SECTION 23 0553 - HVAC IDENTIFICATION

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Identification of products installed under Division 23.

1.02 SUBMITTALS

A. Submit shop drawings under provisions of Section 23 0500. Include list of items identified, wording, letter sizes, and color coding.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

- A. 3M
- B. Kolbi Industries
- C. Seton
- D. W.H. Brady

2.02 MATERIALS

A. General:

1. Plastic Nameplates: Laminated three-layer phenolic with engraved black, 1/4" minimum letters on light contrasting background.

OD of Pipe or Insulation	Marker Length	Size of Letters
Up to and including 1-1/4"	8"	1/2''
1-1/2" to 2"	8"	3/4"
2-1/2" to 6"	12"	1-1/4"
8" to 10"	24"	2-1/2"
Over 10"	32"	3-1/2"
Plastic tags may be used for out	side diameters u	Inder 3/4"

PART 3 - EXECUTION

3.01 INSTALLATION

- A. Install all products per manufacturer's recommendations.
- B. Degrease and clean surfaces to receive adhesive for identification materials.

C. Equipment:

- 1. All equipment not easily identifiable such as controls, relays, gauges, etc.; and all equipment in an area remote from its function such as air handling units, exhaust fans, filters, reheat coils, dampers, etc.; shall have nameplates or plastic tags listing name, function, and drawing symbol. Do not label exposed equipment in public areas.
- 2. Fasten nameplates or plastic tags with stainless steel self-tapping screws or permanently bonding cement.
- 3. Mechanical equipment that is not covered by the U.S. National Appliance Energy Conservation Act (NAECA) of 1987 shall carry a permanent label installed by the manufacturer stating that the equipment complies with the requirements of ASHRAE 90.1.
- D. Miscellaneous:
 - 1. Attach self-adhesive vinyl labels at all duct access doors used to reset fusible links or actuators on fire, fire/smoke, or smoke dampers. Lettering shall be a minimum of 1/2" high. Labels shall indicate damper type.
 - 2. Provide engraved plastic tags at all hydronic or steam system make-up water meters.

END OF SECTION

SECTION 23 0593 - TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Testing, adjusting, and balancing of air systems.
- B. Measurement of final operating condition of HVAC systems.

1.02 QUALITY ASSURANCE

- A. Agency shall be a company specializing in the adjusting and balancing of systems specified in this section with minimum three years' experience. Perform work under supervision of AABC Certified Test and Balance Engineer, NEBB Certified Testing, Balancing and Adjusting Supervisor, SMARTA Certified Air and Hydronic Balancer, or TABB Certified Supervisor.
- B. Work shall be performed in accordance with the requirements of the references listed at the start of this section.

1.03 REFERENCES

H.

- A. AABC National Standards for Total System Balance, Seventh Edition.
- B. ADC Test Code for Grilles, Registers, and Diffusers.
- C. AMCA Publication 203-90; Field Performance Measurement of Fan Systems.
- D. ASHRAE 2019 HVAC Applications Handbook; Chapter 39, Testing, Adjusting and Balancing.
- E. ASHRAE/ANSI Standard 111-2008; Practices for Measurement, Testing, Adjusting and Balancing of Building HVAC&R Systems.
 - NEBB Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems, Ninth Edition, 2019.
 - . SMACNA HVAC Systems; Testing, Adjusting and Balancing (latest edition).
 - TABB International Standards for Environmental Systems Balance.

1.04 SUBMITTALS

- A. Submit copies of report forms, balancing procedures, and the name and qualifications of testing and balancing agency for approval within 30 days after award of Contract.
- B. Electronic Copies:
 - Submit a certified copy of test reports to the Architect/Engineer for approval. Electronic copies shall be in PDF format only. Scanned copies, in PDF format, of paper originals are acceptable. Copies that are not legible will be returned to the Contractor for resubmittal. Do not set any permission restrictions on files; protected, locked, or secured documents will be rejected.
 - 2. Electronic file size shall be limited to a maximum of 10MB. Larger files shall be divided into files that are clearly labeled as "1 of 2", "2 of 2", etc.
 - 3. All text shall be searchable.
 - 4. Bookmarks shall be used. All bookmark titles shall be an active link to the index page and index tabs.

1.05 REPORT FORMS

- A. Submit reports on AABC, SMACNA or NEBB forms. Use custom forms approved by the Architect/Engineer when needed to supply specified information.
- B. Include in the final report a schematic drawing showing each system component, including balancing devices, for each system. Each drawing shall be included with the test reports required for that system. The schematic drawings shall identify all testing points and cross-reference these points to the report forms and procedures.
- C. Refer to PART 4 for required reports.

1.06 WARRANTY/GUARANTEE

- A. The TAB Contractor shall include an extended warranty of 90 days after owner receipt of a completed balancing report, during which time the Owner may request a recheck of terminals, or resetting of any outlet, coil, or device listed in the test report. This warranty shall provide a minimum of 24 manhours of onsite service time. If it is determined that the new test results are not within the design criteria, the balancer shall rebalance the system according to design criteria.
- B. Warranty/Guarantee must meet one of the following programs: TABB International Quality Assurance Program, AABC National Project Performance Guarantee, NEBB's Conformance Certification.

1.07 SCHEDULING

A. Coordinate schedule with other trades. Provide a minimum of seven days' notice to all trades and the Architect/Engineer prior to performing each test.

B. Project will be constructed in phases. Provide balancing report after each phase is complete.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.01 GENERAL REQUIREMENTS

- A. All procedures must conform to a published standard listed in the References article of this section. All equipment shall be adjusted in accordance with the manufacturer's recommendations. Any system not listed in this specification but installed under the contract documents shall be balanced using a procedure from a published standard listed in the References article.
- B. The Balancing Contractor shall incorporate all pertinent documented construction changes (e.g. submittals/shop drawings, change orders, RFIs, ASIs, etc.) and include in the balancing report.
- C. Recorded data shall represent actual measured or observed conditions.
- D. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing is complete, close probe holes and patch insulation with new materials as specified. Restore vapor barrier and finish as specified.
- E. Permanently mark setting of valves, dampers, and other adjustment devices allowing for settings to be restored. Set and lock memory stops.
- F. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, plugging test holes, and restoring thermostats to specified settings.
- G. Installations with systems consisting of multiple components shall be balanced with all system components operating.

3.02 EXAMINATION

- Before beginning work, verify that systems are complete and operable. Ensure the following:
 - General Equipment Requirements:
 - a. Equipment is safe to operate and in normal condition.
 - b. Equipment with moving parts is properly lubricated.

- c. Temperature control systems are complete and operable.
- d. Proper thermal overload protection is in place for electrical equipment.
- e. Direction of rotation of all fans and pumps is correct.
- f. Access doors are closed and end caps are in place.
- 2. Duct System Requirements:
 - a. All filters are clean and in place. If required, install temporary media.
 - b. Duct systems are clean and free of debris.
 - c. Fire/smoke and manual volume dampers are in place, functional and open.
 - d. Air outlets are installed and connected.
 - e. Duct system leakage has been minimized.
- B. Report any defects or deficiencies to Architect/Engineer.
- C. Promptly report items that are abnormal or prevent proper balancing.
- D. If, for design reasons, system cannot be properly balanced, report as soon as observed.
- E. Beginning of work means acceptance of existing conditions.

3.03 PREPARATION

- A. Provide instruments required for testing, adjusting, and balancing operations. Make instruments available to the Architect/Engineer for spot checks during testing.
- B. Instruments shall be calibrated within six months of testing performed for project, or more recently if recommended by the instrument manufacturer.

3.04 INSTALLATION TOLERANCES

- A. + 5% of scheduled values
 - 1. Adjust outdoor air intakes to within + 5% of scheduled values.
 - Adjust supply, return, and exhaust air-handling systems to +10% / -5% of scheduled values.

3.05 ADJUSTING

B.

A.

B.

- After adjustment, take measurements to verify balance has not been disrupted or that disruption has been rectified.
 - Once balancing of systems is complete, at least one damper or valve must be 100% open.

- C. After testing, adjusting and balancing are complete, operate each system and randomly check measurements to verify system is operating as reported in the report. Document any discrepancies.
- D. Contractor responsible for each motor shall also be responsible for replacement sheaves. Coordinate with contractor.
- E. Contractor responsible for pump shall trim impeller to final duty point as instructed by this contractor on all pumps not driven by a VFD. Coordinate with contractor.

3.06 SYSTEM PERFORMANCE REPORT

- A. After the conclusion of balancing operations, utilize the building DDC system or install portable data loggers to simultaneously record temperatures and humidity during summer and winter conditions for a seven-day period, continuous over a weekend, and including at least one period of operation at outside conditions within 5°F wet bulb temperature of maximum summer design condition and within 10°F dry bulb temperature of minimum winter design condition.
- B. Design Conditions:
 - 1. Summer: _106_ °F DB _70_ °F WB
 - 2. Winter: _.31_ °F DB
- C. Architect/Engineer will direct all test locations.
- D. Report of test results shall include original recording and three reproductions.

3.07 SUBMISSION OF REPORTS

A. Fill in test results on appropriate forms.

PART 4 - SYSTEMS TO BE TESTED, ADJUSTED AND BALANCED

4.01 Verification of existing systems.

- Perform a pre-balance of systems serving the area of construction prior to the start of any other work. Do not make adjustments to the systems. If the systems are not operating at maximum capacity, temporarily drive system to maximum and take readings for the system. Return the system to its original state when measurements are complete.
 - 1. Air Handling Unit:
 - a. General Requirements:

- 1) Existing Equipment Tag (if available).
- 2) Location.
 - a) Contractor shall generate existing rooftop units layout on roof and indicate test results respective to each unit on existing unit layout.
- 3) Manufacturer, model, arrangement, class, discharge.
- 4) Fan RPM.
- b. Flow Rate:
 - 1) Supply flow rate (cfm)
 - 2) Return flow rate (cfm)
 - 3) Outside flow rate (cfm)
 - 4) Exhaust flow rate (cfm)
- c. Pressure Drop and Pressure:
 - 1) Filter pressure drop.
 - 2) Total static pressure. (Indicate if across fan or external to unit).
 - 3) Inlet pressure.
 - 4) Discharge pressure.
- 2. Exhaust Fan
 - a. Location.
 - b. Manufacturer and model.
 - c. Flow rate (cfm).
 - d. Total static pressure. (Indicate measurement locations).
 - e. Inlet pressure.
 - f. Discharge pressure.
 - g. Fan RPM.
- B. Report findings to Architect/Engineer on standard forms.
- C. GENERAL REQUIREMENTS
 - Title Page:

D.

- 1. Project name.
- 2. Project location.
- 3. Project Architect.
- 4. Project Engineer (IMEG Corp.).
- 5. Project General Contractor.
- 6. TAB Company name, address, phone number.
- 7. TAB Supervisor's name and certification number.

- 8. TAB Supervisor's signature and date.
- 9. Report date.
- E. Report Index
- F. General Information:
 - 1. Test conditions.
 - 2. Nomenclature used throughout report.
 - 3. Notable system characteristics/discrepancies from design.
 - 4. Test standards followed.
 - 5. Any deficiencies noted.
 - 6. Quality assurance statement.
- G. Instrument List:
 - 1. Instrument.
 - 2. Manufacturer, model, and serial number.
 - 3. Range.
 - 4. Calibration date.

4.02 AIR SYSTEMS

- A. Air Moving Equipment:
 - 1. General Requirements:
 - a. Drawing symbol.
 - b. Location.
 - c. Manufacturer, model, arrangement, class, discharge.
 - d. Fan RPM.
 - e. Multiple RPM fan curve with operating point marked. (Obtain from equipment supplier).
 - 2. Flow Rate:
 - a. Supply flow rate (cfm): specified and actual.
 - b. Return flow rate (cfm): specified and actual.
 - c. Outside flow rate (cfm): specified and actual.
 - d. Exhaust flow rate (cfm): specified and actual.
 - 3. Pressure Drop and Pressure:
 - a. Filter pressure drop: specified and actual.
 - b. Total static pressure: specified and actual. (Indicate if across fan or external to unit).
 - c. Inlet pressure.

- d. Discharge pressure.
- B. Fan Data:
 - 1. Drawing symbol.
 - 2. Location.
 - 3. Manufacturer and model.
 - 4. Flow rate (cfm): specified and actual.
 - 5. Total static pressure: specified and actual. (Indicate measurement locations).
 - 6. Inlet pressure.
 - 7. Discharge pressure.
 - 8. Fan RPM.
- C. Electric Motors:
 - 1. Drawing symbol of equipment served.
 - 2. Manufacturer, Model, Frame.
 - 3. Nameplate: HP, phase, service factor, RPM, operating amps, efficiency.
 - 4. Measured: Amps in each phase.
- END OF SECTION

SECTION 23 0713 - DUCTWORK INSULATION

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Ductwork Insulation.
- B. Insulation Jackets.

1.02 QUALITY ASSURANCE

- A. Applicator: Company specializing in ductwork insulation application with five years minimum experience. When requested, installer shall submit manufacturer's certificate indicating qualifications.
- B. Materials:
 - 1. Listed and labeled for flame spread/smoke developed rating of no more than 25/50 when tested per ASTM E84 or UL 723 as required by code.
 - 2. Fungal Resistance: No growth when tested in accordance with ASTM G21 (antifungal test).
 - 3. Rated velocity on coated air side for air erosion in accordance with UL 181 at 5,000 fpm minimum.
- C. Adhesives: UL listed, meeting NFPA 90A/90B requirements.

1.03 REFERENCES

- A. ANSI/ASHRAE/IES Standard 90.1 (latest published edition) Energy Standard for Buildings Except Low-Rise Residential Buildings.
- B. ANSI/ASTM C553 Mineral Fiber Blanket and Felt Insulation.
- C. ANSI/ASTM C612 Mineral Fiber Block and Board Thermal Insulation.
- D. ASTM E84 Surface Burning Characteristics of Building Materials.
- E. ASTM E136 Standard Test Method for the Behavior of Materials in a Vertical Tube Furnace at 750°C.
- F. ASTM E814 Fire Tests of Through Penetrations Firestops.
- G. ASTM E2336-04 Standard Test Methods for Fire Resistive Grease Duct Enclosure Systems.

- H. ASTM G21 Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.
- I. National Commercial & Industrial Insulation Standards 1999 Edition as published by Midwest Insulation Contractors Association and endorsed by National Insulation Contractors Association.
- J. NFPA 96 Standard for the Installation of Equipment for Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment.
- K. NFPA 255 Surface Burning Characteristics of Building Materials.
- L. UL XHEZ Through Penetration Firestop Systems.
- M. UL 181 Standard for Factory-Made Air Ducts and Air Connectors.
- N. UL 263 Full Scale External Fire Tests with Hose Stream.
- O. UL 723 Surface Burning Characteristics of Building Materials.
- P. UL 1479 Fire Tests of Through Penetrations Firestops.
- Q. California Title 24 Building Energy Efficiency Standards
- R. CMC California Mechanical Code

PART 2 - PRODUCTS

2.01 MATERIALS

- A. Type A: Flexible Fiberglass Outside Wrap; ANSI/ASTM C553; commercial grade; 0.28 / 0.26 (Out-Of-Package/Installed-Compressed 25%) maximum 'K' value at 75°°F; foil scrim Kraft facing, 1.0 lb./cu. ft. density. Submit both "Out of Package" and "Installed-Compressed 25%" K and R-values.
- B. Type C: Flexible Fiberglass Liner; ANSI/ASTM C1071; 0.28 maximum 'K' value at 75°°F; 1.5 lb/cu ft minimum density; coated air side for 5000 fpm air velocity.

	R-VALUE PER THICKNESS							
	THICKNESS	0.5 1	1.5	2	2.5	3	4	5
TYPE	K-FACTOR	R-VAL	UE					
Flexible Fiberglass								
Outside Wrap	0.28		5.4	7.1	8.9	10.7	14.3	17.9
Semi-Rigid Fiberglass	S							
Board Wrap	0.25		6.0	8.0	10.0	12.0	16.0	20.0

Flexible Fiberglass									
Liner	0.28	1.8	3.6	5.4	7.1	8.9	10.7	14.3	17.9
Rigid fiberglass liner	0.23		4.3	6.5	8.7	10.9	13.0	17.4	21.7
Double Wall									
Ductwork	0.27		3.7	5.6	7.4	9.3	11.1	14.8	18.5
Flexible High Temp									
Rigid Preformed									
Fiberglass Acoustical									
Liner	0.23		4.3	6.5	8.7	10.9	13.0	17.4	21.7

2.02 JACKETS

A. Vapor Barrier Jackets: Kraft reinforced foil scrim vapor barrier with self-sealing adhesive joints. Beach puncture resistance ratio of at least 25 units. Tensile strength: 35 psi minimum. Single, self-seal acrylic adhesive on longitudinal jacket laps and butt strips.

2.03 JACKET COVERINGS

A. Aluminum Jackets: ASTM B209; 0.016" thick; smooth or embossed stucco finish with Z edge seams and aluminum bands for outdoor use. Where colored jacket covers are called for, provide factory-applied hard film acrylic paint in color selected by Architect.

PART 3 - EXECUTION

3.01 INSTALLATION

- A. Install materials in accordance with manufacturer's instructions, codes, and industry standards.
- B. Install materials after ductwork has been tested.
- C. Clean surfaces for adhesives.
- D. Provide insulation with vapor barrier when air conveyed may be below ambient temperature.
- E. Exterior Duct Wrap Flexible, Type A:
 - 1. Apply with edges tightly butted.
 - 2. Cut slightly longer than perimeter of duct to insure full thickness at corners. Do not wrap excessively tight.
 - 3. Seal joints with adhesive backed tape.
 - 4. Apply so insulation conforms uniformly and firmly to duct.

- 5. Seal all penetrations of the vapor barrier by strap hangers or slip cable hangers with adhesive backed tape.
- Provide high-density insulation inserts on rectangular ducts at trapeze duct hangers to 6. prevent crushing of insulation. Provide high-density insulation inserts with clamp-on round ducts requiring two (2) rods or straps to prevent crushing of insulation. Maintain continuous vapor barrier through the hanger.
- 7. Tape all joints with Royal Tapes #RT 350 (216-439-7229). Venture Tape 1525CW, or Compac Type FSK. No substitutions will be accepted without written permission from the Architect/Engineer.
- 8. Press tape tightly to the duct covering with a squeegee for a tight continuous seal. Fish mouths and loose tape edges are not acceptable.
- 9. Staples may be used, but must be covered with tape.
- Vapor barrier must be continuous. 10.
- Mechanically fasten on 12" centers at bottom of ducts over 24" wide and on all sides of 11. vertical ducts.
- Interior Insulation Flexible Duct Liner, Type C: F.
 - 1. Observation of Duct Lining:
 - After installation of ductwork, Architect/Engineer may select random observation a. points in each system.
 - At each observation point, cut and remove an 18" x 18" section of 1) ductwork and liner for verification of installation.
 - Random observation points based on one opening per 75 lineal ft. of total 2) duct run.
 - b. When any of the observation points shows non-compliance, additional points will be designated by the Architect/Engineer, and observation repeated. If 20% of points observed do not comply, remove and replace all lined ducts and С.
 - repeat tests. Where replacement is not required, correct all non-compliances. d. At end of observation, repair all duct lining and observation holes by installing
 - standard, insulated, hinged access doors per Section 23 3300. e.
 - Paint or finish to match adjacent duct surfaces.
 - 2. Impale on spindle anchors welded or mechanically fastened to the duct. Adhesive or glue fastened anchors are not acceptable. Maximum anchor spacing per SMACNA Duct Construction Standards or manufacturer's recommendations, whichever is more restrictive. Locate pins less than 3" from corners and at intervals not over 6" around the perimeter at leading and trailing edges. Locate pins within 3" of transverse joints and at intervals not over 16" long the length of the duct. Pins must be long enough to prevent compressing the insulation.
 - 3. In addition to anchors, secure liner with UL listed adhesive covering over 90% of the duct surface.

- 4. Install per the latest edition of the SMACNA Manual.
- 5. Leading edges shall be covered as follows:
 - a. For duct velocities below 3000 fpm, coat leading edges with adhesive. Neatly butt liner without gaps at transverse joints. Cut liner flush with end of the duct section for tight joints with no exposed duct. If adhesive is shop installed, field apply additional adhesive to the end of each duct section for complete adhesion of the liner. Protect edges from dirt and debris.
 - b. For duct velocities above 3000 fpm, cover leading edges with metal nosing. Use nosing on upstream edges of each section of duct. If the duct can be installed in either direction, provide nosing on each end or clearly mark the duct to allow visual verification after installation. Verify duct velocities based on the scheduled air flow rates and determine where metal nosing is required.
 - c. Install metal nosing in the following locations (regardless of velocity):
 - 1) The first three fittings downstream of all fans.
 - At all duct liner interruptions. This includes fire dampers, access doors, branch connections, and all other locations where the edge of the liner is exposed.
 - 3) Trailing edges of transverse joints do not require metal nosings.
- 6. Overlap liner at longitudinal joints. Make longitudinal joints at corners of the duct unless the duct size does not allow this. Coat longitudinal joints with adhesive at velocities over 2500 fpm.
- 7. Seal all damaged duct liner with adhesive and glass cloth. Do not damage duct liner surface coatings.
- 8. Duct dimensions given are net inside dimensions. Increase sheet metal to allow for insulation thickness.
- G. Continue insulation with vapor barrier through penetrations unless code prohibits.
- H. Provide 2" wide, 24" high, 26 gauge, galvanized sheet metal corner protection angles for all externally insulated ductwork extending to a floor or curb.

3.02 SCHEDULE

- A. Refer to Section 23 3100 for scheduling of insulation.
- B. Unless noted otherwise, HVAC plenums and unit housings not pre-insulated at factory shall be insulated to geographical R-value requirements based on California Title 24, R-4.2, R-6 or R-8.

END OF SECTION

SECTION 23 3100 - DUCTWORK

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Galvanized Ductwork
- B. Ductwork Reinforcement
- C. Ductwork Sealants
- D. Rectangular Ductwork
- E. Round Ductwork

I.

- F. Ductwork Penetrations
- 1.02 **REFERENCES:** Conform to all applicable requirements of the following publications:
 - A. ADC Flexible Duct Performance and Installation Standards, 3rd Edition 1996.
 - B. ANSI/ASHRAE/IES Standard 90.1 (latest published edition) Energy Standard for Buildings Except Low-Rise Residential Buildings.
 - C. ASHRAE Handbook 2012 Systems and Equipment; Chapter 19 Duct Construction.
 - D. ASHRAE Handbook 2013 Fundamentals; Chapter 21 Duct Design.
 - E. ASHRAE 170 (latest published edition) Ventilation of Health Care Facilities.
 - F. ASTM A90 Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.
 - G. ASTM A167- Stainless & Heat-Resisting Chromium-Nickel Steel Plate, Sheet, & Strip.
 - H. ASTM A653 Steel Sheet, Zinc-Coated (Galvanized) or zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
 - ASTM A924 Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process.
 - J. ASTM B209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate.

- K. ASTM E90-02 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.
- L. ASTM E413-87 Classification for Rating Sound Insulation.
- M. AWS D9.1M/D9.1 Sheet Metal Welding Code.
- N. CDPH Standard Method V1.1-2010 Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers Version 1.1.
- O. IECC International Energy Conservation Code (latest published edition)
- P. NADCA ACR 2002 Assessment, Cleaning, and Restoration of HVAC Systems.
- Q. NADCA Standard 05 1997 Requirements for the Installation of Service Openings in HVAC Systems.
- R. NFPA 90A Installation of Air-Conditioning and Ventilating Systems.
- S. NFPA 90B Installation of Warm Air Heating and Air- Conditioning Systems.
- T. NFPA 96 Ventilation Control and Fire Protection of Commercial Cooking Equipment.
- U. SCAQMD Rule 1168 South Coast Air Quality Management District Rule 1168 Adhesive and Sealant Applications.
- V. SMACNA Air Duct Leakage Test Manual.
- W. SMACNA HVAC Duct Construction Standards.
- X. SMACNA Phenolic Duct Construction Standard 022.
- Y. SMACNA Round Industrial Duct Construction Standards 1999 Edition.
- Z. UL 181 Factory-Made Air Ducts and Air Connectors.
- AA. UL 181A Closure Systems for Use with Rigid Air Ducts and Air Connectors
- BB. UL 181B Closure Systems for Use with Flexible Air Ducts and Air Connectors.
- CC. UL 1978 Standard for Grease Ducts.
- DD. UL 2221 Standard for Tests of Fire Resistive Grease Duct Enclosure Assemblies.
- EE. CMC California Mechanical Code

FF. CBC California Building Code

1.03 SUBMITTALS

- A. Submit shop drawings per Section 23 0500.
- B. Duct Layout Drawings: Submit detailed duct layout drawings at 1/4" minimum scale complete with the following information:
 - 1. Actual duct routing, ductwork fittings, actual sheet metal dimensions including insulation liner and wrap, duct hanger and support types, ductwork accessories, etc. with lengths and weights noted.
 - 2. Differentiate ducts that are wrapped. Include insulation thickness, type of insulation, and acoustical lagging.
 - 3. Room names and numbers, ceiling types, and ceiling heights.
 - 4. Indicate location of all beams, bar joists, etc. along with bottom of steel elevations for each member.
 - 5. Verify clearances and interferences with other trades prior to preparing drawings. IMEG will provide electronic copies of ventilation drawings for contractor's use if the contractor signs and returns the "Electronic File Transfer" waiver. IMEG will not consider blatant reproductions of original file copies an acceptable alternative for this submittal. Refer also to Section 23 0500.
- C. Duct Leakage Test Summary Report: Upon completion of the pressure test described in Part 3, the Contractor shall submit an air duct leakage test summary report as outlined in the SMACNA HVAC Duct Leakage Test Manual.

1.04 DEFINITIONS

C.

- A. Duct Sizes shown on drawings are inside clear dimensions. Maintain clear dimensions inside any lining.
- B. Transitions are generally not shown in single-line ductwork. Where sizes change at a divided flow fitting, the larger size shall continue through the fitting.
 - Exterior Duct: Ductwork located outside the conditioned envelope including exposed ductwork above the roof, outside exterior walls, in attics above insulated ceilings, inside parking garages, and crawl spaces.
- D. Interior Duct: Ductwork located within the conditioned envelope including return air plenums and indirectly conditioned spaces.

1.05 COORDINATION DRAWINGS

A. Reference Coordination Drawings article in Section 23 0500 for required duct systems electronic CAD drawings to be provided to Coordinating Contractor for inclusion into composite coordination drawings.

- B. Duct drawings shall be at 1/4" minimum scale complete with the following information:
 - 1. Actual duct routing, ductwork fittings, actual sheet metal dimensions including insulation liner and wrap, duct hanger and support types, ductwork accessories, etc. with lengths and weights noted.
 - 2. Differentiate ducts that are lined or wrapped. Include insulation thickness, type of insulation, and acoustical lagging.
 - 3. Location and size of all duct access doors.
 - 4. Room names and numbers, ceiling types, and ceiling heights.
 - 5. Indicate location of all beams, bar joists, etc. along with bottom of steel elevations for each member.
 - 6. IMEG will provide electronic file copies of ventilation drawings for contractor's use if the contractor signs and returns an "Electronic File Transfer" waiver provided by IMEG. IMEG will not consider blatant reproductions of original file copies an acceptable alternative for coordination drawings. Architectural plans will need to be obtained from the Architect.

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS AND SUPPORTS

A. Rectangular Duct - Single Wall:

C.

- 1. General Requirements:
 - a. All ductwork gauges and reinforcements shall be as listed in SMACNA Duct Construction Standards Chapter 2. Where necessary to fit in confined spaces, furnish heaviest duct gauge and least space consuming reinforcement.
 - b. Transitions shall not exceed the angles in Figure 4-7.
- 2. Exceptions and modifications to the 2005 HVAC Duct Construction Standards are:
 - a. All ducts shall be cross-broken or beaded.
 - b. Snap lock seams are not permitted.
 - Turning vanes shall be used in all 90° mitered elbows, unless clearly noted otherwise on the drawings. Vanes shall be as follows:
 - 1) Type 1:

i.

- a) Description: Single wall type with 22-gauge (0.029") or heavier vanes, 3-1/4" blade spacing, and 4" to 4-1/2" radius. Vanes hemmed if recommended by runner manufacturer. Runners shall have extra-long locking tabs. C-value independently tested at below 0.26. EZ Rail II by Sheet Metal Connectors or equal.
- b) Usage: Limited to 3,000 fpm and vane lengths 36" and under.
- 2) Turning vanes shall operate quietly. Repair or replace vanes that rattle or flutter.
- 3) Runners must be installed at a 45^{°°} angle. Elbows with different size inlet and outlet must be radius type.
- 4) Omitting every other vane is prohibited.
- d. Where smooth radius rectangular elbows are shown, they shall be constructed per SMACNA Figure 4-2. Type RE1 shall be constructed with a centerline duct radius R/W of 1.0. Where shown on drawings, Type RE3 elbows with 3 vanes shall be used with centerline duct radius R/W of 0.6 (SMACNA r/W=0.1). RE1 or RE3 elbows may be used where mitered elbows are shown if space permits. Mitered elbows (with or without turning vanes) may not be substituted for radius elbows. Do not make branch takeoffs within 4 duct diameters on the side of the duct downstream from the inside radius of radius elbows.
- e. Rectangular branch and tee connections in ducts over 1" pressure class shall be 45° entry type per Figs. 4-5 and 4-6. Rectangular straight taps are not acceptable above 1" pressure class.
- f. Bellmouth fittings shown on return duct inlets shall expand at a 60-degree total angle horizontally and vertically (space permitting) and have length of at least 25% of the smallest duct dimension.
- g. Round taps off rectangular unlined ducts shall be flanged conical or bellmouth type (equal to Buckley Bellmouth or Sheet Metal Connectors E-Z Tap), or 45° rectangular with transition to round (equal to Sheet Metal Connectors Inc. High Efficiency Takeoff). Straight taps are acceptable if pressure class is 1" or less, round duct is 12" diameter or less, and the tap is not located between fans and TAB devices.
- h. Duct offsets shall be constructed as shown on drawings. Additional offsets required in the field shall be formed of mitered elbows without turning vanes for offsets up to 30°° maximum angle in accordance with SMACNA offset Type 2. Offsets of greater than 30°° angle shall be formed of radius elbows with centerline radius R/W=1.0 or greater. SMACNA Type 1 offsets are not permitted.
 - All lined duct shall utilize dovetail joints where round or conical taps occur. The dovetail joints shall extend past the liner before being folded over.

- j. Slide-on flanged transverse joint systems are acceptable provided they are a manufactured product that has been tested for conformance with Chapter 2 of the SMACNA HVAC Duct Construction Standards for sheet and joint deflection at the specified pressure class.
 - 1) Apply sealant to all inside corners. Holes at corners are not acceptable.
 - 2) Manufacturers:
 - a) Ductmate Industries 25/35/45
 - b) Nexus
 - c) Mez
 - d) WDCI
 - e) Other manufacturers must submit test data and fabrication standards and receive Architect/Engineer's approval before any fabrication begins.
- k. Formed-on flanged transverse joint systems are acceptable provided they are a manufactured product that has been tested for conformance with Chapter 2 of the SMACNA HVAC Duct Construction Standards for sheet and joint deflection at the specified pressure class.
 - 1) Apply sealant to all inside corners. Holes at corners are not acceptable.
 - 2) Flanges shall be 24-gauge minimum (not 26 gauge).
 - 3) Manufacturers:
 - a) Lockformer TDC
 - b) TDF
 - c) United McGill
 - d) Sheet Metal Connectors
 - e) Other manufacturers must submit test data and fabrication standards and receive Architect/Engineer's approval before any fabrication begins.
- B. Round and Spiral Seam Ductwork Single Wall:
 - 1. Conform to applicable portions of Rectangular Duct Section. Round or flat oval ductwork may be substituted for rectangular ductwork where approved by the Architect/Engineer. The spiral seam ductwork shall meet the standards set forth in this specification. The ductwork shall meet or exceed the specified cross-sectional area and insulation requirements. The substitution shall be coordinated with all other trades prior to installation.
 - 2. 90^{°°} elbows shall be smooth radius or have a minimum of five sections with mitered joints and R/D of at least 1.5.

- 3. Duct and fittings shall meet the required minimum gauges listed in chapter 3 of the SMACNA requirements for the specified pressure class. Ribbed and lightweight duct are not permitted.
- 4. Ductwork shall be suitable for velocities up to 5,000 fpm.
- 5. Divided flow fittings may be made as separate fittings or factory installed taps with sound, airtight, continuous welds at intersection of fitting body and tap.
- 6. Spot weld and bond all fitting seams in the pressure shell. Coat galvanizing damaged by welding with corrosion resistant paint to match galvanized duct color.
- 7. Ducts with minor axis less than 22" shall be spiral seam type. Larger ducts may be rolled, longitudinal welded seam type. SMACNA seams RL-2 and RL-3 are not permitted.
- 8. Transverse Joint Connections:
 - a. Crimped joints are not permitted.
 - b. Ducts and fittings 36" in diameter and smaller shall have slip joint connections. Size fitting ends to slip inside mating duct sections with minimum 2-inch insertion length and a stop bead. Use inside slip couplings for duct-to-duct joints, and outside slip couplings for fitting-to-fitting joints.
 - c. Ducts and fittings larger than 36" shall have flanged connections.
 - d. Secure all joints with at least 3 sheet metal screws before sealing.
 - e. Manufacturers, Slide-on Flanges:
 - 1) Ductmate Industries SpiralMate
 - 2) Accuflange
 - 3) Sheet Metal Connectors are acceptable.
 - f. Manufacturers, Self-Sealing Duct Systems:
 - 1) Lindab
 - 2) Ward "Keating Coupling"
- C. Hangers and Supports General Requirements:
 - 1. Hanger and support materials shall be as defined within Materials and Application Specific section below.
 - 2. Strap Hangers: Strap hanger shall be a minimum of 1 inch, 18 gauge attached to the bottom of ducts at 8'-0" OC and as required by CMC/UMC and SMACNA guidelines.

2.02 MATERIAL AND APPLICATION SPECIFIC

- Galvanized Steel:
 - 1. General Requirements:
 - a. Duct and reinforcement materials shall conform to ASTM A653 and A924.

- b. Interior Ductwork and reinforcements: G60 galvanized (0.60 ounces per square foot total zinc coating for two sides per ASTM A90) unless noted otherwise.
- c. Exterior Ductwork: G90 galvanized (0.90 ounces per square foot total zinc coating for two sides per ASTM A90) unless noted otherwise. G60 is not acceptable for exterior use.
- d. Ductwork reinforcement shall be of galvanized steel.
- 2. Duct Hangers and Support Material:
 - a. Ductwork hangers and supports shall be of galvanized or painted steel.
 - b. All fasteners shall be galvanized or cadmium plated.
- B. Duct Hangers and Support Material:
 - 1. Ductwork hangers and supports shall be of galvanized or painted steel.
 - 2. All fasteners shall be galvanized or cadmium plated.

2.03 DUCTWORK REINFORCEMENT

- A. All reinforcement shall be external to the duct except that tie rods may be used with the following limitations.
 - 1. Ducts must be over 18" wide.
 - 2. Duct dimensions must be increased 2" in one dimension (h or w) for each row of tie rods installed.
 - 3. Tie rods must not exceed 1/2" diameter.
 - 4. Manufacturer of tie rod system must certify pressure classifications of various arrangements, and this must be in the shop drawings.

2.04 DUCTWORK SEALANTS

Β.

- A. One-part joint sealers shall be water-based mastic systems that meet the following requirements: maximum 48-hour cure time, service temperature of -20°F to +175°F, resistant to mold, mildew and water, flame spread rating below 25 and smoke-developed rating below 50 when tested in accordance with ASTM E84, suitable for all SMACNA seal classes and pressure classes. Mastic used to seal flexible ductwork shall be marked UL 181B-M.
 - Two-part joint sealers shall consist of a minimum 3" wide mineral-gypsum compound impregnated fiber tape and a liquid sealant. Sealant system shall meet the following requirements: maximum 48-hour cure time, service temperature of 0°F to 200°F, resistant to mold, mildew, and water, flame spread rating below 25 and smoke developed rating below 50 when tested in accordance with ASTM E84, suitable for all SMACNA seal classes and pressure classes.

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- C. Adhesives and Sealants: All sealers, adhesives, and sealants shall comply with the low emitting material limits of the following standards:
 - 1. CDPH Standard Method V1.1-2010 Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions VOC from Indoor Sources Using Environmental Chambers Version 1.1.
 - 2. South Coast Air Quality Management District Rule 1168 Adhesive and Sealant Applications. All adhesives and sealants wet-applied on site shall comply with the applicable chemical content requirements of SCAQMD Rule 1168.
 - South Coast Air Quality Management District Rule SCAQMD 1113 Wet Applied Paints and Coatings. All paints and coatings wet-applied on site must meet the applicable VOC limits of SCAQMD Rule 1113.

PART 3 - EXECUTION

H.

3.01 INSTALLATION

- A. Provide openings in ducts for thermometers and controllers.
- B. Locate ducts with space around equipment for normal operation and maintenance.
- C. Do not install ducts or other equipment above electrical switchboards or panelboards. This includes a dedicated space extending 25 feet from the floor to the structural ceiling with width and depth equal to the electrical equipment. Unless intended to serve these rooms, do not install any ductwork or equipment in electrical rooms, transformer rooms, electrical closets, telephone rooms or elevator machine rooms.
- D. Provide temporary closures of metal or taped polyethylene on open ducts to prevent dust from entering ductwork.
- E. Supply ductwork shall be free of construction debris, and shall comply with Level "B" of the SMACNA Duct Cleanliness for New Construction Guidelines.
 - Repair all duct insulation and liner tears.
- G. Support all duct systems in accordance with the SMACNA HVAC Duct Construction Standards: Metal and Flexible and the SMACNA Seismic Restraint Manual: Guidelines for Mechanical Systems, where applicable. Refer to Section 23 0550 for seismic requirements.
 - Install ducts with hangers and braces designed to withstand, without damage to equipment, seismic force required by California Building Codes.
- I. Adhesives, sealants, tapes, vapor retarders, films, and other supplementary materials added to ducts, plenums, housing panels, silencers, etc. shall have flame spread/smoke developed ratings of under 25/50 per ASTM E84, NFPA 255, or UL 723.

J. All duct support shall extend directly to building structure. Do not support ductwork from pipe hangers unless coordinated with piping contractor prior to installation. Do not allow lighting or ceiling supports to be hung from ductwork or ductwork supports.

3.02 DUCTWORK APPLICATION SCHEDULE

- A. General:
 - 1. Seal Class is per SMACNA HVAC Air Duct Leakage Test Manual
 - 2. Insulation:
 - a. Refer to Section 23 0713 for insulation types.
 - b. Type A insulation (Flexible Fiberglass Wrap) R-values noted are based on installed values (25% compression).
- B. Constant Volume from Fan to Outlet:
 - 1. Shape:
 - a. Rectangular Duct Single Wall
 - b. Round and Flat Oval Spiral Seam Ductwork Single Wall
 - c. Round Snap-Lock Seam Ductwork Single Wall
 - 2. Material: Galvanized Steel
 - 3. Pressure Class: +2"
 - 4. Seal Class: A
 - 5. Insulation:
 - a. ASHRAE 90.1-2019: 1-1/2" thick Type A (R=4.5)
 - 6. Additional Requirements: None

C. Return Duct:

- 1. Shape:
 - a. Rectangular Duct Single Wall
 - b. Round and Flat Oval Spiral Seam Ductwork Single Wall
- 2. Material: Galvanized Steel
- 3. Pressure Class: -2"
- 4. Seal Class: A
- 5. Insulation:
 - a. ASHRAE 90.1-2019: None
 - b. IECC-2021: 1-1/2" thick Type A (R=4.5)

- 6. Additional Requirements: None
- D. General Exhaust Duct:
 - 1. Shape:
 - a. Rectangular Duct Single Wall
 - b. Round and Flat Oval Spiral Seam Ductwork Single Wall
 - 2. Material: Galvanized Steel
 - 3. Pressure Class: -1"
 - 4. Seal Class: A
 - 5. Insulation: None
 - 6. Additional Requirements: None
- E. Relief/Exhaust Air Duct from Fan to Exhaust Outlet:
 - 1. Shape:
 - a. Rectangular Duct Single Wall
 - 2. Material: Galvanized Steel
 - 3. Pressure Class: +2"
 - 4. Seal Class: A
 - 5. Insulation:
 - a. ASHRAE 90.1-2019: 1-1/2" thick Type A (R=4.5)

3.03 DUCTWORK SEALING

- A. General Requirements:
 - 1. Openings, such as rotating shafts, shall be sealed with bushings or similar.
 - 2. Pressure sensitive tape shall not be used as the primary sealant unless it has been certified to comply with UL-181A or UL-181B by an independent testing laboratory and the tape is used in accordance with that certification.
 - 3. All connections shall be sealed including, but not limited to, taps, other branch connections, access doors, access panels, and duct connections to equipment. Sealing that would void product listings is not required. Spiral lock seams need not be sealed.
 - 4. Mastic-based duct sealants shall be applied to joints and seams in minimum 3 inch wide by 20 mil thick bands using brush, putty knife, trowel, or spray, unless manufacturer's data sheet specifies other application methods or requirements.

B. All ducts systems, regardless of pressure class, shall be Seal Class A as defined by Section 5-1 of SMACNA HVAC Air Duct Leakage Test Manual per the Energy Code, unless specifically noted otherwise. Seal Class A shall include sealing of all transverse joints, longitudinal seams, and duct wall penetrations with welds, gaskets, mastics, or fabric-embedded mastic system. Joints are inclusive of, but not limited to, girth joints, branch and sub-branch intersections, duct collar tap-ins, fitting subsections, louver and air terminal connections to ducts, access door and access panel frames and jambs, duct, plenum, and casing abutments to building structures.

END OF SECTION

SECTION 23 7416.12 - PACKAGED ROOFTOP HEAT PUMP UNITS 25 TON AND BELOW

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Packaged Rooftop Unit.
- B. Unit Controls.
- C. Economizers.
- D. Power Exhaust.

1.02 QUALITY ASSURANCE

- A. All insulation inside the unit and in the air stream must comply with the requirement of NFPA 90A (maximum flame spread of 25 and maximum smoke developed of 50).
- B. All units must be UL or ETL listed and must contain UL labeled components.
- C. Fans shall be tested and rated in cabinet in accordance with AMCA Standard 210. All fan assemblies shall be dynamically balanced in cabinet at final assembly.
- D. Conform to ASHRAE 90.1California Energy Code Title 24.
- E. All air handling and distribution equipment mounted outdoors shall be designed to prevent rain intrusion into the airstream when tested at design airflow and with no airflow, using the rain test apparatus described in Section 58 of UL 1995.

1.03 REFERENCES

- A. AHRI 210 Unitary Air Conditioning Equipment.
- B. AHRI 240 Air Source Unitary Heat Pump Equipment.
- C. AHRI 270 Sound Rating of Outdoor Unitary Equipment.
- D. ASHRAE 37 Methods of Testing for Rating Unitary Air Conditioning and Heat Pump Equipment.
- E. ANSI/ASHRAE/IES Standard 90.1 (latest published edition) Energy Standard for Buildings Except Low-Rise Residential Buildings.
- F. NFPA 70 National Electrical Code.

- G. NFPA 90A Installation of Air Conditioning and Ventilating System.
- H. UL Underwriters' Laboratory.

1.04 SUBMITTALS

- A. Submit shop drawings and product data under provisions of Section 23 0500.
- B. Indicate electrical service and duct connections on shop drawings or product data.
- C. Submit manufacturer's installation instructions.
- D. Submit electrical power/controls wiring diagrams and product data indicating general assembly, components, safety controls, and service connections.
- E. Submit fan curves, including minimum and maximum fan speed, with specified operating points clearly plotted.
- F. Provide 8 octave maximum sound power levels at unit discharge and return connection.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Protect units from physical damage by storing off site until roof mounting frames are in place, ready for immediate installation of units.

1.06 OPERATION AND MAINTENANCE DATA

- A. Submit operation and maintenance data.
- B. Include manufacturer's descriptive literature, installation instructions, maintenance and repair data, and parts listing.

1.07 WARRANTY

- Provide five (5) year manufacturer's warranty for compressors.
- B. Provide five (5) year manufacturer's warranty for heat exchanger.
- C. Provide standard year manufacturer's warranty for controls and electrical components (thermostats, VFD, etc.).

1.08 MAINTENANCE SERVICE

A. Contractor shall furnish complete service and maintenance of packaged roof top units for one year from Date of Substantial Completion.

- B. Provide maintenance service with a two-month interval as maximum time period between calls. Provide 24-hour emergency service on breakdowns and malfunctions.
- C. Include maintenance items as outlined in manufacturer's operating and maintenance data, including minimum of four (quarterly) filter replacements, minimum of one fan belt replacement, and controls checkout, seasonal adjustments, and recalibrations.
- D. Submit copy of service call work order or report and include description of work performed to Owner and Architect/Engineer.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

- A. York (Basis of Design)
- B. Daikin
- C. Carrier
- D. Trane
- E. Captive Aire

2.02 MANUFACTURED UNITS

- A. Provide roof-mounted units having electric heating elements, electric refrigeration.
- B. Unit shall be self-contained, packaged, factory assembled, pre-wired and tested, consisting of cabinet and frame, supply fan, electric heating elements, controls, air filters, refrigerant cooling coil and compressor, condenser coil, condenser fan, and a full refrigerant charge.

Unit shall be furnished with non-fused disconnect switch, short fuse protection of all internal electrical components, and all necessary motor starters, contactors, and overcurrent protection.

2.03 FABRICATION

Cabinet: Galvanized steel with baked enamel finish, access doors or removable access panels with quick fasteners screwdriver operated flush cam type Access doors shall be provided at each section (e.g., filter section, supply fan section, etc.). All exterior access panels must be permanently labeled on the outside indicating what is behind the panel. Structural members shall be minimum 18 gauge, with access doors or removable panels of minimum 20 gauge.

- B. Outside Air Intakes: The outside air intakes shall be located a minimum of 15 inches above the roof mounting curb to minimize the effect of heat pickup from the roof during the natural cooling cycle and the effects of snow on the roof during winter operation. Each air intake shall be furnished with rain eliminators.
- C. Insulation: Minimum of 1/2" thick, 1.5 lb./cu.ft. density coated glass fiber insulation on surfaces where conditioned air is handled. Protect edges from erosion.
- D. Air Filters: Two inch thick glass fiber disposable media in metal frames.

2.04 ROOF MOUNTING FRAME AND BASE

A. Roof Mounting Curb: Minimum 12 inches high, minimum 14 gauge galvanized steel, onepiece construction, insulated, all welded, wood nailer.

2.05 FANS/MOTORS

- A. Fans:
 - 1. Supply Fans: centrifugal; SWSI plenum or vane axial fan.
 - 2. All fans shall be aluminum or composite construction with fan shaft: turned, ground and polished steel; keyed to wheel hub.
 - 3. Fan and motor assemblies shall be resiliently mounted.
 - 4. Direct drive motor or with V-belt drive and rubber isolated hinge mounted motor.
 - 5. All fan bearings must be capable of being lubricated by easily accessible grease fittings.
 - 6. All fans must be statically and dynamically balanced.
- B. Motors:
 - 1. Motors shall be open drip-proof with grease lubricated bearings.
 - 2. No equipment shall be selected or operate above 90% of its motor nameplate rating.
 - 3. Motor shall have 1.15 service factor.
 - 4. ECM motors may be provided.
- C. Belt Drive Fans:
 - 1. Belt drive fans must be within ± 10% of scheduled RPM.
 - 2. Belt drive fans shall have slide rails, adjusting screws, anchor bolts, and bedplates.
 - 3. Drives shall be V-belt type with adjustable pitch sheaves for units 20 HP and below. On units over 20 HP, use fixed sheaves. This Contractor shall provide replacement sheaves and belts as required to allow final air balancing.
 - 4. Units used with variable speed drives shall have fixed sheaves. This Contractor shall provide replacement sheaves and belts as required to allow final air balancing.

2.06 EVAPORATOR COIL

- A. Provide copper tube with aluminum fin coil assembly.
- B. Install a drain pan under each cooling coil meeting requirements as outlined in ASHRAE 62.1. The drain pans shall extend the entire width of each coil, including piping and header if in the air stream. The length shall be as necessary to limit water droplet carryover beyond the drain pan to 0.0044oz per ft2 of face area per hour under peak sensible and peak dew point design conditions, considering both latent load and coil face velocity. Pitch drain pans in two directions towards the outlet, with a slope of at least 1/8" per foot.
- C. Provide capillary tubes or thermostatic expansion valves for units of 6 tons capacity and less, and thermostatic expansion valves and alternate row circuiting for units 7.5 tons cooling capacity and larger.
- D. Provide insulation on liquid refrigerant and suction piping between compressor and evaporator coil where not protected by drain pans. Insulation shall be elastomeric cellular foam; ANSI/ASTM C534; flexible plastic; 0.27 maximum 'K' value at 75°F, 25/50 flame spread/smoke developed rating when tested in accordance with ASTM E84 (UL 723). Maximum 1" thick per layer where multiple layers are specified.
- E. Drain Pan Condensate Overflow Switch: Float with integral magnet overflow switch conforming to UL508. Factory installed in drain pan and wired to shut the rooftop unit down with a fault alarm. No standby power required.

2.07 COMPRESSOR

- A. Provide hermetic or semi-hermetic compressors (quantity as scheduled on drawings), 3600 rev/min maximum, resiliently mounted with positive lubrication, high and low pressure safety controls, motor overload protection, suction and discharge service valves and gauge ports, and filter drier.
- B. Provide capacity control by digital scrolls.
- C. Five minute timed off circuit shall delay compressor start.
- D. For heat pump units, provide reversing valve, suction line accumulator, flow control check valve, and solid-state defrost control utilizing thermistors.
- E. The use of hydrochlorofluorocarbon (HCFC) or chlorofluorocarbon (CFC) based refrigerants is prohibited.

2.08 CONDENSER

A. Condenser shall provide design capacity between the minimum and maximum ambient conditions scheduled on the drawings.

- B. Condenser Coil:
 - 1. Round Copper Tube and Aluminum Fins: Construct condenser coils of aluminum fins mechanically bonded to seamless copper tubing. Air test under water to 450 psig. Coils and frame shall include 5000+ hour salt spray resistance (ASTM B117-90).
 - 2. Microchannel: All aluminum brazed fin construction. The maximum allowable working pressure of the condenser is 450 psig. Air test under water to 450 psig.
- C. Condenser Fans: Provide direct drive low noise blade design propeller fans, resiliently mounted with fan guard, motor overload protection, wired to operate with compressor. Fan blade design shall be a dynamic profile for low tip speed. Fan blade shall be aluminum or composite material.
- D. Condenser Motors: Fan motors shall be an ECM type motor for proportional control. The motor shall include thermal overload protection and protect the motor in the case of excessive motor temperatures. The motor shall have phase failure protection and prevent the motor from operation in the event of a loss of phase.
- E. Entire fan assembly shall be statically and dynamically balanced.
- F. Provide refrigerant pressure switches or outdoor thermostat to cycle condenser fans.
- G. Liquid and discharge isolation valves with staged and digital scrolls.

2.09 MIXING SECTION

- A. Dampers: Provide outside, return, and relief dampers with damper operator and control package to automatically vary outside air quantity. Outside air damper shall fail to closed position.
- B. Gaskets: Provide tight fitting dampers with edge gaskets. Gaskets must be mechanically fastened (use of adhesive alone shall not be acceptable). Damper blades shall be gasketed with side seals to provide an air leakage rate of Class 1A at 1" w.c. pressure differential for a 24"x 24" damper.
- C. Damper Actuator: 24 volt with gear train sealed in oil, with spring return on units 7.5 tons cooling capacity and larger.

2.10 ECONOMIZERS

Α.

- Factory installed by approved rooftop unit manufacturer with fully modulating motorized outside air and return air dampers.
- B. To be controlled by dry bulb controller with minimum position setting.

- C. Shall be equipped with 100% capable relief barometric damper relieving up to 100% return air and sealed to meet ASHRAE 90.1 requirements.
- D. Shall be capable of introducing up to 100% outside air.
- E. Shall maintain minimum airflow into the building during occupied period and provide design ventilation rate for full occupancy.
- F. Dampers shall be capable of completely closing when unit is in unoccupied mode.
- G. Outside air damper normally closed and return air damper normally open.
- H. Provide factory installed and tested, outdoor air monitor that controls outdoor air \pm 15% accuracy down to 40 cfm per ton.
- I. Economizer assembly shall be California Title 24 compliant. MicroTech III controls shall display a warning, and write a warning to the BAS, if the economizer malfunctions in accordance with Title 24 specifications.
- J. Provide a field installed duct/space-mounted C02 sensor. Outside air damper position shall modulate between the demand control ventilation limit (minimum position setpoint) and the ventilation limit (maximum non-economizer position setpoint) to satisfy the space requirements. Damper position shall be controlled to the greater of the two command signals, either minimum outside airflow or space IAQ (CO2).
- K. Economizer Fault Detection and Diagnostics (FDD):
 - 1. Air-cooled unitary direct-expansion units that are equipped with an economizer shall include a fault detection and diagnostics system complying with the following:
 - a. The following temperature sensors shall be permanently installed to monitor system operation:
 - 1) Outside air.
 - 2) Supply air.
 - 3) Return air.
 - b. Temperature sensors shall have an accuracy of $\pm 2^{\circ}$ F over the range of 40° F to 80° F.
 - c. Refrigerant pressure sensors, where used, shall have an accuracy of ± 3 percent of full scale.
 - d. The unit controller shall be configured to provide system status by indicating the following:
 - 1) Free cooling available.
 - 2) Economizer enabled.

- 3) Compressor enabled.
- 4) Heating enabled.
- 5) Mixed air low limit cycle active.
- 6) The current value of each sensor.
- e. The unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans, and the heating system can be independently tested and verified.
- f. The fault detection and diagnostics system shall be configured to detect the following faults:
 - 1) Air temperature sensor failure/fault.
 - 2) Not economizing when the unit should be economizing.
 - 3) Economizing when the unit should not be economizing.
 - 4) Damper not modulating.
 - 5) Excess outdoor air.
- g. The unit shall be configured to report faults to a fault management application available for access by day-to-day operating or service personnel or annunciated locally on zone thermostats.

2.11 POWER EXHAUST

- A. Factory installed by economizer supplier or compatible equivalent.
- B. Controlled by economizer controls.
- C. Power exhaust shall be factory wired to electrical section complete with conduit, feeders, disconnect, and overcurrent protection. Power exhaust shall be energized based on building pressure or when dampers open past the adjustable setpoint of the economizer control.
- D. Must comply with Energy Code Fan Power Limitation formula.
- E. Fans:
 - 1. Exhaust Fans: Propeller
 - 2. All fans shall be aluminum or composite construction with fan shaft: turned, ground and polished steel; keyed to wheel hub.
 - 3. Fan and motor assemblies shall be resiliently mounted
 - 4. Direct drive motor.
 - 5. All fan bearings must be capable of being lubricated by easily accessible grease fittings.
 - 6. All fans must be statically and dynamically balanced.

F. Motors:

- 1. Motors shall be open drip-proof with grease lubricated bearings.
- 2. Motors shall be "variable frequency drive rated" when controlled by VFDs. Refer to Section 23 0513.
- 3. No equipment shall be selected or operate above 90% of its motor nameplate rating.
- 4. Motor shall have 1.15 service factor.
- 5. ECM motors may be provided.

2.12 ELECTRICAL

- A. Provide with single point power connection to service all controls, dampers, outlet, and fans, complete with non-fused disconnect switch, short circuit protection of all internal electrical components, and all necessary motor starters, contactors, and over-current protection, transformer, and convenience outlet.
- B. All units must be so constructed that when the electrical section access panel is opened, all electrical power to the unit (with the exception of the 120 volt duplex convenience outlet) is disconnected by means of a single disconnect.
- C. All wiring must be labeled, numbered, and terminate in "spade clips". All terminal strips must be keyed to the wiring numbers. Each control device must be permanently labeled to indicate its function.
- D. Wiring diagrams for all circuits must be permanently affixed to the inside of the electrical section access panel. The markings of terminal strips and wiring must agree with the numbering on the wiring diagrams.
- E. All units shall include a transformer for controls and convenience outlet.
- F. Only one power cable connection to the unit shall be necessary.
- G. Motor shall include phase failure protection and prevent the motor from operation in the event of phase loss.

2.13 OPERATING CONTROLS - SINGLE ZONE UNITS

- When ECM are applied:
 - 1. Single Zone VAV: The unit controller shall proportionally control the ECM motors on the supply fan based on space temperature. The unit controller shall increase/decrease the speed of the supply fan in order to maintain the space temperature within its setpoint and deadband. The unit controller shall provide discharge air temperature control with the compressor modulation.

- B. When variable speed drives are applied:
 - Single Zone VAV: An electronic variable frequency drive shall be provided for the supply air fan. Each drive shall be factory installed out of the airstream in a conditioned cabinet. Drives shall meet UL Standard 95-5V. The completed unit assembly shall be listed by a recognized safety agency, such as ETL. Drives are to be accessible through a hinged door assembly. Mounting arrangements that expose drives to high temperature unfiltered ambient air are not acceptable.
- C. Room thermostat shall incorporate:
 - 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 setpoint for continuous or timed period from one hour to 31 days.
 - 5. Short cycle protection.
 - 6. Programming based on weekdays, Saturday and Sunday.
 - 7. Switch selection features including imperial or metric display, 12 or 24 hour clock, keyboard disable, remote sensor, fan on-auto.
- D. Room thermostat display shall include:
 - 1. Time of day.
 - 2. Actual room temperature.
 - 3. Programmed temperature.
 - 4. Programmed time.
 - 5. Duration of timed override.
 - 6. Day of week.

F.

G.

Α.

- 7. System model indication: heating, cooling, auto, off, fan auto, fan on.
- 8. Stage (heating or cooling) operation.
- E. Provide low limit sequence to close outside air dampers and stop supply fan.
 - Mixed Air Controls: Maintain selected supply air temperature and revert dampers to minimum outside air position on a call for heating and above 75°F ambient, when ambient air enthalpy exceeds return air enthalpy.
 - Dehumidification Controls: Maintain the relative humidity setpoint with the hot refrigerant gas reheat coil.

2.14 OPERATING CONTROLS - VARIABLE VOLUME UNITS

- Temperature transmitter located in supply air shall signal electronic logic panel to control mixing dampers and cooling in sequence to maintain 55°F(adj.).
- B. Control cooling by modulating compressors.

- C. Control logic shall allow adjustable supply air reset under low load or airflow conditions.
- D. Dehumidification Controls: Maintain the relative humidity setpoint with the hot refrigerant gas reheat coil.
- E. Provide two stage morning warm-up thermostat to hold outdoor dampers closed and energize heat until return air temperature reaches set point.
- F. Program Options: Each central control panel is individually configurable as an air conditioner controller for a variable volume system.
- G. Supply Air Temperature Sensor Input: The supply air temperature sensor monitors the air handling unit discharge air temperature. It is used by the central control panel to control the stages of heating and cooling, and to protect the air handling unit from excessively high or low discharge air temperatures. The leaving air temperature sensor requires twisted, shielded pair wire. Terminations are screw terminals.
- H. System Control: The central control panel scans the unit control modules to determine the deviations from temperature setpoint, time of deviation, time from last changeover, and number of UCMs requiring heating or cooling. Based upon this information, the system heat/cool mode and stage of capacity is selected. The central control panel also monitors the system air temperature to ensure that high and low temperature limits are maintained.

2.15 DDC TEMPERATURE CONTROLS

- A. Install standalone control module providing communication between unit controls and packaged DDC temperature control system.
- B. Control module shall be compatible with temperature control system specified in Section 23 0900.

PART 3 - EXECUTION

3.01 EXAMINATION

- A. Verify that roof is ready to receive work and opening dimensions are as indicated on shop drawings and illustrated by the manufacturer.
- B. Verify that proper power supply is available.

3.02 INSTALLATION

A. Install in accordance with manufacturer's instructions.

- B. Mount units on factory built roof mounting curb and provide watertight enclosure to protect ductwork and utility services. Install unit level.
- C. All field wiring shall be in accordance with the National Electrical Code.
- D. P-traps must be provided for all drain pans.
- E. Comb all coils to repair bent fins.
- F. Contractor shall coordinate unit access stair and walkway placement to ensure compliance with OSHA requirements.

END OF SECTION

23 09 23 DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1: GENERAL

- 1.1 Products Furnished but Not Installed Under This Section
 - A. None

1.2 Products Installed but Not Furnished Under This Section

A. None

1.3 Products Not Furnished or Installed Under but Integrated with the Work of This Section

- A. None
- **B.** Communications with Third Party Equipment:

1.4 Related Sections

- A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.
- B. The following sections constitute related work:
 - 1. Section 01 30 00 Administrative Requirements
 - 2. Section 01 60 00 Product Requirements
 - 3. Section 01 80 00 Performance Requirements
 - 4. Section 01 90 00 Life Cycle Activities
 - 5. Section 23 05 00 Common Work Results for HVAC
 - 6. Section 23 20 00 HVAC Piping and Pumps
 - 7. Section 23 30 00 HVAC Air Distribution
 - 8. Section 23 40 00 HVAC Air Cleaning Devices
 - 9. Section 23 50 00 Central Heating Equipment
 - 10. Section 23 60 00 Central Cooling Equipment
 - 11. Section 23 70 00 Central HVAC Equipment
 - 12. Section 23 80 00 Decentralized HVAC Equipment
 - 13. Section 26 05 00 Common Work Results for Electrical
 - 14. Section 26 06 00 Schedules for Electrical
 - 15. Section 26 09 00 Instrumentation and Control for Electrical Systems
 - 16. Section 26 20 00 Low Voltage Electrical Transmission
 - 17. Section 26 29 00 Low-Voltage Controllers (Motor Controllers and VFD Drives)
 - 18. Section 26 30 00 Facility Electrical Power Generating and Storing Equipment (UPS, Backup Generators)
 - 19. Section 26 50 00 Lighting
 - 20. Section 28 00 00 Electronic Safety and Security (includes Fire and Smoke)

1.5 Description

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

- B. System software shall be based on a server/thin client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the owner's local area network, and (at the owner's discretion) over the Internet.
- C. The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.
- D. System shall use the BACnet protocol for communication between the control modules and web server. Communication between the web server and the user's browser shall be HTTP or HTTPS protocol utilizing HTML5. Use of Adobe Flash technology is not acceptable.

1.6 Approved BMS Systems

A. The following are approved control system suppliers, manufacturers, and product lines:

Supplier	Manufacturer	Product Line
Sunbelt Controls, ACCS or Za- retsky	Automated Logic	WebCTRL

The above list does not indicate order of preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.

- B. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
- C. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.7 Quality Assurance

- A. Installer and Manufacturer Qualifications
 - 1. Installer shall have an established working relationship with the Control System Manufacturer and have, as a minimum, 5 years demonstrated experience with installation and support of the manufacturer's product.
 - 2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.

1.8 Codes and Standards

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

- 1. National Electric Code (NEC)
- 2. International Building Code (IBC)
- 3. International Mechanical Code (IMC)
- 4. Underwriters Laboratories (UL/CUL)

5. ANSI/ASHRAE Standard 135, BACnet - A Data Communication Protocol for Building Automation and Control Systems

1.9 System Performance

- A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for display through the user's web browser.
 - 1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
 - 2. Graphic Refresh.A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
 - 3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
 - 4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
 - 5. Alarm Response Time. An object that goes into alarm shall be annunciated at the browser within 45 sec.
 - 6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec.
 - 7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
 - 8. Multiple Alarm Annunciation. Each user, connected to network accessing the system through their browser (workstation), shall receive alarms within 5 seconds of one another.
 - 9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
 - Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.
 Table-1

Measured Variable	Reported Accuracy
Space Temperature	±0.5°C (±1°F)
Ducted Air	±0.5°C (±1°F)
Outside Air	±1.0°C (±2°F)
Dew Point	±1.5°C (±3°F)
Water Temperature	±0.5°C (±1°F)
Delta-T	±0.15° (±0.25°F)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)

Reporting Accuracy

Water Pressure	±2% of full scale (see Note 2)		
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)		
Carbon Monoxide (CO)	±5% of reading		
Carbon Dioxide (CO ₂)	±50 ppm		
			-

Note 1: Accuracy applies to 10%–100% of scale

Note 2: For both absolute and differential pressure

Note 3: Not including utility-supplied meters

Table 2

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

1.10 Submittals

- A. Product Data and Shop Drawings: The contractor shall provide shop drawings and product data on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide submittal data in a digital format on suitable digital media such as a USB drive. The submittal data shall be in standard Microsoft (Word, Excel, etc.) or PDF file formats. The shop drawings shall be formatted to fit on 11" x 17" pages and hardware/software product data shall be formatted to fit on 8.5" x 11" pages. When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submittal is to cover. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:
 - 1. DDC System Hardware
 - a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
 - b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
 - i. Direct digital controllers (controller panels)
 - ii. Transducers and transmitters
 - iii. Sensors (including accuracy data)

- iv. Actuators
- v. Valves
- vi. Relays and switches
- vii. Control panels
- viii. Power supplies
- ix. Batteries
- x. Operator interface equipment
- xi. Wiring
- c. Wiring diagrams and layouts for each control panel. Show termination numbers.
- d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.
- 2. Central System Hardware and Software
 - a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.
 - b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
 - i. Central Processing Unit (CPU) or web server
 - ii. Monitors
 - iii. Keyboards
 - iv. Power supplies
 - v. Battery backups
 - vi. Interface equipment between CPU or server and control panels
 - vii. Operating System software web server
 - viii. Color graphic software
 - ix. Third-party software
 - c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show interface wiring to control system.
 - d. Network riser diagrams of wiring between central control unit and control panels.
- 3. Controlled Systems
 - a. Riser diagrams showing control network layout, communication protocol, and wire types.
 - b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
 - c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
 - d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
 - e. A mounting, wiring, and routing plan-view drawing. The design shall take into account HVAC, electrical, and other systems' design and elevation requirements.

The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.

- f. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
- g. A point list for each control system. List I/O points and software points required to provide specified sequence of operations. Indicate alarmed and trended points.
- 4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.
- 5. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.
- B. Project Documentation.
 - Upon completion of installation, submit record (as-built) documents for approval before final completion. Provide record documents in a digital format on suitable digital media such as a USB drive. The record documents shall be in standard Microsoft (Word, Excel, etc.) or PDF file formats except as noted below. Record documentation shall include the following:
 - a. Project Record Drawings.
 - b. Testing and Commissioning Reports and Checklists.
 - c. Operation and Maintenance (O&M) Manual.
 - d. As-built versions of submittal product data.
 - e. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
 - f. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
 - g. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
 - h. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
 - i. Documentation of programs operating in the system and object database that can be viewed using technician software tools furnished with system.
 - j. Graphic files, programs, and database to be viewed using technician software tools furnished with system.
 - k. List of recommended spare parts with part numbers and suppliers.
 - I. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
 - m. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
 - n. Licenses, guarantees, and warranty documents for equipment and systems.

- Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
- 2. Load into the control system for access by the operator through any operator workstation closeout documentation. There shall be a menu or navigation tab to access the documentation. The documentation can be loaded into the control system in a pdf format. The following documentation shall be included:
 - a. As-built control diagrams including wiring diagrams and sequences of operations for each controller/piece of equipment.
 - b. All IOM data as follows:
 - i. IOM from each equipment manufacturer for each piece of equipment (AHUs, FCUs, Chillers, pumps etc.)
- ii. IOM for each control module and end device installed in the system.
 C. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Engineer will modify course outlines and materials if necessary to meet Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

1.11 Warranty

- A. Warrant work as follows:
 - 1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.
 - 2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
 - 3. If the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
 - 4. All Manufacturer's software/firmware for web server/workstation and controllers shall be updated to the latest versions that are available from the manufacturer within 30 days from the date of end of the warranty. These updates shall be installed and checked out before the end of the warranty.
 - 5. Provide updates to web server software, project-specific software, graphic software, database software, and firmware that resolve the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase inwarranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
 - 6. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired and factory recertified. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.12 Ownership of Proprietary Material

- A. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:
 - 1. Graphics
 - 2. Record drawings
 - 3. Database
 - 4. Application programming code
 - 5. Documentation

PART 2: PRODUCTS

2.1 Materials

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

2.2 Communication

- A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.
- B. All IP based controllers shall be capable of providing IPv4 and IPv6 protocol standards as defined by the Internet Data Communications Standard.
- C. The owner shall furnish and install all communication media, connectors, repeaters and network switches/routers, and network devices necessary to provide a complete and workable high speed Ethernet communications/LAN network meeting or exceeding recommended control network specifications. The owner will provide an active IP/Ethernet port/drop within patch distance to each BMS server and BMS controller for connection to owner's LAN. BMS contractor will furnish and install all communications media, connectors, repeaters, switches/routers, and network devices necessary to provide a complete and workable serial network. Established network requirements such as labeling, testing, administration, and documentation must be provided to controls vendor prior to start of project.
- D. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
- E. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
 - 1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
 - 2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute specified sequences

> of operation. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

- F. Building Control Panels, and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.
- G. System shall be expandable to at least twice the required BACnet objects. No additional licensing/software fees shall be required to add controllers, associated devices, and wiring.
- H. System shall support Web services data exchange with any other system that complies with XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.
 - System shall support Web services read data requests by retrieving requested trend 1. data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.
 - 2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the specified object.
 - For read or write requests, the system shall require user name and password 3. authentication and shall support TLS (Transport Layer Security) or equivalent data encryption.
 - 4. System shall support discovery through a Web services connection or shall provide a tool available through the Operator Interface that will reveal the path/identifier needed to allow a third party Web services device to read data from or write data to any object in the system which supports this service.

2.3 Operator Interface

- A. Operator Interface. The web server shall reside on high-speed network with building controllers. Web pages generated by this server shall be compatible with the latest versions of Microsoft Internet Explorer or Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).
- В. Communication. Web server and controllers shall communicate using BACnet protocol, including BACnet/SC. Web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.
- С. Hardware.
 - Web server and/or workstation. Industry-standard hardware shall meet or exceed 1. DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The web server may also be configured

in client/server fashion to accommodate a "workstation" definition. In "workstation" configuration, the workstation will also perform as a server supplying additional clients as needed. The following hardware requirements apply:

- a. System storage shall have sufficient memory to accommodate:
 - i. All required system software.
 - ii. A DDC database to accommodate, as a minimum, twice the size of the delivered system database.
 - iii. One year of archival trend data based on the points specified to be trended at their specified trend intervals.
- b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
- c. Minimum hardware configuration shall include the following:
 - i. Quad Core Processor
 - ii. 4-24 GB RAM (size dependent on size of system)
 - iii. 500 GB hard disk providing data at 3.0 Gb/sec (size dependent on historical data storage requirements)
 - iv. 16x DVD+/-RW drive
 - v. Qwerty Keyboard
 - vi. Optical Mouse
 - vii. 24-inch LED Color monitor with 75Hz refresh rate and 1080P resolution to provide a minimum screen resolution of 1920 x 1080 pixels.
 - viii. Serial (USB) and network communication ports, with cables as required for proper DDC system operation.
- D. System Software.
 - Operating System. Web server shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the BMS manufacturer's minimum requirements for their software. Acceptable systems include Microsoft Windows 8.1 or 10, Windows Server 2012 R2 or 2016 or 2019 or 2020, Red Hat Enterprise Linux 8.3, or Ubuntu Desktop 18.04 or 20.04 LTS.
 - Security. The web server application shall support Transport Layer Security (TLS) 1.3 capable of encryption of up to 256 bit elliptical curve for transmitting private information over the Internet using HTTPS. Additionally, the web server shall have SHA-2 certificate support capability.
 - 3. Database. System shall support any JDBC (Java DataBase Connectivity) compliant engine. This includes: MS SQL, My SQL, Apache Derby, PostgreSQL and Oracle.
 - 4. The BMS system shall allow an unlimited number of concurrent users.
 - 5. The BMS manufacturer shall provide all software and tools necessary to provide the following capabilities:
 - a. Create and/or edit any programming used in controllers
 - b. Create and/or edit any graphics used in the system
 - c. Software shall not be subscription based and be given to owner at time of turnover. If software is subscription based, manufacturer shall include 10 years of subscription service.
 - d. The owner shall have the ability to install software on a minimum of five (5) additional owner furnished computers without additional licenses or fees.

- 6. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.
 - a. Minimum graphics resolution shall be 1920 x 1080 for display of detailed system graphics.
 - b. Floor Plan Graphics. Floor plan graphics shall be capable of allowing the floor plan graphic to dynamically size relative to the end user's monitor resolution.
 - c. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.
 - d. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
 - e. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
 - f. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, GIF, or SVG. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in or shall only require widely available no-cost plug-ins.
- 7. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system used to create and modify graphics that are saved in the same formats as are used for system graphics.
- 8. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.
- E. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on a standard PC type personal computer with no limit on the number of copies that can be installed under the system license.
 - 1. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
 - 2. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.