

SECTION 23 05 00
COMMON WORK RESULTS FOR HVAC

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Identification for HVAC Piping and Equipment.
 - 2. Sleeves.
 - 3. Mechanical sleeve seals.
 - 4. Formed steel channel.

1.2 FINAL INSPECTIONS

- A. Engineer will make periodic inspections as appropriate and deemed necessary by Engineer. One final inspection for completion of project will be performed by the Engineer. Any and all additional inspections requested by the Contractor or required because of contractor's failure to complete Scope of Work shall be paid for by the Contractor. The cost of additional inspection(s) shall be deducted from the contract amount stated in the agreement between the Owner and the Contractor. Costs for additional inspections shall be assessed at the Engineer's hourly rates.

1.3 SUBMITTALS

- A. Shop Drawings: Submit for piping and equipment identification list of wording, symbols, letter size, and color coding for pipe identification and valve chart and schedule, including valve tag number, location, function, and valve manufacturer's name and model number.
- B. Product Data for Pipe and Equipment Identification: Submit for mechanical identification manufacturers catalog literature for each product required.
- C. All data for Division 23 must be submitted as a single package as the Engineer will commence review only when all data has been received. Submit shop drawings and product data in a 3-ring binder sub-tabbed and grouped to include complete submittals of related system, products, and accessories. Electronic submittals are acceptable in accordance with Paragraph D below. Engineer will commence review only when all data has been received in the format required. Incomplete submittals will not be reviewed until the complete package is received.
- D. Electronic submittals will be reviewed provided the following conditions are met.
 - 1. Complete submittals in pdf format will be reviewed by CSI Specification Division
 - 2. All data for Division 23 must be submitted as a single package as the Engineer will commence review only when all data has been received.
 - 3. Submittals linked to a manufacturer's web site will not be reviewed
 - 4. Re-submittals must highlight changes from previous submittals.
 - 5. Mixed submittals (part paper and part electronic) will not be reviewed
- E. The Contractor shall determine and verify field measurements and field construction criteria for conformance with Drawings and Specifications and for conflicts with other items of Construction past or present. He shall coordinate each submittal with the requirements of the Work and of the Contract Documents and notify the Engineer in writing, at the time of the submission, of any and all deviations in the submittals from requirements of the Work and Contract Documents.
- F. No fabrication or work which requires submittals shall begin until submittals are returned with the Engineer's approval.
- G. Engineer's review does not constitute acceptance or responsibility for accuracy or dimensions, nor shall it relieve the Contractor from meeting any requirements of the Work and Contract Documents, nor shall it constitute approval for any deviation from the Contract

Documents unless such deviations are specifically stated as such on the submittal and specifically allowed by the Engineer by specific written notification for each such variation. The Engineer's review will not relieve the Contractor from responsibility for errors or omissions in the Shop Drawings.

- H. Submit copies of materials for submittal review as required by Division 1.

1.4 PERMITS

- A. Permits necessary for the performance of the work under this contract shall be secured and paid for by the Contractor. Final inspection by the Engineer will not be made or certificate of final payment issued until certificates of satisfactory inspection from the inspection authorities are delivered.

1.5 SUBSTITUTIONS

- A. Prior approval required. When required by Division 1 of the Specifications, materials and equipment in Division 23 will be reviewed for prior approval. Bidder is required to document each request with complete data substantiating compliance of proposed substitution with Contract Documents.
- B. Basis of Design. Equipment/materials indicated in schedules and details shown on the plans form the Basis of Design for this project. Alternate equipment/materials proposed by the contractor must match the specified in dimension, configuration, weight, electrical requirements, etc. Any revision to plans necessary to accommodate the alternate equipment will be the responsibility of the contractor and be reflected in a shop drawing prepared by the contractor and approved by the Engineer.

1.6 TRAINING

- A. The mechanical contractor shall conduct a 4 hour minimum training session with owner designated staff to review all mechanical equipment installed under this contract. At a minimum, the session will include operation and maintenance, programming, filter change requirements, and basic operation of the systems. Contractor shall physically demonstrate the operation of each piece of equipment. A sign in sheet and agenda indicating a list of all equipment reviewed shall be included in the close out documents.

PART 2 PRODUCTS

2.1 IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

- A. Plastic Nameplates: Laminated three-layer plastic with engraved black letters on light background color.
- B. Plastic Tags: Laminated three-layer plastic with engraved black letters on light background color, minimum 1-1/2 inches diameter.
- C. Plastic Pipe Markers: Factory fabricated, flexible, semi-rigid plastic, preformed to fit around pipe or pipe covering. Larger sizes may have maximum sheet size with spring fastener. Color and Lettering: Conform to ASME A13.1.
- D. Plastic Tape Pipe Markers: Flexible, vinyl film tape with pressure sensitive adhesive backing and printed markings. Color and Lettering: Conform to ASME A13.1.
- E. Plastic Underground Pipe Markers: Bright colored continuously printed plastic ribbon tape, minimum 6 inches wide by 4 mil thick, manufactured for direct burial service.

2.2 SLEEVES

- A. Sleeves for Pipes Through Non-fire Rated Floors: 18 gage thick galvanized steel.
- B. Sleeves for Pipes Through Non-fire Rated Beams, Walls, Footings, and Potentially Wet Floors: Steel pipe or 18 gage thick galvanized steel.
- C. Sleeves for Round Ductwork: Galvanized steel.
- D. Sleeves for Rectangular Ductwork: Galvanized steel or wood.

2.3 MECHANICAL SLEEVE SEALS

- A. Manufacturers:
 - 1. Thunderline Link-Seal, Inc.
 - 2. Substitutions: Permitted
- B. Product Description: Modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill annular space between object and sleeve, connected with bolts and pressure plates causing rubber sealing elements to expand when tightened, providing watertight seal and electrical insulation.

2.4 FORMED STEEL CHANNEL

- A. Manufacturers:
 - 1. Allied Tube & Conduit Corp.
 - 2. B-Line Systems
 - 3. Unistrut Corp.
 - 4. Substitutions: Permitted.
- B. Product Description: Galvanized 12 gage thick steel. With holes 1-1/2 inches on center.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Verify openings are ready to receive sleeves.

3.2 INSTALLATION - PIPING AND EQUIPMENT IDENTIFICATION

- A. Install plastic nameplates with adhesive.
- B. Install plastic tags with corrosion resistant metal chain.
- C. Install name plates and labels on all equipment listed in the plans and specifications.

3.3 INSTALLATION - SLEEVES

- A. Exterior watertight entries: Seal with mechanical sleeve seals.
- B. Set sleeves in position in forms. Provide reinforcing around sleeves.
- C. Size sleeves large enough to allow for movement due to expansion and contraction. Provide for continuous insulation wrapping.
- D. Extend sleeves through floors 1 inch above finished floor level. Caulk sleeves.
- E. Where piping or ductwork penetrates floor, ceiling, or wall, close off space between pipe or duct and adjacent work with firestopping insulation and caulk airtight. Provide close fitting metal collar or escutcheon covers at both sides of penetration.
- F. Install chrome plated steel escutcheons at finished surfaces.

3.4 EXISTING SERVICES

- A. The Contractor shall carefully examine the drawings and specifications, visit the site of the work, fully inform himself as to all existing conditions, dimensions and limitations before starting work.
- B. If existing active or non-active services (which are not shown on plans) are encountered that require relocation or disconnection, the Contractor shall notify the Engineer for a decision on proper handling of these services. The Contractor shall not proceed with the work until so authorized.

3.5 SUBSTANTIAL COMPLETION AND FINAL INSPECTION REQUIREMENTS

- A. Before Substantial Completion can be granted, the following items must be completed and submitted to the Owner/Engineer.
 - 1. An approved Test and Balance Report.
 - 2. Operation test.

3. Control diagrams, wiring diagrams, control sequences, and engineering data on components.
 4. 4 hour training session of owner representative on maintenance, operation and control of all equipment.
- B. Prior to the Final Inspection or consideration of Final Payment, the Contractor shall:
1. Provide copies of permits and/or inspection certificates.
 2. Provide a Check-out report.
 3. Provide Operating and Maintenance Manual(s).
 4. Provide equipment warranties.
 5. Provide Record as-built Drawings.
 6. Return keys to the Owner.
 7. Deliver all spare parts.
 8. Touch up any damaged finishes.
 9. Provide a copy of attendance roster for equipment training sessions.

END OF SECTION

SECTION 23 05 93
TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Testing, adjusting, and balancing of air systems.

1.2 SUBMITTALS

- A. Draft Reports: Submit for review prior to final acceptance of Project.
- B. Test Reports: Submit prior to final acceptance of Project and for inclusion in operating and maintenance manuals. Assemble in soft cover, letter size, 3-ring binder, with table of contents page and tabs, and cover identification. Include reduced scale drawings with air outlets and equipment identified to correspond with data sheets, and indicating thermostat locations.

1.3 QUALITY ASSURANCE

- A. Perform Work in accordance with ASHRAE Standard 111-2008. Procedures for Testing, Adjusting and Balancing, AABC Testing and Balancing Procedures, or NEBB Testing Adjusting and Balancing.
- B. Agencies:
 - 1. NEBB. National Environmental Balance Bureau
 - a. Certified TAB Supervisor with not less than 5 years experience in Testing, Adjusting and Balancing.
 - b. Certified TAB Technician with not less than 2 years experience in Testing, Adjusting and Balancing.
 - 2. TABB. Testing, Adjusting and Balancing Bureau.
 - a. Certified TAB Supervision. ITI (International Training Institute) tested TAB Technician with not less than 5 years experience in Testing, Adjusting and Balancing.
 - b. Certified TAB Technician. ITI (International Training Institute) tested TAB Technician with not less than 2 years experience in Testing, Adjusting and Balancing.
 - 3. AABC. American Air Balance Council.
 - a. Supervisor-Certified Test and Balance Engineer (TBE) with not less than 5 years experience in Testing, Adjusting and Balancing.
 - b. Technician-Certified Test and Balance Technician with not less than 2 years experience in Testing, Adjusting and Balancing.
 - 4. Registered Professional Engineer with not less than 5 years experience in Testing, Adjusting and Balancing.
- C. Report Forms: AABC MN-1 National Standards for Total System Balance forms. Forms prepared following ASHRAE 111 or NEBB forms.

PART 2 PRODUCTS

- A. Not Used.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Before starting work, verify systems are complete and operable.
- B. Report defects, deficiencies, or abnormal conditions in mechanical systems preventing system balance.

- C. Beginning of work means acceptance of existing conditions.

3.2 INSTALLATION TOLERANCES

- A. Air Handling Systems: Adjust to within plus or minus 10 percent of design for supply, return and exhaust systems.
- B. Air Outlets and Inlets: Adjust to within plus or minus 10 percent of design.
- C. Domestic Water and Hydronic Systems: Adjust to within plus or minus 10 percent of design.

3.3 AIR SYSTEM PROCEDURE

- A. Adjust air handling and distribution systems to deliver design supply, return, and exhaust air quantities within previously stated tolerances.
- B. Make air quantity measurements in ducts by traverse of entire cross sectional area of duct.
- C. Measure air quantities at air inlets and outlets.
- D. Use volume control devices to regulate air quantities only to extent those adjustments do not create objectionable air motion or sound levels. Change volume using dampers mounted in ducts.
- E. Vary total system air quantities by adjustment of fan speeds. Provide drive changes to accomplish system air flow. Vary branch air quantities by damper regulation.
- F. Measure static air pressure conditions on air supply units, including filter and coil pressure drops, and total pressure across fan. Allow for pressure drop equivalent to 50 percent loading of filters.
- G. Adjust automatic outside air, return air, and exhaust air dampers for design conditions.
- H. Measure temperature conditions across outside air, return air, and exhaust air dampers to check leakage.
- I. At modulating damper locations, take measurements and balance at extreme conditions.

3.4 FIELD QUALITY CONTROL

- A. Verify recorded data represents actually measured or observed conditions.
- B. Permanently mark settings of valves, dampers, and other adjustment devices. Set and lock memory stops.

END OF SECTION

SECTION 23 07 00
HVAC INSULATION

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. HVAC piping insulation, jackets and accessories.
 - 2. HVAC ductwork insulation, jackets, and accessories.

1.2 SUBMITTALS

- A. Product Data: Submit product description, thermal characteristics and list of materials and thickness for each service, and location.
- B. Manufacturer's Installation Instructions: Submit manufacturers published literature indicating proper installation procedures.
- C. Manufacturer's Certificate: Certify products meet or exceed specified requirements.

1.3 QUALITY ASSURANCE

- A. Test pipe insulation for maximum flame spread index of 25 and maximum smoke developed index of not exceeding 50 in accordance with ASTM E84, UL 723, or NFPA 255.
- B. Pipe insulation manufactured in accordance with ASTM C585 for inner and outer diameters.
- C. Factory fabricated fitting covers manufactured in accordance with ASTM C450.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Accept materials on site in original factory packaging, labeled with manufacturer's identification, including product density and thickness.
- B. Protect insulation from weather and construction traffic, dirt, water, chemical, and damage, by storing in original wrapping.

1.5 ENVIRONMENTAL REQUIREMENTS

- A. Install insulation only when ambient temperature and humidity conditions are within range recommended by manufacturer.
- B. Maintain temperature before, during, and after installation for minimum period of 24 hours.

1.6 WARRANTY

- A. Furnish one year manufacturer warranty on all products and services.

PART 2 PRODUCTS

2.1 MANUFACTURER

- A. Manufacturers for Glass Fiber and Mineral Fiber Insulation Products:
 - 1. CertainTeed.
 - 2. Knauf.
 - 3. Johns Manville.
 - 4. Owens-Corning.
 - 5. Substitutions: Permitted.
- B. Manufacturers for Closed Cell Elastomeric Insulation Products:
 - 1. Aeroflex. Aerocell.
 - 2. Armacell, LLC. Armaflex.

3. Nomaco. K-flex.
4. Substitutions: Permitted.
- C. Manufacturers for Polyisocyanurate Foam Insulation Products:
 1. Dow Chemical Company.
 2. Substitutions: Permitted.
- D. Manufacturers for Extruded Polystyrene Insulation Products:
 1. Dow Chemical Company.
 2. Substitutions: Permitted.

2.2 PIPE INSULATION

- A. TYPE P-1: ASTM C547, molded glass fiber pipe insulation.
 1. Thermal Conductivity: 0.23 at 75 degrees F.
 2. Operating Temperature Range: 0 to 850 degrees F.
 3. Vapor Barrier Jacket: ASTM C1136, Type I, factory applied reinforced foil kraft with self-sealing adhesive joints.
 4. Jacket Temperature Limit: minus 20 to 150 degrees F.
- B. Type P-2: ASTM C534, Type I, flexible, closed cell elastomeric insulation, tubular.
 1. Thermal Conductivity: 0.27 at 75° F.
 2. Operating Temperature Range: Minus 70° to 180°F.

2.3 PIPE INSULATION ACCESSORIES

- A. Vapor Retarder Lap Adhesive: Compatible with insulation.
- B. Covering Adhesive Mastic: Compatible with insulation.
- C. Piping Shields: Galvanized steel saddles and inserts not less than 6 inches long, matching thickness and contour of adjoining insulation.
- D. Adhesives: Compatible with insulation.

2.4 DUCTWORK INSULATION

- A. TYPE D-1: ASTM C1290, Type III, flexible glass fiber, commercial grade with factory applied reinforced aluminum foil jacket meeting ASTM C1136, Type II.
 1. Thermal Conductivity: 0.25 at 75 degrees F.
 2. Maximum Operating Temperature: 250 degrees F.
- B. TYPE D-2: ASTM C612, Type IA or IB, rigid glass fiber, with factory applied reinforced aluminum foil facing meeting ASTM C1136, Type II.
 1. Thermal Conductivity: 0.24 at 75 degrees F.
- C. TYPE D-3: ASTM C612, Type IA or IB, rigid glass fiber, no facing.
 1. Thermal Conductivity: 0.24 at 75 degrees F.
- D. TYPE D-4: ASTM C1071, Type I, flexible, antimicrobial glass fiber duct liner with coated air side.
 1. Thermal Conductivity: 0.25 at 75 degrees F.
 2. Maximum Operating Temperature: 250 degrees F.
 3. Maximum Air Velocity: 6,000 feet per minute.
- E. TYPE D-5: ASTM C1071, Type II, rigid, antimicrobial glass fiber duct liner with coated air side.

1. Thermal Conductivity: 0.23 at 75 degrees F.
2. Density: 3.0 pound per cubic foot.
3. Maximum Operating Temperature: 250 degrees F.
4. Maximum Air Velocity: 4,000 feet per minute.
- F. TYPE D-6: ASTM C534, Type II, flexible, closed cell elastomeric insulation, sheet.
 1. Thermal Conductivity: 0.27 at 75 degrees F.
 2. Service Temperature Range: Range: Minus 58 to 180 degrees F.
- G. TYPE D-7: ASTM C534, Type II, flexible, closed cell elastomeric insulation, sheet laminated with thermoplastic rubber membrane.
 1. Thermal Conductivity: 0.27 at 75 degrees F.
 2. Service Temperature Range: Range: Minus 58 to 180 degrees F.
- H. TYPE D-8: Inorganic blanket encapsulated with scrim reinforced foil meeting UL 1978.
 1. Thermal Conductivity: 0.42 at 500 degrees F.
 2. Weight: 1.4 pound per square foot.
 3. Flame spread rating of 0 and smoke developed rating of 0 in accordance with ASTM E84.

2.5 DUCTWORK INSULATION JACKETS

- A. Aluminum Duct Jacket: A foil faced UV resistant, vapor barrier membrane, self-stick, self-healing, with a zero perm rating. Bright white matte finish that meets solar reflectance and emissivity of Cool Roof Rating Council (CRRC) and California Title 24.
 1. Manufacturers: Alumaguard.

2.6 DUCTWORK INSULATION ACCESSORIES

- A. Vapor Retarder Tape:
 1. Kraft paper reinforced with glass fiber yarn and bonded to aluminized film, with pressure sensitive rubber based adhesive.
- B. Vapor Retarder Lap Adhesive: Compatible with insulation.
- C. Adhesive: Waterproof, ASTM E162 fire-retardant type.
- D. Liner Fasteners: Galvanized steel, impact applied with press-on head.
- E. Tie Wire: 0.048 inch stainless steel with twisted ends on maximum 12 inch centers.
- F. Lagging Adhesive: Fire resistive to ASTM E84, NFPA 255 or UL 723.
- G. Impale Anchors: Galvanized steel, 12 gage self-adhesive pad.
- H. Adhesives: Compatible with insulation.
- I. Membrane Adhesives: As recommended by membrane manufacturer.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Verify piping, equipment and ductwork has been tested before applying insulation materials.
- B. Verify surfaces are clean and dry, with foreign material removed.

3.2 INSTALLATION - PIPING SYSTEMS

- A. Piping Exposed to View in Finished Spaces: Locate insulation and cover seams in least visible locations.

- B. Continue insulation through penetrations of building assemblies or portions of assemblies having fire resistance rating of one hour or less. Provide Intumescent firestopping when continuing insulation through assembly. Finish at supports, protrusions, and interruptions. Refer to Section 07 84 00 for penetrations of assemblies with fire resistance rating greater than one hour.
- C. Piping Systems Conveying Fluids Below Ambient Temperature:
1. Insulate entire system including fittings, valves, unions, flanges, strainers, flexible connections, expansion joints, and through hangers.
 2. Furnish factory-applied or field-applied vapor retarder jackets. Secure factory-applied jackets with pressure sensitive adhesive self-sealing longitudinal laps and butt strips. Secure field-applied jackets with outward clinch expanding staples and seal staple penetrations with vapor retarder mastic.
 3. Insulate fittings, joints, and valves with molded insulation of like material and thickness as adjacent pipe. Finish with glass cloth and vapor retarder adhesive or PVC fitting covers.
- D. Glass Fiber Board Insulation:
1. Apply insulation close to equipment by grooving, scoring, and beveling insulation. Fasten insulation to equipment with studs, pins, clips, adhesive, wires, or bands.
 2. Fill joints, cracks, seams, and depressions with bedding compound to form smooth surface. On cold equipment, use vapor retarder cement.
 3. Cover wire mesh or bands with cement to a thickness to remove surface irregularities.
- E. Hot Piping Systems less than 140 degrees F:
1. Furnish factory-applied or field-applied standard jackets. Secure with outward clinch expanding staples or pressure sensitive adhesive system on standard factory-applied jacket and butt strips or both.
 2. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe. Finish with glass cloth and adhesive or PVC fitting covers.
 3. Do not insulate unions and flanges at equipment, but bevel and seal ends of insulation at such locations.
- F. Hot Piping Systems greater than or equal to 140 degrees F:
1. Furnish factory-applied or field-applied standard jackets. Secure with outward clinch expanding staples or pressure sensitive adhesive system on standard factory-applied jacket and butt strips or both.
 2. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe. Finish with glass cloth and adhesive or PVC fitting covers.
 3. Insulate flanges and unions at equipment.
- G. Inserts and Shields:
1. Piping 1-1/2 inches Diameter and Smaller: Install [galvanized] steel shield between pipe hanger and insulation.
 2. Piping 2 inches Diameter and Larger: Install insert between support shield and piping and under finish jacket.
 - a. Insert Configuration: Minimum 6 inches long, of thickness and contour matching adjoining insulation; may be factory fabricated.
 - b. Insert Material: Compression resistant insulating material suitable for planned temperature range and service.

3. Piping Supported by Roller Type Pipe Hangers: Install galvanized steel shield between roller and inserts.
- H. Insulation Terminating Points:
 1. Coil Branch Piping 1 inch and Smaller: Terminate hot water piping at union upstream of the coil control valve.
 2. Chilled Water Coil Branch Piping: Insulate chilled water piping and associated components up to coil connection.
 3. Condensate Piping: Insulate entire piping system and components to prevent condensation.
- I. Pipe Exposed in Mechanical Equipment Rooms or Finished Spaces: Finish with PVC jacket and fitting covers.
- J. Piping Exterior to Building: Provide vapor retarder jacket. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass mesh reinforced vapor retarder cement. Cover with aluminum or stainless steel jacket with seams located at 3 or 9 o'clock position on side of horizontal piping with overlap facing down to shed water or on bottom side of horizontal piping.
- K. Prepare pipe insulation for finish painting. Refer to Division 09.

3.3 INSTALLATION - DUCTWORK SYSTEMS

- A. Duct dimensions indicated on Drawings are finished inside dimensions.
- B. Insulated ductwork conveying air below ambient temperature:
 1. Provide insulation with vapor retarder jackets.
 2. Finish with tape and vapor retarder jacket.
 3. Continue insulation through walls, sleeves, hangers, and other duct penetrations.
 4. Insulate entire system including fittings, joints, flanges, fire dampers, flexible connections, and expansion joints.
- C. Insulated ductwork conveying air above ambient temperature:
 1. Provide with or without standard vapor retarder jacket.
 2. Insulate fittings and joints. Where service access is required, bevel and seal ends of insulation.
- D. Ductwork Exposed in Mechanical Equipment Rooms or Finished Spaces [(below 10 feet above finished floor)]: Finish with [canvas jacket sized for finish painting] [aluminum jacket].
- E. External Glass Fiber Duct Insulation:
 1. Secure insulation with vapor retarder with wires and seal jacket joints with vapor retarder adhesive or tape to match jacket.
 2. Secure insulation without vapor retarder with staples, tape, or wires.
 3. Install without sag on underside of ductwork. Use adhesive or mechanical fasteners where necessary to prevent sagging. Lift ductwork off trapeze hangers and insert spacers.
 4. Seal vapor retarder penetrations by mechanical fasteners with vapor retarder adhesive.
 5. Stop and point insulation around access doors and damper operators to allow operation without disturbing wrapping.
- F. External Elastomeric Duct Insulation:
 1. Adhere to clean oil-free surfaces with full coverage of adhesive.

2. Seal seams and butt joints with manufacturer's recommended adhesive.
 3. When application requires multiple layers, apply with joints staggered.
 4. Insulate standing metal duct seams with insulation of like material and thickness as adjacent duct surface. Apply adhesive at joints with flat duct surfaces.
 5. Lift ductwork off trapeze hangers and insert spacers.
- G. Duct Liner:
1. Adhere insulation with adhesive for 100 percent coverage.
 2. Secure insulation with mechanical liner fasteners. Comply with SMACNA Standards for spacing.
 3. Seal and smooth joints. Seal and coat transverse joints.
 4. Seal liner surface penetrations with adhesive.
 5. Cut insulation for tight overlapped corner joints. Support top pieces of liner at edges with side pieces.
- H. Prepare duct insulation for finish painting. Refer to Division 09.

3.4 SCHEDULES

A. Cooling Services Piping Insulation Schedule:

Condensate Piping from Cooling Coils	P-5	All sizes	0.5
Refrigerant Liquid	N/A	All sizes	N/A
Refrigerant Hot Gas	P-5	All sizes	0.5

B. Ductwork Insulation Schedule:

Supply Ducts (internally insulated)	D-4	R6
Return Ducts (internally insulated)	D-4	R6
Supply Ducts (externally insulated)	D-1	R6
Return Ducts (externally insulated)	D-1	R6
Transfer Air Ducts (internally insulated)	D-4 or D-5	R6

END OF SECTION

SECTION 23 08 00 - COMMISSIONING OF HVAC

PART 1 GENERAL

1.1 SUMMARY

- A. Scope Definition: the Owner intends to include the services of a commissioning agent in the general contract for this building to complete HVAC Commissioning and Functional Performance Testing. The intent of this Section is to indicate support required of the Controls Contractor and Mechanical Contractor in assuring HVAC and controls systems are operating according to design and specification. Further description of Commissioning is included in Section 01 91 00. Specific work required by this section includes: 1) Completion of Construction Checklists included at the end of the Section, 2) Assisting the Commissioning Agent in completion of functional performance testing.
- B. Section Includes:
 - 1. HVAC Commissioning description.
 - 2. HVAC Commissioning responsibilities.
 - 3. Construction Checklists

1.2 COMMISSIONING DESCRIPTION

- A. HVAC Commissioning process includes the following tasks:
 - 1. Testing and startup of HVAC equipment and systems.
 - 2. Equipment and system verification checks.
 - 3. Assistance in functional performance testing to verify testing and balancing, and equipment and system performance.
 - 4. Provide qualified personnel to assist in Commissioning tests, including seasonal testing.
 - 5. Complete and endorse "Construction Checklists" (attached) to assure equipment and systems are fully operational and ready for functional performance testing.
 - 6. Provide equipment, materials, and labor necessary to correct deficiencies found during Commissioning process to fulfill contract and warranty requirements.
 - 7. Provide operation and maintenance information and record drawings to Commissioning Agent for review.
 - 8. Provide training for systems specified in this Section.
- B. Equipment and Systems to Be Commissioned:
 - 1. Variable Volume Terminals
 - 2. Packaged Roof Top unit.
 - 3. Air Handling Units
 - 4. Hydronic Systems
 - 5. Exhaust Fans
 - 6. Fire/Smoke dampers.
 - 7. Automatic temperature control system. (DDC)
 - 8. Variable Frequency Drives.
- C. See "Construction Checklists" at end of this section.

1.3 COMMISSIONING SUBMITTALS - N/A

1.4 CLOSEOUT SUBMITTALS

- A. Project Record Documents: Record revisions to equipment and system documentation necessitated by Commissioning.

- B. Operation and Maintenance Data: Submit revisions to operation and maintenance manuals when necessary revisions are discovered during Commissioning.

1.5 QUALITY ASSURANCE - N/A

1.6 COMMISSIONING RESPONSIBILITIES

A. Equipment or System Installer Commissioning Responsibilities:

1. Attend (2) Commissioning meetings of approximately 2 hour duration.
2. Ensure temperature controls installer performs assigned Commissioning responsibilities as specified below.
3. Provide instructions and demonstrations for Owner's personnel.
4. Ensure subcontractors perform assigned Commissioning responsibilities.
5. Ensure participation of equipment manufacturers in appropriate startup, testing, and training activities when required by individual equipment specifications.
6. Develop startup and initial checkout plan using manufacturer's startup procedures and "Construction Checklists" for equipment and systems to be commissioned.
7. During functional performance testing and startup process, execute HVAC related portions of checklists for equipment and systems to be commissioned.
8. Provide manufacturer's representatives to execute starting of equipment. Ensure representatives are available and present during agreed upon schedules and are in attendance for duration to complete tests, adjustments and problem-solving.
9. Coordinate with equipment manufacturers to determine specific requirements to maintain validity of warranties.
10. Provide personnel to assist Commissioning Authority during equipment or system verification checks and functional performance tests.
11. Prior to functional performance tests, review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during tests.
12. Conduct HVAC system orientation and inspection.

B. Temperature Controls Installer Commissioning Responsibilities:

1. Attend (2) Commissioning meetings of approximately 2 hour duration.
2. Review design for ability of systems to be controlled including the following:
 - a. Confirm proper hardware requirements exist to perform functional performance testing.
 - b. Confirm proper safeties and interlocks are included in design.
 - c. Confirm proper sizing of system control valves and actuators and control valve operation will result in capacity control identified in Contract Documents.
 - d. Confirm proper sizing of system control dampers and actuators and damper operation will result in proper damper positioning.
 - e. Confirm sensors selected are within device ranges.
 - f. Review sequences of operation and obtain clarification from Architect/Engineer.
 - g. Indicate delineation of control between packaged controls and building automation system, listing BAS monitor points and BAS adjustable control points.
3. Inspect, check, and confirm proper operation and performance of control hardware and software provided in other HVAC sections.

4. Submit proposed procedures for performing automatic temperature control system point-to-point checks to Commissioning Authority and Architect/Engineer.
 5. Inspect check and confirm correct installation and operation of automatic temperature control system input and output device operation through point-to-point checks.
 6. Perform training sessions to instruct Owner's personnel in hardware operation, software operation, programming, and application in accordance with Division 1.
 7. Demonstrate system performance and operation to Commissioning Authority during functional performance tests including each mode of operation.
 8. Provide control system technician to assist during Commissioning Authority verification check and functional performance testing.
- C. Testing, Adjusting, and Balancing Agency Commissioning Responsibilities:
1. Attend (2) commissioning meetings of approximately 2 hour duration.
 2. Participate in verification of testing, adjusting, and balancing report for verification or diagnostic purposes. Repeat sample of 10 percent of measurements contained in testing, adjusting, and balancing report as selected by Commissioning Agent.
 3. Assist in performing operation and maintenance training sessions scheduled by Commissioning Agent.
- 1.7 COMMISSIONING MEETINGS
- A. Attend initial Commissioning meeting and progress Commissioning meetings as required by Commissioning Authority. Two meetings anticipated.
- 1.8 SCHEDULING
- A. Prepare schedule indicating anticipated start dates for the following:
1. Piping system pressure testing.
 2. Piping system flushing and cleaning.
 3. Ductwork cleaning.
 4. Ductwork pressure testing.
 5. Equipment and system startups.
 6. Automatic temperature control system checkout.
 7. HVAC system orientation and "Construction Checklists".
 8. Operation and maintenance manual submittals.
 9. Training sessions.
- B. Schedule seasonal tests of equipment and systems during peak weather conditions to observe full-load performance.
- 1.9 COORDINATION
- A. Notify Commissioning Agent minimum of four weeks in advance of the following:
1. Scheduled equipment and system startups.
 2. Scheduled automatic temperature control system checkout.
- B. Coordinate programming of automatic temperature control system with construction and Commissioning schedules.
- PART 2 PRODUCTS
- A. Not Used.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Place HVAC systems and equipment into full operation and continue operation during each working day of Commissioning.
- B. Install replacement sheaves and belts to obtain system performance, as requested by Commissioning Authority.
- C. Install test holes in ductwork and plenums as requested by Commissioning Authority for taking air measurements.
- D. Prior to start of functional performance test, install replacement filters in equipment.

3.2 COMMISSIONING

- A. Seasonal Sensitive Functional Performance Tests:
 - 1. Test heating equipment at winter design temperatures.
 - 2. Test cooling equipment at summer design temperatures.

END OF SECTION

SECTION 23 09 23
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 GENERAL

- 1.1 **SCOPE:** Provide modifications and updates to the existing Andover Control System.
- 1.2 **PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION**
- A. None
- 1.3 **PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION**
- A. None
- 1.4 **PRODUCTS NOT FURNISHED OR INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION**
- A. Communications with Third Party Equipment:
1. Any additional integral control systems included with the products integrated with the work of this section shall be furnished with a BACnet interface for integration into the Direct Digital Control System described in this section.
- 1.5 **RELATED SECTIONS**
- A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.
- B. The following sections constitute related work:
1. Section 23 05 00 - Common Work Results for HVAC
 2. Section 23 20 00 - HVAC Piping and Pumps
- 1.6 **DESCRIPTION**
- A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and an operator workstation. The operator workstation shall provide for overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.
- B. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends, and alarms shall be BACnet objects, see plans for "Sequence of Operation" and "Points List".
- 1.7 **APPROVED CONTROL SYSTEMS**
- A. Use control system hardware and software that meet the requirements of this specification.
- 1.8 **QUALITY ASSURANCE**
- A. Installer and Manufacturer Qualifications
1. Installer shall have an established working relationship with Control System Manufacturer.
 2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
- 1.9 **CODES AND STANDARDS**
- A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:
1. National Electric Code (NEC)

2. International Building Code (IBC)
 - a. Chapter 28 Mechanical
3. International Mechanical Code (IMC)
4. ANSI/ASHRAE Standard 135, BACnet - A Data Communication Protocol for Building Automation and Control Systems

1.10 SYSTEM PERFORMANCE

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

Table 1 Reporting Accuracy	
Measured Variable	Reported Accuracy
Space Temperature	±0.5°C (±1°F)
Ducted Air	±0.5°C (±1°F)
Outside Air	±1.0°C (±2°F)
Dew Point	±1.5°C (±3°F)
Water Temperature	±0.5°C (±1°F)
Delta-T	±0.15°C (±0.25°F)
Relative Humidity	±5% RH

Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO ₂)	±50 ppm

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

Note 2: For both absolute and differential pressure

Note 3: Not including utility-supplied meters

Table 2 Control Stability and Accuracy		
Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential
Space Temperature	±1.0°C (±2.0°F)	
Duct Temperature	±1.5°C (±3°F)	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	

1.11 SUBMITTALS

- A. Product Data and Shop Drawings: Meet requirements of Division 1 on Shop Drawings, Product Data, and Samples. In addition, the contractor shall provide shop drawings or other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as .pdf format. When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve the Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of the contract award. Submittals shall include:
1. DDC System Hardware
 - a. A complete bill of materials to be used indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
 - b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
 - 1) Direct digital controllers (controller panels)
 - 2) Transducers and transmitters
 - 3) Sensors (including accuracy data)
 - 4) Actuators
 - 5) Valves
 - 6) Relays and switches
 - 7) Control panels
 - 8) Power supplies
 - 9) Batteries
 - 10) Operator interface equipment
 - 11) Wiring
 - c. Wiring diagrams and layouts for each control panel. Show termination numbers.
 - d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.
 2. Central System Hardware and Software
 - a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical data.
 - b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
 - 1) Power supplies
 - 2) Battery backups

- c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show interface wiring to control system.
 - d. Network riser diagrams of wiring between central control unit and control panels.
- 3. Controlled Systems
 - a. Riser diagrams showing control network layout, communication protocol, and wire types.
 - b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.
 - c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
 - d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
 - e. A mounting, wiring, and routing plan-view drawing. The design shall take into account HVAC, electrical, and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.
 - f. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
 - g. A point list for each control system. List I/O points and software points specified in Section 23 09 93. Indicate alarmed and trended points.
- 4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.
- 5. A Description of the proposed process along with all report formats and checklists to be used in Section 23 09 23 Article 3.17 (Control System Demonstration and Acceptance).
- 6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules

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

2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.
- C. Project Record Documents. Upon completion of installation, submit three copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and shall include:
1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2006 (or newer) compatible files on magnetic or optical media (file format: .DWG, .DXF, .VSD, or comparable) and as 11" x 17" prints.
 2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 23 09 23 Article 3.17 (Control System Demonstration and Acceptance).
 3. Operation and Maintenance (O&M) Manual.
 4. As-built versions of submittal product data.
 5. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
 6. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
 7. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
 8. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
 9. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
 10. Graphic files, programs, and database on magnetic or optical media.
 11. List of recommended spare parts with part numbers and suppliers.
 12. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
 13. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
 14. Licenses, guarantees, and warranty documents for equipment and systems.
 15. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
- D. Training: Provide two hours of on-site training as scheduled and prescribed by the owner.

1.12 WARRANTY

- A. Warrant work as follows:
1. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in

service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.

2. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
3. If the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
4. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
5. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

1.13 OWNERSHIP OF PROPRIETARY MATERIAL

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

1.14 DEFINITIONS

Term	Definition
BACnet Interoperability Building Blocks (BIBB)	A BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database.
Controller	Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.
Direct Digital Control (DDC)	Microprocessor-based control including Analog/Digital conversion and program logic.
Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.

Term	Definition
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token Passing	Data link protocol as defined by the BACnet standard.
Point-to-Point	Serial communication as defined in the BACnet standard.
Primary Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.
Protocol Implementation Conformance Statement	A written document that identifies the particular options specified by BACnet that are implemented in a device.
Router	A device that connects two or more networks at the network layer.
Wiring	Raceway, fittings, wire, boxes and related items.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. New products must be compatible with the existing system installed in 2003. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2 COMMUNICATION

- A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.
- B. Install new wiring and network devices as required to provide a complete and workable control network. Use existing Ethernet backbone for network segments marked "existing" on project drawings.
- C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
- D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
 - 1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
 - 2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 23 09 93. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.
- E. Workstations, Building Control Panels, and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.
- F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.3 OPERATOR INTERFACE

- A. Operator Interface: The existing operator interface will remain in use and be updated with the new programming and graphics.
- B. System Software.
 - 1. System Graphics. Update the system graphics to include the new boiler and pump additions.
- C. System Applications. All the existing automatic system database configuration, manual controller memory download, system configuration, online help, security, system diagnostics, alarm processing, alarm messaging, alarm reactions, alarm logging and trend logging to remain as previously configured.

2.4 CONTROLLER SOFTWARE

- A. Modify existing software to accommodate boiler and pump modifications. Furnish the following applications for building and energy management. All software applications shall reside and operate in the system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

2.5 CONTROLLERS

- A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 23 09 23 Article 1.9 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.
- B. BACnet.
 - 1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
 - 2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
 - 3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
 - 4. Smart Actuators (SAs). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
 - 5. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
 - 6. BACnet Communication.
 - a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.

- b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
 - c. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
 - d. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
 - e. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
 - f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.
- C. Communication.
 - 1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
 - 2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
 - 3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
 - 4. Stand-Alone Operation. Each piece of equipment specified in Section 23 09 93 shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other methods for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.
- D. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
 - 1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
 - 2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
- E. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.
- F. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.
- G. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
- H. Memory.

1. Controller memory shall support operating system, database, and programming requirements.
 2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
 3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. The system shall automatically download dynamic control parameters following power loss.
- I. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
 - J. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.6 INPUT AND OUTPUT INTERFACE

- A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.
- B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.
- C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.
- D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.
- E. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.
- F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on Building Controllers shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.
- G. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0-10 Vdc or a 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.
- H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.
- I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.
- J. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity

requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.

2.7 POWER SUPPLIES AND LINE FILTERING

- A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
 - 1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. The regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
 - a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
 - b. Line voltage units shall be UL recognized and CSA listed.
- B. Power Line Filtering.
 - 1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
 - 2. Dielectric strength of 1000 V minimum
 - 3. Response time of 10 nanoseconds or less
 - 4. Transverse mode noise attenuation of 65 dB or greater
 - 5. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.8 AUXILIARY CONTROL DEVICES

- A. Binary Temperature Devices.
 - 1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
 - 2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
 - 3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.
- B. Temperature Sensors.
 - 1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
 - 2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m²(10 ft²) of duct cross-section.
 - 3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.

4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.
 5. Differential Sensors. Provide matched sensors for differential temperature measurement.
 6. suitable for intended application and NEMA 1 enclosure unless otherwise specified.
- C. Relays.
1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
 2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable $\pm 100\%$ from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.
- D. Current Transmitters.
1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be $\pm 1\%$ full-scale at 500-ohm maximum burden.
 2. The Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
 3. Unit shall be split-core type for clamp-on installation on existing wiring.
- E. Current Transformers.
1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
 2. Transformers shall be available in various current ratios and shall be selected for $\pm 1\%$ accuracy at 5 A full-scale output.
 3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.
- F. Voltage Transmitters.
1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
 2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be $\pm 1\%$ full-scale at 500-ohm maximum burden.
 3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.
- G. Voltage Transformers.
1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
 2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide $\pm 0.5\%$ accuracy at 24 Vac and 5 VA load.
 3. Windings (except for terminals) shall be completely enclosed with metal or plastic.
- H. Local Control Panels.

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
2. Interconnections between internal and face-mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600-volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.

2.9 WIRING AND RACEWAYS

- A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.
- B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.
- C. Wire Color shall be purple.

PART 3 EXECUTION

3.1 EXAMINATION

- A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.
- B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.
- C. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate - or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others - the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by - and at the expense of - this contractor

3.2 PROTECTION

- A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.
- B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

- A. Site.
 1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.

2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.
- B. Submittals. See Section 23 09 23 Article 1.10 (Submittals).
- C. Test and Balance.
 1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
 2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
 3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
 4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.
- D. Life Safety.
 1. Duct smoke detectors required for air handler shutdown are provided under Division 23. Interlock smoke detectors to air handlers for shutdown as specified in "Sequence of Operation", see plans.
 2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23. Interlock smoke dampers to air handlers as specified in "Sequence of Operation", see plans.
 3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.
- E. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
 1. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in "Sequence of Operation", see plans.
 2. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
 3. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
 4. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.4 GENERAL WORKMANSHIP

- A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.
- B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
- C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).
- D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

- E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 FIELD QUALITY CONTROL

- A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 23 09 23 Article 1.8 (Codes and Standards).
- B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
- C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

3.6 EXISTING EQUIPMENT

- A. Wiring. The contractor may reuse any abandoned wires. The integrity of the wire and its proper application to the installation are the responsibility of the contractor. The wire shall be properly identified and tested in accordance with this specification. Unused or redundant wiring must be properly identified as such.
- B. Local Control Panels. The contractor may reuse any existing local control panel to locate new equipment. All redundant equipment within these panels must be removed. Panel face cover must be patched to fill all holes caused by removal of unused equipment or replaced with new.
- C. Repair. Unless otherwise directed, the contractor is not responsible for repair or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the contractor find existing equipment that requires maintenance, the engineer is to be notified immediately.
- D. Install control panels where shown.
- E. Patch holes and finish to match existing walls.

3.7 WIRING

- A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification. Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.
- B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.
- C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.
- D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.
- E. All wiring in mechanical, electrical, or service rooms or where subject to mechanical damage shall be installed in raceway at levels below 3 m (10ft).
- F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).
- G. Do not install wiring in raceway containing tubing.
- H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.

- I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
- J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.
- K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
- L. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
- M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
- N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
- O. Size of raceway and size and type of wire shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
- P. Include one pull string in each raceway 2.5 cm (1 in.) or larger.
- Q. Use color-coded conductors throughout with conductors of different colors.
- R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
- S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).
- T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
- U. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.
- V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.
- W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
- X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
- Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes and ends not terminating in boxes shall have bushings installed.

3.8 COMMUNICATION WIRING

- A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.
- B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.

- C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.
- D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
- E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.
- F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lightning arrestor shall be installed according to manufacturer's instructions.
- G. All runs of communication wiring shall be unspliced length when that length is commercially available.
- H. All communication wiring shall be labeled to indicate origination and destination data.
- I. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."
- J. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:
 - 1. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
 - 2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
 - 3. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
 - 4. An MS/TP EIA-485 network shall have no T connections.

3.9 INSTALLATION OF SENSORS

- A. Install sensors in accordance with the manufacturer's recommendations.
- B. Mount sensors rigidly and adequately for environment within which the sensor operates.
- C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.
- D. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.
- E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
- F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m² (1 ft²) of coil area.
- G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.
- H. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
- I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
- J. Differential Air Static Pressure.

1. Supply Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
3. Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.
6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.

3.10 WARNING LABELS

- A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the control system.
 1. Labels shall use white lettering (12-point type or larger) on a red background.
 2. Warning labels shall read as follows.

CAUTION
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.

- B. Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects.
 1. Labels shall use white lettering (12-point type or larger) on a red background.
 2. Warning labels shall read as follows.

CAUTION
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.11 IDENTIFICATION OF HARDWARE AND WIRING

- A. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 5 cm (2 in.) of termination with control system address or termination number.
- B. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.
- C. Permanently label or code each point of field terminal strips to show the instrument or item served.
- D. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.
- E. Identify all other control components with permanent labels. All plug-in components shall be labeled such that removal of the component does not remove the label.
- F. Identify room sensors related to terminal boxes or valves with nameplates.

- G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.
- H. Identifiers shall match record documents.

3.12 CONTROLLERS

- A. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in the Points List and the Sequences of Operation.

3.13 PROGRAMMING

- A. Provide sufficient internal memory for the specified sequences of operation and trend logging
- B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See the Sequences of Operation. If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix B to Section 23 09 93 may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.
- C. Software Programming.
 - 1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:
 - a. Text-based:
 - 1) Must provide actions for all possible situations
 - 2) Must be modular and structured
 - 3) Must be commented
 - b. Graphic-based:
 - 1) Must provide actions for all possible situations
 - 2) Must be documented
 - c. Parameter-based:
 - 1) Must provide actions for all possible situations
 - 2) Must be documented.
- D. Operator Interface. Update the existing graphics for all mechanical systems and floor plans of the building. This includes each hot water system, boiler and pumps. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in Section 23 09 93.
 - 1. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

3.14 CONTROL SYSTEM CHECKOUT AND TESTING

- A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration
1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
 2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
 3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
 4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
 5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
 6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
 7. Alarms and Interlocks.
 - a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
 - b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
 - c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action

3.15 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

- A. Demonstration.
1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
 2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
 3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
 4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes.

The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.

5. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:
 - a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
 - b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
 - c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
 - d. Interface to the building fire alarm system.
 - e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and disk formats.
10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

B. Acceptance.

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

3.16 CLEANING

- A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.
- B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.
- C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.17 TRAINING

- A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.
- B. Training shall enable students to accomplish the following objectives.
 - 1. Day-to-day Operators:
 - a. Proficiently operate the system
 - b. Understand control system architecture and configuration
 - c. Understand DDC system components
 - d. Understand system operation, including DDC system control and optimizing routines (algorithms)
 - e. Operate the workstation and peripherals
 - f. Log on and off the system
 - g. Access graphics, point reports, and logs
 - h. Adjust and change system set points, time schedules, and holiday schedules
 - i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
 - j. Understand system drawings and Operation and Maintenance manual
 - k. Understand the job layout and location of control components
 - l. Access data from DDC controllers and ASCs
 - m. Operate portable operator's terminals
 - 2. Advanced Operators:
 - a. Make and change graphics on the workstation
 - b. Create, delete, and modify alarms, including annunciation and routing of these
 - c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
 - d. Create, delete, and modify reports
 - e. Add, remove, and modify system's physical points
 - f. Create, modify, and delete programming
 - g. Add panels when required
 - h. Add operator interface stations
 - i. Create, delete, and modify system displays, both graphical and others
 - j. Perform DDC system field checkout procedures

- k. Perform DDC controller unit operation and maintenance procedures
 - l. Perform workstation and peripheral operation and maintenance procedures
 - m. Perform DDC system diagnostic procedures
 - n. Configure hardware including PC boards, switches, communication, and I/O points
 - o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
 - p. Adjust, calibrate, and replace system components
- 3. System Managers/Administrators:
 - a. Maintain software and prepare backups
 - b. Interface with job-specific, third-party operator software
 - c. Add new users and understand password security procedures
- C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.
- D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.
- E. The instructor(s) shall be factory-trained and experienced in presenting this material.
- F. Classroom training shall be done using a network of working controllers representative of installed hardware.

3.18 SEQUENCES OF OPERATION

- A. See Plans for the Sequences of Operation.

3.19 CONTROLS COMMUNICATION PROTOCOL

- A. General. The electronic controls packaged with this equipment shall communicate with the building direct digital control (DDC) system. The DDC system shall communicate with these controls to read the information and change the control setpoints as shown in the points list, sequences of operation, and control schematics. The information to be communicated between the DDC system and these controls shall be in the standard object format as defined in ANSI/ASHRAE Standard 135 (BACnet). Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of Standard 135.
- B. Distributed Processing. The controller shall be capable of stand-alone operation and shall continue to provide control functions if the network connection is lost.
- C. I/O Capacity. The controller shall contain sufficient I/O capacity to control the target system.
- D. The Controller shall have a physical connection for a laptop computer or a portable operator's tool.
- E. Environment. The hardware shall be suitable for the anticipated ambient conditions.
 - 1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 40°C to 60°C (40°F to 140°F).
 - 2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
- F. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.

- G. Memory. The Controller shall maintain all BIOS and programming information in the event of a power loss for at least 30 days.
- H. Power. Controller shall be able to operate at 90% to 110% of nominal voltage rating.
- I. Transformer. Power supply for the Controller must be rated at minimum of 125% of ASC power consumption and shall be fused or current limiting type.

3.20 START-UP AND CHECKOUT PROCEDURES

- A. Start up, check out, and test all hardware and software and verify communication between all components.
 - 1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
 - 2. Verify that all analog and binary input/output points read properly.
 - 3. Verify alarms and interlocks.
 - 4. Verify operation of the integrated system.

END OF SECTION 23 09 23

SECTION 23 11 00
FACILITY FUEL PIPING

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Pipe hangers and supports.
 - 2. Pipe and pipe fittings.
 - 3. Valves.

1.2 SUBMITTALS

- A. Product Data:
 - 1. Pipe Hangers and Supports: Submit manufacturers catalog data including load carrying capacity.
 - 2. Valves: Submit manufacturers catalog information with valve data and ratings for each service.
- B. Pipe Hangers and Supports: Design data, indicate pipe sizes, load carrying capacity of trapeze, multiple pipe, and riser support hangers.
- C. Manufacturer's Installation Instructions: Submit installation instructions for material and equipment.
- D. Manufacturer's Certificate: Certify products meet or exceed specified requirements.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: Submit spare parts lists and maintenance procedures.

1.4 QUALITY ASSURANCE

- A. Perform Work in accordance with NFPA 54.
- B. List and label flexible connectors in accordance with UL 536.
- C. Maintain one copy of each document on site.

1.5 WARRANTY

- A. Furnish one year manufacturer warranty for materials and services.

PART 2 PRODUCTS

2.1 PIPE HANGERS AND SUPPORTS

- A. Manufacturers:
 - 1. Carpenter & Paterson Inc.
 - 2. Creative Systems Inc.
 - 3. Flex-Weld, Inc.
 - 4. Glope Pipe Hanger Products Inc.
 - 5. Michigan Hanger Co.
 - 6. Superior Valve Co.
 - 7. Substitutions: Permitted.
- B. Conform to ASME B31.9; ASTM F708; MSS SP 58; MSS SP 69 or MSS SP 89.
- C. Hangers for Pipe Sizes 1/2 to 1-1/2 inch: Malleable iron or Carbon steel, adjustable swivel, split ring.
- D. Hangers for Pipe Sizes 2 inches and Over: Carbon steel, adjustable, clevis.
- E. Multiple or Trapeze Hangers: Steel channels with welded spacers and hanger rods.
- F. Wall Support for Pipe Sizes to 3 inches: Cast iron hook.

- G. Wall Support for Pipe Sizes 4 inches and Over: Welded steel bracket and wrought steel clamp.
- H. Vertical Support: Steel riser clamp.
- I. Floor and Roof Support for Pipe Sizes to 4 inches: 6" tall minimum, Cast iron adjustable pipe saddle, lock nut, nipple, floor steel support.
- J. Floor and Roof Support for Pipe Sizes 6 inches and Over: 6" tall minimum, adjustable cast iron roll and stand, steel screws, and concrete pier or steel support.
- K. Copper Pipe Support: Copper-plated, carbon-steel adjustable, ring.

2.2 PIPES AND TUBES

- A. Natural Gas Piping, above Grade:
 - 1. Steel Pipe: ASTM A53/A53M, Grade B, Schedule 40 black, with malleable iron or forged steel fittings, screwed or welded.
 - 2. Copper Tubing: ASTM B88, Type K, annealed with wrought copper fittings and compression joints.

2.3 VALVES

- A. Manufacturers:
 - 1. American Valve
 - 2. FMC Crosby Valve
 - 3. Red-White Valve Corp.
 - 4. Substitutions: Permitted.
- B. Gate Valves:
 - 1. Up to 2 inches: Bronze body, bronze trim, non-rising stem, hand wheel, inside screw, double wedge disc, soldered or threaded.
 - 2. Over 2 inches: Iron body, bronze trim, rising stem, hand wheel, OS&Y, solid wedge, flanged or grooved ends.
- C. Globe Valves:
 - 1. Up to 2 Inches: Bronze body, bronze trim, rising stem and hand wheel, inside screw, renewable composition disc, solder or threaded ends, with back seating capacity.
 - 2. Over 2 inches: Iron body, bronze trim, rising stem, hand wheel, OS&Y, plug type disc, flanged ends, renewable seat and disc.
- D. Ball Valves:
 - 1. Up to 2 inches: Bronze or stainless steel one piece body, chrome plated brass ball, teflon seats and stuffing box ring, lever handle, solder or threaded ends.
 - 2. Over 2 inches: Cast steel flanged body, chrome plated steel ball, Teflon seat and stuffing box seals and lever handle.
- E. Plug Valves:
 - 1. Up to 2 inches: Bronze body, bronze tapered plug, non-lubricated, Teflon packing, threaded ends.
 - 2. Over 2 inches: Cast iron body and plug, pressure lubricated, Teflon packing, flanged ends.
- F. Swing Check Valves:
 - 1. Up to 2 inches: Bronze body and swing disc, solder or threaded ends.
 - 2. Over 2 inches: Iron body, bronze trim, swing disc, renewable disc and seat, flanged ends.

2.4 PIPING SPECIALTIES

- A. Flanges, Unions, and Couplings:
 - 1. Pipe Size 2 inches and Under: Malleable iron unions for threaded ferrous piping; bronze unions for copper pipe, soldered joints.
 - 2. Pipe Size Over 2 inches: Forged steel flanges for ferrous piping; bronze flanges for copper piping; preformed neoprene gaskets.
 - 3. Dielectric Connections: Union with galvanized or plated steel threaded end, copper solder end, water impervious isolation barrier.
- B. Strainers:
 - 1. Size 2 inches and Under: Threaded brass or iron body for 175 psig working pressure, Y pattern with 1/32 inch stainless steel perforated screen.
 - 2. Size 2-1/2 inch to 4 inch: Flanged iron body for 175 psig working pressure, Y pattern with 3/64 inch stainless steel perforated screen.
 - 3. Size 5 inch and Larger: Flanged iron body for 175 psig working pressure, basket pattern with 1/8 inch stainless steel perforated screen.
- C. Flexible Connectors:
 - 1. Corrugated stainless steel hose with single layer of stainless steel exterior braiding, minimum 9 inches long with copper tube ends; for maximum working pressure 300 psig.
- D. Pressure Gages:
 - 1. Gage: ASME B40.1, UL 393 with bourdon tube, rotary brass movement, brass socket, front calibration adjustment, black scale on white background.
 - a. Case: Cast aluminum.
 - b. Bourdon Tube: Brass or Phosphor bronze Type 316 stainless steel.
 - c. Dial Size: 2 inch diameter.
 - d. Mid-Scale Accuracy: One percent.
 - e. Scale: Both psi and kPa.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Verify excavations are to required grade, dry, and not over-excavate.

3.2 PREPARATION

- A. Ream pipe and tube ends. Remove burrs.
- B. Remove scale and dirt, on inside and outside piping before assembly.
- C. Prepare piping connections to equipment with flanges or unions.

3.3 INSTALLATION - INSERTS

- A. Install inserts for placement in concrete forms.
- B. Install inserts for suspending hangers from reinforced concrete slabs and sides of reinforced concrete beams.
- C. Provide hooked rod to concrete reinforcement section for inserts carrying pipe over 4 inches.
- D. Where concrete slabs form finished ceiling, locate inserts flush with slab surface.
- E. Where inserts are omitted, drill through concrete slab from below and provide through-bolt with recessed square steel plate and nut recessed into and grouted flush with slab.

3.4 INSTALLATION - PIPING SYSTEMS

- A. Paint all exposed exterior mounted piping.

- B. Install dielectric connections wherever jointing dissimilar metals.
- C. Install unions downstream of valves and at equipment or apparatus connections.
- D. Route piping parallel to building structure and maintain gradient.
- E. Install piping to maintain headroom. Group piping to conserve space. Group piping whenever practical at common elevations.
- F. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.
- G. Provide clearance in hangers and from structure and other equipment for installation of insulation and access to valves and fittings.
- H. Sleeve pipe passing through partitions, walls and floors. Provide 1" annular clear space between pipe and sleeve.
- I. Install piping system allowing clearance for installation of insulation and access to valves and fittings.
- J. Install identification on piping systems including underground piping. Refer to Section 23 05 00.
- K. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.
- L. Provide capped tee fittings upstream and downstream of all new gas pressure regulators which do not contain vent limiting devices.

3.5 INSTALLATION - VALVES

- A. Install valves with stems upright or horizontal, not inverted.
- B. Install ball valves for shut-off and to isolate equipment, part of systems, or vertical risers.
- C. Install ball valves for throttling or manual flow control services.

3.6 INSTALLATION - PIPING SPECIALTIES

- A. Install pressure gauges with pulsation dampers. Provide needle valve or ball valve to isolate each gauge. Extend nipples and siphons to allow clearance from insulation.
- B. Install gauges in locations where they are easily read from normal operating level. Install vertical to 45 degrees off vertical.
- C. Adjust gauges to final angle, clean windows and lenses, and calibrate to zero.

3.7 INSTALLATION - FUEL PIPING

- A. Install natural gas piping in accordance with ASME B31.2 and ASME B31.4.
- B. Install natural gas piping in accordance with NFPA 54.
- C. Provide clearance for installation of insulation and access to valves and fittings.
- D. Establish elevations of buried piping outside building to provide not less than 1.5 ft of cover.
- E. Provide support for utility meters in accordance with requirements of utility company.
- F. Pipe vents from gas pressure reducing valves to outdoors and terminate in weatherproof hood.
- G. Test natural gas piping in accordance with NFPA 54.

3.8 INSTALLATION - PIPE HANGERS AND SUPPORTS

- A. Support horizontal piping as scheduled.
- B. Install hangers with minimum 1/2 inch space between finished covering and adjacent work.
- C. Place hangers within 12 inches of each horizontal elbow.
- D. Use hangers with 1-1/2 inch minimum vertical adjustment.

- E. Support horizontal cast iron pipe adjacent to each hub, with 5 feet maximum spacing between hangers.
- F. Support vertical piping at every [other] floor. Support vertical cast iron pipe at each floor at hub.
- G. Where piping is installed in parallel and at same elevation, provide multiple pipe or trapeze hangers.
- H. Support riser piping independently of connected horizontal piping.
- I. Provide copper plated hangers and supports for copper piping.
- J. Design hangers for pipe movement without disengagement of supported pipe.
- K. Prime coat exposed steel hangers and supports. Hangers and supports located in crawl spaces, pipe shafts, and suspended ceiling spaces are not considered exposed.

3.9 SERVICE CONNECTIONS

- A. Coordinate with local gas company to install new gas service line to new meter and regulator assembly. The cost for this service shall be included in the contractor's bid. All trenching, backfill and [surface replacement] shall also be included in the contractors bid.

3.10 SCHEDULES

SUPPORT OF PIPING

STEEL PIPE, NOMINAL SIZE OF PIPE (inches)	SPACING OF SUPPORTS (feet)		NOMINAL SIZE OF TUBING (SMOOTH WALL) (inch O.D.)	SPACING OF SUPPORTS (feet)
1/2	6		1/2	4
3/4 or 1	8		5/8 or 3/4	6
1-1/4 or larger (horizontal)	10		7/8 or 1 (horizontal)	8
1-1/4 or larger (vertical)	Every floor level		1 or larger (vertical)	Every floor level

SPECIFICATIONS FOR THREADING METALLIC PIPE

IRON PIPE SIZE (inches)	APPROXIMATE LENGTH OF THREADED PORTION (inches)	APPROXIMATE NUMBER OF THREAD TO BE CUT
1/2	3/4	10
3/4	3/4	10
1	7/8	10
1-1/4	1	11
1-1/2	1	11
2	1	11
2-1/2	1-1/2	12
≥3	Welded	Welded

Note: Refer to manufacturer's recommendations for grooved end piping systems.

END OF SECTION

SECTION 23 30 00
HVAC AIR DISTRIBUTION

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Ductwork.
 - 2. Ductwork accessories.
 - 3. Air Outlets.
 - 4. Filters.

1.2 SUBMITTALS

- A. Product Data:
 - 1. Submit sizes, capacities, materials, controls and connections to other work.
 - 2. Submit catalog performance ratings, construction, electric and duct connections, flashing and dimensions for fans and exhausters.
- B. Operation and Maintenance Data: Submit instructions for lubrication, motor and drive replacement, spare parts lists, and wiring diagrams.
- C. Manufacturer's Installation Instructions: Submit relevant instructions.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: Submit instructions for filter replacement, spare parts lists, and wiring diagrams.

1.4 QUALITY ASSURANCE

- A. Maintain one copy of each document on site.

PART 2 PRODUCTS

2.1 DUCTWORK

- A. Duct Materials:
 - 1. Manufacturers:
 - a. United McGill
 - b. Semco
 - c. Tangent Air
 - d. Substitutions: Permitted.
 - 2. Galvanized Steel Ducts: ASTM A653/A653M galvanized steel sheet, lock-forming quality, having G90 zinc coating of in conformance with ASTM A90/A90M.
 - 3. Steel Ducts: ASTM A1008/A1008M
 - 4. Stainless-Steel Ducts: Comply with ASTM A 480/A 480M, Type 304.
 - 5. Aluminum Ducts: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.
 - 6. Fasteners: Rivets, bolts, or sheet metal screws.
 - 7. Hanger Rod: ASTM A36/A36M; steel , galvanized; threaded both ends, threaded one end, or continuously threaded.
- B. Ductwork Fabrication:
 - 1. Fabricate and support rectangular ducts in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible and as indicated on Drawings. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.

2. Fabricate and support round ducts with longitudinal seams in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible (Round Duct Construction Standards), and as indicated on Drawings. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.
 3. Construct T's, bends, and elbows with minimum radius 1-1/2 times centerline duct width. Where not possible and where rectangular elbows are used, provide turning vanes. Where acoustical lining is indicated, furnish turning vanes of perforated metal with glass fiber insulation.
 4. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.
 5. Fabricate continuously welded round and oval duct fittings two gages heavier than duct gages indicated in SMACNA Standard. Minimum 4 inch cemented slip joint, brazed or electric welded. Prime coat welded joints.
 6. Provide standard 45-degree lateral wye takeoffs. When space does not allow 45-degree lateral wye takeoff, use 90-degree conical tee connections.
 7. All ductwork to be constructed per SMACNA low pressure classification, 2.0"w.c. max. see table 6-1 of the IMC.
 8. As a minimum all ductwork shall be sealed to SMACNA Class B.
- C. Insulated Flexible Ducts:
1. Manufacturers:
 - a. Atco
 - b. Substitutions: Permitted.
 2. Product Description: Two ply vinyl film supported by helical wound spring steel wire; fiberglass insulation; polyethylene or aluminized vapor barrier film.
 - a. Pressure Rating: 10 inches wg positive and 1.0 inches wg negative.
 - b. Maximum Velocity: 4000 fpm.
 - c. Temperature Range: -10 degrees F to 160 degrees F.
 - d. Thermal Resistance: 4.2 square feet-hour-degree F per BTU.
 3. Product Description: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helical wound spring steel wire; fiberglass insulation; polyethylene or aluminized vapor barrier film.
 - a. Pressure Rating: 10 inches wg positive and 1.0 inches wg negative.
 - b. Maximum Velocity: 4000 fpm.
 - c. Temperature Range: -20 degrees F to 210 degrees F.
 - d. Thermal Resistance: 4.2 square feet-hour-degree F per BTU.
- D. Single Wall Spiral Round Ducts:
1. Manufacturers:
 - a. McGill AirFlow Corporation
 - b. Semco Incorporated
 - c. Tangent Air Corp.
 - d. Spiral Mfg. Co., Inc.
 - e. Substitutions: Permitted.
 2. Product Description: UL 181, Class 1, round spiral lock seam duct constructed of galvanized steel.

3. Duct Coating: Polyvinyl chloride plastic, 4 mil thick on outside. Temperature range: minus 30 degrees F to 200 degrees F. [Underslats installation only]

4. Construct duct with the following minimum gages:

Diameter	Gage
3 inches to 14 inches	26
15 inches to 26 inches	24
28 inches to 36 inches	22
38 inches to 50 inches	20
52 inches to 84 inches	18

5. Construct fittings with the following minimum gages:

Diameter	Gauge
3 inches to 14 inches	24
15 inches to 26 inches	22
28 inches to 36 inches	20
38 inches to 50 inches	20
52 inches to 60 inches	18
62 inches to 84 inches	16

E. Transverse Duct Connection System:

1. Manufacturers:
 - a. Cedinor
 - b. Ductmate
 - c. Substitutions: Permitted.
2. Product Description: SMACNA "E" rated; SMACNA "F" rated or SMACNA "J" rated rigidity class connection, interlocking angle, and duct edge connection system with sealant, gasket, cleats, and corner clips.

2.2 DUCT ACCESSORIES

A. Volume Control Dampers:

1. Fabricate in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, and as indicated on Drawings.
2. Fabricate splitter dampers of material matching duct gage to 24 inches size in each direction, and two gages heavier for larger sizes. Secure with continuous hinge or rod. Operate with a minimum 1/4 inch diameter rod.
3. Fabricate single blade dampers for duct sizes to 12 x 30 inch.
4. Fabricate multi-blade damper of opposed blade pattern with maximum blade sizes 8 x 72 inch. Assemble center and edge crimped blades in prime coated or galvanized channel frame with suitable hardware.
5. Except in round ductwork 12 inches and smaller, furnish end bearings.
6. Furnish locking, indicating quadrant regulators on single and multi-blade dampers. Where width exceeds 30 inches, furnish regulator at both ends.

B. Turning Devices:

1. Multi-blade device with blades aligned in short dimension; steel or aluminum construction; with individually adjustable blades, mounting straps.
2. Multi-blade device with radius blades attached to pivoting frame and bracket, steel or aluminum construction, with push-pull operator strap.

- C. Flexible Duct Connections:
 - 1. UL listed fire-retardant neoprene coated woven glass fiber fabric to NFPA 90A, approximately 3 inches wide, crimped into metal edging strip.

2.3 AIR OUTLETS AND INLETS

- A. Manufacturers:
 - 1. Price
 - 2. Krueger
 - 3. Titus
 - 4. Tuttle and Bailey
 - 5. Substitutions: Permitted.
- B. Ceiling Diffusers: Square, stamped or spun, multi-core type diffuser to discharge air in 360 degree pattern, with sectoring baffles where indicated; baked enamel off-white finish.
- C. Linear Slots: Extruded aluminum with pattern controller to change direction and volume of airflow and optional plenum.
- D. Return Grilles: Ceiling mounted, egg crate type.
- E. Variable Air Volume Diffuser: Square ceiling diffuser that shall deliver a 360 degree horizontal air pattern and shall modulate air volume to maintain a room air temperature setting. A variable position damper ring shall be digitally controlled by an onboard circuit board and powered by a capacitor on the control board. The capacitor shall be charged by a solar collection panel on the plaque face of the diffuser. The unit shall require no electrical or control connections.
The diffuser shall be capable of standalone operation, controlled wirelessly by a remote solar-powered wall sensor or interface with building automation through a wireless gateway.

2.4 FILTERS

- A. Manufacturers: as provided with equipment.
- B. Construction Filters: provide one extra set of filters with each piece of equipment. Replace upon completion of construction.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Verify sizes of equipment connections before fabricating transitions.
- B. Verify rated walls are ready for fire damper installation.
- C. Verify ducts and equipment installations are ready for accessories.
- D. Check location of air outlets and inlets and make necessary adjustments in position to conform to architectural features, symmetry, and lighting arrangement.

3.2 INSTALLATION

- A. Metal Ducts: Install in accordance with SMACNA Duct Construction Standards - Metal and Flexible.
- B. All longitudinal and transverse joints, seams, and connections of supply and return ducts operating at a static pressure less than 2.0" w.g. shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes installed in accordance with manufacturer's installation instructions.
- C. Connect flexible ducts to metal ducts with liquid adhesive plus tape or draw bands.
- D. Use crimp joints with or without bead for joining round duct sizes 8 inches and smaller with crimp in direction of airflow.

- E. Install flexible connections immediately adjacent to fans and motorized equipment. Install flexible connections specified between fan inlet and discharge ductwork. Prevent flexible connectors being in tension while running.
- F. Prevent passage of unfiltered air around filters by installing felt, rubber, or neoprene gaskets.
- G. Cut openings in ductwork to accommodate thermometers and controllers. Cut pitot tube openings for testing of systems, complete with metal cap with spring device or screw to eliminate against air leakage.
- H. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities. Apply duct insulation specified in Section 23 07 00.
- I. During construction install temporary closures of metal or taped polyethylene on open ductwork to prevent construction dust from entering ductwork system.
- J. Install balancing dampers on duct take-off to diffusers and grilles and registers, regardless of whether dampers are specified as part of diffuser, or grille and register assembly.
- K. Do not operate fans until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.
- L. Install sheaves required for final air balance.

END OF SECTION

SECTION 23 54 00
FURNACES

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Forced air furnaces with refrigerant cooling coils, and condensing units.

1.2 SUBMITTALS

- A. Product Data: Submit dimensions, connections, arrangement, accessories, capacities, manufacturer's installation instructions and controls.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: Submit spare parts lists.

1.4 QUALITY ASSURANCE

- A. Furnace Performance Requirements: Conform to minimum efficiency prescribed by ASHRAE 90.1-2010 when tested in accordance with DOE 10 CFR.
- B. Cooling Performance Requirements: Energy Efficiency Rating (EER) not less than prescribed by ASHRAE 90.1-2010 when used in combination with compressors and evaporator coils when tested in accordance with ARI 210/240.
- C. Maintain one copy of each document on site.

1.5 WARRANTY

- A. Furnish one year manufacturer warranty for heat exchangers and refrigeration compressors.

PART 2 PRODUCTS

2.1 FORCED AIR FURNACES

- A. Manufacturers:
 - 1. The Trane Company
 - 2. Carrier Corp.
 - 3. Substitutions: Permitted
- B. Units: Self-contained, condensing, packaged, factory assembled, pre-wired unit consisting of cabinet, supply fan, heating element, controls, air filter, humidifier, and accessories; wired for single power connection with control transformer.
 - 1. Air Flow Configuration: Upflow
 - 2. Heating: Natural gas fired
 - 3. Electric Refrigeration: Refrigerant cooling coil and outdoor package containing compressor, condenser coil and condenser fan.
 - 4. Accessories: Concentric vent kit, condensate neutralization kit.
- C. Cabinet: Steel with baked enamel finish and access doors with safety interlock switch.
- D. Supply Fan: Centrifugal type rubber mounted with direct or belt drive, adjustable variable pitch motor pulley, motor.
- E. Heat Exchanger: Stainless steel.
- F. Gas Burner:
 - 1. Atmospheric type with adjustable combustion air supply.

2. Gas valve capable of 100 percent safety gas shut-off; 24 volt combining pressure regulation, safety pilot, manual set (On-Off), pilot filtration, automatic electric valve.
3. Electronic pilot ignition, with hot surface igniter.
- G. Furnace Operating Controls:
 1. Room Thermostat: Cycles burner to maintain room temperature setting.
 2. Supply Fan Control: Energize from bonnet temperature independent of burner controls, with adjustable timed off delay and fixed timed on delay, with manual switch for continuous fan operation.
- H. Air Filters: 2" filter rack with MERV13 filters.
- I. Furnace Refrigeration Package:
 1. Evaporator Coil: Copper tube aluminum fin assembly, galvanized drain pan, drain connection, refrigerant piping connections, restricted distributor or thermostatic expansion valve, steel cabinet with baked enamel finish and insulation.
 2. Compressor: Hermetic, 3600 rpm, resiliently mounted integral with condenser, with positive lubrication, crankcase heater, high pressure control, motor overload protection, service valves and drier. Include time delay control to prevent short cycling.
 3. Refrigeration Accessories: Filter Drier, high-pressure switch (manual reset), low pressure switch (automatic reset), service valves and gauge ports, and thermometer well (in liquid line). Furnish thermostatic expansion valves. Furnish refrigerant lines, factory cleaned, dried, pressurized and sealed, with insulated suction line.
 4. Air Cooled Condenser: ARI 520; aluminum fin and copper tube coil, with direct drive axial propeller fan resiliently mounted, galvanized fan guard.
 5. Refrigeration Operating Controls:
 - a. Room Thermostat: Cycles condensing unit and supply fan to maintain room temperature setting.
 - b. Low Ambient Kit: Furnish refrigerant pressure switch to cycle condenser fan.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Install in accordance with NFPA 54
- B. Mount counter flow furnaces installed on combustible floors on additive base.
- C. Install drain piping from cooling coils and heat exchanger to nearest floor drain.
- D. Install refrigerant piping to remote condenser.
- E. Connect natural gas piping to supply.
- F. Mount air cooled condenser-compressor package on 4" concrete pad.
- G. Install flexible duct connections on inlet and outlet of furnaces.

END OF SECTION

SECTION 23 63 13
AIR-COOLED REFRIGERANT CONDENSERS

PART 1 GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Refrigerant piping specialties.
 - 2. Condensing units.

1.2 SUBMITTALS

- A. Shop Drawings: Indicate piping system layout.
- B. Product Data: Submit capacities, schematic layout of system, piping and electrical connections, manufacturer's installation instructions, wiring diagram, loads on mounting feet, sound data and controls.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: Submit spare parts list and recommended maintenance schedule.

1.4 QUALITY ASSURANCE

- A. Construction and Ratings: In accordance with ARI 210/240, ARI 365 or ARI 460. Testing in accordance with ASHRAE 20.
- B. Performance Ratings: Energy Efficiency Ratio (EER) not less than prescribed by ASHRAE 90.1 when tested in accordance with ARI 210/240, ARI 365 or ARI 460.
- C. Maintain one copy of each document on site.

1.5 WARRANTY

- A. Furnish one year manufacturer warranty for compressors.

PART 2 PRODUCTS

2.1 REFRIGERANT PIPING SPECIALTIES

- A. Manufacturers:
 - 1. Trane
 - 2. Carrier
 - 3. Substitutions: Permitted.
- B. Moisture and Liquid Indicators: Single port type, UL listed, with copper or brass body, flared or solder ends, sight glass, color coded paper moisture indicator and plastic cap.
- C. Diaphragm Packless Valves: UL listed, globe or angle pattern, forged brass body and bonnet, phosphor bronze and stainless-steel diaphragms, rising stem and hand wheel, stainless steel spring, nylon seat disc, solder, or flared ends.
- D. Packed Angle Valves: Forged brass or nickel-plated forged steel, forged brass seal caps with copper gasket, rising stem and seat, molded stem packing, solder or flared ends.
- E. Packed Ball Valves: Two piece forged brass body with Teflon ball seals and copper tube extensions, brass bonnet and seal cap, chrome plated ball, stem with neoprene ring stem seals.
- F. Straight Line or Angle Line Type Strainers: Brass or steel shell, steel cap and flange, and replaceable cartridge, with screen of stainless-steel wire.
- G. Straight Line, Non-Cleanable Type Strainers: Steel shell, copper plated fittings and stainless-steel wire screen.

- H. Globe Type Check Valves: Cast bronze or forged brass body, forged brass cap with neoprene seal, brass guide and disc holder, phosphor-bronze or stainless-steel spring, Teflon seat disc.
- I. Straight Through Type Check Valves: Brass body and disc, phosphor bronze or stainless-steel spring, neoprene seat.
- J. Straight Through or Angle Type Pressure Relief Valves: Brass body and disc, neoprene seat, factory sealed and ASME stamped.
- K. Replaceable Cartridge Angle Type Filter Dryers: UL listed brass shell and bronze cap, perforated brass shell and molded desiccant filter core.
- L. Permanent Straight Through Type Filter Dryers: UL listed, steel shell with molded desiccant filter core.
- M. Solenoid Valves:
 - 1. Valve: Pilot operated; copper or brass body and internal parts, synthetic seat, stainless steel stem and plunger assembly, with flared, solder, or threaded ends. Furnish stem allowing manual operation in case of coil failure.
 - 2. Coil Assembly: UL listed, replaceable with molded electromagnetic coil, moisture, and fungus proof, with surge protector and color-coded lead wires.
- N. Expansion Valves:
 - 1. Angle or Straight Through Type: Brass body, internal or external equalizer, adjustable super heat setting, replaceable inlet strainer, with replaceable capillary tube and remote sensing bulb well.
 - 2. Selection: Select for maximum load at design operating pressure and minimum 10 degrees F super heat.
- O. Receivers: UL listed, steel, with taps for inlet, outlet, and pressure relief valve.
- P. Flexible Connectors: Corrugated bronze hose with single layer of exterior braiding, minimum 9 inches long with copper tube ends.

2.2 CONDENSING UNITS

- A. Manufacturers:
 - 1. Trane.
 - 2. Carrier.
 - 3. Substitutions: Permitted.
- B. Units: Self-contained, packaged, factory assembled and wired units for outdoor use consisting of cabinet, compressors, condensing coil and fans, integral sub-cooling coil, controls, liquid receiver.
- C. Cabinet: Galvanized steel with baked enamel finish and removable access doors or panels with quick fasteners.
- D. Compressor: Hermetically sealed, 1750 rpm, resiliently mounted compressor with positive lubrication, crankcase heater, cylinder unloaders with electric solenoids, motor overload protection, service valves, and filter drier.
- E. Condenser:
 - 1. Coil: Seamless copper tubing with aluminum fins.
 - 2. Fans: Vertical discharge, direct drive axial fans, resiliently mounted with guard and motor.
 - 3. Motors: Permanently lubricated ball bearing motors with built-in current and overload protection.
- F. Controls:

1. High- and low-pressure cutouts for compressor, oil pressure control, non-recycling pump-down, and reset relay.
2. Low ambient controls to allow operation down to 55 degrees F ambient temperature.
3. Timer circuits to prevent rapid loading and unloading of compressor.

2.3 ELECTRICAL CHARACTERISTICS AND COMPONENTS

- A. Disconnect Switch: Field mount near equipment.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Install expansion valve sensing bulb immediately downstream of evaporator on suction line. Install external equalizer piping on expansion valves with refrigerant distributor connected to evaporator.
- B. Install flexible connectors parallel to compressor shaft.
- C. Install units on rubber in shear.
- D. Charge system with refrigerant and put system into operation, and test equipment performance. Furnish cooling season startup, and winter season shutdown for first year of operation.
- E. Connect inlet and outlet of condensing units to piping as indicated on Drawings.

3.2 APPLICATION

- A. Install line size liquid indicators in main liquid line leaving condenser. When the system contains a receiver, install in liquid line leaving receiver.
- B. Install line size strainer upstream of each automatic valve. Where multiple expansion valves with integral strainers are used install a single main liquid line strainer.
- C. On steel piping systems, install strainer in suction line.
- D. Install shut-off valve on each side of strainer.
- E. Install permanent filter-dryers in low temperature systems and systems using hermetic compressors.
- F. Install replaceable cartridge filter-dryers with three-valve bypass assembly to allow isolation of dryers for servicing.
- G. Install filter-dryers in liquid line adjacent to receivers and for each solenoid valve.
- H. Install solenoid valves, in liquid line of single or multiple evaporator systems, and in oil bleeder lines from flooded evaporators to stop flow of oil and refrigerant into suction line when system shuts down.
- I. Install refrigerant charging valve connections in liquid line between receiver shut-off valve and expansion valve.
- J. Install flexible connectors near compressors connections.

END OF SECTION