SECTION 23 3114
DUCTWORK

PART 1 - GENERAL

1.01 RELATED WORK

A. Section 23 0000 - General Mechanical Requirements (submittal requirements)

B. Section 23 0529 - Mechanical Piping and Equipment Supporting Devices

C. Section 23 0700 - Mechanical Systems Insulation

D. Section 23 0595 - Air Systems Test Adjust Balance

E. Section 23 0901 - Control Systems Integration

F. Section 23 3314 - Ductwork Specialties

1.02 SUBMITTALS

A. For each duct system, submit schedule utilizing reinforcement tables from SMACNA HVAC Duct Construction Standards Metal and Flexible where applicable. Each duct system schedule shall include, but not be limited to, the following:
   1. Name of Contractor/manufacturer fabricating each duct system
   2. Material and gauge
   3. Pressure class
   4. Transverse joint type and length and reinforcement rigidity class with designated joint T number or proprietary duct connection if utilized for each system
   5. Certified test results of proprietary joint products, if used, tested in accordance with SMACNA procedures
   6. Intermediate reinforcement spacing and rigidity class with metal angle dimensions and gauge
   7. Type of longitudinal seam
   8. Fitting construction details
   9. Support methods including spacing, upper attachments, and lower attachments
   10. Sealant and gasket
   11. Sealing class

B. Duct leakage testing methods, apparatus and apparatus certification signifying meter is in conformance with ASME Requirements for testing meters.

C. Submit the following information for welded sheet metal ductwork:
   1. Welding Procedure Specification (WPS) for welded joints. Form to be similar to AWS D9.1/D9.1M Sheet Metal Welding Code, Annex "D".
   2. Procedure Qualification Record (PQR) for each WPS. Form to be similar to ANSI/AWS D9.1/D9.1M Sheet Metal Welding Code, Annex "E".
   3. Welder and Welding Operator Qualification Test Record (satisfactory performance) for each field or shop welder. Form to be similar to ANSI/ AWS D9.1/D9.1M Sheet Metal Welding Code, Annex "F".

1.03 DELIVERY, STORAGE, AND HANDLING

A. Protect duct and fittings from damage due to normal handling during shipment and storage. Protection shall be applied to ends of duct to prevent dirt and moisture from entering ducts and fittings.

1.04 DESCRIPTION

A. Furnish and erect ductwork free of objectionable vibration, chatter, and pulsations. Verify dimensions at site, making field measurements and drawings necessary for fabrication and erection.

B. Duct sizes indicated are net inside dimensions.

C. Where size for a duct segment is not indicated, the duct segment size shall be equal to the largest duct segment to which it is connected. Transition to smaller size shall occur on side of fitting where smaller size is indicated.

1.05 DESIGN CRITERIA

A. All products shall conform to NFPA 90A, and shall possess flame spread rating of not over 25 and smoke developed rating no higher than 50.

B. Unless otherwise indicated, construct all ductwork of galvanized sheet metal for pressure class not less than 2" WG for positive pressure ductwork and not greater than -2" WG for negative pressure ductwork.

C. Ductwork shall comply with Local, State and Federal requirements.

D. Use material, weight, thickness, gauge, construction, and installation methods as outlined in the following SMACNA publications, unless noted otherwise:
   1. HVAC Duct Construction Standards Metal and Flexible, 3rd Edition, 2005
   2. HVAC Air Duct Leakage Test Manual, 2nd Edition, 2012
   3. Round Industrial Duct Construction Standards, 2nd Edition, 1999
   4. Rectangular Industrial Duct Construction Standards, 2nd Printing 2004
   5. Accepted Industry Practice for Industrial Duct Construction, 2nd Edition, 2008
   6. Thermoset FRP Duct Construction Manual" 1st Edition (1997)
   7. Phenolic Duct Construction Standards ANSI/SMACNA 022 (2015)
   8. SMACNA Sheet Metal Welding Guide – 3rd Edition, 2007

E. Unless otherwise indicated, pressure class for VAV system supply ductwork between supply fan discharge and air terminal device inlet shall be equal to static pressure at fan discharge but not less than 4" WG; pressure class for ductwork on suction side of air handling unit and suction side of return fan shall be equal to static pressure at inlet of return fan but not less than -2" WG.

F. Unless otherwise indicated, pressure class for fume hood exhaust ductwork between exhaust fan inlet and exhaust air terminal device outlet shall be equal to static pressure at exhaust fan inlet but not less than -4" WG.

G. Duct transverse joints and reinforcement material, including angle ring flanges and stiffeners, shall be of same material as duct.

PART 2 - PRODUCTS

2.01 GALVANIZED STEEL SHEET

A. Lock Former Quality (LFQ), cold rolled, open hearth soft steel sheet capable of double seaming without fracture, ASTM A924/A924M or ASTM A653/A653M . Galvanized coating shall be G90.

B. Use G90 Galvaneal or Zinc grip where painting is specified.

2.02 MANUFACTURED ROUND DUCTWORK (POSITIVE PRESSURE)

A. Single Wall:
   1. Manufacturers: Lindab, Semco or McGill AirFlow, or approved equal, equal to McGill AirFlow Uni-Seal duct and fittings suitable to positive 10" WG.
   2. Ducts shall be machine formed round and/or flat oval as shown on drawings, constructed of G90 galvanized steel per ASTM A653, CS Type B. Use spiral lockseam construction. Longitudinal seam construction may be used for ductwork over 80" diameter with minimum 16 ga. Use fittings as indicated on drawings, as specified, and as required in accordance with manufacturer's published data.
   3. Unless otherwise indicated, connection shall be slip type with minimum 2" insertion length or flanged joint in accordance with manufacturer's recommendations. When flange joints are required, use Van Stone flange with neoprene gasket. Face flange may be integral (machine formed on duct end) or welded to duct. Backing flange shall be free-floating for bolt-hole alignment. Seal shall be at face-to-face flanges.
   4. Internal bracing is not allowed.
   5. Pre-sealed snaplock pipe system “Greenseam +” as manufactured by Ductmate Industries may be used for low pressure supply air duct.

2.03 DUCT SEALANTS AND GASKETS

A. Sealant:

SECTION 23 0513
MOTORS FOR MECHANICAL EQUIPMENT

PART 1 - GENERAL

1.01 SUBMITTALS

A. Product Data including the following:
   1. Manufacturer
   2. hp, voltage, phase, hertz, rpm
   3. Motor type
   4. Enclosure type
   5. Frame type
   6. Insulation class
   7. NEMA design designation
   8. Service factor
   9. Nominal efficiency at full load
   10. Power factor at full load
   11. Full load amperes
   12. Bearings
   13. Mountings
   14. Dimensions
   15. Weight
   16. Shaft grounding brush for motors driven by Variable Frequency Drives (VFD)

1.02 PRODUCT CRITERIA

A. Motors covered by this Specification shall conform to applicable requirements of NEMA, IEEE, ANSI, and NEC Standards and shall be UL Listed where applicable for service specified.

B. Motors shall be designed for conditions in which they will be required to perform; i.e., general purpose, splash proof, explosion proof, standard duty, high torque or other special type as required by equipment manufacturers.

C. Select motors so they do not exceed nameplate rating nor operate into service factor to meet specified duty.

D. Motors located inside air handling units or exposed located in outdoor or wash down environments shall have totally enclosed fan cooled (TEFC) enclosures.

E. Motors shall be furnished for starting in accordance with utility requirements and be compatible with starters specified hereinafter or under Electrical sections of Specifications.
   1. Refer to Section 26 2913 - Enclosed Controllers for reduced voltage starting requirements.
   2. Starters for NEMA rated 200 or 230 V motors, 25 hp and above shall be reduced voltage starting type.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials shall be new and guaranteed for service intended.

2.02 ELECTRICALLY COMMUTATED MOTORS (ECM)

A. Motor assembly shall be designed for use on direct drive fans or pumps and shall be electrically commutated, DC, brushless type, specifically designed for use with 120 V or 208-230/277 V, 60 Hz single-phase electrical input or three-phase, 60 Hz electrical input as scheduled.

B. Motor speed shall be variable via compatible input signal and shall be complete with and operated by single-phase integrated controller/inverter that operates wound stator and senses rotor position to electronically commutate stator. Motor shall maintain minimum of 70% efficiency over entire operating range.

C. Motors shall:

1. have permanently lubricated ball bearings
2. be designed for synchronous rotation.
3. be permanent magnet type with near-zero rotor losses.
4. be able to be mounted with shaft in horizontal or vertical orientation.
5. be controllable from local and remote speed-control adjustments
6. be designed to overcome reverse rotation without affecting life expectancy

D. Speed Control (Drive):
1. Motor manufacturer shall provide factory installed PWM speed control drive for local (manual) and remote speed adjustment. Local PWM drive shall be field adjustable with standard screwdriver. Drive shall also be capable of receiving 0-10 vdc signal from DDC controller to control fan or pump speed.
2. Drive shall provide soft start and adjustable speed change ramp rate.
3. Drive shall provide motor protection consisting of locked rotor, over-current, and thermal overload protection at minimum.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install materials in accordance with drawings, approved Shop Drawings and manufacturer's recommendations.

END OF SECTION

SECTION 23 0529
MECHANICAL PIPING AND EQUIPMENT SUPPORTING DEVICES

PART 1 - GENERAL

1.01 RELATED WORK

A. Section 23 0700 - Mechanical Systems Insulation

B. Section 23 0550 - Vibration Isolation

C. Section 23 3114 - Ductwork

1.02 REFERENCE

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

1.03 DESCRIPTION

A. Provide all supporting devices not provided as part of building structure or indicated on structural drawings or structural details, as specified and as required for proper supporting, anchoring, and guiding of piping, equipment, materials and systems.

B. Support for all conditions of operation, including variations in installed and operating weight of equipment, piping and ductwork, to prevent excess stress and allow for proper expansion and contraction.

1.04 SUBMITTALS

A. Product Data for each piping system for all pipe sizes and all applicable equipment including the following:
   1. Manufacturer's name
   2. Model numbers
   3. Materials of construction and load ratings lbs.
   4. Schedule of hangers and support devices with pipe support spacing
   5. Insulated pipe supports along with application chart or table including pipe support spacing.
   6. Insulation protection saddles and weight bearing insulation table
   7. Details and calculations for sizing supplementary steel utilized for trapeze or specially designed supports
   8. Structural attachments, concrete inserts, and concrete anchors. Submit ICC-ES Evaluation Report for each type of concrete insert and anchor.
   9. Calculations and drawings for concrete inserts and anchors for each application shall be submitted when requested by Owner or Engineer.
   10. Drawings showing specific locations of any weld attachments to structure, including weight supported by such attachments
   11. Drawings showing specific locations of any suspended loads which exceed 100 lbs within joist chord panel to be attached to open web steel joist structural members. Include weight supported by such attachments. (Panel is length of chord between two adjacent diagonal web members at point of connection to chord.)
   12. Equipment mounting devices
   13. Pipe guides and anchors
   14. All other appropriate data

B. Submittals in PDF format shall be organized using PDF bookmarks per detailed instructions on assembling submittal packages identified under Submittal Requirements section of 23 0000 - General Mechanical Requirements

C. Calculations and drawings prepared by the Contractor's structural engineer shall be submitted bearing the stamp of a licensed Structural Engineer registered in project jurisdiction, for approval.

1.05 DESIGN CRITERIA

A. Materials and application of pipe hangers and supports shall conform to the latest requirements of ANSI B31/ASME B31.1 Code for Pressure Piping and MSS Standard Practice SP-58-2018 (Pipe Hangers

and Supports Materials, Design, Manufacture, Selection, Application, and Installation), except as supplemented or modified herein.

B. Support materials shall be steel or stainless steel unless specifically indicated.

C. Support devices shall be factory fabricated and have published load ratings.

D. Unless otherwise indicated, design supports, anchors, and related components with safety factor in accordance with AISC Manual of Steel Construction, but not less than 2.0.

E. Determine maximum deflection using the following equation.

F. Maximum deflection of support members, including trapeze supports, shall be in accordance with the following equation, but shall not exceed 0.3":
   1. D = L/240
      D = Max deflection in inches
      L = Support member length in inches

G. Unless otherwise indicated, hangers, support devices and hardware shall be steel and shall have factory standard black, primed, galvanized or electroplated finish for indoor application, and hot-dipped galvanized finish for outdoor application and corrosive atmospheres. Coat cut edges, welds or any damaged finish with galvanized paint.
   1. Corrosive atmospheres include the following locations:
      a. Exterior locations
      b. Chemical storage and hazardous waste storage rooms
      c. Food service/kitchen areas
      d. Locker/shower rooms
      e. Meter pits
      f. Utility tunnels
      g. Cage wash room (dirty and clean)
      h. Sterilizer/autoclave room

H. Materials in contact with pipe shall be galvanically compatible with piping material to eliminate conductive path for galvanic corrosion. Where piping and support materials have galvanic potential, Provide galvanic separation, such as nonmetallic coating or inserts between piping and metallic supports. Pipe insulation is acceptable galvanic separation. Materials in contact with pipe shall be galvanically compatible with piping material to eliminate conductive path for galvanic corrosion. Where piping and support materials have galvanic potential, provide galvanic separation, such as nonmetallic coating or inserts between piping and metallic supports. Pipe insulation is acceptable galvanic separation. Galvanic potential shall be determined by table below:

	Galvanized Steel	Carbon Steel	Stainless Steel (Type 304 or 316)	Copper Brass Bronze
Copper, Brass, Bronze	Yes	Yes	No	NA
Stainless Steel (Type 304 or 316)	Yes Note (1)	Yes Note (1)	NA	
Carbon Steel	No	NA		
Galvanized Steel	NA			

(1) Required where stainless steel surface area near interface is equal or greater than steel surface area

I. Unless otherwise indicated, steel support devices exposed to ventilation air stream shall be stainless steel or steel with either galvanized finish or paint finish. Paint type shall be approved by Architect.

J. This Contractor is responsible for proper placement and sizing of supporting devices to accommodate insulation thickness and pitching of pipe. Coordinate with Contractor performing work specified in Section 22 0700 - Plumbing Insulation.

K. In addition to hangers specified in this Section, piping connected to pumps, compressors, and similar rotating or reciprocating equipment shall have vibration isolation hangers or supports for specified distance from such equipment. Refer to Section 23 0550 - Vibration Isolation for required distance.

L. Piping connected to coils, which are in assembly mounted on vibration isolators, shall have vibration isolation hangers or supports as indicated above. Piping connected to coils, which are in equipment where fan assembly is separately isolated by vibration isolators and flexible connections, does not require additional vibration isolation hangers or supports. Refer to Section 23 0550 - Vibration Isolation for flexible connections, vibration isolators and additional requirements.

M. Where piping can be conveniently grouped to allow trapeze type supports, supporting steel shall be by means of standard structural shapes.

N. Hangers and rods shall be plumb when pipelines are at their normal operating temperatures.

O. Unless otherwise indicated, continuous insert channels are not allowed.

P. Punching, drilling, or welding of building structural steel is not allowed unless approved by Structural Engineer.

Q. Refer to Structural Documents and ICC-ES Evaluation Report for application of concrete inserts and concrete anchors.

R. Lateral braces shall be designed and detailed to apply loads as directly as possible to structural floor slabs, roof decks, or other building lateral elements. Braces shall not be applied to bottom flanges of steel beams or bottom chords of open web steel joists.

S. Coordinate with Contractor for any proposed weld attachments to building structure. This may result in use of welding codes or standards, which may apply to "structural work". and may necessitate repair of fireproofing and/or extension of fireproofing to support members. Execution of this work may be assigned to General Trades responsible for building structural steel. Cost for this work, however, will remain the responsibility of this Contractor.

T. Top or bottom chords of open web steel joists may be used to support loads, provided total load within panel does not exceed 100 lbs and load is placed concentric to joist. (Panel is length of chord between two adjacent diagonal web members at point of connection to chord).

U. Where fire rated fiberglass products are used for channel and support devices, the following properties shall apply:
   1. Flame Spread Properties
      a. Polyester Fiberglass (PF) Class 1 ASTM E84
      b. Vinylester Fiberglass (VF) Class 1 ASTM E84

V. Fasteners including concrete anchors for seismic application shall have ICC Evaluation Service Report (ESR) and meet requirements of local authorities.

PART 2 - PRODUCTS

2.01 STRUCTURAL SUPPORTS

A. Unless specifically indicated on structural drawings, design and provide all supporting devices including miscellaneous steel (angles, channels, beams, etc.), required for proper support of piping, equipment and materials.

2.02 PIPE HANGERS AND SUPPORTS (METALLIC)

A. Manufacturers: Anvil, Erico, Tolco, PHD, National Pipe Hanger Corporation, or B-Line, equal to Anvil figures listed. Corresponding MSS Type is indicated where applicable.

B. Clevis and Roller Type Hangers:

System	Pipe Size	Clevis	Roller
Hot Pipes with Insulation (105°F and above)	2" and smaller	65 (MSS Type-1), 260 (MSS Type-1)	---
	2-1/2" to 6"	---	171 (MSS Type-41), 181 (MSS Type-43)
	8" and larger	---	171 (MSS Type-41)
Cold Pipes with Insulation (33°F to 60°F)	2" and smaller	65 (MSS Type-1), 260 (MSS Type-1)	---
	2-1/2" and larger	260 (MSS Type-1), 295 (MSS Type-1)	---

C. Flat Surfaces (Trapeze, Rack Type):
   1. Use structural steel members such as struts, angles, channels and beams to support pipes as required. Select members properly for pipe support types and loading conditions. Refer to Part 1 for design criteria. Submit support details with type of members selected and load calculations. Provide straps, clamps, rollers or slides indicated below at each support point.
   2. Provide non-ferrous trapeze supports where noted on plans.

System	Pipe Size	Straps or Clamps	Rollers	Slides
Hot Pipes with Insulation (105°F and above)	2" and smaller	Anvil Klo-Shure	---	---
	2-1/2" and larger	---	171 or 177(MSS Type-41), 271 (MSS Type-45), 274 (MSS Type-	257 or 436 with 212 or 432 clamps, Type 1, 2 or 3 for longitudinal movement only.

System	Pipe Size	Straps or Clamps	Rollers	Slides
			46)	Type 4, 5 or 6 for both longitudinal and transverse movement
Ambient Bare Steel Pipes (61°F to 104°F)	6" and smaller 8" and larger	B-Line BVT Unistrut Cush-a-Clamp	---	---
Ambient Bare (Copper) pipes (61°F to104°F)	all sizes	B-Line BVT Unistrut Cush-a – Clump		
Cold Pipes with Insulation (33°F to 60°F)	10" and smaller	137 (MSS Type-24)	---	---
	12" and larger	432	171 or 177 (MSS Type-41), 271 (MSS Type-45), 274 (MSS Type-46)	257 or 436 with 212 or 432 clamps, Type 1, 2 or 3 for longitudinal movement only and Type 4, 5 or 6 for both longitudinal and transverse movement.

2.03 INSULATION PROTECTION SHIELDS

A. Anvil Fig. 167 (MSS Type-40) constructed of galvanized carbon steel. Per the latest edition of Standard MSS SP-58, select shield to accommodate outer diameter of insulation. Shield length and gauge for insulation compression strength not less than 15 psi, shall be as follows:

Pipe Size	Length	Gauge
1/4"thru 3"	12"	18
4"	12"	16
5"thru 6"	18"	16
8" thru 14"	24"	14
16" thru 24"	24"	12

2.04 INSULATED PIPE SUPPORTS

A. Description:
   1. Products designed specifically for weight-bearing support of insulated pipes. Apply products in accordance with manufacturer's recommendations and requirements indicated below:
   2. Refer to PART 3 – EXECUTION for application of Type A, Type B, and Type C Insulated Pipe Supports specified below.

B. General:
   1. Supports shall be designed and rated for applied load, including weight of pipe, fluid, insulation, and any other imposed loads, with minimum 1.5 safety factor. Ratings shall be published by manufacturer and included in submittals.

2. Load ratings shall be established by pipe support manufacturer based upon testing and analysis conforming to the latest editions of ASME B31.1 and MSS SP-58.
3. High compressive strength inserts utilized to support loads shall encircle circumference of pipe. Block-style inserts are not allowed.
4. Supports shall be suitable for hot or cold pipe service as applicable.
5. Submit chart or table indicating selected model along with pipe sizes, rated loads, support device types and support spacing for each piping system.
6. Pipe support spacing shall be in accordance with manufacturer's recommendations but shall not exceed maximum spacing indicated under Hanger and Support Spacing in Part 3 of this Section.
7. Testing of insulation for compressive strength properties shall comply with ASTM D1621.
8. Insulation thickness shall match adjacent pipe insulation thickness.
9. Integrity of vapor barrier jacket shall be maintained continuously through support assembly.
10. Insulated pipe support style shall be specifically selected for the application and shall consider the following criteria at minimum:
    a. Vertical, lateral and axial support design load limits.
    b. Vertical, lateral, and axial support design travel limits
    c. Temperature of support, at pipe surface, and ambient conditions
    d. Test or pre-operational loads that may exceed normal operating conditions
    e. Material for any items that will be welded directly to the pipe
    f. Loading and displacements caused by seismic, hydraulic surge, or other forces
    g. Temperature at support steel
11. All steel components shall have corrosion protection coating consisting of hot-dip galvanizing or zinc-rich primer coating.

C. Type A Insulated Pipe Supports (Light Duty)
1. Description:
    a. Pipe insulation specified in Section 22 0700 - Plumbing Insulation with insulation protection shields specified in this Section. Weight-bearing inserts are not required.
    b. Type B or Type C supports may be utilized in lieu of Type A supports.

D. Type B Insulated Pipe Supports (Standard Duty):
1. Manufacturers:
    a. SNAPP ITZ insulation inserts by KB Enterprise, Tru-Balance Insulated Saddles by Buckaroos, Inc., Value Engineered Products, or approved equal.
    b. Klo-Shure insulation couplings may be used for cold pipes insulated with elastomeric insulation. Mount shall be 7 Series Strup Mount with metal clamps or Clevis System for clevis hangers.
    c. Type C supports may be utilized in lieu of Type B supports”
    d. Contractor may propose to utilize contractor-fabricated insulated pipe supports in lieu of manufactured Type B Supports. Use of contractor-fabricated assemblies is subject to approval of appropriate submittal data. Submit detail drawings of assemblies and product data showing equivalency to specified manufactured products for approval.
2. Description:
    a. Load-rated assembly consisting of high compressive strength insulation material completely encompassing circumference of pipe, vapor barrier jacket, and insulation protection shield.
    b. Insulation protection shield shall conform to ANSI/MSS SP-58. Shield shall be G90 galvanized steel and shall span full circumference of pipe insulation. Half-shields spanning lower 180° degrees arc of insulation outer circumference will be acceptable when used with clevis hangers.
    c. Axial length of insulation material shall be not less than 9" or 2" longer than insulation protection shields (1" minimum on each end), whichever is longer.
3. Insulation Materials:
    a. Hot Pipes 105°F to 250°F:
        1) Rigid closed cell, polyisocyanurate or phenolic insulation by ITW, Resolco, or Kingspan. Minimum compressive strength shall be 100 psi.

b. Hot Pipes 251°F to 1200°F:
   1) High-density calcium silicate insulation similar to Johns Manville Thermo-12 Gold. Minimum compressive strength shall be 100 psi.
c. Cold Pipes 60°F and below:
   1) Rigid closed cell, polyisocyanurate, phenolic insulation similar to ITW, Resolco, Kingspan, or cellular glass insulation similar to Pittsburgh Corning Foamglas.

E. Type C Insulated Pipe Supports (Heavy Duty):
1. Manufacturers:
   a. Pipe Shields, Inc., Bergen Pipe Supports, or Rilco equal to Pipe Shields models listed.
   b. Unless otherwise indicated, pre-insulated pipe supports shall be as indicated in the following schedule. Model numbers are based on Pipe Shields, Inc.
      1) Pipe supported on hangers: Model “A” Series and Model “D” Series
      2) Pipe supported on flat surfaces and pipe rollers: Models “A” Series
      3) Pipe supported on slides: Model "B" Series with lateral guide or restraint
      4) Pipe anchors: Model “C” Series
      5) Riser clamps: Model “E” Series with thrust plates. Select proper model for restraint for downward load or upward load.
   c. Contractor may propose to utilize contractor-fabricated insulated pipe supports in lieu of manufactured Type C Supports. Use of contractor-fabricated assemblies is subject to approval of appropriate submittal data. Submit detail drawings of assemblies and product data showing equivalency to specified manufactured products for approval.
2. Description:
   a. Load-rated assembly consisting of high compressive strength insulation material completely encircling circumference of pipe, vapor barrier jacket system incorporating structural inserts and insulation protection shield/casing where applicable.
3. Insulation Material:
   a. Water-resistant high density calcium silicate with minimum density of 208 kg/m^3(13 lb/ft^3) and compressive strength not less than 100 psi. Thermal conductivity shall be not more than 0.055 W/m°C at 24°C(0.38 Btu·in/(hr·sq ft °F) at 75°F.
   b. Structural Inserts:
      1) Structural inserts used by manufacturer to reinforce between pipe and insulation jacket for clamping devices shall be water-resistant high compressive strength inorganic materials selected by manufacturer for desired combination of structural strength and insulating properties. Structural inserts shall have minimum compressive strength of 600 psi. Thermal conductivity shall be not more than 0.084 W/m°C at 24°C(0.58 Btu·in/(hr·ft^2°F) at 75°F.
   c. Jacket:
      1) Jacket shall consist of G90 galvanized steel conforming to ASTM A653/A653M and shall provide complete vapor barrier around insulation and bearing surface for protection of insulation.
      2) When recommended by manufacturer, use reinforced insulation protection shield at support bearing surface. Insulation shall extend 1" beyond insulation protection shield to maintain vapor barrier integrity.

2.05 HANGER RODS (METALLIC)

A. Rods shall conform to the latest MSS Standards except as modified herein. Furnish rods complete with adjusting and lock nuts.

B. Rods shall have electroplated zinc or hot dip galvanized finish.

C. Unless otherwise indicated, size rods for individual hangers and trapeze support as indicated in the following schedule. Rod size may be reduced one size for double rod hangers. Total weight of equipment, including valves, fittings, pipe, pipe content and insulation, shall not exceed limits indicated.

D. Provide non-ferrous hanger rods where noted on plans.

Max. Pipe Size With Single Rigid Rod	Rod Diameter	Max Load of Hanger Rod (Not exceeding 650°F Service Temp.)
2"	3/8"	730 lbs
3"	1/2"	1350 lbs
5"	5/8"	1350 lbs
8"	3/4"	3230 lbs
12"	7/8"	4480 lbs
18"	1"	5900 lbs
30"	1-1/4"	9500 lbs

2.06 BOLTS, NUTS, STUDS AND WASHERS

A. ASTM A307, electroplated zinc finish

2.07 ROD ATTACHMENTS

A. Anvil Fig. 290 (MSS Type-17), galvanized finish

2.08 U-BOLTS

A. Anvil Fig. 137 (MSS Type-24), galvanized finish

2.09 BEAM CLAMPS

A. Beam Clamps: Anvil Fig. 133/134 (MSS Type-21), 218 (MSS Type-30), 228 (MSS Type-28 or 29) and 292 (MSS Type-28 or 29)

B. Top Beam Clamps: Anvil Fig. 227 (MSS Type-25)

C. C-Clamps: Anvil Fig. 86, 92 or 93 (MSS Type-19 or 23) with set screw and lock nut

2.10 ADJUSTABLE PIPE SADDLE SUPPORTS

A. Anvil Fig. 264 (MSS Type-38), galvanized finish. Provide Anvil Fig. 63 Type T stanchion with base, galvanized finish, where applicable.

2.11 CONCRETE INSERTS (WOODEN FORMED CONCRETE)

A. Anvil Fig. 281 or 282, or Hilti KCM-WF or DeWalt Wood-Knocker II+, suitable for rod diameter and weight supported.

2.12 CONCRETE INSERTS (METAL DECK FORMED CONCRETE)

A. Tolco No. 109DD, DeWalt Pan-Knoker II+, "Bang-It+", Hilti KCM-MD or KCM-PD, or MSCO No. MX34.

2.13 CONCRETE ANCHORS

A. Manufacturers: Hilti, DeWalt or Red Head

B. Anchors shall be selected, sized, and detailed by Contractor’s structural engineer registered in project’s jurisdiction, based on project conditions and in accordance with project building code.

C. Anchors shall meet ICC Acceptance Criteria, and ICC-ES Evaluation Reports (ESRs) shall specifically list the current applicable codes.

D. Anchors installed in hardened concrete for purpose of transmitting structural loads from one connected element to another, or for safety related elements such as sprinkler pipes, heavy suspended pipes, and barrier rails shall have ICC-ES report demonstrating anchors have met requirements of AC 193 for mechanical anchors in concrete elements.

E. Post-installed expansion anchors and undercut anchors installed in hardened concrete shall be qualified for strength design and tested according to ACI 355.2. Designs shall be per the requirements of ACI 318, Appendix D.

F. Anchors shall be zinc plated in accordance with ASTM B633.

G. Select anchors with load ratings based on cracked concrete conditions.

2.14 CONTINUOUS INSERT CHANNELS

A. Manufacturers: Unistrut, Anvil, B-Line, Michigan, Halfen, Hilti or Kindorf. Brackets inserts and accessories shall be suitable for channel insert selected.

B. Length and support capabilities to be suitable for supporting plumbing piping in vicinity.

2.15 METAL FRAMING SUPPORT SYSTEM (STRUT SYSTEM)

A. Manufacturers: Unistrut, B-Line Strut Systems, Anvil-Strut, Power-Strut, Erico, Superstrut, Kindorf, Hilti, and Hydra-Zorb

B. Channels shall have epoxy paint or electroplated zinc finish.

C. Channels shall not be lighter than 12 ga.

2.16 PIPE MOUNTING PEDESTALS

A. Equal to Roof Products & System Corporation consisting of equipment rail, "U" shaped mounting brackets, galvanized threaded rod and cast iron pipe rollers. Rail shall have built-in raised cant to match roof deck insulation.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install supports to allow for free expansion of piping. Support piping from building structural members using concrete inserts, beam clamps, ceiling plates, wall brackets, or floor stands. At no time shall hangers and supports overload building structural members. Fasten ceiling plates and wall brackets securely to structure and test to demonstrate adequacy of fastening.

B. Select and size building attachments properly in accordance with MSS Standards and manufacturer's published load rating information.

C. Coordinate hanger and support installation to properly group piping of all trades.

D. Suspend piping hangers by means of hanger rods. Perforated band iron and flat wire (strap iron) are not allowed.

E. Piping and ductwork shall be supported independently from other piping or ductwork.

F. Pipe hangers and supports shall not penetrate vapor barrier of pipe insulation.

G. Do not support equipment, or piping from metal roof decking or ceiling grid.

H. Install adequate supports so as not to over stress either piping or equipment to which piping is connected.

I. Refer to Section 23 0000 - General Mechanical Requirements for requirements of personnel injury protection guards for supporting devices.

3.02 HANGER AND SUPPORT SPACING

A. Space pipe hangers and supports for horizontal pipe accordance with the following schedule, with exceptions as indicated herein:

B. Steel Pipe (Standard Weight and Extra Strong):

Pipe Size	Max Spacing
1-1/4" and smaller	7 ft
1-1/2"	9 ft
2"	10 ft
2-1/2"	11 ft
3"	12 ft
4"	14 ft
6"	17 ft
8"	19 ft
10" and larger	20 ft

C. Steel Pipe (Standard Weight and Extra Strong):

Pipe Size	Max Spacing
1-1/4"	7 ft-0"
1-1/2"	9 ft-0"
2"	10 ft-0"
2-1/2"	11 ft-0"
3"	12 ft-0"

D. Copper Tube (Unless Otherwise Noted):

Pipe Size	Max Spacing
3/4" and smaller	5 ft
1" 1-1/4"	6 ft
1-1/2"2-1/2"	8 ft
3" and larger	10 ft

E. Maximum spacing shown above may be restricted by strength of attachment to building structure. Submit data with calculations with published load ratings showing attachment to be utilized and maximum spacing allowable for that type of attachment and pipe size.

F. Spacing less than indicated above may be required to conform to building structure design or loading limitations.

G. Spacing less than indicated may be required depending on compressive strength of pipe insulation and insulated pipe supports.

H. If pipe size changes between support points, maximum spacing shall be based on the smaller pipe size.

I. If trapeze hangers are used to support multiple services, spacing shall be based on the most restrictive pipe size and material on trapeze hanger.

J. For non-metallic pipe, follow manufacturer's installation recommendations in addition to requirements noted herein.

K. Install supports for vertical piping and anchors as recommended by pipe manufacturer.

L. Place hangers and supports to meet requirements of Section 23 2116 - Pipe and Pipe Fittings or specific pipe system sections, with regard to pitch for drainage and venting and clearance between services.

M. Hangers and supports shall bear on outside of insulation when pipes are to be insulated.

N. Place hangers and supports within 1 ft of each fitting, such as elbows and tees, and at each valve, strainer, and other piping specialty for piping 4" and larger.

O. Place hanger or support at first elbow upstream of pump inlet and first elbow downstream of pump outlet.

3.03 INSULATED PIPE SUPPORTS APPLICATION

A. Install insulated pipe support at each support point of insulated pipe.

B. Pipe Size 1-1/2" and Smaller:
   1. Use Type A insulated pipe support. Pipe insulation specified in Section 22 0700 - Plumbing Insulation shall be continuous through support points.
   2. Use one shield (bottom) for clevis hanger.
   3. Use 2 shields (top and bottom) for roller hanger/support or strap/clamp support. Apply 2 metal straps to hold top and bottom shields onto insulation jacket.
   4. Type B or Type C insulated pipe supports may be used in lieu of Type A support.

C. Pipe Size 2") through 5":
   1. Use Type B insulated pipe supports. Refer to Part 2 for acceptable products.
   2. Type C insulated pipe supports may be used in lieu of Type B supports.

D. Pipe Size 6" and Larger:
   1. Use Type C insulated pipe supports. Refer to Part 2 for applicable products.

3.04 PIPE FLOOR SUPPORTS

A. Unless specifically shown otherwise, use adjustable pipe saddle supports with associated stanchion similar to Anvil Fig. 264/63. Select supports properly for weight and height of pipe stand.

3.05 CONCRETE INSERTS

A. Concrete insert application, size, loading, and placement shall be this Contractor’s responsibility.

B. Coordinate placement of inserts before concrete pour. Minimize use of inserts and anchors after concrete pour.

3.06 CONTINUOUS INSERT CHANNELS

A. Mount continuous insert channels when used for pipe support on 8 ft-0" maximum centers and 8 ft-0" from corners.

3.07 BEAM CLAMPS

A. Provide locknut for hanging rod at clamp.

B. C-clamps are allowed for rod size 3/8" or smaller and only for static loading such as air piping, cold water piping, fire protection piping and, other similar piping. C-clamps are not allowed for hot water piping and steam and steam condensate piping, except hot water runouts to terminal heating devices.

C. C-clamps are not allowed for open web steel joist application.

D. C-clamps are not allowed for seismic application.

3.08 TRAPEZE SUPPORTS

A. Construct trapeze supports with struts, angles, or channels and hang them by inserts or welded beam attachments and rods.

B. If trapeze supports are used to support multiple services, support spacing shall be based on the most restrictive pipe size and material on trapeze supports.

C. Refer to Part 1, Design Criteria for maximum deflection allowed for trapeze supports.

3.09 PIPE MOUNTING PEDESTALS

A. Use for all piping on roof. Install bottom of pedestal flat on roof deck, insulate exterior of pedestal, flash and counter flash.

3.10 CONCRETE ANCHORS

A. Anchor application, size, and placement shall be this Contractor’s responsibility.

END OF SECTION

SECTION 23 0901
CONTROL SYSTEMS INTEGRATION

PART 1 GENERAL

1.01 RELATED WORK

A. Section 23 0553 – Mechanical Systems Identification
B. Section 23 0594 – Water Systems Test Adjust Balance
C. Section 23 0595 – Air Systems Test Adjust Balance
D. Section 23 2116 – Pipe and Pipe Fittings
E. Section 23 2118 – Valves
F. Section 23 2120 – Piping Specialties
G. Section 23 3114 – Ductwork
H. Section 23 3314 – Ductwork Specialties
I. Section 23 8214 – Heating and Cooling Terminal Devices
J. Section 26 0533 – Raceway and Boxes for Electrical Systems

1.02 CONTRACTOR SHALL FURNISH AND INSTALL A DIRECT DIGITAL CONTROL SYSTEM. THE SYSTEM SHALL UTILIZE ELECTRONIC SENSING, MICROPROCESSOR-BASED DIGITAL CONTROL, AND ELECTRONIC ACTUATION OF DAMPERS AND VALVES TO PERFORM CONTROL SEQUENCES AND FUNCTIONS SPECIFIED. THE SYSTEM FOR THIS PROJECT WILL GENERALLY CONSIST OF MONITORING AND CONTROL OF SYSTEMS LISTED BELOW. REFERENCE ALSO CONTROLS DRAWINGS, SEQUENCES OF OPERATION, AND POINT LISTS.

A. Automation and/or monitoring for the various systems such as but not limited to:
   1. Air Handlers
   2. Zone Terminal Units
   3. Supply and Return Air Terminals
   4. Laboratory Controls
   5. Occupancy Sensors

B. In addition to monitored and controlled equipment, this section also includes:
   1. Communication and Low voltage cable and pathway requirements.
   2. Power requirements.
   3. Instrumentation – Product specifications and Installation requirements.
   4. Other miscellaneous items required but not specified for a complete operational system.
   5. Supply and Return Air Terminals

C. Products supplied but not typically installed under this section:
   1. Control Valves
   2. Control Dampers
   3. Supply and Return Air Terminals
   4. Instrument wells
   5. Flow Meters

1.03 REFERENCED STANDARDS

A. Computing Devices
B. Smoke Control Listing (Ninth Edition)
C. Temperature-Indicating and Regulating Equipment
D. Energy Management Systems
E. Comply with NEMA Standards pertaining to components and devices for electrical controls
F. National Electrical Code

1.04 DEFINITIONS

A. The following abbreviations, acronyms, and definitions apply to and are used within this Guide Specification:
   1. Control device to provide motion of valve or damper in response to control signal.
   2. Air Handling Unit
   3. Analog Input
   4. Siemens Apogee Level Network (Ethernet based)
   5. Analog Output
   6. A continuously variable system or value not having discrete levels. Typically exists within a defined range of limiting values
   7. Software routine used to adjust tuning parameters based on historical or real-time data
   8. Application Specific Controller
   9. Building Automation System
   10. Building Level Controller – Supervisory control panel and the primary means of communication outside the building. May also act as a global controller, implementing building wide global strategies and energy management routines.
   11. Commissioning Authority
   12. A BAS pre-programmed arrangement of software algorithms, logical computation, target values and limits as required to attain the defined operational control objectives.
   13. Direct Digital Control
   14. Direct Digital Control Panel
   15. A two-state system where an “ON” condition is represented by one discrete signal level and an “OFF” condition is represented by a second discrete signal level each separated by a defined deadband. Digital Inputs and Digital Outputs are examples
   16. Discrete Input
   17. Discrete Output
   18. Electronically Erasable Programmable Read Only Memory
   19. Electromagnetic Interference
   20. Electrical Metallic Tubing
   21. Electric to Pneumatic
   22. A network computer with a hard disk drive.
   23. Fail Closed position of control device or actuator. Device moves to closed position on loss of control signal or energy source.
   24. Fail Open position of control device or actuator. Device moves to open position on loss of control signal or energy source.
   25. Supply but not install.
   26. Fume Hood Controller
   27. Graphical User Interface
   28. Input/Output (typically referring to points monitored by a system).
   29. Current to pneumatic transducer
   30. Device used for sensing input parameters or used for actuation
   31. Internet Protocol
   32. Hand Off Auto
   33. To mount, but not furnish.
   34. Local Area Network
   35. Lab Supply Air Terminal Controller
   36. Information Technology
   37. Local Operator Terminal
   38. Movement of a control device through an entire range of values proportional to an infinitely variable input value.
   39. Control device with actuator.
   40. Normally Closed position of switch contacts after control signal is removed.
   41. Normally Open position of switch contacts after control signal is removed.
   42. DDCP, user workstation, or other control device connected to communications network.

43. Same as actuator
44. Florida State University
45. Operator's Work Station (Personal Computer with Intranet / Internet capability)
46. IBM-compatible Personal Computer from a recognized major manufacturer. PC "clones" assembled by a third-party subcontractor are not acceptable
47. Personal Digital Assistant
48. Mode of communication between controllers in which each device connected to network has equal status and each shares its database values with all other devices connected to network.
49. Siemens primary Tier 2 and Tier 1 communication protocols
50. Proportional control, control mode with continuous linear relationship between observed input signal and final controlled output element.
51. Proportional - Integral control, control mode with continuous proportional output plus additional change in output based on both amount and duration of change in controlled variable (Reset control).
52. Proportional - Integral - Derivative control, control mode with continuous correction of final controlled output element versus input signal based on proportional error, its time history (reset), and rate at which it is changing (derivative).
53. Project Manager capable of making project and personnel decisions.
54. Analog or discrete instrument with addressable database value
55. A set of rules and standards governing the on-line exchange of data between control systems of the same or different manufacturers.
56. To "furnish" and "install"
57. Radio Frequency
58. Radio Frequency Interference
59. Device for implementation of Network Layer Protocol
60. Room Pressure Monitor
61. Same as Auto-Tune
62. Electric two position actuator.
63. Includes all of programmed digital processor software, preprogrammed firmware and project specific digital process programming and database entries and definitions as generally understood in the control industry for real-time, on-line, integrated control system configurations.
64. A network computer without a hard disk drive.
65. LAN and/or WAN communication network. Building to building communication or high speed Ethernet communication level running within a specific building.
66. Building level communication or low speed tier running under a building level supervisory controller.
67. Variable Air Volume
68. Variable Frequency Drive
69. Wide Area Network

1.05 SYSTEMS DESCRIPTION

A. Acceptable control system manufacturer :
   1. Siemens Industry, Inc.
   2. Apogee Systems as supplied by local supporting factory branch only.

B. Scope includes labor and materials including but not limited to:
   1. Tools and other equipment
   2. Software, licenses, configurations and database entries,
   3. Interfaces, wiring, tubing, labeling,
   4. Engineering and calculations
   5. Calibration, testing, verifications, training and other services,
   6. Documentation, samples, submittals,
   7. Permits, professional licenses, etc.
   8. Other Administrative fees such as parking, shipping, handling, etc.

C. Provide a complete system and be accessible via manufacturer's specific server system using a web browser interface implemented over the Owner's intranet. Internet access is managed by FSU Utilities and shall be granted only via FSU authorized Siemens Server Administration.

D. The BAS network includes but is not limited to the following:
   1. Connection to existing network servers.
   2. Communications equipment needed to support the in-building communication BAS network.
   3. Intelligent and addressable elements and end devices.
   4. Third-party equipment interfaces.
   5. Other components required for a complete and working BAS.

E. The BAS Network shall utilize an architecture capable of the following:
   1. Utilizing standard Ethernet communications operating at a minimum speed of 10/100 Mb/sec.
   2. The BAS network shall support both copper and optical fiber communication media at the Tier 1 level.

F. The system shall be compatible with the FSU IT network.

G. The BAS shall be fully expandable with the addition of hardware and/or software. Expansion shall not require removal of existing DDCP, sensors, actuators, or communication networks.

H. System must be of a modular design to ensure reliability and system performance.

I. All electrical work required as an integral part of this section is work of this section.

J. Provide final power connections including conduit, wire, and/or control panel disconnect switches to all control devices from appropriate electrical j-box.

K. Include the following integrated features, functions and services:
   1. Operator information, alarm management and control functions at any operator's console without the need to purchase special software from the contractor or BAS manufacturer for those consoles.
   2. Information management including monitoring, transmission, archiving, retrieval, and reporting functions
   3. Diagnostic monitoring and reporting of BAS functions
   4. Energy management
   5. Wireless Device capability
   6. Data Analytics/Fault Detection
   7. Automated Commissioning
   8. Advanced Alarm Management
   9. Measurement and Verification

1.06 QUALITY ASSURANCE:

A. Provide components not specifically indicated or specified, but necessary to make system function within the described intent of contract documents and sequence of operation.

B. All electrical products to be listed and labeled by UL and comply with NEMA Standards.

C. Control wiring shall be in accordance with National Electric Code.

D. The Contractor shall have qualified technicians within a 50 mile radius of Project Site and have the ability to comply with a two hour on-site response time.

E. Provide a competent and experienced Project Manager with a minimum of 5 years' experience with similar projects.

F. Engineering services shall be performed by factory-trained engineers.

G. System shall be installed by factory trained mechanical and electrical installers either in direct employ of this Contractor or by subcontractors who are under direct supervision of this Contractor.

H. Use only manufacturer trained technicians who are skilled, experienced, trained, and familiar with the specific equipment, software and configurations to be provided under this section.

I. Coordinate with the Owner to ensure that the BAS will perform in the Owner's IT environment without disruption to any of the other activities taking place on that LAN or WAN.

J. Coordinate timely delivery of materials and supervise activities of other trade contractors to install inline devices such as immersion wells, pressure tappings, any associated shut-off valves, flow switches, level switches, flow meters, air flow stations, and other such items furnished under this section but installed by other trades.

K. Select sensors and transducers to most closely match the expected sensing or control range.

L. Mark and detail exact location of inline devices, wells, and taps to be installed by Mechanical Contractor on coordination drawings and confirm locations in the field.

M. Instrumentation with factory J-boxes shall not be used as junction boxes.

N. Install control equipment, wiring and air piping in neat and workmanlike manner to satisfaction of A/E, and in accordance with manufacturer's recommendations. Maintain clearances, straight length distances, etc. required for proper operation of each device.

O. Install control devices in accessible location. Coordinate all control device locations with other trade contractors. Contractor to report to A/E conditions that prevent reasonable accessibility.

P. Wire VFD's so that all safeties and interlocks remain operational (inclusive of isolation dampers, isolation valves, end switches, interlocks, safeties etc) when drive is placed in Auto, Hand or Bypass mode.

Q. Provide weather protection cover or weatherproof control devices where required for control devices located outdoors.

R. All control devices located outdoors shall be rated for the anticipated environment.

S. Include provisions for supplemental ventilation when control devices must be located within outdoor control panels and when control devices are not rated the planned environment.

T. All digital equipment furnished under this contract shall have been tested and made to comply with limits for Class A computing device pursuant to Subpart J of Part 15 of FCC Rules.

U. Acceptance Criteria: The system shall report all values with an end-to-end accuracy equal to or better than those listed below: The intent of this guideline is to establish criteria for the Control Contractor with regard to calibration and acceptance. Reference specific instrumentation sections for required accuracies.

Measured Variable	**Criteria**
Space Temperature	+/- 1.0°F
Ducted Air (Single Probe)	+/- 0.5°F
Ducted Air (Averaging)	+/-1.0 °F
Outside Air	+/- 2.0 Deg F
Water Temp	+/- 0.5°F
Relative Humidity (duct and space)	+/- 5% RH
Air Flow (Terminal unit)	+/- 5% (CFM) of reading
Air Flow (Measuring Station)	+/- 5% (CFM) of full scale
Air Pressure (ducts)	+/- 0.10 in WC
Air Pressure (space)	+/- 0.01 in WC
Electrical (A, V, W, PF)	5% of reading

1. Stability of Control: Control loops shall maintain measured variable at setpoint within the tolerances listed below and shall, upon any change to the feedback variable recover within 5 minutes of the initial event. The intent of this guideline is to establish criteria for the Control Contractor, and A/E with regard to control loops and acceptance.

Controlled Variable	**Control Accuracy**	**Range of Medium**
Air Pressure (ducts)	+/- 0.2 in WC	-6 to +6 in WC
Air Pressure (room)	+/- 0.020 in WC	-0.100 to +0.100 in WC

Air flow	+/- 100 CFM or 2% of setpoint (whichever is less)
Temperature	+/- 1.0 Deg F
Room Temperature	+/- 1.0 Deg F
Humidity	+/- 3% RH

2. Provide all points required to implement control sequences specified, whether or not they are listed in schedules.
3. All outputs, whether sequenced or not, shall have separate programmable hardware outputs. For air handling units, minimum outside air, maximum (economizer) outside air, return, relief air, smoke dampers, heating valves, cooling valves, etc., shall each have a separate output.
4. Point and Alarming expectations: The system shall include points and alarms as described in Contract Drawings.

PART 2 PRODUCTS

2.01 SOFTWARE:

A. Data Storage and Archiving:
   1. Trend data shall be stored at the stand alone BLC/AAC/DDCP panels, and uploaded automatically to server hard disk storage when archival is desired or when local trend storage capacity drops below 20%. All critical points or controlled points shall be trended and stored on Vendor specific server as may be defined by FSU facilities. Storage capacity shall be based on an initial sample rate for all points at 15 minutes. Server capacity is maintained by FSU facilities however, should support a minimum five years of trend data. The contractor and FSU under separate agreement is responsible for upgrading existing server as needed to support the additional project points and required memory. Ensure the server will maintain no less than 100% spare capacity.

B. Control Software Description for BLC/AAC/DDCP include:
   1. The ability to perform the following pre-tested stand-alone control algorithms:
      a. Two-position control
      b. Proportional control
      c. Proportional plus integral control
      d. Proportional, integral, plus derivative control
      e. Automatic tuning of control loops with enable/disable capabilities
      f. Equipment Cycling Protection: Include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
      g. Heavy Equipment Delays: Provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads (user selectable).
      h. Power Fail-Motor Restart: Upon the resumption of normal power, the BLC/AAC panel shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation.
   2. The ability to perform all of the following energy management routines:
      a. Time-of-day scheduling
      b. Calendar-based scheduling
      c. Holiday scheduling
      d. Temporary schedule overrides
      e. Start-Stop Time Optimization
      f. Automatic Daylight Savings Time Switch-over
      g. Night setup and setback control
      h. Enthalpy switch-over (economizer)
      i. Peak demand limiting
      j. Totalization (runtime, flow, Btu, kWh, etc.)
   3. Read and display the value of any property, including all required properties, supported optional properties, and proprietary extensions of every object located within each networked device.

4. The ability to execute custom, job-specific processes to automatically perform calculations and special control routines.
    a. Incorporate measured or calculated data from other DDC controllers on the network.
    b. Issue commands to points in other DDC controllers on the network.
    c. Support 30 characters, English language point names, structured for searching and logs.
    d. Directly send a text message to a specified device or cause the execution of an alarm message at any connected thin client PC, dial-up connection to a remote device or cause the execution of a remote connection to a remote device such as a printer, pager, PDA or cell phone.
    e. Include a HELP function key.
    f. Incorporate comment lines for program clarity.

C. Alarm management:
1. Monitor and direct alarm information to operator devices.
2. Generate custom written operator alarm message (to be developed by the Contractor and Owner in conjunction with the project) and advisories to operator I/O devices.
3. Perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost.
    a. At no time shall the ability of the BLC/AAC to report alarms be affected by either a remote PC, local I/O device or communications with other panels on the network.
    b. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
4. Authorized users shall have the ability to manually inhibit alarm reporting for each point.
5. Alarm destinations shall be included so that alarms are indicated and printed at a pre-defined FSU reporting device, or transaction log.
    a. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs based on time (after hour's destinations) and/or based on priority.
    b. Alarms shall directly send an alarm message to specified client PC destination or cause the execution of a connection to a remote device (owner to designate) and cause the execution of a communications connection to a remote wireless device (pager, hand held, email or Pocket PC device).
    c. Alarm messages, and point graphic assignments alarms shall have accurate descriptions and response instructions, so that alarms may be quickly associated with appropriate graphic display.
6. Alarm reports shall be sent to multiple WEB connected PC's, cell phones or PDA's and shall send alarm reports.

D. A variety of historical data collection utilities shall be provided to manually or automatically sample, store, and display system data for points as specified in the I/O summary.
1. Any point, physical or calculated shall be capable of trending.
2. Any point, regardless of physical location on the network, may be collected and stored in each BLC/AAC point group.
3. Two methods of collection shall be allowed: either by a pre-defined schedule or upon a pre-defined change of value. Sample intervals of 1 minute to 7 days shall be provided.
4. Each BLC/AAC shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.
5. BLC/AAC units shall provide high resolution sampling capability for verification of control loop performance.
6. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary.

E. BLC/AAC units shall be capable of automatically accumulating and storing run time hours for digital input and output points and automatically sample, calculate and store consumption totals for analog and digital pulse input type points, as specified in the point I/O schedule.

F. The building level network shall allow the BLC/AAC units to access any data from or send control commands and alarm reports directly to any other BLC/AAC or combination of controllers on the network without dependence upon a central or intermediate processing device.

G. The building level network shall also allow any BLC/AAC to access, edit, modify. add, delete, back up, and restore all system point database and all programs.

H. Failsafe hardware shall be provided such that BAS failures result in immediate return to local control. If the controller uses database values from other controllers, and the communication network fails or malfunctions, control loop outputs shall continue to function using last value received from BAS.

I. The BLC/AAC shall automatically call for a new database download from the server upon loss or corruption of a database. An operator with sufficient access privileges may in addition, activate a database download manually from the server.

2.02 APPLICATION SPECIFIC CONTROLLERS (ASC'S) (VAVS, FCUS, LABORATORY CONTROLS, ETC.)

A. Performance and capacity of AAC/BLC units shall be extended through the use of stand-alone remote ASC'S for VAV terminals, fan coil units, unit ventilators, heat pumps, small single zone air handlers etc.
   1. Controllers shall be capable of field configuration and program uploads and downloads.
   2. Controllers shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network.
   3. Controllers shall be a microprocessor-based, multi-tasking, real-time digital control processor.

B. Alarm Management: Each ASC shall perform its own limit and status monitoring and analysis to maximize network performance by reducing unnecessary communications.

C. ASC'S shall include all point inputs and outputs necessary to perform the specified control sequences. Analog outputs shall be industry standard signals such as 4-20ma proportional signals, 0-5 Vdc or 0-10 Vdc proportional signals allowing for interface to a variety of modulating actuators.

2.03 CONTROL WIRING AND PATHWAYS

A. All cables (< 50 VAC/VDC) used within control system shall contain an overall jacket (plenum rated).

B. Instrumentation I/O Conductors (<50 Volts and Under):
   1. No wire smaller than #18 AWG shall be used unless otherwise specified by the manufacturer such as thermostat, sensor, communication wiring.
   2. Provide isolated instrument grounding system per manufacturer's recommendations and project requirements.
   3. Conductors shall have UL listed plenum rated teflon insulation.

C. Communication Cable:
   1. Manufacturer approved cable labeled "BAS Communication" no less than 10 ft. intervals. Provide additional shielding and grounding per applicable manufacturer's recommendations and/or job site conditions. Conductors shall have UL listed plenum rated teflon insulation.

2.04 LOCAL CONTROL PANELS

A. Local control panels shall be constructed of steel, high strength composite, or extruded aluminum with hinged door and keyed lock, with baked enamel finish of manufacturer's standard color. Construction shall comply with NEMA 1 standards for interior panels, NEMA 4X for exterior panels.

B. Panel mounted controlling instruments, temperature indicators, relays, switches and gauges shall be factory installed and permanently labeled. Devices shall be located inside or flush mounted on face of panel.

2.05 NETWORK ROUTERS & BRIDGES:

A. The BAS shall use the campus Wide Area Network (WAN) for communication to the campus vendor specific server.

B. The communication between the central server and the buildings DDC controllers shall be Siemens ALN Ethernet.

2.06 SERVERS

A. Servers are existing.

2.07 CONTROL VALVES

A. General
   1. If control valve sizes are not shown or scheduled, refer to Part 3 of this Section for sizing criteria.
   2. Use 2 port (normally open or closed based on sequence of operation) or 3 port ball type valves for control unless otherwise noted.

B. Ball Valves (Hot Water and Cooling Coil Applications)
   1. Valves shall be bronze or brass body, 150 psi rating. Ball valves larger than 4” are not permitted.
   2. Valves shall have stainless steel ball and stem, valve stem seals with dual EPDM O-Rings, rangeability must be greater than 150:1, and shall have equal percentage flow characteristics.

2.08 DAMPER AND VALVE ACTUATORS

A. Damper and valve actuators shall be electric type.

B. Each actuator shall be full-proportioning or two-position type as required or specified, and shall be provided with spring-return for fail open or fail closed position for fire, freeze, occupant safety, equipment protection, moisture, heating or cooling protection on power interruption as indicated and/or as required.

C. Analog Electronic:
   1. Actuators shall be electric motor/gear drives which respond proportionally to analog voltage or current input. Stroke time for major equipment shall be 90 seconds or less for 90□ rotation. Stroke time for terminal equipment shall be compatible with its associated local controller, but no more than 6 minutes.
   2. Provide spring return feature for fail open or closed positions as required by control sequence and for critical application devices.
   3. Reheat terminal units - Utilize factory assembled ball valve with horizontal mount; non-spring return proportional actuator (0-10 Vdc, 0-5Vdc, floating or 4-20ma). Electric actuator installed on ball valves shall have a separate and distinct operating handle used to position the valve into any desired position once power is removed or a valve failure occurs. Similar to Siemens Ball or Belimo B2 CCV Series valve/actuators
   4. Actuators for terminal heating/cooling equipment shall be configured to fail to last position.
   5. Provide standard cable from actuator to controller unit.

D. Discrete Two-Position Electric:
   1. Actuators shall be hydraulic or electric motor/gear drives for two-position control. Stroke time shall be 90 seconds or less for 90° rotation.
   2. Provide spring return feature for fail open or closed positions as required by control sequence.
   3. Provide adjustable end switches as required by control sequence for isolation and 100% oa unit dampers.

2.09 GENERAL INSTRUMENTATION

A. Analog Electronic Instrument Indicators:
   1. Electronic indicators, used for displaying sensor and/or output values as measured by current or voltage, shall be panel mount type and at least 2" square. Output may be analog needle type or digital with 1/2" high LED or backlit LCD displays.
   2. Electronic indicators shall be marked in appropriate units (Degrees, psi, %RH, gpm, cfm, etc.) and with appropriate range of values. Panel mounted indicators shall have minimum accuracy of 1% of scale range. Digital units shall be scaled to show 3 digits plus 1 decimal point.

2.10 DISCRETE ELECTRIC INSTRUMENTATION

A. General
   1. Electrical devices, switches, and relays shall be UL listed and of type meeting current and voltage characteristics of the project.
   2. Outdoor unit enclosures shall be NEMA 4 with concealed adjustment.

3. Ratings of normally open and closed contacts shall be adequate for applied load (Minimum 5 amps at 240 volts).
4. Accuracy of devices shall be ± 1% of scale with adjustable offset unless otherwise specified.

B. Temperature Low Limit Switches
1. Electric 2-position 4 wire, 2 circuit temperature sensing element with manual reset. Controls shall be capable of opening circuit if any one-foot length of sensing element is subject to temperature below established setpoint.
2. Sensing element shall not be less than one lineal foot per square foot of coil surface area. Unless otherwise indicated, calibrate temperature switch setpoint to 38°F.
3. Low Limit switches shall be hardwired into safety circuit of motor control device. Additional contact shall be used for BAS feedback.
4. Location of installed device – must be accessible from outside of unit, must be protected from the water and must be mounted no more than 60” AFF. Provide remote (hardwired) reset switch when conditions require device to be mounted above 60” AFF.
5. Provide multiple devices for large AHUs where required to ensure complete coverage.

C. Relays
1. Equal to IDEC type or RIB series. Coil shall match control circuit characteristics. All relays shall include LED indication of status.
2. Where HOA capability is required (i.e. AAC), relays must include an integral HOA function with override feedback.
3. Provide DIN rail mountable (Snap type) mounting sockets.

D. Pressure Switches
1. Adjustable set point, differential pressure type. Select switches for accuracy, ranges (20 to 80% of operating range) and dead-band to match process conditions, electrical requirements and to implement intended functions.
2. Pressure differential switches for air systems shall have pressure rating of at least 10" WG.
3. Pressure indicating differential switches for air systems shall be equal to Cleveland AFS series photohelic gauge.

E. Position Switches (End Switches)
1. Rotary switches shall consist of switch mounted on a ½” damper crank arm (Similar to Kele & Associates TS-475).
2. Door position switches shall be magnetic proximity type.

F. Current Switches
1. Induction type sensor clamped over a single phase of AC electrical power conductor shall be solid-state sensor with adjustable threshold and normally open contacts. Each current switch shall be selected for proper operating range of current.
2. VFD and NON-VFD Applications (Similar to Hawkeye Model 904,934).
3. The sensor shall be capable of detecting motor belt or coupling loss when mounted on the load side of variable frequency drives
4. The current sensor shall be factory programmed to detect motor undercurrent situations (belt or coupling loss) on variable or constant volume loads, no calibration required.
5. The current sensor shall store the motor current operating parameters in non-volatile memory.
6. The current sensor shall have a push button reset to clear the memory if the operating parameters change or the sensor is moved to a different load.
   a. Transition current: 75 mA at 1 A setpoint
2.5 A at 10 A setpoint
   b. Hysteresis: 0.015 A at 1 A setpoint
0.20 A at 10 A setpoint
   c. Response Time: Less than 0.5 seconds

2.11 ANALOG ELECTRONIC INSTRUMENTATION

A. Wall Mounted Space Sensors
1. Sensors shall be platinum RTD type, with the following minimum performance:

a. Temperature Coefficient of Resistivity (TCR): .00385 ohm/ohm/°C
b. Conformance: DIN-IEC 751
c. Operating Range: -50 to 500°F
0 to 99% RH
d. Unless otherwise stated, space sensor covers shall be factory standard cover

B. Room Thermostats
1. Setpoint range shall be resettable only from remote BAS or from any server/client PC. Temperature sensors shall be compatible with the associated controlled devices (e.g. DDC air terminal controller). Mounting box shall be recessed type unless otherwise indicated, or required by the building construction materials.
2. ASC connected Room Temperature Sensors shall incorporate manufacturers standard element and an integral portable operator terminal plug-in port.
3. Temporary override push-button/timers shall be installed at all ASC connected Room Temperature Sensors.
4. Provide warmer/cooler setpoint adjustment. Minimum and maximum adjustable range shall be set through the BAS only.
5. Unless otherwise stated, Room Thermostat covers shall be factory standard cover.
6. Unless otherwise stated, room thermostat shall include a local LCD display.

C. Combination Space Temperature And Humidity Sensors/Transmitters
1. Low-voltage combination space temperature and humidity sensors shall incorporate concealed elements and a portable operator terminal plug-in port under the cover.
2. Temperature sensors shall be compatible with the associated controlled devices (e.g. DDC air terminal controller). Mounting box shall be recessed type unless otherwise indicated, or required by the building construction materials.
3. Meet the following minimum requirements:
a. Temperature:
1) Temperature Sensor: 100 or 1000 Ohm platinum or nickel RTD
2) Temperature Coefficient: 0.00385 ohm/ohm/°C
3) Accuracy: ± 0.5° F between 50-104° F (temperature)
4) Operating Range: -10 to 160°F
5) Output Ranges: 2-wire, 4 to 20 mA or 3-wire, 0 to 5, 0 to 10 VDC or 4 to 20 mA (24 VAC)
b. Humidity:
1) Temperature Compensated: Full range of % RH signal
2) Response Time: 30 seconds for 63% step
3) Accuracy Range: ±2% RH between 10 to 90% RH Span (including hysteresis, linearity repeatability).
4) Sensing Element: Resistance or Capacitance humidity sensor
5) Operating % RH Range: 10 to 90% RH(non-condensing)
6) Long Term Stability: Less than 2% rh drift per year
7) Supply Voltage: 18 to 36 VDC / VAC
8) Output Ranges: 4 to 20 mA; 0 to 5, 0 to 10 VDC
9) Cover plates shall be manufacturer's standard white plastic covers.
4. Temporary override push-button/timers shall be installed at all ASC connected Combination Sensors.
5. Provide warmer/cooler setpoint adjustment. Minimum and maximum adjustable range shall be set through the BAS only.
6. Unless otherwise stated, covers shall be factory standard cover.
7. Unless otherwise stated, sensors shall include a local LCD display.

D. Duct Mounted Probe Temperature Sensors
1. Platinum RTD type, with the following minimum performance:
Temperature Coefficient: .00385 ohm/ohm/°C

Accuracy:	+/- 0.1% at 32°F (Class B)
Conformance:	DIN-IEC 751
Operating Range:	0 to 150°F
	0 to 99% RH

2. Furnish sensors as shown on drawings or required for proper operation.

E. Rotary (Damper) Position Sensors:
1. Manufacturers: Keller & Associates, Fisher Controls or Westlock.
2. Provide position 4-20 mA transmitter with potentiometer type (variable resistance) sensor for damper position measurement. Measurement to be linear to damper stroke.
3. Power Supply: 24 VDC unregulated
4. Accuracy: ± 1% of output span
5. Repeatability: ± 0.5% of full span
6. Maximum Temperature: 125°F

PART 3 EXECUTION

3.01 SOFTWARE

A. Coordinate graphics and points for consistency with existing campus system.

B. Continuously archive all data in standard database platform. Including but not limited to:
1. I/O points
2. Software points such as:
3. Alarm limits
4. Setpoints
5. Parameters
6. Schedules
7. Alarm messages
8. Reports
9. Trends/History

C. Provide BAS Reports including:
1. Alarm Summary
2. Schedules
3. Control Loop Performance
4. Equipment specific energy performance calculations such as Energy Recovery Devices.
5. Measurement and verification reports consistent with the requirements of the M+V plan developed by a separate 3rd party agent.

D. The Contractor shall enable the owner to implement long term trending for all physical input and output points and all set-points. At a minimum, contractor shall configure control loop trending to include controlled variable, setpoint, and output from actuated device. The initial trend interval settings shall be set to 15 minutes. In addition, the Contractor may increase the resolution of all control loop trending to every 5 minutes during the testing/acceptance phase (minimum of 2 weeks) subject to the approval of the owner. Coordinate all trending requirements with Owner and demonstrate coordination with submittals.

E. Alarming:
1. Coordinate all alarming requirements with Owner and demonstrate coordination with submittals.
2. The Contractor shall create enhanced alarm programs for all system points. These points shall be programmed for appropriate seasonal high or low alarm limits. Enhanced alarm programs shall prevent abnormal alarms from occurring when the associated system has been deactivated. For example: air handler mixed air, preheat, cooling, humidity, and static pressure control points, building chilled water, heating water system control points, etc. Alarms shall occur only while systems are active and being supplied with chilled/hot water or steam at normal operating temperatures and pressures. Alarm destinations, alarm messages, and point graphic assignments shall be included so that alarms are indicated and printed at a pre-defined Owner

reporting device and recorded on a transaction log. Alarms shall have accurate descriptions and response instructions, so that alarms may be quickly associated with appropriate graphic display.

3. The Contractor shall define the specific system reactions for each point. Alarms shall be enhanced and prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. The Contractor shall initially define all point priority levels for handling of all system alarms. Users shall have the ability to manually inhibit alarm reporting for each point.
4. Alarm reports and messages shall be directed to a user-defined list of operator devices or PCs based on time (after hour destinations) and/or based on priority.
5. In addition to the points descriptor and the time and date, the Contractor shall create, print, display and store an alarm message for each point to more fully describe the alarm condition or to direct operator response. Alarm events may be configured to send an alarm message to a specified client e-mail address, cellular phone number via SMS text messaging.
6. Provide alarm suppression to minimize nuisance alarms from higher level alarms (level 1 is highest priority):

Level 1 Alarms	Level 2 Alarms	Level 3 Alarms
Chilled Water Temperature	Air Handling Unit Discharge Temperature	Room Air Temperature
Hot Water Temperature	Air Handling Unit Discharge Temperature	Room Air Temperature
Generator On or Power Lost to Building	Air Handling Unit and Exhaust Systems (Not on Emergency Power) Alarms	
Upon restoration of normal power provide delays and or other methods to suppress nuisance alarms during restarting of equipment.		
	Air Handling Unit Static Pressure	Room Pressurization and Flow Alarms
	Exhaust Fans Off	Room Pressurization and Flow Alarms

F. Graphic Displays:
   1. Coordinate all graphic requirements with the Owner and demonstrate coordination with submittals.
   2. Provide a color graphic system flow diagram display for each system with all points as indicated on the point list.
   3. Provide graphics for each floor plans of the building as a minimum. Size graphics to allow the operator to read room numbers and descriptions. Incorporate the capability to navigate section to section as required to view entire floor and to navigate floor to floor.
   4. Color shall be used to indicate normal and alarm conditions within all spaces. Color or common border lines shall be used to link HVAC equipment with zone(s) served.
   5. User shall be able to access the various system schematics and floor plans via a graphical penetration scheme and/or menu selection.
   6. User shall be able to penetrate from floor plan to associated HVAC system text based display.
   7. Create enhanced alarm programs for all system points. These points shall be programmed for appropriate seasonal high or low alarm limits.
   8. Refer to the following graphics guideline section and Graphic Standards - Appendix B for additional examples and samples.

3.02 GRAPHICAL STANDARD GUIDELINES

A. Large Area Floor Plan Graphic: When a link to a particular floor is selected, the screen will show an overall floor plan view divided into sections. This intermediate screen is necessary in large buildings where detailed floor plan view with room numbers and sensors displaying room air conditions are not

possible. In the case of a building with floor plans containing few rooms per floor, this screen can be omitted. The floor plan will accurately represent the as-built layout of rooms in the building.

1. The divisions of the partial floor plan sections should be based on the zones served by different air handling equipment. If that strategy does not produce the desired effects, the second best option is to divide the floor plan in equal parts.
2. Each section will actively inform user of any alarm conditions within the section by changing from a green to red background color.
3. Each section will have a link to take the user to a more detailed floor plan screen. In the bottom left hand corner of the screen are links to other floors arranged in a tree, the three shall also indicate alarm conditions present on each floor.

B. Floor Plan Section: The floor plan section screen shows the floor plan layout in more detail with room numbers and sensors displaying room environmental conditions. Each sensor and room number act as a link to the corresponding room system graphic, room background color is green under normal operation and red when any of the analog or binary inputs are outside their alarm limits.

1. The bottom left hand corner of the screen features links to different floors described previously, as well as a key plan of the sectioned view of the overall floor plan. Each section acts as an indicator and a link, when any room is in alarm mode in a particular section, that section turns red, otherwise it remains green. The user can move between section screens by selecting the appropriate link. Bottom of the page will have links to associated as-built HVAC, electrical, and piping plans.
2. Locations of panel mounted static pressure sensors and building pressure sensors reference points will be indicated on the floor plan graphic.

C. General Lab: When user selects a link to general lab space the graphics link will bring up a room with relevant air valves and their associated control points. Air valves will have their respective tags displayed on their icons, (per as-built drawings). The air valve command position and air valve feedback will be listed next to each air valve.

1. The screen title block will list the room number with the air valves listed in the parentheses.
2. The air change rate information shall be calculated and based on the room volume and the air flowing out of the room. Positive rooms shall use the total supply and negative rooms shall use the total exhaust.
3. Zone temperature will have its effective/actual (after local adjustment) heating and cooling set-points listed, if temperature deviates outside those values the point will go into alarm mode.
4. All analog will have their corresponding set-points displayed, the parameter list button will be a link to all settings not shown on the room screen. The user will be able to change all settings, all analog and binary inputs will be read only points with the user having the ability to take them out of service.

D. System Summary Screens: Summary screens shall be developed for each system as described below. All summaries shall be customized for the specific project and application. All system summary screens shall be linked to the specific system graphic, floor plan and/or home page as applicable.

1. General system summary screens (can be generated within any reporting tool)
2. All points in the building.
3. All points in a user-defined group of points including per system log reports.
4. All points currently in alarm in the building.
5. All schedules.
6. All points in an override condition.
7. System specific summary screens.
8. Include an AHU terminal unit summary screen for each AHU that serves multiple terminal units. The summary screen shall include the following information and shall be continuously updated with real time data.

AIR TERMINAL SUMMARY						
ROOM #	**DEVICE ID**	**ROOM TEMP**	**ROOM TARGET**	**SA TEMP**	**CLG VLV CMD**	**HTG VLV CMD**
FAN S/S	**FAN STATUS**	**HEAT/ COOL**	**DMPR CMD**	**AIR FLOW**	**AHU #**	**DESIGN CFM**

3.03 CONTROL WIRING AND PATHWAYS

A. Provide all electrical wiring required for a complete and functional control system, including power circuit to control panels and field devices in accordance with all applicable local codes and the latest version of National Electric Code and NFPA when applicable.

B. Sizing of cable, conduit, j-boxes and raceways to accommodate system with 25% spare capacity. Minimum conduit size shall be ¾" at all locations. All wall mount devices shall be in conduit and routed to nearest accessible ceiling location stubouts shall be a minimum of 12" from wall line.

C. Labeled wiring with unique tag to match I/O device identifier tag (e.g. sensor DA-T wire shall be labeled at panel and device as "DA-T"). Communication cable shall be labeled with Loop/Trunk #, previous and destination device (e.g. L1VAV101/VAV102 would be used to label the loop 1 communication bus between VAV101 and VAV102)

D. Low voltage wiring concealed above accessible ceilings does not require raceway, however, cables run above accessible ceilings shall be run within a j-hook pathway system spaced no more than 4 ft apart. Cables run in concealed areas or within un-accessible spaces shall be installed in EMT. Run pathways and cables parallel and perpendicular to building structure.

E. Flexible Metal Conduit shall be used for vibration isolation and shall be limited to 3 feet in length when terminating to vibrating equipment. Flexible Metal Conduit shall be UL listed.

F. Run direct current instrument conductors separately from alternating current conductors. Where allowed by NEC wiring classification, AC-DC route crossings shall be at 90 degrees. Install special sensor to converter cables in accordance with drawings or in compliance with manufacturer's instructions. Extra precautions shall be taken when pulling and shortening these "vendor furnished" cables. Any extra length on these cables shall be neatly coiled into minimum 3" diameter coils and installed into junction box.

G. BAS Network Communication Cable:
   1. Run communication or low voltage power cable in separate pathways or in j-hooks with proper clearances.
   2. Install special cable connectors in accordance with manufacturer's recommendations.
   3. BAS network communication cable shall not be spliced unless a terminal strip enclosure is used.
   4. BAS network communication shall be shielded with the shields taped back where applicable.

H. All control wiring located in mechanical or exposed spaces shall be run in EMT.

I. All Input / Output wiring shall be shielded in accordance with equipment requirements.

J. Control panels and operator's terminals serving equipment fed by emergency power shall also be served by emergency power. Locate LOT and its UPS where shown on plans.

K. Raceway Identification. All the covers to junction and pull boxes of the BAS raceway system shall be painted white.

3.04 LOCAL CONTROL PANELS

A. Provide local control panel for each system where more than one control device requires field mounting (air handling units, miscellaneous control system including pump controls, etc.). Single devices may be mounted exposed on piping or ductwork. Install local control panel where indicated on drawings or suitable location adjacent to system served. Do not mount panels on equipment.

B. Mount panel on wall with suitable brackets or on floor with self-supporting stand.

C. Mount top of panel no higher than 6 feet above floor.

D. Install panels so front cover door can swing full open without interference and maintain a minimum of 36" clearance.

E. Unless otherwise indicated, mount controllers, adjusting switches, pressure gages, temperature indicators and other indicating or manually operated devices inside panel with permanent labels identifying device and controlled device or function.

F. Labels shall correspond to control drawing tags and identifiers.

G. Panel shall be labeled with location and breaker number of power feed.

H. Network Routers & Bridges

I. Coordinate final location with Owner and other trades.

3.05 APPLICATION SPECIFIC CONTROLLERS (ASC'S)

A. Provide the following types of application specific controllers (embedded or as a predefined software application) as a minimum:
   1. Variable Air Volume (VAV) boxes
   2. Constant Air Volume (CAV) boxes
   3. Chilled Beams
   4. Fan Coil Units
   5. Small AHU'S
   6. Room Pressurization

3.06 SERVERS:

A. Archive all historical data such as trends, alarm and event histories, and transaction logs on existing server.

3.07 CONTROL VALVES

A. Furnish control valves as shown on drawings and/or as required to perform control sequence specified.

B. Coordinate the installation of control valves.

C. Sizing:

D. Select control valves to meet their intended service without cavitations. Provide cavitation calculations for modulating globe control valves over 250°F and all modulating butterfly valves over 60°F.
   1. Valve body ratings indicated in Part 2 are minimum required. Valve body, trim and packing selected shall be designed to withstand maximum pressure and temperature encountered in the systems.
   2. Submit engineering calculations used for sizing modulating control valves. Control valves serving terminal devices may be sized based on flow ranges for each pump system.
   3. Calculations for sizing modulating valves shall be based on actual characteristics of equipment and system being installed.
      a. Valve calculations shall include information such as pump head or available pressure; branch piping circuit losses including all pipe, fittings, valves, and coils; flow rates; and pressure losses of other in-line devices.
      b. Obtaining adequate system information necessary for sizing valves.

E. Design criteria for sizing modulating valves shall be based on two port, or 3 port, fail open or fail closed, as shown on plans, equal percentage valves unless otherwise specified.

F. Heating control valves shall be full port ball valve and shall be selected for a minimum of 25% of equipment subcircuit pressure drop, but not more than maximum available pump head allowing minimum 2 psi drop for balance valve.

G. Size three-way mixing or diverting valves not directly associated with pump sub-circuit, for 3-5 psi pressure drop.

H. Terminal reheat control valves shall be ball type and shall be selected for a minimum of 25% of equipment subcircuit pressure drop, but not more than maximum available pump head allowing minimum 2 psi drop for balance valve.

I. Cooling control valves may be full port ball, or butterfly type and shall be selected for minimum of 10% of equipment subcircuit pressure drop, but not more than maximum available pump head allowing minimum 2 psi drop for balance valve.

J. Select control valves based on pressure drop calculations using Cv values at 100% stroke.

K. Subcircuit is defined as all branch supply and return piping to terminal device, including all valve, coil, control valves, and balance valve.

3.08 CONTROL DAMPERS

A. Furnish control dampers as shown on drawings and/or as required to perform control sequence specified except those furnished with other equipment.

B. Coordinate the installation of control dampers.

C. Sizing
   1. Calculations for sizing dampers shall be based on actual characteristics of ductwork system being installed.
   2. Opposed blade dampers shall be sized for minimum of 10% of duct section pressure drop. Parallel blade dampers shall be sized for minimum of 30% of duct section pressure drop. Duct section is defined as ductwork containing flow control damper starting with inlet or branch tee and ending with outlet or branch tee.
   3. Calculate actual duct pressure drops for each duct section containing modulating damper using latest version of ASHRAE Handbook of Fundamentals.
   4. If control system fixes pressure drop, use those pressure setpoints. Use duct blank-offs to provide additional pressure drop as required to obtain linear damper response.
   5. Contractor is responsible for obtaining adequate system information necessary for sizing.
   6. Contractor to provide dampers as shown on drawings or as scheduled.
   7. Two position dampers shall be sized as close as possible to duct size, but in no case is damper size to be less than duct area.

3.09 DISCRETE ELECTRIC INSTRUMENTATION

A. General:
   1. Terminate at terminal blocks inside enclosures unless otherwise specified.
   2. Include auxiliary contact for remote status indication of safety devices.

B. Relays:
   1. Provide control relays where indicated on drawings or as required to accomplish sequences.
   2. Provide DIN mounted relays in control panels.
   3. Provide RIB type relays for field control devices mounted on exterior of starter or VFD.
   4. Mount relay for easy accessibility.
   5. Mount relay for easy visual accessibility.

C. Current Switches:
   1. Provide current switches where indicated on drawings or as required to accomplish sequences.
   2. Locate in starter or VFD or in an appropriate adjacent enclosure.

D. Transmitters and Indicators:

1. Locate transmitters at sensing device or within 100 ft for remote mounted transmitters. For hot systems (150°F and higher) mount electronics on side of pipe or remotely mount. For indicating type instruments, locate indicating element within 6 ft of floor with readout easily visible from floor level. Provide remote readouts if necessary.

3.10 ANALOG ELECTRONIC INSTRUMENTATION

A. Wall Mounted Space Sensors:
   1. Install space thermostats/sensors where indicated, as required to perform specified controls, or directed to meet job site conditions.
   2. Mount space sensors 4 ft above floor unless otherwise indicated.
   3. Any room sensor mounted on exterior walls shall be mounted on thermally insulated sub-base.
   4. Relocate room sensors if required due to draft, interferences with cabinets, writing board, etc., or improper sensing.
   5. Provide a conduit from sensor box to above the ceiling where it shall stub out into an accessible area parallel with the ceiling.

B. Room Thermostats
   1. Install space thermostats where indicated, as required to perform specified controls, or directed to meet job site conditions.
   2. Mount thermostats at 4 ft above floor unless otherwise indicated.
   3. Any room thermostat mounted on exterior walls shall be mounted on thermally insulated sub-base.
   4. Relocate room thermostats if required due to draft, interferences with cabinets, writing board, etc., or improper sensing.
   5. Provide a conduit from thermostat box to above the ceiling where it shall stub out into an accessible area parallel with the ceiling.

C. Combination Space Temperature And Humidity Sensors/Transmitters
   1. Install sensors where indicated, as required to perform specified controls, or directed to meet job site conditions. Provide combination space temperature and humidity sensors in zones as shown on control drawings, including but not limited to chilled beam zones.
   2. Mount sensors at 4 ft above floor unless otherwise indicated.
   3. Any sensor mounted on exterior walls shall be mounted on thermally insulated sub-base.
   4. Relocate sensor if required due to draft, interferences with cabinets, writing board, etc., or improper sensing.
   5. Provide a conduit from sensor box to above the ceiling where it shall stub out into an accessible area parallel with the ceiling.

D. Insertion Temperature Sensors
   1. Provide sensors where shown or drawings or to accomplish sequences.
   2. Install wet sensors in stainless steel or brass wells with thermal grease.

END OF SECTION

SECTION 23 0700
MECHANICAL SYSTEMS INSULATION

PART 1 - GENERAL

1.01 RELATED WORK

A. Section 23 0529 - Mechanical Piping and Equipment Supporting Devices

B. Section 23 0553 - Mechanical Systems Identification (pipe jacket color chart)

C. Section 23 3114 - Ductwork

1.02 DESCRIPTION

A. Provide insulating materials and accessories as required for mechanical systems as specified below.

B. Insulating products delivered to construction site shall be labeled with manufacturer's name and description of materials.

1.03 DEFINITIONS

A. Concealed areas, where indicated in this Section, shall apply to shafts, furred spaces and space above finished ceilings, inaccessible tunnels and crawl spaces. All other areas, including walk-through tunnels, shall be considered as exposed.

B. Unless otherwise indicated, unit of thermal conductivity is BTU in(h ft2'F).

C. Interstitial spaces are considered as concealed areas.

1.04 SUBMITTALS

A. Product Data for each piping system for all pipe sizes, each ductwork system but not limited to, the following:
   1. Manufacturer's name
   2. Schedule of insulating materials
   3. Insulation material and thickness
   4. Jacket
   5. Adhesives
   6. Fastening methods
   7. Fitting materials
   8. Intended use of each material
   9. Manufacturer's data sheets indicating density, thermal characteristics, temperature ratings
   10. Insulation installation details (manufacturer's installation instruction/details, Contractor's installation details, MICA plates where applicable)
   11. All other appropriate data

1.05 DELIVERY, STORAGE AND HANDLING

A. Insulation material shall be delivered to project site in original, unbroken factory packaging labeled with product designation and thickness. Shipment of materials from manufacturer to installation location shall be in weather-tight transportation. Protect insulation materials from moisture and weather during storage and installation. Protect insulation material against long exposure to UV light from sun.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Insulation:
   1. Owens Corning, Johns Manville, Manson, Knauf or CertainTeed similar to product indicated except where product of manufacturers not listed above is specifically identified for special type of insulation.

B. Coatings, Mastics, Sealants and Adhesives:
   1. Foster, Childers, Design Polymerics, Vimasco, Miracle or Pittsburgh Corning

2.02 MATERIALS

A. Products used for or related to air conditioning and ventilating systems shall conform to NFPA 90A possessing flame spread index of not over 25 and smoke developed index no higher than 50.

B. Unless otherwise indicated, all products, material itself or on composite basis, shall have flame spread index not more than 25 and smoke developed index not more than 50, when tested in accordance with ASTM E84 or UL 723.

C. Insulation shall not contain formaldehyde.

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

E. Insulation applied on stainless steel shall meet requirements of ASTM C795 and NRC 1.36.

2.03 INSULATION

A. Insulation materials shall be fire retardant, moisture and mildew resistant, vermin proof, and suitable to receive jackets, adhesives and coatings as indicated.

B. Glass fiber insulation shall be of inert inorganic material, non-corrosive to mechanical surfaces.

C. Insulating cement shall be Quick-Cote by PK Insulation MFG Co. or Ryder GP, with dry density of no more than 38 lb/ft3 thermal conductivity of 0.96 at 400°F mean temperature, and service temperature to 1200°F.

D. Filling and finishing cement shall be Super-Stik by PK Insulation MFG Co., or Ryder MW, with dry density of no more than 24 lb/ft3, thermal conductivity of 0.74 at 500°F mean temperature, and service temperature to 1900°F.

E. Type A Insulation (Flexible Elastomeric):
   1. Flexible, closed-cell, elastomeric cellular insulation.
      a. ASTM Standard: ASTM C534/C534M, Type I (tube form) or Type II (sheet form), Grade I
      b. Thermal Conductivity: Maximum 0.28 at 75°F mean temperature
      c. Water Vapor Permeability: Maximum 0.08 perm-inch
      d. Water Absorption: Maximum 0.2 % by volume
      e. Service Temperature: -297 to 220°F
   2. Manufacturers/Products:
      a. Armacell, AP Armaflex or AP Armaflex FS
      b. Aeroflex, Aerocel
      c. K-Flex, Insul-Tube

F. Type F Insulation (Flexible Fiberglass Blanket):
   1. Flexible fiberglass blanket insulation, faced with specified jacket.
      a. ASTM Standard: ASTM C1290
      b. Density: Minimum 0.75 lb/ft3
      c. Thermal Conductivity: Maximum 0.30 at 75°F mean temperature
      d. Service Temperature: Maximum 250°F.
   2. Manufacturers/Products:
      a. Johns Manville, Microlite EQ FSK
      b. Owens Corning, All Service Duct Wrap
      c. Knauf, Atmosphere Duct Wrap

G. Type G Insulation (Cellular Glass):
   1. 100% cellular glass cells with no organic material, noncombustible.
      a. ASTM Standard: ASTM C552, Type I (block) or Type II (pipe), Grade 6
      b. Density: Minimum nominal 7.18 lb/ft3
      c. Thermal Conductivity: Maximum 0.31 at 75°F mean temperature
      d. Compressive Strength: Minimum 90 psi,
      e. Water Vapor Permeability: 0.00 perm-"
      f. Water Absorption: Maximum 0.2% by volume
      g. Service Temperature: -450 - 900°F
   2. Manufacturers/Products:
      a. Owens Corning, Foamglas

H. Type R Insulation (Rigid Mineral Fiber Pipe Insulation):
   1. Mineral fiber (fiberglass) preformed pipe insulation faced with specified jacket.
      a. ASTM Standard: ASTM C547, Type I
      b. Density: Minimum nominal 3 lb/ft3
         1) Thermal Conductivity: Maximum 0.23 at 75°F and 0.29 at 200°F
         2) 0.29 at 200°F mean temperature
      c. Service Temperature: To 850°F
   2. Manufacturers/Products:
      a. Johns Manville, Micro-Lok HP
      b. Owens Corning, ASJ Max Fiberglas Pipe Insulation
      c. Knauf, Earthwool 1000° Pipe Insulation

I. Type R Insulation (Rigid Mineral Fiber Board Insulation):
   1. Mineral fiber (fiberglass) duct and equipment insulation faced with specified jacket.
      a. ASTM Standard: ASTM C612, Type IA and IB
      b. Density: Minimum nominal 3 lb/ft3
      c. Thermal Conductivity: Maximum 0.23 at 75°F mean temperature
      d. Service Temperature: To 450°F
   2. Manufacturers/Products:
      a. Johns Manville, 800 Series Spin-Glas, Type 814
      b. Owens Corning, Fiberglas Fiberglass 700 Series, Type 703
      c. Knauf, Earthwool Insulation Board

2.04 JACKETS

A. Jacket puncture resistances shall be based on ASTM D781 test methods. Vapor barrier permeance ratings shall be based on ASTM E96/E96M Procedure A.

B. Type A-1 Jacket (Aluminum Roll Jacketing):
   1. Factory fabricated 0.016" thick, ASTM B209/B209M, Type 3003 or 3105, stucco embossed aluminum jacket with integrally bonded moisture barrier/retarder consisting of 3 layers of polymer films with total thickness of 3 mil.
   2. Fitting covers shall be factory fabricated from not lighter than thick, Type 3003 or 1100 aluminum. For large pipes, where factory fabricated fitting covers are not available, Contractor shall fabricate fitting covers from like sheet materials.
   3. Manufacturers/Products:
      a. Johns Manville, Aluminum Jacketing
      b. RPR Products, Insul-Mate

C. Type D-1 Jacket:
   1. Heavy-duty, fire retardant material with glass fiber reinforcing. Jackets shall have neat, white Kraft finish suitable for painting, with beach puncture resistance of 50 units minimum. Vapor barrier shall be adhered to inner surface of jacket. Permeance shall not exceed 0.02 perm.
   2. Manufacturers/Products:
      a. Owens Corning, ASJ Max
      b. Johns Manville, ASJ-4535
      c. Knauf, ASJ+

D. Type D-2 Jacket:
   1. Glass fiber reinforced foil Kraft laminate with permeance not exceeding 0.02 perm and beach puncture resistance 25 units minimum.
   2. Manufacturers/Products:
      a. Owens Corning, FRK
      b. Johns Manville, FSK
      c. Knauf, FSK

E. Type P-1 Jackets:

1. Heavy-duty, fire retardant material with glass fiber reinforcing and self-sealing lap. Jacket shall have neat, white Kraft finish suitable for painting, with burst strength of 1.5 Joules(50 beach units) minimum and tensile strength 45 lbs/in minimum. Vapor barrier shall be adhered to inner surface of jacket. Permeance shall not exceed 0.02 perm.
2. Manufacturers/Products:
   a. Owens Corning, ASJ-SSL
   b. Johns Manville, ASJ
   c. Knauf, ASJ+

2.05 ADHESIVES, MASTIC, COATINGS, SEALANTS, AND REINFORCING MATERIALS

A. Products shall be compatible with surfaces and materials on which they are applied and shall be suitable for use at operating temperatures of systems to which they are applied.

B. Products shall be fire retardant, moisture resistant and mildew resistant and vermin proof.

C. Vapor Barrier Mastic: Below ambient insulation. Water vapor permeance shall be less than 0.08 perms at 45 mils dry film thickness per ASTM F1249.
   1. Foster 30-33
   2. Childers CP-33
   3. Vimasco 749

D. Weather Barrier Breather Mastic: Above ambient insulation. Permeance shall be greater than 1.0 perms at 1/16" dry film thickness per ASTM E96/E96M.
   1. Foster 46-50 Weatherite
   2. Childers CP-10/CP-11 Vi Cryl
   3. Vimasco WC-5

E. Lagging Adhesive/Coatings: Indoors applications used in conjunction with canvas/glass cloth.
   1. Foster 30-36
   2. Childers CP-50 AMV1
   3. Vimasco 713

F. Metal jacketing sealant for aluminum jacketing:
   1. Foster 95-44 Elastolar
   2. Childers CP-76 Chil Byl
   3. Pittsburgh Corning 727

G. Insulation joint sealant for Type P, Type PP, and Type G insulation:
   1. Foster 95-50 Flextra
   2. Childers CP-76 Chil Byl
   3. Pittsburgh Corning CW Sealant

H. Glass fiber fabric reinforcing shall be 10 x 10 mesh similar to Childers Chil Glas #10 or Foster Mast A Fab.

I. Wire mesh reinforcing shall be 22 ga, 1" galvanized.

J. Insulation cement shall be ANSI/ASTM C195, hydraulic setting mineral wool.

K. Finishing cement shall be ASTM C449.

L. Butt joint and longitudinal joint adhesive for Type A insulation shall be Armstrong 520, Rubatex 373, Childers CP-82 or Foster 85-75.

M. Weather-resistant protective finish for Type A insulation shall be equal to Armstrong WB Armaflex finish or Foster 30-64 elastomeric coating.

2.06 METAL BANDS AND WIRES

A. Aluminum bands shall be 0.5 x 0.20" up to 48" diameter and 0.75 x 0.020" over 48" diameter.

B. Stainless steel bands shall be 0.5 x 0.015" or 0.75 x 0.015".

C. Stainless steel wires shall be 16 ga.

2.07 INSULATION FASTENERS

A. Insulation fasteners shall be cup head weld pins, galvanized low carbon steel, minimum 12 ga (0.105”)) pins.

B. Washer edge shall be beveled.

C. Fasteners shall be stainless steel for stainless steel ductwork application.

D. Insulation fasteners using adhesive are not allowed.

PART 3 - EXECUTION

3.01 APPLICATION

A. Provide insulation and jackets with minimum insulation thickness as indicated in the following schedule. The schedule applies to both exposed and concealed applications unless noted otherwise:

Piping System							
		Minimum Insulation Thickness According to Pipe Size					
Service	Jacket Type	Insulation Type	3/4" and Smaller	1" - 1-1/4"	1-1/2" - 3"	4" - 6"	8" and Larger
Heating Hot Water 141-200°F	P-1	R	1-1/2"	1-1/2"	2"	2"	2"
Chilled Water (Interior) 40-60°F	P-1	G	1"	1-1/2"	1-1/2"	2"	2"
Cooling Coil Condensate Drain	---	A	3/4"	3/4"	3/4"	3/4"	3/4"

Ductwork/Equipment & Systems			
Service	Jacket Type	Insulation Type	Insulation Thickness
Supply/Return Ducts Exposed	D-1	R	1-1/2"
Supply/Return Ducts Concealed	D-2	F	2"

3.02 INSTALLATION - GENERAL

A. All insulation installation methods shall be performed in accordance with the latest edition of National Commercial and Industrial Insulation Standards published by MICA (Midwest Insulation Contractors Association) and manufacturer's installation instructions, except as modified in this Section of specifications.

B. Install products with good workmanship, with smooth and even surfaces. Use full-length factory-furnished material where possible. Do not use scrap pieces.

C. Apply insulation only on clean, dry surfaces, after all rust and scale have been removed and testing of systems has been completed. Do not insulate any section of system that must be pressure tested until after it has been successfully tested. Any removal and reinstallation to correct system defects prior to end of guarantee period shall be accomplished at no expense to Owner.

D. Install insulating materials with necessary joints and terminations, to permit easy access and removal of equipment sections where inspection, service or repair is required, and to allow for expansion.

E. Where possible longitudinal joints in jackets shall face toward wall or ceiling.

F. Apply insulation to each pipe or duct individually. Common insulation applied to adjacent pipes or ducts will not be accepted.

G. Unless otherwise indicated, pipe and duct insulation shall be continuous through walls and floors.

H. Where multiple layers of insulation are used, stagger and secure each layer with metal bands.

I. Where penetrations occur through fire-rated walls, partitions, or floors, provide fire-stopping system as specified in Section 23 0000 - General Mechanical Requirements and Section 07 8400 - Firestopping.

J. Insulate the following systems for complete vapor barrier protection:
   1. Chilled Water
   2. Insulated ductwork

3. Piping and/or equipment with surface temperature below 60°F

K. Apply Type A insulation for insulation and jackets requiring vapor barrier protection where specified insulations are cut for mounting sensors, control devices, parts of valves, devices or components which extend out from specified insulation to prevent condensation.

3.03 PIPING, VALVE AND FITTING INSULATION

A. Apply insulation to pipe, unions, flanges, fittings, valves and piping specialties with butt joints and longitudinal seams closed tightly. Valve insulation shall cover entire valve body including bonnets and packing nuts.

B. Laps on factory-applied jackets shall be 2" minimum width firmly cemented with lap adhesive, or shall be pressure sealing type lap.

C. Cover joints with factory furnished tape 3" minimum width) to match jacket. Cement firmly with lap adhesive. On systems requiring a vapor barrier (ASJ), vaporseal all longitudinal and butt joints ASJ/Saran seams with 4"wide coat of vapor barrier mastic or 3" minimum tape.

D. Where staples are used, they shall be on 6" maximum centers. When used for systems requiring vapor barrier, cover lap and staples with finish coat of vapor barrier mastic or 3" minimum tape.

E. For finishing of insulated pipe fittings and valves where surface temperature of insulation is not higher than 125°F, use one piece PVC fitting covers, minimum thickness of 20 mil, Fitting cover shall be Johns Manville Zeston 2000 PVC, PROTO Fitting Covers, or similar by other manufacturers listed. Where fitting and valve insulation requires vapor barrier, seal joints of PVC covers with vapor barrier adhesives. Insulation type, R-value and density of insulation used at fittings shall match insulation of adjacent piping. Install insulation at pipe fittings and valves completely prior to applying PVC covers.
   1. For Type R (Rigid glass fiber) pipe insulation, PVC fitting covers with flexible mineral fiber blanket insulation inserts are acceptable, except those located in mechanical rooms within 6 ft above floor. For fitting covers located in mechanical room within 6 ft above floor, insulation inserts shall be pre-molded rigid fiber glass type wrapped around elbows.

F. Stove pipe style insulation on elbows (Detail A on Plate 2-200 of MICA 8th Edition) is not allowed. It may be used for closed cell elastomeric insulation.

G. Where terminations of pipe insulation are required, insulation shall have tapered ends, built up and finished as specified for fittings.

H. For pipes 1" and smaller, install specified pipe insulation and jacket continuous through hanger or support locations. Install insulation protection shields to protect insulation from compressing.

I. For pipes 1-1/2" and larger, where manufactured pre-insulated pipe supports are used at hanger or support locations, extend insulation to insulated pipe supports. Where vapor barrier is required, this Contractor shall be responsible for continuity of vapor barrier at insulated pipe supports 3" wide vapor barrier tape on hot and cold systems at pipe supports.

J. For pre-insulated pipe supports and insulation protection shields, refer to Section 23 0529 - Mechanical Piping and Equipment Supporting Devices.

K. For Contractor-fabricated anchors, secure insulation directly to pipe surface and extend insulation up anchor for distance of 4 times insulation thickness. For pre-insulated anchors, cover entire surface of anchors with Type A insulation. Where applicable, take special care to assure vapor seal at anchor.

L. Where mechanical grooved pipe connections are used in piping system, insulate couplings as specified for pipe.

M. Piping, fittings, and valves not to be insulated:
   1. Heating hot water piping inside fin tube radiation enclosures
   2. Control valves and balancing valves for heating terminal devices
   3. Valves and steam traps furnished with removable insulation/jacket

3.04 EQUIPMENT INSULATION

A. Install removable insulation where access is required for cleaning, repair and inspection. Construct removable insulation with Type A insulation for cold equipment and Type R insulation with V-1 jacket for hot equipment. Do not apply bonding adhesive to equipment surface.

B. Provide removable insulating blankets on expansion joints.

C. Do not insulate over equipment nameplates or ASME stamps. Bevel and seal insulation at these locations.

D. Equipment not to be insulated:
   1. Equipment furnished with factory insulation.

3.05 DUCTWORK AND COMPONENTS

A. Apply duct insulation evenly over duct surface. Unless otherwise indicated, insulation and jacket shall run continuously between duct and duct supports. Maintain insulation thickness specified over duct reinforcing members.

B. Insulation may be installed outside of support for rectangular or oval ducts having width 60" or smaller or round ducts 24" or smaller, and supported with strap hangers, provided that vapor barrier integrity is maintained at strap penetration.

C. Securing glass fiber insulation (Type F, R, and RR) for rectangular or oval ductwork.
   1. Horizontal ductwork:
      a. Secure to bottom of duct where duct width is 24" diameter or greater.
      b. Secure to sides of duct where duct side is 24" diameter or greater.
   2. Vertical ductwork:
      a. Secure to all sides where duct width is 18" diameter or greater.
   3. Install fasteners as required to secure, but not over 18" on center and within 3" of butt joint or edge.
   4. Fastener shall be weld pin mechanical type.

D. Fastening insulation anchors to ductwork with adhesives is not allowed. Where weld pin fasteners are used, install them without damage to interior galvanized surface. Where weld pin fasteners cannot be used, use other type of fasteners such as metal bands.

E. Where insulation is required for ductwork, provide insulation over entire ductwork system, including system components such as filters, mixing air chambers, sound attenuators, air measuring stations, reheat coils, etc. For fire dampers, smoke dampers and combination F/S dampers in ductwork requiring insulation, install insulation and jacket to wall and apply vapor barrier sealant to prevent condensation.

F. Provide insulation over back pan or plenum of supply air diffusers, registers, or grilles primary air plenums of active chilled beams, and unlined boots after termination point of flexible ducts or rigid duct insulation to prevent sweating.

G. Where vapor barrier jackets are specified, pins and staples if used shall be jacketed over with matching material using 4" tape. Vaporseal insulation seams, punctures, and tears with two 4" wide tape.

H. Insulation without factory jacket shall be cut and mitered to suit surface. Build up voids, seams and joints with insulating cement, cover with glass fabric as specified herein and finish to smooth surface.

I. D-1 jackets:
   1. Butt together joints and seams firmly, cover with glass fiber fabric 4" minimum width.

J. D-2 jackets:
   1. Butt together joints and seams firmly and cover with 4" wide FSK tape.

K. Ductwork not to be insulated:
   1. Internally lined ductwork
   2. Ductwork components with factory installed insulation

3.06 TYPE G INSULATION (CELLULAR GLASS)

A. Install cellular glass insulation system in strict accordance with manufacturer's installation instructions.

B. Chilled Water Piping (Interior):

1. Butter joints of insulation with Pittseal 727 or 444N Sealant. Apply insulation to pipe and fittings with joints tightly fitted and sealed full depth with joint sealant. Secure each length of insulation with 1" wide filament tape and stainless steel wire over tape. Apply insulation with joints fitted to eliminate voids. Eliminate voids by refitting or replacing insulation. Do not fill voids with joint sealer.
2. Finish with specified jacket, joints and laps sealed with fire rated adhesive. Finish elbows and fittings with white PC-79 polyester fabric coated with Pittcote 404.

END OF SECTION

SECTION 23 2116
PIPE AND PIPE FITTINGS

PART 1 - GENERAL

1.01 RELATED WORK

A. Section 23 0000 - General Mechanical Requirements (submittal requirements)

B. Section 23 0594 - Water Systems Test Adjust Balance

C. Section 23 2118 - Valves

D. Section 23 2120 - Piping Specialties

1.02 DESCRIPTION

A. Specification of an item in this or any other sections shall not relieve Contractor from providing all items, articles, materials, operations, methods, labor, equipment and incidentals necessary for a complete and functional system.

B. Use only new material, free of defects, rust and scale, and guarantee for services intended.

C. Use material meeting the latest revision of ASTM specifications as listed in this specification.

D. Follow local codes if they require other types of pipe or joints.

E. Manufacturer, pressure class, size and heat code of each fitting and flange shall be permanently identified on its body in accordance with MSS SP-25.

F. Where size for a pipe segment is not indicated, the pipe segment size shall be equal to the largest pipe segment to which it is connected. Transition to smaller size shall occur on the side of fitting where smaller size is indicated.

G. Unless otherwise indicated, fittings and accessories connected to pipe shall be of the same material and wall thickness as the pipe.

H. Unless otherwise indicated, construct piping for highest pressures and temperatures in respective system in accordance with the latest revision of the applicable Sections of ASME Code for pressure piping, ASME B31 including the following:
   1. ASME B31.9 : Building Services Piping

1.03 SUBMITTALS

A. Submittals shall be in PDF format and shall include bookmarks to each product to enhance navigation and facilitate review process.

B. Shop Drawings for each piping system for all pipe sizes including the following:
   1. Name of system
   2. Pipe; ASTM number, grade if known, type, wall thickness, material
   3. Fittings; ASME number, grade if known, class, type, wall thickness, material
   4. Joint type
   5. Flanges; ASTM number, grade, class, type, material
   6. Bolts and nuts; material
   7. Thread joint sealants; material
   8. Flange gaskets; material, rating
   9. Unions; ASTM number, type, material, rating
   10. Test pressure and media
   11. Pipe flushing/cleaning plan
   12. Pipe cleaning method
   13. All other appropriate data

C. Provide Flushing and Cleaning Plan:
   1. Submit pipe flushing/cleaning plan for water, fluid, steam and condensate systems for approval. Plan shall detail methods for compliance with requirements of this section, including:
      a. Flushing and cleaning procedure narratives.

b. Size, power source, and connection points of contractor provided pumps that will be used for flushing and cleaning.
c. If Contractor proposes to utilize project system pumps, method of protecting pumps from damage and developing required velocity of section of piping to be flushed.
d. Method of sectionalizing piping to obtain required velocity.
e. Minimum velocities at each section of pipe, clearly indicating any sections where 2 yd/s(6 fps) cannot be achieved.
f. Location and means of temporary bypasses for coils, control valves and other equipment.
g. Flushing schedule and drawings or diagrams that will be used for inspection and sign off prior to and after procedure, at Owner's option.

2. Submit documents showing verification of flushing/cleaning following specified requirements and results.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Furnish pipe with plastic end-caps/plugs on each end of pipe. Maintain end-caps/plugs through shipping, storage and handling to prevent pipe-end damage and eliminate dirt and construction debris from accumulating inside of pipe.

B. Where possible, store materials inside and protect from weather. Where necessary to store outside, elevate well above grade and enclose with durable, waterproof wrapping.

C. Before shipping, all carbon steel piping shall be free of rust and scale, and furnished with plastic end caps/plugs on each end of pipe.

1.05 FLANGES

A. Use either flat faced or raised-face flanges for mating with flat-faced or raised-face flanges.

B. Welding Neck Flanges:
1. All flanges shall be welding neck type unless otherwise indicated.

C. Slip-on Flanges:
1. Slip-on flanges shall not be used without specific approval of Engineer. Contractor shall submit written request for use of slip-on flange for specific instance where use of welding neck flange is problematic. Slip-on flanges over 4" pipe size are prohibited for any application under ASME B31.1.

D. Bore dimension of flange shall match inside diameter of connecting pipe.

E. Bolts and Nuts:
1. Threads shall be in accordance with ANSI/ASME B31.1, Class 2A tolerance for external threads and Class 2B tolerance for internal threads. Threads shall be coarse-thread series except that alloy steel bolting 1-1/8" and larger in diameter shall be 8 pitch thread series.
2. Threaded rods are not allowed in lieu of bolts.

F. Where allowed under specific piping systems specified in this section, use of low strength (ASTM A307) bolts shall be limited to service temperatures of 400°F and used only with non-metallic flat ring gaskets.

PART 2 - PRODUCTS

2.01 HEATING HOT WATER (THROUGH 250 PSIG/250°F)

A. 2" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
2. Fittings: ASME B16.22, wrought copper solder joint
3. Joint: ASTM B32, lead free solder, similar to Bridgit, Silvabrite, Silverflow or Canfield
4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint. No unions to be used for line sizes 3/4" and smaller. Unions shall be used for line sizes 1" and larger.
5. Flanges: Class 150, ASME B16.24, ASTM B61 or AASTM B62 cast copper alloy
6. Bolts and Nuts
a. Type 316 stainless steel bolts conforming to ASTM A193/A193M Grade B8M Class 1 or Class 2 with Type 316 stainless steel nuts conforming to ASTM A194/A194M Grade 8M. Use 316 SS washers.

7. Gaskets:
    a. ASME B16.21 and ASTM F104 flat ring type, asbestos-free, compressed inorganic fiber with nitrile binder.
    b. Gasket thickness: 1/16"
    c. Maximum Seating Stress (y): 3050 psi
    d. Minimum Gasket Factor (m): 4.2
8. Use solder joints for valves and piping specialties in copper piping, unless otherwise specified.
9. Press Joint Option:
    a. Contractor may use press copper fittings as manufactured by Viega, Other acceptable manufacturers are Nibco and Elkhart. “Push-to-connect” or “push-in” fittings, which are not press-type, will not be accepted.
    b. Fittings: Copper press fittings with EPDM seal, 0 to 250°F, maximum 200 psi.
    c. Joints: Press joints by fitting manufacturer approved tool.
10. T-Drill option:
    a. Contractor may use mechanically formed tee connections in lieu of wrought copper tee fittings, for branch takeoffs up to one half (1/2) diameter of main. Mechanically formed tees shall be formed by use of T-Drill machine in accordance with ASME B31.1 and T-Drill manufacturer's installation recommendation. Forming method shall be UL Listed.
    b. Mechanically formed tee connections shall be made by workers trained and certified by T-Drill manufacturer. Connections shall comply with American Welding Society lap joint weld, and joints shall be brazed in accordance with Copper Development Association Copper Tube Handbook using BCuP series filler metal.
    c. Owner reserves right to require destructive testing on 3 joints to ensure quality of joints. Contractor shall repair with new materials without any cost to Owner.
    d. Submit a formed tee sample made by each worker for approval. Sample shall be 1" main with (1/2" branch connection.

B. Contractor may use carbon steel as specified below in lieu of copper tube for 2" and smaller.
1. Pipe: ASTM A53/A53M Grade B, Type E or S or ASTM A106/A106M Grade B, standard weight, carbon steel
2. Fittings: ASTM A197/A197M/ASME B16.3, Class 150, malleable iron, threaded
3. Unions: ASTM A197/A197M/ASME B16.39, black malleable iron ground joint, bronze or brass to iron, Class 250

2.02 CHILLED WATER

A. 2" and Smaller:
1. Pipe: ASTM B88 seamless, Type L, hard temper copper tube
2. Fittings: ASME B16.22, wrought copper solder joint
3. Joint: ASTM B32, lead free solder, similar to Bridgit (by Harris), Silvabrite (by LucasMilhaupt), Silverflow (by Canfield Technolgies), or Canfield (by Canfield Technologies)
4. Unions: ASME B16.18 cast copper alloy or ASME B16.22 wrought copper solder joint. Unions shall not be used for lines sizes 3/4" and smaller. Unions shall be used for line sizes 1" and larger.
5. Flanges: ASME B16.24, Class 150, ASTM B61 or ASTM B62 cast copper alloy
6. Bolts and Nuts:
    a. Type 316 stainless steel bolts conforming to ASTM A193/A193M, Grade B8M Class 1 or Class 2 with Type 316 stainless steel nuts conforming to ASTM A194/A194M, Grade 8M. Use 316 SS washers.
7. Use solder joints for valves and piping specialties in copper piping, unless otherwise specified.
8. Press Joint Option:
    a. Contractor may use press copper fittings as manufactured by Viega. Other acceptable manufacturers are Nibco and Elkhart.
    b. Fittings: Copper press fittings with EPDM seal, 0 to 250°F, maximum 200 psi.
    c. Joints: Press joints by fitting manufacturer approved tool.

B. Contractor may use carbon steel as specified below in lieu of copper pipe for 2" and smaller.

1. Pipe: ASTM A53/A53M Grade B, Type E or S or ASTM A106/A106M Grade B, standard weight, carbon steel
2. Fittings: ASTM A126/ASME B16.4, Class 125, cast iron, threaded or ASME B16.3, Class 150, malleable iron, threaded.
3. Unions: ASTM A197/A197M/ASME B16.39, black malleable iron ground joint, bronze or brass to iron, Class 250

2.03 COOLING COIL CONDENSATE DRAIN

A. Piping shall be one of the following, unless otherwise indicated on drawings:
   1. Copper
      a. Pipe: ASTM B88 Type M, hard temper copper tubing
      b. Fittings: ASME B16.22 wrought copper fittings
      c. Joint: ASTM B32, 95-5 tin-antimony solder, Bridgit or Silvabrite

2.04 DIELECTRIC UNIONS, FLANGES AND FITTINGS (STEEL PIPE TO COPPER PIPE)

A. 2" and Smaller:
   1. Use bronze ball valves specified in Section 23 2118 - Valves for dielectric purpose.
   2. Dielectric fittings similar to Victaulic Style 647 or Clearflow Dielectric Waterway fittings may be used in lieu of dielectric unions for pipe sizes 2" and smaller.
      a. Clearflow fittings shall be ASTM A53/A53M electro zinc-plated steel pipe with high temperature polyolefin polymer liner, suitable for continuous use at temperatures up to 230°F and pressures up to 300 psig.
   3. ASTM A197/A197M/ASME B16, equal to Stockham Figure 693-1/2, Watts Series 3000 or Wilkins (Zurn) Model DU series dielectric unions with EPDM dielectric gasket, 250 psi at 180°F.

2.05 DIELECTRIC UNIONS, FLANGES AND FITTINGS (STEEL TO STEEL PIPE)

A. 1" and Smaller: Similar to Epco model HA-B with dielectric gasket, 250 psi at 210°F.

B. 1-1/2" and Larger: Similar to Epco model W with bolt insulators, dielectric gasket, bolts and nuts, 175 psi at 210°F. Pikotek model VSC dielectric gasket with viton sealing element, G-10 sleeve and double washers, suitable to 350°F, may be used with specified flanges.

PART 3 - EXECUTION

3.01 GENERAL

A. Remove foreign materials before erection. Ream ends of piping to remove burrs.

B. Install piping parallel to building walls and ceilings and at such heights so as not to obstruct any portion of window, doorway, stairway, or passageway. Install piping to allow adequate service space for equipment. Refer to drawings and/or manufacturer's recommendations. Install vertical piping plumb. Where interferences develop in field, offset or reroute piping as required to clear such interferences. In all cases, consult drawings for exact location of pipe spaces, ceiling heights, door and window openings or other architectural details before installing piping.

C. Provide anchors, expansion joints, swing joints and expansion loops so that piping may expand and contract without damage to itself, equipment or building.

D. Mitered elbows, welded branch connections, notched tees, and "orange peel" reducers are not allowed. Unless specifically indicated, reducing flanges and reducing bushings are not allowed. Reducing bushings may be used for air vents and instrumentation connections.

E. Bullhead tees (use of "branch" connection as only inlet or only outlet of tee) are not allowed.

F. Unless otherwise indicated, use fittings as specified in Part 2 of this Section for elbows, tees, reducers, etc.

G. Diverging tees (one inlet, two outlets) shall have inlet on “run” of tee. Converging tees (two inlets, one outlet) shall have outlet on “run” of tee. Bullhead tees will not be allowed unless specifically indicated or with approval of engineer.

H. "Weldolets" with outlet size 2-1/2" and larger and "Threadolets" or "Sockolets" with outlet size 2" and smaller may be used for branch connections up to one pipe size smaller than main. Use "Threadolets"

where threaded fittings are specified and use "Sockolets" where socket weld fittings are specified. Install in accordance with PFI (Pipe Fabrication Institute) Standard ES49.

I. Install drains throughout systems to permit complete drainage of entire system.

J. Do not install piping over electrical panelboards, switchgear, switchboards or motor control centers.

K. Install valves, control valves and piping specialties, including items furnished by others, as specified and/or detailed.

L. Make connections to equipment installed by others where that equipment requires piping services indicated in this Section.

M. For piping within the scope of ASME B31.1 Power Piping, transfer piping material specification and "Heat Number" to each segment of pipe prior to cutting.

3.02 THREADED PIPE JOINTS

A. Threads of pipe and fittings shall conform to ASME B1.20.1.

B. Ream pipe ends after cutting and clean before erection. Apply thread sealants to cleaned male threads. Assemble joint to appropriate depth and remove any excess pipe joint compound from tightened joint.

3.03 FLANGED JOINTS

A. Clean flange surfaces and align them parallel. Bolt holes of gaskets shall be cut slightly larger than bolt diameter. Gasket ID shall be slightly larger than flange ID.

B. Position gasket concentrically so compression is equally distributed over entire gasket surface.

C. Lubricate bolts and run nuts down by hand.

D. By using torque wrench, tighten nuts in the proper sequence so gasket is compressed evenly, and to the appropriate torque specified by bolt manufacturer.

E. Re-torque bolts 12 to 24 h after start up.

3.04 COPPER PIPE JOINTS

A. Cutting of tubing shall not make tubing out of round. Ream cut tube ends to full inside diameter.

B. Remove slivers and burrs remaining from tube cut by reaming and filing both pipe surfaces. Clean fitting and tube with emery or sand cloth. Remove residue from cleaning operation, apply flux and assemble joint. Use solder or brazing to secure joint as specified for specific piping service.

C. Press Joint Option:
   1. Cut pipe square and ream before assembly
   2. Insert pipe fully into fitting and mark on pipe at shoulder of fitting
   3. Check fitting alignment against mark on pipe to ensure pipe is fully engaged
   4. Press joint with press tool approved by fitting manufacturer

3.05 WATER SYSTEMS

A. Unless otherwise indicated, install horizontal piping level. Install manual air vents at all high points where air may collect. If vent is not in accessible location, extend air vent piping to nearest code acceptable drain location with vent valve located at nearest accessible location to pipe.

B. Main branches and runouts to terminal equipment may be made at top, top 45°, side or bottom 45° of main provided that there are drain valves suitably located for complete system drainage and manual air vents are located as described above.

C. Unless otherwise indicated, use top or top 45° connection to main for upfeed risers, and use side or bottom 45° connection to main for downfeed risers. Bottom connection is not allowed.

D. Use minimum of 3 elbows in each pipeline to terminal equipment to provide flexibility for expansion and contraction of piping systems. Offset pipe connections at equipment to allow for service, such as removal of terminal device.

E. Unless otherwise indicated, use concentric fittings for changes in pipe sizes and for valves smaller than pipe sizes.

F. Notch and dimple branch tubes. Braze joints. Apply heat properly so that pipe and tee do not distort. Remove distorted connections.

G. Where mechanically formed tee fittings are allowed, form mechanically extracted collars in continuous operation, consisting of drilling pilot hole and drawing out tube surface to form collar having height of not less than 3 times thickness of tube wall. Collaring device to be adjustable.

3.06 COOLING COIL CONDENSATE DRAIN

A. Trap each cooling coil drain pan connection with trap seal of sufficient depth to prevent conditioned air from moving through piping. Extend drain piping to nearest code approved drain location. Construct trap with plugged tee for cleanout purposes.

B. Pitch pipe down at not less than 1/8" per ft for proper drainage.

C. Where copper piping is allowed, joints and fittings may be secured with 95-5 tin-antimony solder or brazing alloys.

3.07 DIELECTRIC UNIONS AND FITTINGS

A. Install dielectric unions, flanges or fittings in main and branch piping of water systems at each point where copper to steel pipe connection occurs. Dielectric unions or fittings shall not be used at terminal device connections.

B. Concealed dielectric unions and fittings are not allowed.

3.08 UNIONS AND FLANGES

A. Install union or flange at each automatic control valve and at each piping specialty or piece of equipment that requires tube pull or removal for maintenance, repair or replacement. If required, provide additional unions or flanges in order to facilitate removal of piping sections that interfere with tube pulls or equipment removal. Where valve is located at piece of equipment, provide flange or union connection on equipment side of valve.

B. Concealed unions or flanges are not allowed.

END OF SECTION

1. Flexible, water based, adhesive sealant compounded specifically for sealing joints and seams in ductwork. Hardcast, McGill AirSeal, Ductmate PROseal, Mon-Eco Industries, Childers, Foster, or Design Polymerics.
2. Sealants shall be UL 723 (ASTM E84) classified, and meet NFPA 90A and 90B.
3. Select sealants as recommended by manufacturer for specific application.
4. Duct tapes are not allowed.

B. Gaskets:
1. Butyl, copolymer or neoprene based tape similar to Ductmate 440 Gasket Tape or Neoprene Gasket Tape for flanged joints.

C. Duct Sealant and Gaskets for Laboratory Exhaust Ductwork:
1. Sealant shall be similar to Hardcast Sure-Grip 404 or Ductmate Proseal.
2. Gasket material shall be Butyl tape similar to Ductmate 440 Gasket tape or neoprene gaskets.
3. Gasket thickness and width shall be as required for flange and surface irregularities to seal joint airtight.

D. Duct sealant for high temperature ductwork:
1. Sealant shall be 100% silicone and rated to 500°F continuous operation, similar to Surebond SB-188 or ASI 600.

2.04 CABLE SUSPENSION SYSTEM

A. Cable suspension systems are not allowed.

PART 3 - EXECUTION

3.01 GENERAL

A. Unless otherwise indicated, install ductwork level, parallel , and/or perpendicular to building structure, walls, and ceilings and at such heights not to obstruct any portion of ceiling, window, doorway, stairway, or passageway. Install ductwork to allow adequate access and service space for equipment. Refer to drawings and/or manufacturer's recommendations. Install vertical ductwork plumb. Where interferences develop in field, offset or reroute ductwork as required to clear such interferences. In all cases, consult drawings for exact location of duct spaces, ceiling heights, door and window openings or other architectural details before installing ductwork.

B. Make allowances for beams, pipes or other obstructions in building construction and for work of other contractors. Check plans showing work of other trades and consult with Engineer in event of interference. Transform, divide, or offset ducts as required, in such a manner as to maintain same cross sectional area of duct as indicated on drawings. Where it is necessary to install pipes or similar obstructions through ducts, consult with Engineer and obtain written approval from Engineer and Owner. If approved, provide streamlined encasement or collar designed in accordance with SMACNA Standards and seal to prevent air leakage.

C. Ductwork shall be free of kinks and dents.

D. Fabricate and install duct, fittings, joints, seams, reinforcement, supports, sealing, liner, etc., in sizes indicated on drawings and in accordance with manufacturer's published data and SMACNA Standards except as modified in this section of specifications or on drawings.

E. Provide transitions where different size or different shape ductwork segments are connected. Use concentric transitions unless otherwise shown. Unless otherwise indicated, make diverging transitions with maximum angle of 15° per side (30° total diverging) and converging transitions with maximum angle of 25° per side (50° total converging).

F. Provide transitions at ductwork system components and connections to equipment. Refer to Specification Section 23 3713 - Diffusers, Registers and Grilles, for additional information regarding diffuser/register/grille connections.

G. Refer to ductwork symbols list on drawings for additional and dimensional requirements for fittings.

H. Seal duct seams and joints to meet SMACNA Seal Class A as minimum for all ductwork including low-pressure ductwork.

I. Construct ductwork so that interior surfaces are smooth. Internal duct hangers and internal bracing are not allowed. Refer to Part 1, Design Criteria for internal tie rods.

J. Support coils, filters, air terminals, dampers, sound attenuator devices or other devices installed in duct systems with angles or channels and make all connections to such equipment including equipment furnished by others. Secure frames with gaskets, nuts, bolts and washers.

K. Air terminal devices may be supported by strap hangers if air terminal manufacturer approves. Strap hangers are not allowed for fan powered devices, double wall type and Titus Steri-Loc type devices.

L. Install outside air intake duct to pitch down at minimum 1" per 20 ft toward intake louver or plenum and to drain to outside of building. Solder or seal seams to form watertight joints.

M. Install exhaust air duct to pitch down at minimum 1" per 20 ft toward exhaust louver.

N. Blank off unused portion of outside air intake or exhaust louvers.

O. Where 2 different metal ducts meet, install joint in such a manner that metal ducts do not contact each other by using proper gasket seal or compound.

P. Install motor operated dampers and connect to or install equipment furnished by others. Provide necessary blank-off plates or transitions to mount control dampers as specified in Section 23 0901 - Control Systems Integration.

Q. Do not install ductwork over electrical panelboards, switchgear, switchboards or motor control centers.

R. When original galvanized finish is altered or damaged, apply field galvanizing paint as follows:
   1. Prepare surface with use of power sanders or wire brushes to remove rust, paint, etc.
   2. Apply cold galvanizing material equal to ZRC Products, Inc.

3.02 ELBOWS

A. Rectangular Duct:
   1. Use radius elbows with centerline radius to width ratio of 1.5 (SMACNA Type RE 1).
   2. Where 1.5 centerline radius elbows do not fit due to limited space, use radius elbows with centerline radius to width ratio of 1.0 (SMACNA Type RE1 or RE-3).
   3. Where 1.0 centerline radius elbows do not fit, use radius elbows with centerline radius to width ratio of 0.75 (SMACNA Type RE-1 or RE-3) or 45° throat with radius heel elbows (SMACNA Type RE 8).
   4. Use single splitter vanes for 1.0 radius elbows, 0.75 radius elbows and 45° throat with radius heel elbows for elbows witdth 18" and over.
   5. Fabricate splitter vanes in accordance with SMACNA HVAC Duct Construction Standards, Chart 4-1, (page. 4.11) and Figure 4-9 (page. 4.13).
   6. Square throat elbows with or without turning vanes are not allowed unless specifically indicated. Square throat elbows without turning vanes may be used for transfer air ducts.

B. Round and Oval Duct:
   1. Unless specific type is indicated, use radius elbows with centerline radius to diameter ratio of 1.5 regardless of duct velocity. Where 1.5 radius elbows do not fit due to limited space, use 1.0 radius elbows.

3.03 LONGITUDINAL SEAM

A. Rectangular Duct:
   1. Unless otherwise indicated, use Pittsburgh lock seam.
   2. Seal longitudinal seams with approved sealant or pre-sealed with encapsulated mastic.
   3. Button punch snap lock construction is not allowed for ductwork in chases and areas above inaccessible ceiling.
   4. Button punch snap lock construction is not allowed on aluminum ductwork.
   5. Button punch snap lock construction (SMACNA L-2) may be used for ductwork that is both 2" WG (+ or -) and lower, and 36" and smaller in width or height. For ductwork over 24" in width or height, add screw 4" from each end.

B. Round and Oval Duct:

1. Unless otherwise indicated, longitudinal seams shall be in accordance with SMACNA HVAC Duct Construction Standards with the following exceptions.
    a. SMACNA Snaplock Seam Types 6A, 6B, 7 and 8 shown in Figure 3-2 are not allowed.

3.04 TRANSVERSE JOINT

A. Rectangular Duct:
1. Transverse joints shall be in accordance with SMACNA HVAC Duct Construction Standards.
2. Ductmate 25/35/45 connection systems with corner clips or optional nuts and bolts may be used. Incorporate use of all Ductmate accessories to ensure integrity of transverse connection. Install joints in strict accordance with the latest edition of Ductmate 25/35/45 Assembly and Installation Instruction Manual and Duct Construction Standards. Nexus or WDCI will be acceptable.
3. Lockformers TDC or Engles TDF may be used in accordance with T-25 flanges of SMACNA HVAC Duct Construction Standards Metal and Flexible, 2005, provided that corner pieces with bolts are used. If TDF/TDC flanges are damaged, replace the damaged joint(s) by straightening and reinforcing with minimum 1-1/2" x 1-1/2" x 1/4" angle at each side of transverse joint.

B. Round Duct:
1. Unless otherwise indicated, use beaded sleeve joints (SMACNA RT-1) with minimum 2" insertion length or flange joints (SMACNA RT-2 or RT-2A).
2. Connection systems manufactured by Ductmate Industries (Spiralmate and Ovalmate) or McGill AirFlow (Uni-flange) may be used for supply air ductwork.
3. AccuFlange connected systems may be used with gaskets specified in Part 2 of this Section.

3.05 DUCT SUPPORTS

A. Unless otherwise indicated, use straps or Z bar hangers with 3/8" rods to support rectangular ducts 60" wide and smaller and trapeze hangers with rods or angles to support rectangular ducts over 60" wide.
1. Use trapeze hangers to support externally insulated ductwork with weight bearing inserts. Refer to Section 23 0700 - Mechanical Systems Insulation and details.

B. For round ducts 24" diameter or smaller, use single hanger.
1. Cable Suspension System may be used up to 24" diameter at spaces higher than 8 ft above floor or platform.
2. Round Duct Strap Bracket by Ductmate Industries may be used up to 24" diameter.

C. Refer to Section 23 0700 - Mechanical Systems Insulation for ductwork insulation, weight bearing inserts and insulation protection shield requirements.

D. The following upper attachments, upper attachment devices, lower hanger attachments, hanger devices, and/or hanger attachments are not allowed except where specifically indicated:
1. Hook or loop
2. Nailed pin fasteners
3. Expansion nails without washers
4. Powder actuated fasteners (forced entry anchors).
    a. Exception: Forced entry anchors may be used for upper attachments of flexible ductwork supports.
5. Beam or "C" clamps without retaining clips or friction clamps (provide retaining clips for "C" clamps)
6. Non-factory manufactured upper attachments for metal pan deck including rods, straps, or weded studs directly attached to metal deck (Items 16 through 21 shown in Fig 5-4 of SMACNA HVAC Duct Construction Standards)
7. Wire hanger shown in Fig. 5-5 of SMACNA HVAC Duct Construction Standards
8. Trapeze hangers supported by wires or straps
9. Drilled hole with attachment to structural steel
10. Lag screw expansion anchor
11. Rivets
12. Non-metallic hangers or straps

SECTION 23 8214
HEATING AND COOLING TERMINAL DEVICES

PART 1 - GENERAL

1.01 RELATED WORK

A. Section 23 0513 - Motors for Mechanical Equipment

1.02 SUBMITTALS

A. Shop Drawings for all items in this Section including the following:
   1. Manufacturer's name and model number
   2. Identification as referenced in the documents
   3. Capacities/ratings
   4. Materials of construction
   5. Dimensions and weights
   6. Color selection chart where applicable
   7. Wiring diagrams
   8. Motor data (refer to Section 23 0513 - Motors for Mechanical Equipment)
   9. For chilled beams, submit performance data from independent testing agency. Performance data to include cooling capacity at supply water temperatures scheduled, air pressure drop, sound data, and water pressure drop for each beam length.
   10. All other appropriate data

1.03 REFERENCE STANDARDS AND DESIGN CRITERIA

A. Duct Reheat Coils: Ratings shall be certified in accordance with AHRI 410 Standard for Forced-Circulation Air-Coling and Air-Heating Coils for reheat coils, unit heaters, cabinet unit heaters and air curtain door heaters.

B. Units including electrical work shall be UL Listed.

1.04 ELECTRICALLY COMMUTATED (EC) MOTORS

A. Where EC motors are indicated in Part 2 of this Section, such motors shall comply with Section 23 0513 - Motors for Mechanical Equipment.

PART 2 - PRODUCTS

2.01 FAN COIL UNITS

A. Manufacturers: Enviro-Tec, York, JCI, Carrier, Trane, Daikin, Rittling, International Environmental Corporation (IEC), Greenheck, or Modine

B. Unit data shall be certified in accordance with AHRI 430 (I-P) or AHRI 440 (I-P).

C. Coils shall be constructed of 3/8”, 1/2" or 5/8" OD seamless copper tubes with aluminum fins suitable for maximum working pressure to 300 psig and temperatures to 200ºF. Coil stub outs shall be 5/8" OD copper tubing. Furnish coils with manual air vents. Coil performance data shall be in accordance with AHRI 410.

D. Units shall be furnished with centrifugal fans, separate hot and chilled water coils as scheduled, speed selection switches, condensate drain pans, and galvanized steel casings.

E. Drain Pans
   1. Primary condensate drain pans shall be single wall; heavy gauge galvanized steel for corrosion resistance and extend under the entire cooling coil. Drain pans shall be of one-piece construction and be positively sloped for condensate removal.
   2. Drain pans shall be field reversible for right-hand or left-hand connections.
   3. Drain pan shall be externally insulated with fire retardant, closed cell foam insulation. Insulation shall carry no more than 25/50 Flame Spread and Smoke Developed Rating per ASTM E84 and UL 723 and Antimicrobial Performance Rating of 0, no observed growth, per ASTM G21.
   4. Furnish drain pan with secondary drain connection located at higher level than primary drain connection for condensate overflow.

5. Furnish drain pan with condensate overflow switch conforming to UL 508 for condensate overflow unit fan shut off. Locate switch just below secondary drain connection. Pipe secondary drain to primary drain line before p-trap.

F. Units shall be furnished with 18 ga steel cabinet enclosing unit components including coils, and access to all internal mechanical and electrical devices. Cabinets of exposed units shall have baked enamel finish in one of manufacturer's standard colors, selected by Architect. Cabinets of concealed units may be prime coated or galvanized steel. Ducted units shall be furnished with supply and return duct collars.

G. Fan wheels shall be aluminum or galvanized steel construction, centrifugal forward-curved and double-width type, statically and dynamically balanced.

H. Units shall be acoustically and thermally insulated with minimum 1/2” glass fiber insulation. Drain pans shall be constructed of galvanized steel insulated with minimum 1/4" fire retardant closed cell foam. Drain pan shall be constructed in compliance with ASHRAE 62.1-2010 and insulation shall meet requirements of NFPA 90A.

I. Each unit shall include readily accessible filter rack. Furnish 2 sets of 2“ thick minimum efficiency MERV-8, based on ASHRAE Test Standard 52.2, throwaway glass fiber filter for each unit.

J. Motors:
1. Furnish units with direct-drive electrically commutated (EC) motor with manual speed control. Refer to Section 23 0513 - Motors for Mechanical Equipment.
2. Furnish units with direct drive electrically commutated (EC) motor. Motor shall be capable of accepting 2-10VDC output from BAS. Refer to Section 23 0513 - Motors for Mechanical Equipment.

K. Electrical:
1. Provide factory mounted fused disconnect switch.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install units as indicated on drawings, and according to manufacturer's installation instructions.

B. Install branch piping to each unit with minimum of 3 elbows to allow for expansion and contraction.

C. Protect units during construction against entry of foreign matter and construction dirt.

D. Unless otherwise shown on drawings, mount vertical type wall mounted heating units 12” above finished floor.

3.02 FAN COIL UNITS

A. Mount units above concealed ceilings or as shown on drawings with ample clearances for coil pull and filter service.

B. Provide vibration isolation hangers for support of each unit.

C. Duct connections to fan coil units shall use flexible duct connections.

END OF SECTION

c. Typewritten valve schedule indicating valve number, fixture/equipment or areas served by each numbered valve. Incorporate into O&M manual.
d. For additional O&M manual requirements, refer to Section 230000.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials and Equipment:
1. Materials and equipment in system shall be new and current products of manufacturer regularly engaged in production of such materials and equipment.
2. Where 2 or more pieces of equipment are required to perform interrelated functions, they shall be products of same manufacturer.
3. Clean and cap pipe after fabrication and prior to placing pipe in building.
4. Pipe shall be marked with removable tags. No permanent markings are to remain on unpainted pipe located in exposed areas

B. Approval Guides:
1. Unless otherwise shown, products shall be UL Listed in the latest publication of the UL Fire Protection Equipment Directory for service intended.

2.02 SPRINKLERS

A. Manufacturers:
1. Unless otherwise noted below, sprinklers shall be manufactured by Tyco Fire Products, Viking, Victaulic, Reliable, or equal.

B. Temperature class of sprinklers and cover plates shall vary if installed close to heat sources, under skylights, areas of higher ambient temperatures, or in special hazard areas. Refer to NFPA 13 for requirements.

C. Provide high pressure sprinklers where pressures exceed 175 psi working water pressure.

D. Light hazard and Ordinary Hazard occupancies shall utilize quick-response type sprinklers.

E. Architect will review deviations from specified styles for approval prior to installation.

F. Unless otherwise noted, provide the following type(s) of sprinklers:
1. In unfinished areas such as mechanical spaces:
a. Standard coverage, brass upright or pendent; Tyco Fire Products Model TY-FRB, Viking Microfast, or equal.
b. Extended coverage, brass upright or pendent; Tyco Fire Products Model EC-11 or EC-14, Viking ECOH-ELO, or equal, designed and installed per its listing.
2. In unfinished areas where conditions do not permit installation of upright or pendent sprinkler:
a. Standard coverage, brass sidewall; Tyco Fire Products Model TY-FRB, Viking Microfast horizontal (HSW) or vertical (VSW) sidewall or equal.
3. In areas with finished ceilings:
a. Standard coverage, concealed pendent; Tyco Fire Products Model RFII, Viking Mirage, or equal sprinkler with flat cover plate, mounted flush with ceiling. Cover plate shall be factory-finished (i.e. by manufacturer). Finish to be bright white**.**
b. Standard coverage, semi-recessed; Tyco Fire Products TY-FRB, Viking Microfast, or equal. Sprinkler and escutcheon shall be factory-finished (i.e. by manufacturer). Finish to be bright white.

G. Submit samples for examination and approval when appearance is different than sprinkler specified.

H. Spare Sprinkler Cabinets:
1. Shall be complete with required number of spare sprinklers of each type and temperature rating per NFPA 13.
2. Shall be provided with at least one sprinkler wrench for each type of sprinkler installed.
3. Provide multiple cabinets to meet this requirement.
4. Coordinate cabinet locations with Owner's representative.

2.03 FIRE PROTECTION PIPE JOINTS AND FITTINGS

A. Above Ground:
1. Steel Pipe: Steel fire protection pipe shall be selected according to nominal pipe diameter. Schedule 30, Schedule 7, or similar thin-walled steel pipes are prohibited.
   a. Carbon (Black) Steel Pipe, 2" and smaller:
      1) Schedule 40, ASTM A795/A795M or ASTM A53/A53M
   b. Carbon (Black) Steel Pipe, larger than 2':
      1) Schedule 10, ASTM A135/A135M
      2) Schedule 40, ASTM A795/A795M or ASTM A53/A53M
2. Steel Pipe Joints:
   a. Black Steel Pipe Joints:
      1) Threaded, tapered pipe threads, ANSI B1.20.1
      2) Flanged, cast iron,175 psi CWP rating, ANSI B16.1, square head machine bolts with semi-finished hexagon nuts, ASTM A183, neoprene gasket
      3) Welded, welding electrodes shall be Lincoln or equal with coating and diameter as recommended by manufacturer for type and thickness of work being done.
      4) Cut or roll grooved, with mechanical coupling.
      5) Factory-welded pipe outlets, threaded or grooved
3. Steel Pipe Fittings:
   a. Black Steel Fittings:
      1) Cast iron threaded fittings, Class 125,175 psi CWP rating, ASME B16.4
      2) Ductile iron threaded fittings, Class 150, 175 psi CWP rating, ASME B16.3
      3) Malleable iron threaded fittings, Class 150 or 300, ASTM A197/A197M /ANSI B16.3.
      4) Cast iron flanged fittings, Class 125, 175 psi CWP rating, ANSI B16.1
      5) Carbon steel butt weld fittings, ASTM A234/A234M Grade WPB/American Society of Mechanical Engineers ASME B16.9, standard weight, seamless
      6) Mechanical grooved fittings, ASTM A536 ductile iron, ASTM A47/A47M malleable iron or ASTM A53/A53M fabricated steel, 175 psi CWP rating, malleable iron conforming to ASTM A47/A47M.
         (a) Acceptable manufacturers: Victaulic, SPF/Anvil, Tyco Grinnell, Viking, or equal.
         (b) Flexible Couplings: Victaulic Style 75, or equal.
         (c) Rigid Couplings: Victaulic Style 009N, Victaulic Style 07, Victaulic Style 005H, or equal. Single-bolt or hinged couplings are prohibited.
         (d) Wet systems gasket: Grade E EPDM gasket per Ul 157 and UL 213
         (e) Rigid or zero flex type couplings shall be provided when operating pressures cause piping to move out of place or sway on hangers. Flexible couplings may be used where pipe is braced or clamped into rigid position.
         (f) Fitting, gasket, and coupling shall be furnished by same manufacturer.
         (g) Pre-fabricated, one-piece assemblies that contain the fitting housing, gaskets, and bolts are prohibited.
4. Threaded bushings are prohibited.
5. Plain end couplings such as Roust-A-Bouts, Plainloks or similar fittings are prohibited.
6. Slip-style fittings such as Wardlox or similar fittings are prohibited.
7. Adjustable drop nipples are prohibited.
8. Outlet fittings inserted into holes drilled into piping such as Victaulic Style 923 are prohibited.
9. Outlet couplings such as Victaulic Style 72 are prohibited.
10. Grooved reducing couplings such as Victaulic Style 750 are prohibited.
11. Dielectric Fittings:
   a. Acceptable manufacturers: Epco Sales, Lochinvar, Watts Regulator Co., Wilkins, or equal
   b. Insulating nipple, metal casing, inert thermoplastic lining, Clearflow dielectric fitting by Perfection Corporation or equal.
      1) Dielectric unions 2" and smaller; dielectric flanges 2" and larger; with iron female pipe thread to copper solder joint or brass female pipe thread end connections, non-asbestos

gaskets, and pressure rating of not less than 175 psi at 180°F. Provide high pressure type when pressures exceed 175 psi water working pressure.

2.04 HANGERS

A. Acceptable manufacturers: Afcon, Anvil, Eaton, Pentair, Tolco, or equal

B. Concrete expansion hangers, when provided, are to be Hilti, Illinois Tool Works (ITW), Powers Fasteners, or equal

C. Screw anchors for concrete, when provided, are to be Hilti, Illinois Tool Works (ITW), Powers Fasteners, or equal.

D. Screw anchors for steel structure, when provided, are to be Illinois Tool Works (ITW), Powers Fasteners, or equal.

E. Screw anchors for wood structure, when provided, are to be Illinois Tool Works (ITW), Powers Fasteners, or equal.

F. Hanger rods shall comply with Manufacturer Standardization Society (MSS) standards and manufacturer's published load rating.

G. Provide hanger rod, hanger rod attachments, pipe stands, bolts, U-bolts, nuts, studs and washers with electroplated zinc coating or with hot-dipped galvanized finish.

H. Riser clamps shall be electroplated zinc coated or have a hot-dipped galvanized finish and shall not protrude more than 2" beyond edge of hole, Anvil Fig. 261 or equal.

PART 3 - EXECUTION

3.01 GENERAL

A. Fire Protection System Layout and Installation Drawings:
   1. Contractor shall review Design Drawings and Specifications, and shall provide installation drawings, calculations, and product datasheets.
   2. Conceal sprinkler piping above ceilings where possible.
   3. Contractor shall consult with Architect during development of piping layout to avoid conflicts with general appearance. Pipe routing is a critical issue due to attributes of this building.
   4. Contractor shall be responsible to have examined "Reflected Ceiling" drawings as well as Mechanical, Electrical, Piping, Information Technology, Structural and Architectural building plans prior to system layout.
   5. Contractor shall coordinate routing of piping with other trades and Architect.
   6. Contractor shall participate in coordination process and shall not install piping prior to coordination with other trades.
   7. Provide identification sign (enamel on metal) for valves per NFPA requirements. .

3.02 DESIGN CRITERIA

A. Flow Test: Refer to drawings for flow test results.

B. Sprinkler Contractor, prior to preparation of installation drawings and hydraulic design calculations, shall ensure that a hydrant flow test is conducted within the last 12 months.

C. Send current hydrant flow test data to Engineer.

D. Hydraulically calculated system shall be designed to a minimum of 10 psi (70 kPa) below available water flow curve.

E. Systems that are hydraulically calculated must include 1.2 factor for design area.

F. Basis of Design: Refer to drawings.

G. Hose Streams:
   1. Add 100 gpm hose stream to sprinkler zone hydraulic calculations for Light Hazard Occupancies.
   2. Add 250 gpm hose stream to sprinkler zone hydraulic calculations for Ordinary Hazard Occupancies.

3.03 INSPECTION

A. Investigate site conditions; verify utility locations and elevations before start of excavation. Forward discrepancies to Architect/Engineer before proceeding with construction.

3.04 INSTALLATION

A. Install hydraulically designed sprinkler system and associated accessories according to requirements of NFPA 13 and as shown on drawings.

B. Keep materials within listed temperature range to assure jointing in accordance with manufacturer's requirements.

C. Pipe and fittings shall be of corresponding materials when assembled.

D. Above Ground Pipe:
   1. Provide pipe identification system with flow directional arrows on fire protection pipe in accordance with manufacturer’s installation instructions. For additional information, refer to Section 22 0553 - Plumbing Systems Identification.
   2. Make joints of threaded pipe by cutting pipe square and reaming inside.
   3. Exposed pipe threads shall be protected by one of the following methods
      a. Coat bare threads with corrosion inhibitive paint, equal to Rust-Oleum. Apply paint per manufacturer’s instructions.
      b. Cover bare threads with thread tape or joint compound. Use of thread tape and joint compound shall not be excessive.
   4. Joints for mechanically coupled pipe shall be made according to manufacturer's instructions. Use manufacturer’s gasket lubricant sparingly.
   5. Welded joints shall be made in fabrication shop. Welding at project site is prohibited.
   6. Changes in pipe sizes shall utilize one of the following installation methods:
      a. Concentric threaded reducers. Threaded bushings are prohibited.
      b. Concentric grooved reducers. Reducing couplings such as Victaulic Style 750 are prohibited.
      c. Threaded reducing elbows and tees
      d. Grooved reducing elbows and tees such as Victaulic No. 25 and No. 29T
      e. Groove x Thread End-Of-Run fitting such as Victaulic No. 67
      f. Shop-fabricated threaded or grooved weld-o-lets
   7. Provide readily removable fittings at end of cross-mains. Minimum size of flushing connection shall be 2".

E. Sprinkler heads
   1. Install sprinklers as recommended by manufacturer. Sprinklers shall be set level and at locations to avoid interference with spray pattern of sprinkler. When ducts and lights are obstructions to sprinkler distribution, provide additional sprinklers beneath obstruction.
   2. Feed sprinklers, installed in finished ceilings, with flexible sprinkler drop, swing joint, or return bend arrangement for final positioning in ceiling grid pattern during construction phases.
   3. All arm-over and flexible sprinkler fittings shall be taken from the sides or top of the branch line. No arm-overs or flexible sprinkler fittings shall be connected to the bottom of the branch line.
   4. Sprinklers are required to be installed in the center of ceiling tiles
   5. Provide minimum 1" outlets with sprigs for sprinklers located in shelled spaces.

F. Drain line detailed adjacent to standpipe/sprinkler risers shall be considered as part of Sprinkler System from combination test/auxiliary drain valve for each zone or sub-zone shown on plans to plumbing receptacle.

G. Provide auxiliary drains at low points of systems per requirements of NFPA 13.

H. Clamp-on or saddle type fittings (i.e. mechanical tees) are not allowed. Outlet fittings inserted into holes drilled into piping or pipe-o-lets are not allowed.

I. Provide reducing fittings or provide shop fabricated weld-o-lets to change pipe sizes in sprinkler/standpipe systems. No bushings or grooved reducing couplings, such as Victaulic Style 750, are allowed.

J. System Drains, Inspector’s Test Connections, and Auxiliary Drains

1. Provide system drain lines sized in accordance with NFPA 13.
2. System drains shall discharge to one of the following locations:
   a. Provide auxiliary drains at low points of systems in accordance with NFPA 13.

K. Hangers, Bracing, and Restraint of System Piping:
1. Provide hangers and associated parts to support piping in perfect alignment without sagging or interference, to permit free expansion and contraction, and meet requirements of NFPA 13 and manufacturer's installation instructions.
2. Select and size building attachments per Manufacturer Standardization Society (MSS) standards and manufacturer's published load rating.
3. Coordinate hanger support installation to group piping of all trades.
4. Hang pipe from building members using either concrete inserts for concrete construction or beam clamps for steel construction. Installation shall comply with manufacturer's installation instructions. Expansion type inserts may be used for branch piping.
5. Hang pipe from steel purlins via side or bottom screw applications. Install steel screws with restraining nuts. Installation shall comply with manufacturer's installation instructions.
6. Restraining clips/clamps are required in locations where vibration may be a concern. Refer to Section 23 0550 - Vibration Isolation, for additional information regarding restraining clips/clamps.
7. Suspend hangers by means of electroplated zinc or hot-dipped galvanized finish hanger rods. Perforated band iron and flat wire straps (strap iron) are not allowed.
8. Mains larger than 4" in diameter when installed parallel to open web joists shall not be supported from a single joist. Mains larger than 4" in diameter when installed parallel to joists, shall be supported by trapeze hanger assembly and shall be positioned equally between two joists. Trapeze hangers shall be positioned to load joists at panel points only
9. Support pipe from top flange of beams.
10. Where joists are used, locations of pipe supports shall be approved by the structural engineer prior to installation.
11. Supporting equipment or piping from metal roof deck is prohibited.

L. Install pressure gauges as required in manufacturer's installation instructions, and as required per NFPA standards.

3.05 CLEANING

A. Clean systems after installation is complete.

B. Clean piping both internally and externally to remove dirt, plaster dust, or other foreign materials. When external surfaces of piping are rusted, clean and restore surface to original condition. Replacement of heavily soiled and deteriorated materials shall be done at the Contractor's expense.

C. Clean equipment as recommended by manufacturers. Thoroughly clean equipment of stains, paint spots, dirt, dust, and any other foreign materials. Remove temporary labels not used for instruction or operation.

3.06 TESTING

A. Refer to testing paragraph of Section 22 0000 - General Plumbing Requirements.

B. Perform all NFPA required acceptance tests.

C. Test sprinkler system as entire system or partial system. System shall be hydrostatically tested at not less than 200 psi or 50 psi above static pressure in excess of 150 psi for 2 h. No leakage allowed. Replace defective joints with new materials. No caulking of defective joints allowed. Re-test system after defective joints are replaced, until satisfactory results are obtained.

D. Hydrostatically test piping between the exterior fire department connection (FDC) and the check valve in the fire department inlet pipe in the same manner as the balance of the system.

E. Pipe shall not be concealed until satisfactorily pressure tested.

F. Conduct drain test. Record static pressure and residual pressure per NFPA 13.

G. Owner's representative or engineer may witness tests. Contractor shall notify Owner and Engineer a minimum of 3 days in advance to allow for participation.

H. Log of tests shall be kept at job site and shall identify:
   1. Who performed test
   2. Time of test
   3. Date of test
   4. Section of system tested
   5. Results of test
   6. Completed Contractor's Material and Test Certification form(s) from NFPA 13

I. Operate flow and pressure switches to test that signals are transmitted to Fire Alarm Control Panel.

J. Conduct forward flow test of backflow preventer in accordance with NFPA 13 and NFPA 24.

3.07 WARRANTY

A. Installing contractor shall warranty system installation for a minimum of 1 year from date of substantial completion.

B. Installing contractor in combination with flexible sprinkler head manufacturer shall provide a warranty of 5 years from date of substantial completion related to leak assurance and water damage.

C. Manufacturer shall warranty all components for 2 years from date of start-up.

END OF SECTION