report:

1. After completion of startup service, manufacturer shall issue a report for each separate system.
2. Report shall include complete documentation describing each startup check, the result, and any corrective action required.

3. Manufacturer shall electronically record not less than two hours of continuous operation of each system and submit with report for historical reference.

    a. All available system operating parameters shall be included in the information submitted.

E. Witness:

1. Invite Commissioning Agent to witness startup service procedures.
2. Provide written notice not less than 20 business days before start of startup service.

3.14 ADJUSTING

A. Adjust equipment and components to function smoothly, and lubricate as recommended by manufacturer.

B. Adjust initial temperature and humidity set points. Adjust initial airflow settings and discharge airflow patterns.

C. Set field-adjustable switches and circuit-breaker trip ranges according to VRF HVAC system manufacturer's written instructions, and as indicated.

D. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.15 PROTECTION

A. Protect products from moisture and water damage. Remove and replace products that are wet, moisture damaged, or mold damaged.

B. Protect equipment from physical damage. Replace equipment with physical damage that cannot be repaired to new condition. Observable surface imperfections shall be grounds for removal and replacement.

C. Protect equipment from electrical damage. Replace equipment suffering electrical damage.

D. Cover and seal openings of equipment to keep inside of equipment clean. Do not remove covers until finish work is complete.

3.16 DEMONSTRATION

A. Contractor shall engage a VRF HVAC system manufacturer's factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain entire system.

B. Instructor:

1. Instructor shall be factory trained and certified by VRF HVAC system manufacturer with current training on the system(s), equipment, and controls that are installed.

C. Schedule and Duration:

1. Schedule training with Owner at least 20 business days before first training session.
2. Training shall occur before Owner occupancy.
3. Training shall be held at mutually agreed date and time during normal business hours.
4. Perform not less than eight total hours of training.

D. Location: Owner shall provide a suitable on-site location to host classroom training.

E. Training Attendees: Assume three people.

F. Training Attendance: For record purposes, document training attendees at the start of each new training session. Record attendee's name, signature, phone number, and e-mail address.

G. Training Format: Individual training modules shall include classroom training followed by hands-on field demonstration and training.

H. Training Materials: Provide training materials in electronic format to each attendee.

1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
2. Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.

I. Acceptance: Obtain Owner written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION 238129

SECTION 238216.14 - ELECTRIC-RESISTANCE AIR COILS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Electric-resistance air coils.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
2. Include rated capacities, operating characteristics, and pressure drops for each air coil.

B. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Coil Assembly: Comply with UL 1995.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

C. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

D. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5, "Systems and Equipment," and Section 7, "Construction and Startup."

E. Equally balance heater electrical load for each step across all electrical phases.

F. Part-Load Operation: Provide arrangement with operation staged for uninterrupted operation over the full range of airflow down to the minimum airflow indicated.

2.2 ELECTRIC-RESISTANCE AIR COILS

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

1. Brasch Manufacturing Co., Inc.
2. Chromalox, Inc.
3. INDEECO.

B. Source Limitations: Obtain electric-resistance air coils from single source from single manufacturer.

C. Heating Elements:

1. Open Elements:

a. Open-coil resistance wire of 80 percent nickel and 20 percent chromium; supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in a frame.
b. Safety Screens: Install safety screens to protect operators from accidentally coming into direct connect with elements.

D. Frame: Galvanized steel; minimum 0.079 inch thick for flanged mounting. Include intermediate element support brackets equally spaced at a maximum of 36 inches o.c. across electric-resistance air coil.

E. Terminal Box/Control Panel: [Unit mounted] [Remote mounted] [Unit or remote mounting arrangement indicated on Drawings]; with disconnection means and overcurrent protection.

1. Enclosure: NEMA 250, Type 12 enclosure complying with UL 50.
2. Full-face-hinged door with lock and key latching device(s).
3. Factory insulate terminal box to prevent condensation from occurring within box.
4. Install a laminated elementary wiring diagram on inside face of heater control panel door or in another protected location than visible be service personnel. Wiring diagram to match installation.

F. Controls:

1. Safety Controls: Each heater is to be provided with the following factory-mounted safety controls:

a. Disk-type thermal cutout switch with automatic reset.
b. Airflow Proving Switch: Pressure differential type; with pressure range selected to ensure reliable operation throughout full range of air-handling unit airflow down to minimum airflow indicated.

2. SCR Control: Silicone-controlled rectifier (SCR) for 100 percent stepless capacity control.
3. Remote Monitoring and Control: Include control devices necessary to interface with remote-control signals, including the following:

a. Heater on/off control.
b. Monitoring heater on/off status.
c. High-temperature alarm.
d. Low-airflow alarm.
e. Heater capacity control.

G. Electrical:

1. Single-Point Field Power Connection: Install and wire the heater to accommodate a single field electrical connection for electrical power.
2. Disconnecting Means: Provide each heater with a main electrical power connection, door mounted and interlocking, and disconnecting means to prevent access into panel, unless switched to the off position.

   a. [Fused disconnect switch] [Nonfused disconnect switch] [Circuit breaker] with lockable handle.

3. Factory install and wire branch circuit fusing or circuit breakers in accordance with NFPA 70.
4. Pilot Lights: Include labeled pilot lights on face of control panel for the following:

   a. Power on.

5. Terminations: Wire terminations and field interface terminations to labeled terminal strips.
6. Control Transformer: Size control circuit transformer for load.
7. Labeling: Label each electrical device with a laminated phenolic tag.

H. Nameplate: Include the following data:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.
5. Coil identification (indicated on Drawings).

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.

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

3.2 INSTALLATION

A. Install coils level and plumb.

B. Install coils in metal ducts and casings constructed in accordance with SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."

C. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least [1/2 inch] <Insert dimension> high.

3.4 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

3.5 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections with the assistance of a factory-authorized service representative.

D. Tests and Inspections:

1. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

E. Prepare test and inspection reports.

END OF SECTION 238216.14

SECTION 238239.13 - CABINET UNIT HEATERS

PART 1 GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes cabinet unit heaters with centrifugal fans and electric-resistance heating coils.

1.3 DEFINITIONS

A. CWP: Cold working pressure.

B. DDC: Direct digital control.

C. PTFE: Polytetrafluoroethylene plastic.

D. TFE: Tetrafluoroethylene plastic.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include location and size of each field connection.
4. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
5. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Method of attaching hangers to building structure.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For cabinet unit heaters to include in emergency, operation, and maintenance manuals.

PART 2 PRODUCTS

2.1 DESCRIPTION

A. Factory-assembled and -tested unit complying with AHRI 440.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with UL 2021.

2.2 PERFORMANCE REQUIREMENTS

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

C. Seismic Performance: Cabinet unit heaters shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7] <Insert requirement>.

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

2.3 CABINETS

A. Material: Steel with [factory prime coating, ready for field painting] [baked-enamel finish with manufacturer's standard paint, in color selected by Architect] [baked-enamel finish with manufacturer's custom paint, in color selected by Architect].

1. Vertical Unit, Exposed Front Panels: Minimum 0.0677-inch- thick galvanized sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners.

2.4 FILTERS

A. Material: Washable Foam, MERV 3.

2.5 COILS

A. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, mounted in ceramic inserts in galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

2.6 CONTROLS

A. Fan and Motor Board: Removable.

1. Fan: Forward curved, [high static,]double width, centrifugal, directly connected to motor; thermoplastic or painted-steel wheels and aluminum, painted-steel, or galvanized-steel fan scrolls.
2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
3. Wiring Terminations: Connect motor to chassis wiring with plug connection.

B. Control devices and operational sequences are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC."

C. Basic Unit Controls:

1. Control voltage transformer.
2. Wall -mounted thermostat with the following features:
3. Wall -mounted temperature sensor.
4. Data entry and access port.

a. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

D. Interface with DDC System for HVAC Requirements:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at central workstation.
3. Interface shall be BAC-net compatible for central DDC system for HVAC workstation and include the following functions:

E. Electrical Connection: Factory-wired motors and controls for a single field connection.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas to receive cabinet unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for [piping and]electrical connections to verify actual locations before unit-heater installation.

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

3.2 INSTALLATION

A. Install wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 079200 "Joint Sealants."

B. Install cabinet unit heaters to comply with NFPA 90A.

C. Suspend cabinet unit heaters from structure with elastomeric hangers[and seismic restraints]. Vibration isolators[and seismic restraints] are specified in [Section 230548 "Vibration and Seismic Controls for HVAC."] [Section 230548.13 "Vibration Controls for HVAC."]

D. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

E. Install new filters in each fan-coil unit within two weeks of Substantial Completion.

3.3 CONNECTIONS

A. Comply with safety requirements in UL 1995.

B. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of cabinet unit heater. Hydronic specialties are specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

C. Unless otherwise indicated, install union and gate or ball valve on steam-supply connection and union, strainer, steam trap, and gate or ball valve on condensate-return connection of cabinet unit heater. Steam specialties are specified in Section 232216 "Steam and Condensate Heating Piping Specialties."

D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Perform the following tests and inspections[with the assistance of a factory-authorized service representative]:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

B. Units will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.5 ADJUSTING

A. Adjust initial temperature set points.

END OF SECTION 238239.13