SECTION 230800 - COMMISSIONING OF MECHANICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes systems commissioning process requirements for HVAC&R and domestic hot water systems in accordance with IECC, Section C408 Requirements.

B. The Commissioning Agency shall be directly contracted with Simpson County Schools.

C. Proposals for Commissioning Services shall be submitted the same date and time as the project Bid Opening. Proposals may be sent electronically to Mr. Jwain White, Marcum Engineering (jwhite@marcumengineering.net).

1.2 QUALIFICATIONS AND EXPERIENCE:

A. At a minimum, the Commissioning Authority's qualifications and experience shall include the following:

1. Membership in the Building Commissioning Association.
2. Membership in the AABC Commissioning Group.
3. At least two (2) completed commissioning projects and two (2) years of experience with buildings of the type, scope and complexity of the proposed project.
4. At least one (1) AABC-Certified Commissioning Authority (CxA) on staff who will be directly involved in the commissioning efforts for this project and is familiar with the Commissioning submittal process.

1.3 ALLOWANCES

A. Labor, instrumentation, tools, and equipment costs for technicians for the performance of commissioning testing shall be furnished per this Section.

1.4 SUBMITTALS

A. Certificates of readiness.

B. Certificates of completion of installation, pre-start, and startup activities.

C. Commissioning plan.

D. Commissioning Report

E. Documents required by the Authority Having Jurisdiction in accordance with current edition of the IECC requirements.

1.5 REFERENCES

A. International Energy Conservation Code – Current Edition.

B. ACG Commissioning Guideline – 2005.

C. ASHRAE Guideline 0 – 2005: The Commissioning Process.

D. ASHRAE Guideline 1.1 – 2007: HVAC & R Technical Requirements for the Commissioning Process.

E. NECA 90 – 2009: Standard for Commissioning Building Electrical Systems.

1.6 COMMISSIONING

A. All systems and equipment including controls as specified shall be commissioned in accordance with IECC. The Commissioning Authority shall be retained by the Contractor and shall be certified as a Commissioning Authority by AABC.

B. The intent of the Commissioning Process is to fulfill all the requirements of IECC for the systems described herein. Provide all necessary commissioning activities to assure compliance with referenced standards.

C. This specification has been included for reference to define roles and responsibilities. Each contractor should review this procedure and be fully aware of their responsibilities in carrying out the required fundamental commissioning activities.

1.7 RELATED DOCUMENTS

A. Contract drawings and specifications, general provisions of the contract, including general and supplementary conditions, architectural, electrical, and mechanical provisions, and Division-1 Specification sections apply to work of this section.

1.8 DESCRIPTION OF WORK

A. The purpose of the commissioning process is to provide the owner/operator of the facility with a high level of assurance that the building systems have been installed in the specified manner and operate within the performance guidelines set forth in the Contract Documents. The Commissioning Authority (CxA) shall provide the Owner with an unbiased, objective view of the systems' installation, operation, and performance. This process is not intended to take away or reduce the responsibility of the Design Team or installing Contractors to provide a finished product. Commissioning is intended to enhance the quality of system start-up and aid in the orderly transfer of systems for beneficial use by the Owner. The CxA will be a member of the construction team, administrating and coordinating commissioning activities with the Design Team, General Contractor, Subcontractors, manufacturers, equipment suppliers, and the Owner.

1.9 ROLES AND RESPONSIBILITIES OF THE COMMISSIONING AGENCY

A. Mission: The primary point of responsibility is to inform the General Contractor, the Owner and Design Team on the status, integration, and performance of mechanical and electrical systems within the facility.

B. Information: The CxA shall function as a catalyst and initiator to disseminate information and assist the design and construction teams in implementing system verification, functional performance testing, and conformance with the intended design of each system during design and construction. Services include conducting a commissioning kick-off meeting, producing commissioning process documentation, writing a Commissioning Plan, writing system verification checklists and functional performance tests to be

performed by the Commissioning Authority with support by the installing contractor, reviewing documentation of executed commissioning process elements, reviewing the Test and Balance (TAB) Report, maintaining a resolution tracking process, documenting proper distribution of performance and operating information to the Owner's staff, and producing a Commissioning Report.

C. Quality Assurance: Assist the responsible parties to maintain a high-quality level of installation by meeting or exceeding prevailing standards and specifications.

D. Documentation of Tests: The contractor shall assist in documenting the results of the performance testing directly and/or assure that the appropriate technicians document testing. The CxA shall write documents in standard formats to be used by the commissioning team.

E. Deficiencies: The CxA shall provide technical expertise to facilitate and verify the correction of deficiencies found during the commissioning process.

F. Resolution of Deficiencies: The CxA is to remain an independent party with specific technical knowledge of the project. The CxA shall investigate the scope and extent of problems and facilitate communication to determine responsibilities by delineating specifications. The CxA shall monitor resolution for conformance with Contract Documents and prevailing industry standards.

G. Acceptance: The CxA shall document the date of acceptance as determined by the Construction Manager, General Contractor, Owner and Design Team. System Verification Checklists and Functional Performance Test results shall be used by the Owner in determining the start of the warranty period for HVAC systems and subsystems.

H. O&M Material: The CxA will review operating and maintenance materials for mechanical/electrical systems.

I. Phasing: The CxA will review phasing plans as provided by the General Contractor relating to temporary use of HVAC equipment, O&M considerations, warranty issues, impact of construction sequencing on occupied areas, and interruption of services from the existing equipment.

J. Independence: The CxA shall be an independent third-party agency and shall report directly to the Engineer and Architect.

1.10 MECHANICAL SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS

A. HVAC Controls
B. Roof-Top Air Handing Units
C. Dust Collection Systems
D. Central Welding Fume Extraction System
E. Ductless Split Air-Conditioning Systems
F. Exhaust Fans
G. Makeup air units
H. Unit and radiant heaters.
I. High Volume Low Speed Fans
J. Louvers, hoods and associated dampers
K. Domestic Hot Water Systems including hot water recirculation

1.11 COMMISSIONING DOCUMENTATION

A. Provide the following information to the CxA for inclusion in the commissioning plan:

1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.
2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
3. Process and schedule for completing construction checklists and manufacturer's pre-start and startup checklists for HVAC&R and domestic hot water systems.
4. Certificate of readiness, signed by the Contractor, certifying that HVAC&R, domestic hot water systems, and associated controls are ready for testing.
5. Certificate of completion certifying that installation, pre-start checks, and startup procedures have been completed.
6. Test and inspection reports and certificates.
7. Corrective action documents.
8. Verification of testing, adjusting, and balancing reports.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 COMMISSIONING PLAN

A. Commissioning Team

1. The Commissioning Team (CT) shall consist of key parties involved in design, construction and testing of this facility. It is necessary for each agency to appoint team members that will have long-term commitments to this project. Switching team members during the project will reduce the ability of the CT to provide continuity and acceptable results to the building owner. Team members must maintain an ongoing supervisory position on this project. One team member shall be provided by each of the parties listed:

    a. Owner – Chad Drake – Simpson County Schools (O)
    b. Commissioning Authority – TBD – (CxA)
    c. Architect – Greg Hosfield – RTA (A)
    d. Mechanical Design Engineer – Jwain White, PE – Marcum Engineering (ME)
    e. General Contractor – TBD (GC)
    f. HVAC Contractor – TBD (HC)
    g. Electrical Contractor – TBD (EC)
    h. Controls Contractor – TBD (CC)
    i. Testing, Adjusting and Balancing Contractor – TBD (TABC)

2. Commissioning Meetings

    a. Commissioning meetings will be held in conjunction with progress meetings as necessary. The CxA will be provided with minutes for site progress meetings. Commissioning meetings will be used to address problems that alter the Construction Documents or affect the commissioning process. These meetings provide an open forum for exchange of ideas between contractors, vendors, designers, users and owners.

3. Resolution Tracking Forms (RTF)

    a. The use of Resolution Tracking Forms is a method employed by the CxA to monitor and record problems, their causes, and solutions. The use of these lists promotes communication between the installing contractors, design team, commissioning agent, and owner, in order to expedite their resolution in a timely manner.

b. The CxA will regularly submit RTF's to the CT in order to document and resolve deficiencies as quickly as possible. The frequency of RTF submission will be adjusted as project conditions dictate.

4. System Verification Checklists (SVC) / Manufacturer's Checklists

a. The CxA will write SVC's based on the Construction Documents. These tests will be created for systems and subsystems. See SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS articles above. Draft copies will be submitted to the CT for review and comment prior to placement on the job site. A master copy of the SVC's will be bound in a three-ring binder and placed on the job site for use by the installing contractors. No system will be started until the appropriate SVC's have been completed.
b. The CxA will review the SVC for each piece of equipment prior to start-up. Equipment will be released for start-up only after these checklists have been completed and reviewed by the CxA with assistance from the installing contractor.
c. Prior to start-up, the CxA must also review the equipment manufacturer's checklists. These lists must be completed by the installing contractor and reviewed by the CxA before start-up can commence.

5. Start-Up

a. The appropriate contractors and/or manufacturer's representative will be required on site to perform start-up. No system will be started until the appropriate SVC's have been completed. No system will be started until the manufacturer's checklists have been completed. Start-up will be performed according to the manufacturer's recommended procedures. The CxA will review completeness of installation in conjunction with progress meetings prior to starting equipment.
b. CT members involved in installation, fabrication, manufacture, control, or design of equipment are required to be present at the time of start-up. A factory-authorized technician will be on site to start equipment when required by the specifications. This will minimize delays in bringing equipment on line and expedite acceptable functional performance in accordance with the Construction Documents.

6. Controls Monitoring

a. Close monitoring of the Control Contractor's progress will promote efficient coordination of the TAB work. The CC will be expected to submit point-to-point checklists verifying that work has been completed and all systems are ready for TAB work and Functional Performance Tests. Programming and graphics will be surveyed by the CxA for completeness and conformance with the Construction Documents and the owner's scheduling requirements.

7. TAB Monitoring

a. The preliminary TAB report set-up will be reviewed by the CxA prior to HVAC equipment start-up, in order to assure that the final TAB report format and content is acceptable.
b. TAB work will be monitored so that any problems that prevent or hinder proper balancing can be addressed and corrected with minimal delays. Addressing TAB problems as quickly as possible assures that functional performance tests and owner training will take place on schedule.
c. A pencil copy of the TAB report will be reviewed prior to submission of the final TAB report. A written review will be submitted to the TAB contractor and to the Design Team (DT) for their comments. A TAB report approved by the DT will be required before Functional Performance Testing can be carried out. The CxA will visit the site during the TAB process in order to assist TABC and CC in the effective completion of their scope of work.

8. Functional Performance Tests (FPT)

   a. The CxA will write FPT's based on the Construction Documents. These tests will be created for systems and subsystems. See SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS articles above.
   b. Each major system will be tested by the CXA with assistance from the installing contractor. These activities will be coordinated by the contractor with the CxA, the design team, and the owner's staff to allow their participation if they so elect. Witnessing the FPT's could serve as a compliment to the O&M Training. No FPT's will be performed until the system and related subsystems have been started, the TAB report has been submitted and reviewed, and the completion of the control system has been documented through point-to-point checklists and other documentation.

9. The Functional Performance Tests shall include HVAC, Mechanical and Electrical equipment.

   a. HVAC systems will be tested to assure that the building as an integrated system operates properly, and to verify that interlocks and interactions between new equipment and systems function according to Construction Documents.
   b. Off-season mode testing will be implemented as necessary to assure conformance with the Construction Documents. Installing contractors will be expected to participate.
   c. The electrical trade representative will demonstrate to the CxA: Electrical life safety/egress systems operate as specified and are properly integrated to respond as intended.

10. Building Turn-Over / Owner Orientation / User Training

   a. The CxA will assist contractors prepare, coordinate and review O&M manuals, working with contractors to achieve specificity and completeness.
   b. The CxA will review as-built drawings, working with contractors to achieve specificity and completeness.
   c. Owner training will be coordinated with the assistance of the CxA. The installing contractor or manufacturer's representative will provide the training to be attended by the Owner's personnel. This training should include both classroom training and hands-on operational training as specified. The MC and EC shall DVD record this training for future use. The CxA will visit the site during the turnover and training period to assure that any on-going HVAC and/or electrical related problems are being addressed and corrected in a timely and efficient manner.
   d. The CxA will assist the owner/user with warranty issues.
   e. The CxA will assist in the coordination of off-season testing, calibrating, and servicing as specified in the contract documents.

11. Warranty Review

   a. The CxA will participate in an 11th month walk-through to observe the operation of the building systems. This will include a review meeting with the owner's personnel, a discussion of warranty issues, energy usage, maintenance practices, usage changes, and chronic problems, as well as other issues affecting the owner and the operation of the HVAC systems

3.2 RESPONSIBILITIES OF INSTALLING CONTRACTORS

A. General Contractor – GC Representative (GC)

1. Assure full cooperation of all parties in the Mechanical and Electrical Systems commissioning process.
2. Assure acceptable representation, with the means and authority to prepare and coordinate execution of the fundamental commissioning program as described in the contract documents.
3. Assure that the CxA shall receive a copy of all construction documents, addenda, change orders and appropriate approved submittals and shop drawings for review and use in development of the commissioning plan.
4. Coordinate inclusion of commissioning activities in the construction schedule.
5. Manage participation of appropriate contractors and vendors according to the contract documents and construction schedule.
6. Issue a statement when work has been completed, and that the final test reports have been submitted for review.
7. Issue a statement that control systems have been completely installed, programmed, and calibrated.
8. Facilitate resolution of deficiencies identified by observation or performance testing.
9. Prepare Operations & Maintenance (O&M) documents as required by specification and contract documents.
10. Coordinate execution of seasonal or deferred performance testing required by the construction documents, including notification of the CxA.
11. Coordinate correction or augmentation of O&M documents resulting from off-season mode or deferred testing.

B. Mechanical/HVAC Contractor – Mechanical/HVAC Trade Representative (MC/HC)

1. Assure cooperation and participation of specialty sub-contractors such as sheet metal, piping, refrigeration, and TAB in commissioning activities.
2. Assure participation of major equipment manufacturers in appropriate startup, training, and testing activities.
3. Attend commissioning meetings scheduled by the CxA.
4. Assist the CxA in execution of System Verification Checklists (SVC's) and Functional Performance Tests (FPT's).
5. Prepare preliminary schedule for HVAC system inspections, O & M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, system verification, performance testing, and system completion for review by the CxA. Update schedule as appropriate throughout the construction period.
6. Assist the CxA in execution of System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of HVAC equipment.
7. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve compliance with Construction Documents.
8. Notify the CxA a minimum of two (2) weeks in advance of scheduled system start-up.
9. Update drawings to as-built condition and review with the CxA throughout the construction process.
10. Schedule vendor and subcontractor provided training sessions as required by project specifications.
11. Provide written notification to CC and CxA that the following work has been completed in accordance with the project specifications, and that the equipment, systems and sub-systems are operating in accordance with Owner's Project Requirements:

    a. HVAC equipment including fans, air handling units, dehumidification units, ductwork, dampers, terminal devices, etc.
    b. Fire detection and smoke detection devices furnished under other divisions as they affect the operation of the HVAC systems.
    c. That the BAS is functioning in accordance with Construction Documents.

12. Assist the CxA in executing the Functional Performance Tests as required to achieve compliance with Construction Documents.

13. Provide off-season mode testing as required to achieve compliance with Construction Documents.
14. Provide O&M Training as required by project specifications.
15. Provide a complete set of as-built drawings and O & M manuals for review. The CxA shall review the as-built drawings and O&M manuals concurrently with the design team.

C. Testing, Adjusting and Balancing Contractor (TABC)

1. Attend commissioning meetings scheduled by the CxA.
2. Submit the TAB procedures and preliminary TAB report to the CxA for review at least two weeks prior to beginning TAB work.
3. Notify the CxA a minimum of two weeks in advance of scheduled TAB work.
4. Assist the CxA and installing contractor in executing SVC's and FPT's.
5. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve compliance with Construction Documents.
6. Participate in verification of the TAB report, which will consist of repeating any selected measurement contained in the TAB report where required by the CxA for verification or diagnostic purposes.
7. Participate in the Functional Performance Tests as required to achieve compliance with Construction Documents.
8. Provide sound and vibration source data where required to assist in diagnosis of areas exhibiting unacceptable levels of noise or vibration.
9. Participate in the off-season mode testing as required to achieve compliance with Construction Documents.
10. Participate in O&M Training as required by project specifications.

D. Controls Contractor - Control System Trade Representative (CC)

1. Review control sequence and component selection for conformance with Construction Documents.

    a. Verify that specified safeties and interlocks have been selected.
    b. Verify proper selection of control dampers and actuators based on design parameters.

2. Verify that sensor selection conforms to Construction Documents.
3. Attend commissioning meetings scheduled by the contractor.
4. Provide the following submittals to the CxA:

    a. Hardware and software submittals.
    b. Control panel shop drawings.
    c. Narrative description of control sequences for each HVAC system and subsystem.
    d. Schematics showing all control points, sensor locations, point names, actuators, controllers and where necessary, points of access.
    e. A list of all control points, including analog inputs, analog outputs, digital inputs and digital outputs. Include the values of all parameters for each system point. Provide a separate list for each stand-alone control unit.
    f. A complete listing of all software routines employed in operating the control system. Also, provide a program narrative that describes the logic flow of the software and the functions of each routine and sub-routine. The narrative should also explain individual math or logic operations that are not clear from reading the software listing.
    g. Hardware operation and maintenance manuals.
    h. Application software and project applications code manuals.
    i. Panel and equipment insert documents.

5. Verify that specified interfaces provided by others are compatible with BAS hardware and software.
6. Coordinate installation and programming of BAS with construction and commissioning schedules.

7. Assist CxA and installing contractor in executing System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of HVAC equipment.
8. Provide control system technician to assist during equipment startup, TAB, and Functional Performance Tests.
9. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve compliance with Construction Documents.
10. Participate in the Functional Performance Tests as required by the project specifications.
11. Provide a control system technician to demonstrate the HVAC system during FPT's.
12. Provide system modifications to achieve system operation as defined by the Construction Documents.
13. Provide support and coordination for TAB contractor. Provide all devices and all software for the TAB to use in completing TAB procedures.
14. Participate in the Functional Performance Tests as required to achieve compliance with Construction Documents.
15. Participate in the off-season mode testing as required to achieve compliance with Construction Documents.
16. Participate in O&M Training as required by project specifications. Include training on hardware operations and programming.
17. Ensure cooperation and participation of specialty sub-Trade Representatives such as ductwork, piping, refrigeration, and other applicable specialties.
18. Coordinate this commissioning program with the Electrical Trade Representative.
19. Attend initial pre-commissioning coordination meeting scheduled by the CxA.
20. Attend initial training session and conduct maintenance orientation and inspection at completion of equipment installation. Update drawings to existing conditions and review with the CxA prior to Substantial Completion.
21. Obtain O&M data on all equipment and assemble in binders using tabs as required. Submit to Designer of Record for approval prior to the distribution to the owner.
22. Conduct the specified orientation, inspection, demonstration, and training as requested by the owner. Update drawings to the existing conditions and review with the CxA prior to the inspection.
23. Notify the CxA of the time for start of the TAB work. Attend the initial TAB meeting for the review of the TAB procedures.
24. Participate in and schedule vendors and other Trade Representatives to participate in the training sessions set up by the contractor.
25. Conduct a Maintenance orientation and inspection with hands on training. Update drawings to the record condition to date and review with the Commissioning Agent prior to the orientation.
26. Attend all regularly scheduled commissioning coordination meetings.
27. Provide written confirmation that completed System Verification Checklists and manufacturers' checklists have been completed in accordance with the plans and specifications and that they are functioning as designed. Point-to-point verification and sequence of operations verification documents must be submitted to the CxA prior to executing Functional Performance Tests.
28. Demonstrate the performance of each piece of equipment to the contractor and Owner representatives. Schedule the TAB, Control, and other sub-Trade Representatives as may apply to demonstrate the performance of the equipment and systems.
29. Provide a set of accurate existing drawings to the Engineer of Record for inclusion into record documents.

E. Electrical Contractor - Electrical Trade Representative (EC)

1. Verify proper hardware specifications exist for performance as defined by the Construction Documents.
2. Verify proper safeties and interlocks are included in the design of electrical connections for HVAC equipment.
3. Attend commissioning meetings scheduled by the CxA.
4. Verify proper installation and performance of all electrical services provided.

5. Assist CxA in execution of System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of HVAC and electrical equipment.
6. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve compliance with Construction Documents.
7. Provide an electrical system technician to assist during verification performance testing.
8. Participate in the Functional Performance Tests as required to achieve compliance with Construction Documents.
9. Participate in the off-season mode testing as required to achieve compliance with Construction Documents.
10. Participate in O&M Training as required by project specifications.
11. Ensure cooperation and participation of specialty trade representatives.
12. Ensure participation of major equipment manufacturers and their representatives.
13. Coordinate this commissioning program with the Mechanical Trade Representative.
14. Attend initial pre-commissioning coordination meeting scheduled by the Commissioning Agent. Prepare necessary preliminary schedule for Maintenance orientation and inspections, O & M manual submission, training sessions, test, and job completion for use by the Commissioning Agent. Update schedule as appropriate throughout the construction period.
15. Attend initial training session and conduct maintenance orientation and inspection at the equipment placement completion stage. Update drawings to the record condition, to date, and review with the Commissioning Agent prior to the Maintenance orientation and inspection meeting.
16. Obtain O & M data on all equipment and assemble in binders using tabs as required. Submit to Engineer of Record for approval prior to the Distribution completion stage.
17. Conduct the second Maintenance orientation and inspection at the Distribution completion stage. Update drawings to the record condition, to date, and review with the Commissioning Agent prior to the inspection.
18. Participate in and schedule vendors and other Trade Representatives to participate in the training sessions set up by the Commissioning Agent.
19. Conduct a Maintenance orientation and inspection with hands on training. Update drawings to the record condition to date and review with the Commissioning Agent prior to the orientation.
20. Attend all regularly scheduled commissioning coordination meetings.
21. Provide written certification and completed System Verification Checklists and checklists documenting that the following work has been completed in accordance with the plans and specifications and that they are functioning as designed. This certification must be submitted to the Commissioning Agent prior to the final verification:

    a. Correct labeling of all circuits with connected equipment.

22. Demonstrate the performance of each piece of equipment to the Commissioning Agent. Schedule sub-Trade Representatives as may apply to demonstrate the performance of the equipment and systems.
23. Provide set of record mark-ups to the Engineer of Record for inclusion into record documents.

END OF SECTION 230800

SECTION 230900R - INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes, but is not limited to the furnishing of all material equipment and services necessary for the complete installation of a system of automatic temperature controls and monitor equipment for the following basic systems:

1. Packaged Roof-Top Units
2. Makeup Air Units.
3. Ventilating/Exhaust Fans including intake dampers indicated for BAS controls
4. Gas Unit Heaters
5. Gas Radiant Tube Unit Heaters
6. Electric Radiant Ceiling Panels

B. Equipment not on BAS:

1. Dust Collection Systems
2. Welding Fume Extraction System
3. High Volume Low Speed (HVLS) Fans
4. Ductless Split Heat Pump Systems
5. Ventilating/Exhaust Fans indicated for local, manual or occupancy controls
6. Lighting Controls

C. Related Sections:

1. Section 230800 “Commissioning of Mechanical and Electrical Systems” for requirements that relate to this Section.
2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to this Section.

D. The Contractor shall provide all control wiring as required for a complete and fully functional system, including but not limited to all HVAC equipment, sensors, transducers, controllers, panels, and interface modules.

1.2 DEFINITIONS

A. BACnet: a communications protocol, defined by ANSI / ASHRAE™ Standard 135-2004

B. BAS: Building Automation System

C. DDC: Direct Digital Controls

D. GUI: Graphical User Interface

E. IPsec: Internet Protocol Security

F. JACE: Java Application Control Engine

G. MSTP: Master Slave Token Passing Protocol DDC – Direct Digital Controls – Also inferred to mean HVAC Controls, Building Automation System, Controls, Temperature Controls, etc.

H. TCC – Temperature Controls Contractor. Also inferred to mean HVAC Controls Contractor, BAS Contractor, Controls Contractor, Installer, etc.

I. TCP/IP: Transmission Control Protocol/Internet Protocol

J. UNC: Universal Network Controller VPN: Virtual Private Network

1.3 SUBMITTALS

A. Shop Drawings:

1. Include manufacturer's technical literature for each control device.
2. Bill of materials of equipment indicating quantity, manufacturer, and model number, cross referenced to Component Tag on Plans.
3. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and all other control devices.
4. Wiring Diagrams: Power, signal, and control wiring, with wire number identification.
5. Written description of sequence of operation, and either: 1) programming ladder logic diagrams, or 2) control logic block diagrams, fully populated with initial set- point and control values.
6. Schedule of dampers and valves including size, leakage, torque requirements and flow characteristics.
7. DDC System Hardware:

    a. Wiring diagrams for control units with termination numbers.
    b. Schematic diagrams and scaled floor plans for field sensors and control hardware.
    c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
    d. Points list.

8. Control System Software:

    a. Summary List of Standard Graphic Palettes being utilized.
    b. Summary List of points to be displayed on each Standard Graphic.
    c. Summary List of all Custom Graphics to be developed, including:

        1) Floor Plans
        2) RTU Schematics
        3) Makeup Air Units
        4) Gas Radiant Tube Heaters

    d. Summary list of points to be displayed on these custom graphics.

9. Data Communications Protocol Certificates: Certify that proposed DDC system component complies with BACnet standards.
10. Project Work Schedule: Provide a Gantt or Critical Path Work Schedule developed in conjunction with the Divisions 23 and 26 Contractors demonstrating the plan to have the HVAC systems installed and operational in ample time to complete functional performance tests prior to the substantial completion deadline; and ample time between substantial and final completion for the Commissioning Team to complete functional testing.

B. Operation and maintenance data. For instrumentation and control system components to include in emergency, operation, and maintenance manuals. Include the following:

1. Maintenance instructions and lists of spare parts for each type of control device.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

C. Field quality-control checklists.

1.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Controls Provider Qualifications: The control systems provider shall be the controls manufacturer's authorized representative, who is trained and approved for installation of the system components required for this Project. The Controls Provider will be responsible for the installation quality and warranty.

1. The Controls Provider shall have a minimum rated qualification of five (5) years of installation experience with the manufacturer and shall provide documentation in the submittal package verifying longevity of the installing company's relationship with the manufacturer.
2. Supervision, calibration, and checkout of the system shall be by the employees of the Controls Provider.
3. The Controls Provider shall have a full-service facility within Kentucky or surrounding States that is staffed with engineers/technicians trained in integrating interoperable systems and fully capable of providing BACnet programming and instruction.
4. The Controls Provider shall have support within 200 statute miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment to perform routine and emergency maintenance service on all system components.

C. Where DDCs are specified as factory mounted equipment, the Controls System Supplier is responsible for coordinating all controls, actuators, valve assemblies, and sensors specified are fully compatible and shall be capable of seamless interfacing with all BACnet protocol requirements specified.

PART 2 - PRODUCTS

2.1 SYSTEM ARCHITECTURE

A. BAS shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in ANSI/ASHRAE Standard 135-2001 BACnet network with architecture below.

B. Zone Controls (Level 1) data shall be uploaded to Field Cabinets (Level 2) at a rate required to successfully implement the specified sequence of operation and no less than every two (2) minutes.

C. Field Cabinets (Level 2) shall contain sufficient memory to implement the specified sequence of operations and be capable of trending all physical points with full loading of all connected zone controllers on five (5) minute intervals. Additionally, the field cabinets shall be able to store and time stamp this trended data over a 24-hour duration. Field Cabinets shall be BACNet.

D. Front End (Level 3) Software shall reside on a PC and/or server, capable of running robust high speed hardware Ethernet data link using open standard TCP/IP connections. BACnet open protocol is a requirement for Level 3.

2.2 ALARM MANAGER

A. Provide an alarm manager that displays prioritized alarms with descriptions, equipment, and time-date stamp and allows acknowledgment.

2.3 WEB ACCESSIBLE INTERFACES

A. Provide web accessible and mobile device interfaceable HVAC zone temperature control screens.

B. Provide a screen(s) that shows the entire floor plan, shows all temperature-controlled zones (boundaries), shows sensor location for each zone, indicates equipment dedicated for each zone, and displays the space temperature with the color coding described below. This shall be indicated on an accurate, scale floor plan that several Owner representatives can easily understand space temperatures, alarms, and change temperature settings. With a higher tier password, this screen can lead to additional screens for equipment, sensors, systems, etc.

2.4 DDC EQUIPMENT

A. Acceptable Manufacturers:

1. Alerton Inc.
2. Distech
3. Reliable Controls Corporation
4. Schneider
5. Trane
6. Engineer’s Pre-Approved equal.

B. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.

1. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation.
2. Stand-alone mode control functions operate regardless of network status. Functions include the following:

    a. Global communications.
    b. Discrete/digital, analog, and pulse I/O.
    c. Monitoring, controlling, or addressing data points.
    d. Software applications, scheduling, and alarm processing.
    e. Testing and developing control algorithms without disrupting field hardware and controlled environment.

C. Local Control Units: Modular, comprising processor board with electronically programmable, nonvolatile, read-only memory; and backup power source.

1. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.

2. Stand-alone mode control functions operate regardless of network status. Functions include the following:

   a. Global communications.
   b. Discrete/digital, analog, and pulse I/O.
   c. Monitoring, controlling, or addressing data points.

3. Local operator interface provides for download from or upload to operator workstation.

D. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.

1. Binary Inputs: Allow monitoring of on-off signals without external power.
2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
3. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation.
5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA).
6. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
7. Universal I/Os: Provide software selectable binary or analog outputs.

E. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity.

1. Basis of Design: Functional Devices, Inc. Model PSH500A.

2.5 OWNERSHIP OF SOFTWARE, TOOLKITS, LICENSES

A. It is a requirement that the ownership of all BAS controllers, software and licenses be in the name of Owner.

B. All programming intellectual property associated with the BAS software shall be tendered to and owned by Owner with full disclosure.

C. Owner shall be provided a copy of all the tool kits required to operate, adjust, and program all BAS products.

D. All software shall include a perpetual license and will be hosted on the supervisor.

E. Warranties of all BAS Hardware shall be in the name of Owner.

2.6 NETWORK REQUIREMENTS

A. Owner IT Standards apply to all elements of BAS installation where the BAS / Control device is networked on the Owner IT network.

B. Where sub-networks are established for communication between the networked controllers and lower-level controllers or devices; the Division 26 low voltage cabling, identification, pathways, and other applicable specifications shall apply.

C. The coordination of IP addresses, porting and other networking requirements shall be through the Owner IT representative.

D. Controls Provider Access

1. An authorized Controls Provider Technician / Engineer will be granted VPN access. Username and Password credentials will be provided to the appropriate service technicians.
2. The Controls Provider's network must meet certain IPsec requirements, access outside this IPsec network will be denied.
3. Password strength must meet certain minimum requirements.
4. Access will only be available until the Contract warranty period expires.

2.7 UNITARY CONTROLLERS

A. Unitary controllers shall be capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.

1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or card connected with ribbon cable; memory with bios; and 72-hour battery backup.
2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. Perform scheduling with real-time clock. Perform automatic system diagnostics; monitor system and report failures.
3. Enclosure: Dustproof.

2.8 ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Thermistor Temperature Sensors and Transmitters:

1. Manufacturers:

a. ACI
b. BEC Controls Corporation.
c. DDC Equipment.
d. MAMAC Systems, Inc.
e. RDF Corporation.
f. RE Technologies (Kele).
g. Approved equal.

2. Space Temperature Accuracy: Plus or minus 1 deg F at calibration point.
3. Ducted Air and Water Temperature Accuracy: Plus or minus 0.5 deg F at calibration point.
4. Wire: Twisted, shielded-pair cable.
5. Insertion Elements in Ducts: Single point, 8 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft.
6. Averaging Elements in Ducts: 18 inches long, rigid; use where prone to temperature stratification or where ducts are larger than 10 sq. ft.
7. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches.
8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.

9. Room sensors in public areas such as stairways, corridors, restrooms, etc., shall have wall sensors located in the area specified. Wall sensors shall be flush, stainless steel plate.

C. Humidity Sensors: Bulk polymer sensor element.

1. Manufacturers:

a. ACI.
b. BEC Controls Corporation.
c. General Eastern.
d. MAMAC Systems, Inc.
e. RE Technologies (Kele).
f. TCS/Basys Controls.
g. Approved equal.

2. Accuracy: 1 percent full range with linear output.
3. Room Sensor Range: 20 to 80 percent relative humidity.
4. Duct Sensor: 20 to 80 percent relative humidity range with element guard and mounting plate.
5. Outside-Air Sensor: 20 to 80 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of minus 22 to plus 185 deg F.

D. Pressure Transmitters/Transducers:

1. Manufacturers:

a. BEC Controls Corporation.
b. MAMAC Systems, Inc.
c. Modus.
d. Setra.
e. TCS/Basys Controls.
f. Approved equal.

2. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.

a. Water Pressure Sensor Accuracy: 1 percent of full scale
b. Duct Air Pressure Sensor Accuracy: 0.01” wg
c. Output: 4 to 20 mA.
d. Duct Static-Pressure Range: 0- to 5-inch wg.

3. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure; linear output 4 to 20 mA.
4. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure and tested to 300-psig; linear output 4 to 20 mA. Provide with three valve bypass assembly.
5. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
6. Pressure Transmitters: Direct acting for gas or liquid service; range suitable for system; linear output 4 to 20 mA.

2.9 STATUS SENSORS

A. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.

B. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.

C. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.

D. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

2.10 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.

1. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
2. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
3. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
4. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
5. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.

B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.

1. Manufacturers:

    a. Belimo Aircontrols (USA), Inc.
    b. Honeywell.
    c. RE Technologies (Kele).
    d. Approved equal.

2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
3. Dampers: Size for running torque calculated as follows:

    a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
    b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
    c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft of damper.
    d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
    e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.
    f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.

4. Coupling: V-bolt and V-shaped, toothed cradle.
5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
6. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
7. Power Requirements (Two-Position Spring Return): 24 or 120-V ac.
8. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.

9. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
10. Temperature Rating: 40 to 104 deg F.
11. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F.
12. Run Time: Based on application.

2.11 DAMPERS

A. Manufacturers:

1. Air Balance Inc.
2. Greenheck.
3. Ruskin
4. TAMCO (T. A. Morrison & Co. Inc.).
5. United Enertech Corp.
6. Approved equal.

B. Dampers: AMCA-rated, opposed-blade design; 0.108-inch- minimum thick, galvanized-steel or 0.125-inch- minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch- thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.

1. Secure blades to 1/2-inch- diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Operating Temperature Range: From minus 40 to plus 200 deg F.
3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4-inch wg when damper is held by torque of 50 in. x lbf; when tested according to AMCA 500D.

2.12 CONTROL CABLE

A. Data Line Cable: Shielded, twisted-pair cable or other media recommended by manufacturer.

B. Low-Voltage Control Cable: Multiple conductor, color-coded, No. 20 AWG copper, minimum.

1. Conductor Sheath: Metallic conduit for exposed cable routing, such as in mechanical rooms.
2. Ordinary switching Circuits: Three conductors, unless otherwise required.
3. Switching Circuits with Pilot Lights or Locator Feature: Five conductors, unless otherwise required.

C. Cables above ceiling shall be Plenum Rated.

2.13 CONTROL ENCLOSURES

A. Unitized NEMA 1 cabinet with suitable brackets for wall or floor mounting, located adjacent to each system under automatic control. Provide common keying for all panels.

B. Label all control panels in accordance with Section “Identification of Electrical Systems”. Provide each panel with unique number or designation.

C. Control enclosures shall be fabricated and UL listed per NFPA 70 requirements.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices above the floor, as specified on drawings.

B. Install automatic dampers.

C. Install damper motors on outside of duct in indoor areas, unless inside AHU in accessible section.

D. Install labels and nameplates to identify control components.

E. Install electronic cables according to manufacturer's recommendations.

3.2 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install signal and communication cable according to the following:

1. Conceal cable, except in mechanical rooms and areas where other conduit is exposed.
2. Cable above ceilings may be installed in J-hooks, D-rings, or cable tray.
3. Low-voltage wiring in existing stud walls may be fished to thermostat location without conduit.
4. Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.
5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of equipment.

B. Install 120V power wiring according to the following:

1. Route in conduit.
2. Electrical work required for interlocks and operation of temperature control system shall be provided by Temperature Controls Contractor (TCC) in accordance with Division 26, Electrical and all National and Local codes enforced by the Authority Having Jurisdiction (AHJ).
3. 120V power for HVAC controls not indicated on E Drawings shall be provided by the TCC and be fed from dedicated circuits in the new or existing distribution panels and not connected to circuits for receptacles or lighting. Label the circuits used within the distribution panels and coordinate their selection with the Division 26 contractor.Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

C. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.3 Calibrating and adjusting.

A. Calibrate instruments.

1. Make three-point calibration test for both linearity and accuracy for each analog instrument.
2. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
3. Control system inputs and outputs:

    a. Check analog inputs at 0, 50, and 100 percent of span.
    b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
    c. Check digital inputs using jumper wire.
    d. Check digital outputs using ohmmeter to test for contact making or breaking.
    e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.

4. Temperature:

    a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
    b. Calibrate temperature switches to make or break contacts.

5. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
6. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
7. Provide diagnostic and test instruments for calibration and adjustment of system.
8. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Coordinate with CxA for all functional performance tests.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
2. Test and adjust controls and safeties.
3. Test calibration of controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
4. Test each point through its full operating range to verify that safety and operating control set points are as required.
5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
6. Test each system for compliance with sequence of operation.
7. Test software and hardware interlocks.

C. DDC Verification:

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check instrument tubing for proper fittings, slope, material, and support.
5. Check temperature instruments and material and length of sensing elements.
6. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment has been provided.
7. Check DDC system as follows:

    a. Verify that DDC controller power supply is from emergency power supply, if applicable.
    b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
    c. Verify that spare I/O capacity has been provided.
    d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.5 TRAINING

A. Provide a minimum of twelve (12) hours of on-site or classroom training throughout the contract period for personnel designated by the Owner. Each session must be coordinated with the building Owner. Train the designated staff of Owners Representative and Owner to enable them to:

1. Proficiently operate the system.
2. Understand control system architecture and configuration.
3. Understand DDC system components.
4. Understand system operation, including DDC system control and optimizing routines (algorithms).
5. Log on and off the system.
6. Access graphics point reports and logs.
7. Adjust and change system set points, time schedules, and holiday schedules.
8. Recognize malfunctions of the system by alarm log and graphical visual signals.
9. Understand system drawings and Operation and Maintenance manual.
10. Understand the system layout and location of control components.
11. Access data from DDC controllers.

3.6 WARRANTY AND MAINTENANCE REQUIREMENTS

A. All components, system software, and parts furnished and installed by the Control Systems Supplier shall be guaranteed against defects in materials and workmanship for one (1) year of substantial completion unless extended warranty by owner or manufacturer is greater than one (1) year. Labor to repair, re-program, or replace these components shall be furnished by the Control Systems Supplier at no charge during normal working hours during the warranty period.

B. Materials furnished but not installed by the Control Systems Supplier shall be covered by warranty to the extent of the product only. Installation labor shall be the responsibility of the trade contractor performing the installation.

C. All corrective software modifications made during warranty periods shall be updated on all user documentation and on user and manufacturer archived software disks.

D. Occupancy Adjustments: Within one year of date of Substantial Completion, provide up to three (3) project site visits, when requested by Owner, to adjust and calibrate components and to assist Owner's personnel in making program changes and in adjusting sensors and controls to suit actual conditions.

E. The Control Systems Supplier shall respond to the owner's request for warranty service within forty-eight (48) standard working hours. Emergency service shall be available within twenty-four (24) hours.

F. Any changes made to the control system, including set-points, programming, schedules, or calibrations shall be documented on the Owner’s work order to clarify the adjustments made in addition to updating user documentation.

END OF SECTION 230900

SECTION 230993 – SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes control sequences of operation for HVAC systems, subsystems, and equipment:

1. Packaged Roof-Top Units
2. Makeup Air Units.
3. Ventilating/Exhaust Fans including intake dampers indicated for BAS controls
4. Gas Unit Heaters
5. Gas Radiant Tube Unit Heaters
6. Electric Radiant Ceiling Panels

B. See 230900 "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

C. The Contractor shall be responsible for providing all materials, equipment, and labor to complete all project requirements listed within this Section.

D. Temperature Controls Contractor shall provide the devices indicated on the Drawings and those required for these sequences.

1.2 OCCUPANCY SCHEDULES

A. CTE Building Occupancy Schedule shall be Occupied Mode Monday-Friday 7:00am – 5:00pm and Unoccupied Mode at other times.

B. Alternative School Building Occupancy Schedule shall be Occupied Mode Monday-Friday 7:00am – 5:00pm and Unoccupied Mode at other times.

C. Other areas shall have the ability to be scheduled but shall initially be in occupied mode continuously.

D. Scheduler shall allow programming of occupied/ non-occupied times for each RTU zone.

E. Scheduler shall have these features:

1. Times, setpoints and other parameters are to be adjustable.
2. Editable for holidays or scheduled events.
3. Daylight savings automatic adjustment.

PART 2 - SEQUENCES OF OPERATIONS

2.1 PACKAGED ROOF TOP UNITS (RTUs)

A. Start Up: Upon start up command,

1. Supply fan starts and is proven.
2. Temperature control sequence activates.

B. Shut Down: Upon shut down command,

1. Supply fan stops.
2. Compressor stops and outside air damper closes.

C. Supply Fan Control

1. Supply Fan Start/Stop

a. Supply fan shall run when system is in the Occupied Mode, Setup Mode, and Setback Mode (i.e., all modes except unoccupied).

2. Zone Temperature Control

a. Operate compressor and gas heat by factory controls to maintain zone temperature at setpoint.
b. During Occupied Mode, Setup and Setback Modes, occupied mode setpoints shall be used.
c. During Unoccupied Mode, unoccupied mode setpoints shall be used.

D. Outside Air Control

a. During occupied mode, outside air damper shall open to position determined during TAB to achieve outside air design airflow indicated on RTU Schedule on drawings.
b. During unoccupied mode, including setup and setback, outside air damper shall be closed.

E. Economizer Mode

1. Modulate outside and return air dampers when it is possible to use free cooling of outside air.
2. Economizer shall be limited by outside air dew point.
3. Economizer shall be integrated so that mechanical cooling is enabled if economizer is not able to meet cooling demand.

F. Unoccupied Operation

1. In the unoccupied mode, the unit shall be shut off. If the space temperature as sensed by the zone sensor exceeds the unoccupied cooling setpoint of 80°F or drops below the unoccupied heating setpoint of 58°F, the fan shall start and the heating or cooling valve shall modulate for either heating or cooling until the unoccupied setpoint is reached.

M. Override Operation – When override is initiated at a thermostat, the unit shall operate as if in occupied mode for 2 hours or other time duration programmed.

N. Safeties:

1. Provide alarm if temperature varies 5 °F (adj.) from set-point.
2. The following safeties shut down supply fan and activate shut down sequence:

a. Drain pan float switch.

b. Overhead door open switch (RTU-A6 serving Multi-purpose Room only). Provide switch with a binary input point.

O. Operator interface: Display the following data for each unit (as applicable):

1. System graphic.

2. System occupied/unoccupied mode indication.
3. System on-off indication.
4. System fan on-off command and status indication.
5. Outside air temperature indication.
6. Compressor indication (stages on).
7. Return air temperature and relative humidity indication.
8. Supply air and Outside Air Temperatures Reset Max & Min Parameters
9. Discharge air temperature indication. (°F)
10. Outside air damper position.
11. Ambient air dewpoint temperature indication
12. Alarm output for failure.

2.3 MAKEUP AIR UNIT

A. Sequence:

1. Unit shall operate to maintain room temperature at 60F during occupied mode when outside air temperature is below 50F.
2. Unit shall operate heating under its factory-mounted controls.

B. Operator Interface: Display the following on operator workstation display terminal:

1. System graphic.
2. System on-off indication.
3. System exhaust fan on-off command and status indication.
4. System heat command and status indication.
5. Alarm for failures.

2.4 VENTILATING / EXHAUST FANS

A. Ventilating fans shall operate per the control method indicated in the equipment schedule.

B. Ventilating fans indicated for “BAS” control shall be controlled and monitored by the BAS as indicated in this Section. Furnish and install current monitors to verify unit operation.

1. EF-13 (SBCA): Temperature-based thermostat.
2. EF-15 (Training Tower): Temperature-based thermostat with ability for local override operation. Open damper in L-2 when EF-15 operates
3. EF-16 (Storage): Operate 4 hours per day (adjustable) to reduce build-up of vapors of potential hazardous storage. Open damper in L-3 when EF-16 operates.
4. EF-17A and EF-17B (Apparatus Bay):

    a. Operate fans in stages when either of the following occurs.

        1) Zone temperature exceeds 80F
        2) Carbon monoxide (CO) level exceeds 50 ppm
        3) Nitrogen dioxide (NO2) exceeds 5 ppm

    b. Operate one fan initially and operate the second one as required based on control loop.
    c. Open associated intake damper (L-1A or L-1B) for each fan for cross-flow in the apparatus bay when the respective fan operates.

5. EF-19 (Mezzanine): Temperature-based thermostat. Open damper in L-4 when EF-19 operates.

C. Ventilation Fans EF-C6 (Ag Lab), EF-C9 (Welding Lab), and EF-C10 (Construction Lab)

1. These fans shall each operate by the on/off/auto switch for each.

   a. Auto mode – When the ventilation set-point temperature is exceeded for the space, the fan shall start and operate continuously until the space temperature falls below the set-point.
   b. On Mode – Fan shall operate continuously.
   c. Off Mode – Fan shall not operate.

2. Associated Damper: Open the damper of the associated louver or hood as indicated in Ventilating Fan Schedule before the fan operates.
3. Operator Interface: Display the following data:

   a. System graphic.
   b. Ventilation on-off indication.
   c. Space temperature indication.
   d. Space set-point temperature 78°F, (adjustable).
   e. Fan status indication.
   f. Alarm for fan failure or space temperatures that exceed 95°F, (adjustable).

D. Operator interface: Display the following data for each unit (as applicable):

1. System Graphic.
2. Space temperature.
3. Unit status (on/off) – via CT Meter.
4. Damper position command and status indication (open/closed)

2.5 GAS RADIANT TUBE AND UNIT HEATERS

A. Sequence:

1. Heaters shall operate based on a local thermostat and have remote monitoring through BAS.

B. Operator Interface: Display the following data:

1. System graphic.
2. Space temperature indication.
3. Space temperature set-point.
4. Unit command and status.
5. Alarm for low space temperature, 40°F, adjustable.

2.6 ELECTRIC RADIANT CEILING PANELS

A. Sequence:

1. Heaters shall operate based on a local thermostat and have remote monitoring through BAS.

B. Operator Interface: Display the following data:

1. System graphic.
2. Space temperature indication.
3. Space temperature set-point.
4. Unit command and status.

5. Alarm for low space temperature, 40°F, adjustable.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993

SECTION 231123 - FACILITY NATURAL-GAS PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Pipes, tubes, and fittings.
2. Piping and tubing joining materials.
3. Valves.
4. Pressure Regulators.

B. This section also applies to propane piping.

1.2 PERFORMANCE REQUIREMENTS

A. Minimum Operating-Pressure Ratings:

1. Piping and Valves: 100 psig minimum unless otherwise indicated.

1.3 SUBMITTALS

A. Welding certificates.

B. Operation and maintenance data.

1.4 QUALITY ASSURANCE

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

B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.

1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.

B. PE Pipe: ASTM D 2513, SDR 11.

1. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.
2. PE Transition Fittings: Factory-fabricated fittings with PE pipe complying with ASTM D 2513, SDR 11; and steel pipe complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
3. Anodeless Service-Line Risers: Factory fabricated, and leak tested.

    a. Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet.
    b. Casing: Steel pipe complying with ASTM A 53/A 53M, Schedule 40, black steel, Type E or S, Grade B, with corrosion-protective coating covering. Vent casing aboveground.
    c. Aboveground Portion: PE transition fitting.
    d. Outlet shall be threaded or suitable for welded connection.
    e. Tracer wire connection.
    f. Ultraviolet shield.
    g. Stake supports with factory finish to match steel pipe casing or carrier pipe.

4. Transition Service-Line Risers: Factory fabricated, and leak tested.

    a. Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet connected to steel pipe complying with ASTM A 53/A 53M, Schedule 40, Type E or S, Grade B, with corrosion-protective coating for aboveground outlet.
    b. Outlet shall be threaded or suitable for welded connection.
    c. Bridging sleeve over mechanical coupling.
    d. Factory-connected anode.
    e. Tracer wire connection.
    f. Ultraviolet shield.
    g. Stake supports with factory finish to match steel pipe casing or carrier pipe.

2.2 JOINING MATERIALS

A. Joint Compound and Tape: Suitable for natural gas.

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

2.3 MANUAL GAS SHUTOFF VALVES

A. See "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.

B. General Requirements for Metallic Valves, NPS 2 and Smaller: Comply with ASME B16.33.

1. CWP Rating: 125 psig.
2. Threaded Ends: Comply with ASME B1.20.1.
3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
4. Tamperproof Feature: Locking feature for valves indicated in "Aboveground Manual Gas Shutoff Valve Schedule" Articles.

C. Bronze Plug Valves: MSS SP-78.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Lee Brass Company.
    b. McDonald, A. Y. Mfg. Co.
    c. Approved equal.

2. Body: Bronze, complying with ASTM B 584.
3. Plug: Bronze.
4. Ends: Threaded, socket, as indicated in Aboveground Manual Gas Shutoff Valve Schedule" Articles.
5. Operator: Square head or lug type with tamperproof feature.
6. Pressure Class: 125 psig.
7. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

2.4 PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for natural gas.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for regulators NPS 2 and smaller.

B. Line Pressure Regulators: Comply with ANSI Z21.80.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. American Meter Company.
    b. Fisher Control Valves and Regulators; Division of Emerson Process Management.
    c. Richards Industries; Jordan Valve Div.
    d. Approved equal.

2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: as specified on drawings.

2.5 DIELECTRIC UNIONS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Capitol Manufacturing Company.

2. Hart Industries International, Inc.
3. McDonald, A. Y. Mfg. Co.
4. Watts Regulator Co.
5. Wilkins; Zurn Plumbing Products Group.
6. Approved equal.

B. Minimum Operating-Pressure Rating: 150 psig.

C. Combination fitting of copper alloy and ferrous materials.

D. Insulating materials suitable for natural gas.

E. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.

2.6 SLEEVES

A. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.

PART 3 - EXECUTION

3.1 OUTDOOR PIPING INSTALLATION

A. Comply with National Fuel Gas Code, NFPA 54 for installation and purging of natural-gas piping.

B. Underground natural-gas piping shall be one of the following:

1. PE pipe and fittings joined by heat fusion; service-line risers with tracer wire terminated in an accessible location.
2. Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

C. Aboveground natural-gas piping shall be one of the following:

1. Steel pipe with malleable-iron fittings and threaded joints.
2. Steel pipe with wrought-steel fittings and welded joints.

D. Install underground, natural-gas piping buried at least 36 inches below finished grade.

E. Install underground, PE, natural-gas piping according to ASTM D 2774.

F. Install fittings for changes in direction and branch connections.

G. Exterior-Wall Pipe Penetrations: Seal penetrations using steel pipe sleeves and caulk. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve.

3.2 INDOOR PIPING INSTALLATION

A. Aboveground, branch piping NPS 1 and smaller shall be the following:

1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
2. Steel pipe with malleable-iron fittings and threaded joints.

B. Aboveground, distribution piping shall be one of the following:

1. Steel pipe with malleable-iron fittings and threaded joints.
2. Steel pipe with wrought-steel fittings and welded joints.

C. Comply with National Fuel Gas Code, NFPA 54 for installation and purging of natural-gas piping.

D. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations.

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

F. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

G. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

H. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

I. Locate valves for easy access.

J. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.

K. Install piping free of sags and bends.

L. Install fittings for changes in direction and branch connections.

M. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.

N. Verify final equipment locations for roughing-in.

O. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

P. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.

1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 6 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.

Q. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.

R. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.

S. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.

T. Connect branch piping from top or side of horizontal piping.

U. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment.

V. Do not use natural-gas piping as grounding electrode.

W. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.

X. Prepare, prime, and paint all exposed piping, hangers, and supports. Color shall be selected by Architect.

3.3 VALVE INSTALLATION

A. Install overpressure protection devices with maintenance access space adequate for servicing and testing.

3.4 PIPING JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Threaded Joints:

1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
2. Cut threads full and clean using sharp dies.
3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

D. Welded Joints:

1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
2. Bevel plain ends of steel pipe.
3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

E. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.

1. Plain-End Pipe and Fittings: Use butt fusion.

3.5 HANGER AND SUPPORT INSTALLATION

A. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 1 and Smaller: Maximum span, 96 inches; minimum rod size, 3/8 inch.
2. NPS 1-1/4: Maximum span, 108 inches; minimum rod size, 3/8 inch.

3. NPS 1-1/2 and NPS 2: Maximum span, 108 inches; minimum rod size, 1/2 inch.

3.6 CONNECTIONS

A. Connect to utility's gas main according to utility's procedures and requirements.

B. Install natural-gas piping electrically continuous and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.

C. Install piping adjacent to appliances to allow service and maintenance of appliances.

D. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 48 inches of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.

E. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.7 LABELING AND IDENTIFYING

A. Identify piping as to contents and flow direction as specified in Section “Identification for Mechanical Piping and Equipment.”

B. Install continuous tracer wire on underground piping. Secure ends of tracer wire on each end to prevent accidental damage.

3.8 FIELD QUALITY CONTROL

A. Test, inspect, and purge natural gas according to the NFPA 54, National Fuel Gas Code and authorities having jurisdiction.

B. Natural-gas piping will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.9 OUTDOOR PIPING SCHEDULE

A. Underground natural-gas piping shall be one of the following:

1. PE pipe and fittings joined by heat fusion; service-line risers with tracer wire terminated in an accessible location.

B. Aboveground natural-gas piping NPS 2 and Smaller shall be the following:

1. Steel pipe with malleable-iron fittings and threaded joints.

C. Above ground natural-gas piping exposed to greater than 14-inch wc normal operation.

1. Steel pipe with wrought-steel fittings and welded joints.

3.10 INDOOR PIPING SCHEDULE

A. Aboveground, branch, and distribution piping shall be the following:

1. NPS 2½ and Larger: Steel pipe with wrought-steel fittings and welded joints.
2. Any size pipe exposed to greater than 14-inch wc pressure for normal operation: Steel pipe with wrought steel fittings and welded joints.

3.11 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Valves for pipe sizes NPS 4 and smaller at service meter shall be the following:

1. Bronze plug valve.

B. Distribution piping valves for pipe sizes NPS 4 and smaller shall be one of the following:

1. Bronze plug valve.

C. Valves in branch piping for single appliance shall be one of the following:

1. Bronze plug valve.

END OF SECTION 231123

SECTION 232113 - CONDENSATE PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:

1. Condensate-drain piping.

1.2 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Condensate-Drain Piping: 150 deg F.

PART 2 - PRODUCTS

2.1 PLASTIC PIPE AND FITTINGS

A. PVC Plastic Pipe: ASTM D 1785, Schedules 40 and 80, plain ends as indicated in Part 3 "Piping Applications" Article.

B. PVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe; ASTM D 2467 for Schedule 80 pipe.

C. PVC Solvent Cement: ASTM D 2564.

2.2 JOINING MATERIALS

A. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

B. Solvent Cements for Joining Plastic Piping:

1. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Condensate-Drain Piping: Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

3.2 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

C. Install piping at indicated slopes.

D. Install piping free of sags and bends.

E. Install fittings for changes in direction and branch connections.

F. Reduce pipe sizes using concentric reducer fitting installed with flat side on bottom.

G. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the side of the main pipe.

H. Identify piping as to contents and flow direction.

3.3 PAINTING

A. Paint outdoor PVC condensate pipe with a white, water-based latex paint to protect from UV degradation.

3.4 HANGERS AND SUPPORTS

A. Install the following pipe attachments:

1. On plastic pipe, install pads or cushions on bearing surfaces to prevent hanger from scratching pipe.

B. Plastic Piping Hanger Spacing: Space hangers according to pipe manufacturer's written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.

3.5 PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. PVC Nonpressure Piping: Join according to ASTM D 2855.

3.6 EQUIPMENT CONNECTIONS

A. Piping shall be the same size or larger than equipment connections.

3.7 FIELD QUALITY CONTROL

A. Flush piping systems with clean water; then remove and clean or replace strainer screens.

END OF SECTION 232113

SECTION 232300 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes refrigerant piping used for air-conditioning applications.

1.2 PERFORMANCE REQUIREMENTS

A. Line Test Pressure for Refrigerant R-410A:

1. Suction Lines for Air-Conditioning Applications: 315 psig.
2. Hot-Gas and Liquid Lines: 550 psig.

1.3 SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop based on manufacturer's test data.

1. Refrigerant piping indicated on Drawings is schematic only. Size piping layout, including oil traps, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment and in compliance with manufacturer’s requirements.

B. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. Comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

B. Comply with ASHRAE 34 “Designation and Safety Classification of Refrigerants.”

C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.5 PRODUCT STORAGE AND HANDLING

A. Store piping in a clean and protected area with end caps in place to ensure that piping interior and exterior are clean when installed.

PART 2 - PRODUCTS

2.1 COPPER PIPE AND FITTINGS

A. Copper Tube: ASTM B 280, Type ACR.

B. Wrought-Copper Fittings: ASME B16.22.

C. Wrought-Copper Unions: ASME B16.22.

D. Brazing Filler Metals: AWS A5.8.

2.2 VALVES AND SPECIALTIES

A. Isolation Valves:

1. Body and Bonnet: Forged brass or cast bronze.
2. Packing: Molded stem, back seating, and replaceable under pressure.
3. Operator: ¼ Turn.
4. Seat: Non-rotating, self-aligning polytetrafluoroethylene.
5. Seal Cap: Forged-brass or valox hex cap.
6. End Connections: Brazed.
7. Working Pressure Rating: 850 psig.
8. Maximum Operating Temperature: 300 deg F.

2.3 REFRIGERANTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Atofina Chemicals, Inc.
2. DuPont Company.
3. Honeywell, Inc.
4. Approved equal.

B. ASHRAE 34, R-410A: Azeotrope.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Suction, Hot Gas, and Liquid Lines for Conventional Air-Conditioning Applications: Copper, Type ACR, hard-temper piping and wrought-copper fittings with brazed joints.

3.2 VALVE AND SPECIALTY APPLICATIONS

A. Install isolation valves in suction, discharge and liquid lines of each terminal unit as specified.

3.3 PIPING INSTALLATION

A. Install refrigerant piping according to ASHRAE 15.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping adjacent to machines to allow service and maintenance.

F. Install piping free of sags and bends.

G. Install fittings for changes in direction and branch connections.

H. Select system components with pressure rating equal to or greater than system operating pressure.

I. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

J. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels if valves or equipment requiring maintenance are concealed behind finished surfaces.

K. Slope refrigerant piping as follows:

1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
2. Install horizontal suction lines with a uniform slope downward to compressor.
3. Install traps to entrain oil in vertical runs.
4. Liquid lines may be installed level.

L. When brazing, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

M. Install pipe sleeves at penetrations in interior and exterior walls and floor assemblies as specified in Section “Common Work Results for Mechanical”.

N. Seal penetrations through fire and smoke barriers as required by code.

O. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.

P. Install sleeves through floors, walls, or ceilings, sized to permit installation of full-thickness insulation.

Q. Seal pipe penetrations through exterior walls as specified in Section “Common Work Results for Mechanical”.

R. Identify refrigerant piping and valves as specified in Section “Identification for Mechanical Piping and Equipment”.

3.4 PIPE JOINT CONSTRUCTION

A. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."

1. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper pipe.
2. Use Type BAg, cadmium-free silver alloy for joining copper with bronze.

3.5 HANGERS AND SUPPORTS

A. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
2. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

B. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:

1. NPS 1/4: Maximum span, 60 inches; minimum rod size, 3/8 inch.
2. NPS 3/8: Maximum span, 60 inches; minimum rod size, 3/8 inch.
3. NPS 1/2: Maximum span, 60 inches; minimum rod size, 3/8 inch.
4. NPS 5/8: Maximum span, 60 inches; minimum rod size, 3/8 inch.
5. NPS 3/4: Maximum span, 60 inches; minimum rod size, 3/8 inch.
6. NPS 7/8: Maximum span, 60 inches; minimum rod size, 3/8 inch.
7. NPS 1: Maximum span, 72 inches; minimum rod size, 3/8 inch.
8. NPS 1-1/8: Maximum span, 72 inches; minimum rod size, 3/8 inch.

3.6 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Comply with ASME B31.5, Chapter VI.
2. Test refrigerant piping and specialties. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in Part 1 "Performance Requirements" Article.

    a. Fill system with nitrogen to the required test pressure.
    b. System shall maintain test pressure at the manifold gage throughout duration of test.
    c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
    d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

3.7 SYSTEM CHARGING

A. Charge system using the following procedures:

1. Install core in filter dryers after leak test but before evacuation.
2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
4. Charge system with a new filter-dryer core in charging line.

3.8 ADJUSTING

A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.

B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.

C. Adjust set-point temperature of air-conditioning controllers to the system design temperature.

D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:

1. Verify that compressor oil level is correct.
2. Open compressor suction and discharge valves.
3. Check open compressor-motor alignment and verify lubrication for motors and bearings.

END OF SECTION 232300

SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Rectangular ducts and fittings.
2. Round ducts and fittings.
3. Sheet metal materials.
4. Sealants and gaskets.
5. Hangers and supports.

1.2 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated.

1. Static-Pressure Classes:

a. Supply Ducts (RTUs): 2-inch wg.
b. Supply Ducts (Makeup air unit and other): 1-inch wg.
c. Return Ducts (Negative Pressure): 1-inch wg.
d. General Exhaust Ducts (Negative Pressure): 1-inch wg.
e. Welding Fume Extraction: (Negative Pressure): 12-inch wg.
f. Dust Collection Exhaust: (Negative Pressure): 8-inch wg.

2. Leakage Class:

a. Round Supply-Air Duct: 3 cfm/100 sq. ft. at 1-inch wg.
b. Rectangular Supply-Air Duct: 6 cfm/100 sq. ft. at 1-inch wg.
c. Flexible Supply-Air Duct: 6 cfm/100 sq. ft. at 1-inch wg.
d. Welding Fume Extraction: per equipment manufacturer’s recommendations.
e. Dust Collection Exhaust: per equipment manufacturer’s recommendations.

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".

1.3 AIR LEAKAGE TESTING OF THE DUCTWORK SYSTEMS:

A. It is the intent of this section to ensure that all ductwork installed has minimal air leakage.

B. Air leakage testing shall be accomplished by an AABC certified company. Refer to the Test & Balance specifications.

C. A duct pre-installation conference shall be held prior to the installation of the ductwork. Present should be the Owner’s representative, Engineer, Test & Balance Contractor, General Contractor, Mechanical

Contractor, Sheet Metal Contractor, and Insulation Contractor. At this meeting, the contractor shall advise all of the duct materials and sealant materials to be used to meet the air leakage allowances.

D. The duct systems which will require 100% testing are as follows:

1. All supply air duct systems.
2. All return air duct systems.
3. All exhaust air duct systems.

E. If the first test does not meet the requirements set forth in this Section and Section "Testing, Adjusting, and Balancing for HVAC," the ductwork shall be resealed and retested until the system(s) maintain an acceptable leakage rate. All remediation and additional testing shall be paid by the Mechanical Contractor.

F. Do not insulate the air systems prior to testing.

G. The maximum allowable supply, return, exhaust, relief/exhaust, and outside air leakage rate is 5.0% of the systems design CFM when the ductwork is pressurized to duct pressure class (1.0" or 2.0" WG as indicated above). Example: the supply air fan rated capacity is 10,000 CFM, the allowable leakage is 500 CFM.

H. All sheet metal ductwork associated with the systems shall be tested. Flexible ductwork shall not be tested. Cap the main duct prior to the central equipment fan connection. Also cap the branch ducts which serve the diffusers at the location in which flexible duct will be installed. Cap ends with sheet metal caps. Seal caps well to avoid air loss at this location. This air loss, from the caps, is included in the noted leakage rate.

I. The noted allowable leakage rate is the total allowable. It shall include leakage associated with the following:

1. All ductwork as described in above paragraphs.
2. Access doors.
3. Volume dampers.
4. End caps used to seal ducts.

J. If any duct system fails a test, the Contractor shall reseal the system. It shall then be retested until the duct system meets the leakage allotment at no additional cost to the Owner. TAB Agency shall be compensated for all additional testing by the Mechanical Contractor.

K. Use of foil tape to pass tests is not acceptable.

1.4 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Shop Drawings:

1. Fittings.
2. Hangers and supports, including methods for duct and building attachment and vibration isolation.

C. Welding certificates.

1.5 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

PART 2 - PRODUCTS

2.1 RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

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

a. Eastern Sheetmetal.
b. Lindab Inc.
c. McGill AirFlow LLC.
d. SEMCO Incorporated.
e. Sheet Metal Connectors, Inc.
f. Spiral Manufacturing Co., Inc.
g. Approved equal.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Transverse Joints - Round Duct," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Seams - Round Duct and Fittings," for static-

pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A480/A480M, Type 316, cold rolled, annealed sheet. Exposed surface shall be No. 3.

D. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

E. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.4 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel.

C. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.

D. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

E. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.5 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1, "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."

C. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

D. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

E. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

F. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

G. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 SEAM AND JOINT SEALING

A. Seal duct seams and joints for duct static-pressure and leakage classes specified in "Performance Requirements" Article, according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 1-2, "Standard Duct Sealing Requirements," unless otherwise indicated.

B. Seal Classes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 1-2, "Standard Duct Sealing Requirements."

3.4 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1, "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

A. Make connections to equipment with flexible connectors.

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 DUCT SCHEDULE

A. Fabricate supply, return, exhaust, and relief/exhaust air ducts with galvanized sheet steel except as follows:

1. Dishwasher Hood Exhaust Ducts:

a. Type 304, stainless-steel sheet.
b. Exposed to View: No. 4 finish.
c. Concealed: No. 2D finish.
d. Welded seams and flanged joints with watertight EPDM gaskets.

2. Exterior, not insulated: Aluminum or Stainless Steel.

A. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel.

B. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."

a. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."

2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-3, "Round Duct Elbows."

a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.

b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.
c. Round Elbows, 14 Inches and Larger in Diameter: Welded.

C. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-6, "Branch Connections."

a. Rectangular Main to Rectangular Branch: 45-degree entry.
b. Rectangular Main to Round Branch: 45-degree entry.

2. Round: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible,".

a. Round main to Round Branch: 45-degree lateral.
b. 90-degree conical tee’s and saddle taps are not acceptable.

END OF SECTION 233113

SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Manual volume dampers.
2. Turning vanes.
3. Duct mounted access doors.
4. Flexible connectors.
5. Flexible ducts.
6. Duct accessory hardware.

1.2 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with AMCA 500-D testing for damper rating.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653.

1. Galvanized Coating Designation: G90.
2. Exposed-Surface Finish: Mill phosphatized.

C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts.

D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.2 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

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

    a. Arrow United Air.
    b. Greenheck Fan Corporation.
    c. Nailor Industries.
    d. Ruskin Company.
    e. United Enertech.
    f. Approved equal.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:

    a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
    b. Mitered and welded corners.
    c. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

    a. Multiple or single blade.
    b. Opposed-blade design.
    c. Stiffen damper blades for stability.
    d. Galvanized-steel, 0.064 inch thick.

6. Blade Axles: Galvanized steel.
7. Bearings:

    a. Molded synthetic.
    b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.
9. Stand-off with Locking Quadrant: 2 inch minimum

2.3 TURNING VANES

A. Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

B. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."

C. Vane Construction: Double wall.

2.4 DUCT-MOUNTED ACCESS DOORS

A. Subject to compliance with requirements, provide products by one of the following:

1. Arrow United Air.

2. Greenheck Fan Corporation.
3. Nailor Industries.
4. Ruskin Company.
5. United Enertech.
6. Approved equal.

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."

1. Door:

a. Double wall, rectangular.
b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
c. Hinges and Latches: 1-by-1-inch piano hinge and cam latches.
d. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
b. Access Doors up to 18 Inches Square: Piano hinge and two sash locks.

2.5 FLEXIBLE CONNECTORS

A. Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Ventfabrics, Inc.
3. Approved equal.

B. Flexible connectors for AHU supply duct connection shall be rated for 8 inches w.g. static pressure.

C. Materials: Flame-retardant or noncombustible fabrics.

D. Coatings and Adhesives: Comply with UL 181, Class 1.

E. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to 2 strips of 2-3/4-inch- wide, 0.028-inch- thick, galvanized sheet steel or 0.032-inch- thick aluminum sheets. Provide metal compatible with connected ducts.

F. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd.
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.

2.6 FLEXIBLE DUCTS

A. Subject to compliance with requirements, provide products by one of the following:

1. Atco.

2. Hart and Cooley.
3. ThermaFlex.
4. Approved equal.

B. Insulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 10 to plus 160 deg F.
4. Insulation Value: R-6.0 minimum.

C. Flexible Duct Connectors:

1. Clamps: Nylon strap in sizes 3 through 8 inches, to suit duct size.

2.7 DUCT ACCESSORY HARDWARE

A. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts use stainless steel accessories in stainless-steel ducts.

C. Install volume dampers at points on supply, return, and relief/exhaust systems where branches extend from larger ducts.

1. Install steel volume dampers in steel ducts.

D. Set dampers to fully open position before testing, adjusting, and balancing.

E. Install flexible connectors to connect ducts to equipment.

F. Connect diffusers to low-pressure ducts with maximum 60-inch lengths of flexible duct clamped or strapped in place.

G. Connect flexible ducts to metal ducts with draw bands.

H. Install access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. Adjacent to and close enough to fire dampers to reset or reinstall fusible links.
2. Elsewhere as indicated.

I. Install access doors with swing against duct static pressure.

J. Access door sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.

K. Label access doors.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Inspect turning vanes for proper and secure installation.
4. Operate fire dampers to verify full range of movements and verify that the proper heat response device is installed.

END OF SECTION 233300

SECTION 233423 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Ceiling mounted ventilators.
2. In-line centrifugal fans.
3. Centrifugal roof ventilators.

1.2 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

B. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

C. UL Standard: Power ventilators shall comply with UL 705.

PART 2 - PRODUCTS

2.1 CEILING-MOUNTING VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Greenheck.
2. Loren Cook Company.
3. Aerovent
4. Captive Aire
5. Approved equal.

B. Description: Centrifugal fans designed for installing in ceiling or for concealed in-line applications.

C. Housing: Steel, lined with acoustical insulation.

D. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

E. Grille: Aluminum with white enamel finish.

F. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

G. Accessories:

1. As specified on drawings.

2.2 IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Greenheck.
2. Loren Cook Company.
3. Aerovent
4. Captive Aire
5. Approved equal.

B. Description: In-line, direct-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

C. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

D. Direct-Driven Units: Motor mounted out of airstream, factory wired to disconnect switch located on outside of fan housing.

E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

F. Accessories:

1. Companion Flanges: For inlet and outlet duct connections.
2. Motor Cover: Epoxy-coated steel.
3. As specified on drawings.

2.3 CENTRIFUGAL ROOF VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Greenheck.
2. Loren Cook Company.
3. Aerovent
4. Captive Aire
5. Approved equal.

B. Description: Direct drive driven as specified centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Housing: Removable, spun-aluminum, dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone.

D. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

E. Accessories, as specified on drawings:

1. Disconnect Switch: Non-fusible type, with thermal-overload protection mounted outside fan housing, factory wired through an internal aluminum conduit.

F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.

1. Configuration: Built-in cant and mounting flange.
2. Overall Height: As specified on drawings.
3. Pitch Mounting: Manufacture curb for roof slope.
4. Metal Liner: Galvanized steel.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.

B. Support units using elastomeric mounts having a static deflection of 1 inch.

C. Suspend units from structure; use all-thread supports.

D. Install units with clearances for service and maintenance.

E. Label units according to requirements.

F. Duct installation and connection requirements are specified in other Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors.

G. Install ducts adjacent to power ventilators to allow service and maintenance.

H. Secure roof-mounting fans to roof curbs with cadmium-plated hardware.

I. Seal base of roof-mounting fans to roof curbs.

3.2 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Adjust damper linkages for proper damper operation.
5. Verify lubrication for bearings and other moving parts.
6. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
7. Remove and replace malfunctioning units and retest as specified above.
8. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.

9. Shut unit down and reconnect automatic temperature-control operators.

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

END OF SECTION 233423