PROJECT MANUAL
INCLUDING CONSTRUCTION SPECIFICATIONS

for

V-S035, - TERMINAL C ASC LEVEL 2 EMERGENCY EGRESS (D/B)

ORLANDO INTERNATIONAL AIRPORT

Orlando, Florida 32827

CONTRACT DOCUMENTS
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GREATER ORLANDO AVIATION AUTHORITY

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operation and maintenance manuals.

C. Submit details of insulated removable covers using the actual equipment dimensions, concrete base sizes and piping arrangements.

1.5 GENERAL REQUIREMENTS

A. Factory-applied insulation is specified under the applicable equipment Section of these specifications. It is listed here for reference only.

B. Packages and standard containers of materials shall be delivered unopened to job site and shall have the manufacturer's label attached giving a complete description of the material.

1.6 DEFINITIONS

A. The term "exposed" means exposed to view in finished spaces, in equipment rooms, in fan rooms, in closets, in utility corridors, in tunnels, on roof, in storage rooms, and in other spaces as indicated.

B. The term "concealed" means concealed from view, and includes all spaces not defined as exposed.

C. The term "unconditioned" space shall mean all places where the temperature surrounding the pipe has not been conditioned consistent with conditioned spaces, and shall include mechanical equipment rooms, non-active ceiling plenums, and non-accessible chases. This term shall also include conditioned spaces where the humidity levels are allowed to rise above 70% RH.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Foamglass Insulation:

~~1.~~3. Pittsburgh Corning
~~2.~~4. Cell-U-Foam Corp.
~~3.~~5. Owner Approved Substitution

B. Insulation Coatings, Mastics, Adhesives, and Sealants

1. Foster
2. Pittsburgh Corning
3. Armacell

2.2 MATERIALS

A. Pipe Insulation (60F and below):

1. Foamglas: Rigid, preformed sections of 100% rigid cellular glass complying with ASTM C552 standards, non-absorptive of moisture after immersion, water vapor permeability 0.00 perm/in. impervious to common acids (except hydrofluoric), non-combustible, 90 PSI compressive strength when capped with hot asphalt, 7.5 #/cu.ft. density, thermal conductivity

0.28 BTU-In./Hr./Sq.Ft./F @ 50°F.

B. Equipment Insulation:

1. Foamglas: Sections of 100% rigid cellular glass, non-absorptive of moisture after immersion, water vapor permeability 0.00 perm/in., impervious to common acids (except hydrofluoric), non-combustible, 100 PSI compressive strength when capped with hot asphalt, 8.5 #/cu.ft. density, thermal conductivity 0.32 BTU-In/Hr./Sq.Ft./F @ 50°F.

C. Insulation Accessories:

1. Aluminum Pipe Jacket and Fitting Covers: Jacket shall be 0.016" thick (26 gauge) embossed aluminum, sized to provide a 2" (min.) lap joint both longitudinally and circumferentially, with 3/4" min. wide x 0.015" min. (30 gauge) thick draw bands. Fitting covers shall be aluminum, 0.025" (22 gauge), min., thickness.

D. Cold Pipe Hanger Support Blocks: Lightweight, rigid, closed cell material having 100 lb/sq.in. compressive strength when capped with hot asphalt according to ASTM C240.

E. Accessories:

1. PVC pipe jacket and fitting covers used with insulation for pipe, elbows, tees, couplings, 25/50 flame/smoke ratings, suitable for temperatures to 500°F.
2. Corner angles shall be minimum 28 gauge, 1 inch by 1 inch aluminum adhered to 2 inch by 2 inch heavy kraft paper.
3. Staples shall be outward clinching type, Type 304 or 316 stainless steel in accord with ASTM A 167 or Monel® coated or Owner Approved Substitution.
4. Wire shall be soft annealed galvanized, or copper, 16 gauge, or nickel copper alloy.
5. Vapor Barrier Coating: Air drying flexible water based coating used for applying a vapor barrier coating with reinforcing mesh at all below ambient piping/equipment insulated elbows, fittings, and valves. All vapor retarder film (ASJ) seams on below ambient piping/equipment shall also be vapor sealed with vapor barrier coating. Suitable for temperatures to -20F and 180°F, dried film not to exceed 25 for flame spread and 50 for smoke development when tested per ASTM E 84-84A method. Maximum Perm rating of 0.08 as tested by ASTM E96, Procedure A at 45 mils dry. Childers CP-34 Vapor Retardant coating, Foster 30-65 Vapor Fas® Coating, or Owner Approved Substitution
6. Acrylic Finish and Vapor Barrier Coatings:
   a. Foamglass Insulation: Air drying flexible water based coating used for applying a vapor barrier seal over microscopic cracks that develop in the insulation. Suitable for temperatures to 180°F, wet and dried film not to exceed 25 for flame spread and 50 for smoke development when tested per ASTM E 84-84A method. Maximum Perm rating of 0.08 as tested by ASTM E96, Procedure A at 45 mils dry. Childers CP-34 Vapor Retardant coating, Foster 30-65 Vapor Fas® Coating,

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all insulation in strict accordance with the manufacturers written installation instructions.

B. All insulation work shall be performed by skilled mechanics regularly engaged in the insulation trade.

C. Properly coordinate the insulation work with the other trades so that installation is performed with a minimum of conflict.

D. Insulation shall not be applied on any piping or duct system requiring testing until testing is completed and approved by Owner's Representative.

E. Insulation shall not be applied until all systems are clean, dry, free of dirt, dust or grease.

F. The finished installation shall present a neat and acceptable appearance which includes but is not limited to: all jackets smooth, all vapor barriers sealed properly, no evidence of "ballooning" of the jackets, or sagging insulation, all valves, dampers, gauges, unions, etc. accessible. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness. The Owner's Representative shall be the final judge of acceptance of workmanship.

~~F.~~

G. All equipment nameplates on hot equipment shall be left uncovered. All equipment nameplates on cold equipment shall have a removable section sized to expose the nameplate. This section shall be clearly marked "NAMEPLATE".

H. If proper maintenance procedures require access to the insulated equipment removable panels, sections or covers shall be provided to accomplish this. These access devices shall be constructed in a manner to assure easy access and sturdy construction. The contractor shall assume the responsibility to coordinate all equipment requiring insulation to be either factory or field insulated.

I. Insulation and accessories shall be applied only at suitable application temperature and conditions as recommended by the manufacturer. Do not apply insulation to any surface while it is wet.

J. The insulation subcontractor is responsible for proper material storage at the work site. Insulation shall be protected from moisture and weather during storage and installation. Where installed interior to the building, the spaces shall be conditioned to 60% RH or lower during installation, and maintained throughout project construction.

K. Insulation which has sustained moisture damage, torn jackets, or other damage due to improper storage or other reasons shall not be used. If evidence of this is sighted the Owner's representative reserves the right to require the insulating contractor to remove any and/or all insulation until the Owner's Representative is satisfied that there is no longer any inferior insulation installed on this project.

L. Insulation, fabric and jacketing shall be protected from damage during construction. Damage by the insulator shall be repaired without cost to the Owner. Damage by others shall be reported in writing to the contractor.

~~M. The insulation subcontractor is responsible for proper material storage at the work site.~~

~~N.~~M. Work performed prior to receipt of approved documents or submittals, which later proves to be incorrect or inappropriate, shall be promptly replaced by the contractor without cost to the purchaser.

~~O.~~N. Insulation shall not be installed until adequate access and clearances at control mechanisms, dampers, sleeves, columns and walls have been provided.

~~P.~~O. All insulation at handholes, access doors or other openings, and adjacent to flanges and valves shall be neatly finished where exposed to view.

~~Q.~~P. Where an insulated pipe or ductwork passes through a sleeve or opening in a non-rated partition, the full specified thickness of the insulation shall pass through the sleeve or opening. Where an insulated pipe or ductwork passes through a rated partition, the insulation shall be stopped at the partition. The void between the pipe and the sleeve shall be sealed with an approved fire-stopping material, and the insulation trimmed and sealed to the partition sufficient to cover the sleeve.

~~R.~~Q. All materials, accessories and methods of installation and fabrication are subject to the Owner's Representatives inspection and approval during any phase of the work.

~~S.~~R. The insulation subcontractor shall prevent the accumulation of insulation debris in the buildings and on the premises of the Owner.

~~T.~~S. The insulation subcontractor shall be responsible for his own safety program at the work site, and shall provide instruction on safe practices for his workers assigned to the project. All employees are subject to the work rules at the job site.

~~U.~~T. The insulation subcontractor shall familiarize himself with the progress and execution of the job and notify the proper parties of interferences and any problems with the proper installation of his materials.

3.2 INSTALLATION

A. Pipe Insulation:

1. General:

a. All locations where the insulated surface is supported by hangers, the insulation shall be protected by shields or saddles properly skimmed to maintain a smooth outer surface, and proper insulation thickness. Glycol and Chilled water piping, shall have a section of foamglas insulation installed between the pipe and shield to provide continuous insulation. If the possibility exists that the hanger may conduct the temperature of the conveyed medium and thus cause condensation or personal injury due to high temperature, the hanger shall also be insulated. Joints between foamglas and pipe insulation shall be properly sealed with insulation joint sealant on all longitudinal and butt joints.

b. All devices connected to or in line with the piping system shall be insulated greater than or equal to the connecting piping. This includes but is not limited to valves, air separators, expansion tanks, control valves, control devices, gauge connections, thermometer stems, chemical feed equipment, piping flexible connectors, etc. This is particularly important on ice water and refrigerant lines.

c. Insulate exterior surfaces of all anchors and guides for glycol and chilled water.

d. A complete moisture and vapor barrier shall be installed wherever insulation is penetrated by hangers or other projections through insulation and in contact with cold surfaces for which a vapor seal is specified.

e. Cover fittings, flanges, unions, valves, anchors, and accessories with premolded or segmented insulation of the same thickness and material as the adjoining pipe insulation. Apply vapor barrier coating and reinforcing mesh in two coats to a minimum dry thickness of 32 mils on all below ambient piping. Where nesting size insulation is used overlap pipe insulation 2 inches or one pipe diameter. Fill voids with insulating cement and trowel smooth. Elbows shall have not less than 3 segments per elbow. Secure insulation with wire or tape until finish is applied. Blanket inserts in lieu of premolded or segmented insulation is not allowed. Cover fittings with preformed PVC fitting covers.

f. Wrap all pressure gauge taps, thermometer wells and all other penetrations through insulation with closed cell insulation tape so as to prevent condensation.
g. Seal all raw edges of insulation with vapor barrier coating or lagging adhesive.
h. For piping supported by hangers outdoors, apply a rainshield to prevent water entry.

2. Foamglas:

a. Below ambient piping: All joints, both longitudinal and circumferential shall be sealed with an insulation joint sealant.
b. Thickness shown for refrigeration pipe to be obtained by use of two layers of insulation with staggered joints.
c. Above ambient piping finish: Weather barrier breather mastic. Foster 46-50, Childers CP-10 or Pittcote 404.
d. Below ambient piping finish:

i. Before PVC jacket is used, seal all insulated elbows, fittings, and valves with vapor barrier coating and reinforcing mesh.
ii. Exposed Indoors: Provide PVC jacket over all insulation that shall be sealed with an acrylic latex finish.
iii. Concealed: Provide PVC jacket over fittings fabricated from insulation sections or sheet. Provide ASJ over all other. Vapor seal ASJ with vapor barrier coating.
iv. Exposed Outdoors: Provide acrylic latex finish and aluminum pipe jacket.

B. Equipment Insulation:

1. Vessel and Large Pipe Insulation:

a. Insulation shall be of the same material as the piping which serves it and it shall be layered to obtain the required thickness. Maximum of 1-1/2" thick per layer.
b. Surfaces shall be insulated with 2 inch thick closed cell elastomeric insulation board or pipe insulation, as applicable.
c. All joints shall be staggered to avoid thermal gaps.
d. Sheet size shall be as large as possible to minimize seams. Do not use "scraps".
e. Securing shall be by welded studs and/or non-corrosive banding wire. Do not weld brackets, clips or other devices to ASME coded pressure vessels or piping. Insulation pins or studs shall be as specified and installed in accordance with NCIA standards.
f. Finish shall be with PVC jacket or galvanized steel mesh wire and a finish coat of insulating cement minimum of 1/4" thick. After cement has cured apply glass lagging cloth and proper coating as directed by manufacturer. All corners shall have metal corner beads and provide acrylic latex finish.

2. Removable Covers:

a. Equipment specified to have removable covers shall have insulation as specified in Paragraph 2.4, fastened to the inside surfaces of a 20 gauge galvanized sheet metal equipment cover.
b. The covers shall be of a sectionalized design, and shall be custom-fitted around each piece of equipment. For ease of removal, joints between sections shall coincide with the splits or joints in the equipment. Joints between sections of the cover shall be held together with quick-connect trunk latches, and shall be gasketed to form a vapor-tite seal cover (for the passage of pipes, etc.) shall be provided with closed cell elastomeric collars to ensure a tight fit.
c. The box shall be fitted around each piece of equipment and split for removal to coincide with the split in the casing. The sections of the box shall be held together with quick disconnect trunk latches. Joints between box sections shall be gasketed to form a

vapor seal. Void spaces in the box shall be packed with flexible fiberglass insulation. Openings around pump casing shall be provided with closed cell elastomeric collar to ensure tight fit.

d. Provide acrylic latex finish.
e. Coordinate the piping of the drain, vent, gauge, and control lines to exit through the base or back section of the removable cover. The insulation of these pipes shall be totally independent of the removable cover.
f. Pipe strainers shall also have removable covers for insulation to facilitate service and maintenance.

3. Glycol and Chilled Water Compression Tank and Filtering Systems: Surfaces shall be insulated with 2 inch thick closed cell elastomeric insulation board or pipe insulation, as applicable. Finish as specified for vessel and large pipe insulation.

C. Cold Pipe Hanger Support Blocks:

1. Provide on all chilled fluid systems pipe hangers and supports.
2. Apply Foster 46-50, Childers CP-10 or Pittcote 404 acrylic latex mastic filler over insulation and on ends.
3. Apply Pittseal 444, Foster 95-44 Elastolar, Foster 95-50 or Childers CP-76 Chil Byl joint and penetration sealant at joint between foamglas and adjacent insulation.
4. Provide vapor barrier system to match the vapor barrier on the adjacent system.
5. Provide 20 gauge (min.) galvanized shield between the insulation and the hanger or support.

D. Aluminum Pipe Jacket:

1. Provide aluminum jacket over all exposed pipe insulation located outdoors.
2. Align all seams.
3. Securing shall be with 3/4" wide draw bands. Maximum band spacing 18" on center.
4. All openings and voids shall be sealed air and water tight with metal jacketing sealant. Foster 95-44 Elastolar or Childers CP-76 Chil Byl or Owner Approved Substitution.

E. PVC Jacket:

1. Provide PVC sheet jacket over all exposed, indoor piping or insulation.
2. Provide PVC pipe jacket over all exposed, indoor foamglas or elastomeric pipe insulation.
3. Provide PVC fitting covers over all fittings fabricated from insulation sections or sheet material.
4. PVC pipe jacket shall be applied with special attention given to achieving positive seal at all longitudinal and circumferential joints using a welding solvent on the longitudinal joint as recommended by the manufacturer. Slip joints to have 4" minimum lap and no welding solvent.

F. Flexible Acrylic Latex:

1. Apply two coats to glass cloth jacket, concealed foamglas and closed cell elastomeric insulation.
2. Refer to Division 09 for color to be used. If no instructions are given, provide a white finish.

3.3 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F:

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

a. Cellular Glass: 1-1/2 inches thick.

B. Chilled Water, 40 Deg F and below~~below 40 Deg F~~:

1. NPS 1 to NPS 16: Insulation shall be one of the following:

a. Cellular Glass: 4~~1-1/2~~ inches thick.

C. Condenser Water, located in the PreConditioned Air Plant, above 40 Deg F:

1. NPS 1 to NPS 14: Insulation shall be one of the following:

a. Cellular Glass: ~~1-1/~~2 inches thick.

3.4 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Concealed:

1. None.

D. Piping, Exposed in finished spaces – PreConditioned Air Plant:

1. Aluminum, Smooth: 0.016 inch thick.

E. Piping, Exposed in unfinished spaces up to six feet above floor – Mechanical Rooms:

1. None.

3.5 OUTDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F:

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

a. Cellular Glass: 1-1/2 inches thick.

B. Chilled Water, 40 Deg F and below:

1. NPS 1 to NPS 12: Insulation shall be one of the following:

a. Cellular Glass: 4 inches thick.

3.6 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Exposed:

1. Aluminum, Smooth: 0.016 inch thick.

3.7 MISCELLANEOUS ITEMS

A. General: Provide insulation of any portion of a system or piece of equipment not previously discussed where ambient operating conditions will allow condensation to occur or whose surface temperature exceeds 115°F. Insulation materials and method shall be as directed by the Designer.

B. Final Inspection: At final inspection, the finished surfaces of all exposed insulation shall be clean and without stains or blemishes. Repair and clean the insulation surfaces and, if necessary, to obtain a new appearance, shall coat discolored surfaces with off-white latex water-base semi-gloss paint or lagging adhesive, without a change in the contract price.

3.8 Pipe Label Color Schedule:

A. Glycol-Water Piping:

1. Background Color: Green.
2. Letter Color: White.
3. Band Color: Gold

~~B.~~

~~3.8 Pipe Label Color Schedule:~~

~~A. Glycol-Water Piping:~~

~~1. Background Color: Green.~~
~~2. Letter Color: White.~~
~~3. Band Color: Gold~~

END OF SECTION 23 07 00.01

SECTION 23 07 19 - HVAC INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to this Section.

1.2 SUMMARY

A. Section includes insulating the following HVAC systems:

1. Condensate drain piping, indoors and outdoors.
2. Chilled-water and brine piping, indoors and outdoors.
3. Condenser-water piping, indoors and outdoors.
4. Duct Systems Insulation.
5. Heated fuel-oil piping, indoors and outdoors.
6. Engine exhaust piping.
7. Equipment Insulation
8. Cold Pipe Hanger Support Blocks
9. Accessories

1.3 SUBMITTALS

A. Action Submittals:
1. Submit schedule indicating type of insulation, thickness, vapor barrier or coating by system and size.
2. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
   b. Detail attachment and covering of heat tracing inside insulation.
   c. Detail insulation application at pipe expansion joints for each type of insulation.
   d. Detail insulation application at mechanical couplings, grove-joint piping, elbows, fittings, flanges, valves, and specialties for each type of insulation.
   e. Detail removable insulation at piping specialties.
   f. Detail application of field-applied jackets.
   g. Detail application at linkages of control devices.

4. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use.
   a. Preformed Pipe Insulation Materials: 12 inches long by NPS 2.
   b. Sheet Form Insulation Materials: 12 inches square.
   c. Jacket Materials for Pipe: 12 inches long by NPS 2.
   d. Sheet Jacket Materials: 12 inches square.
   e. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
   1. Product Data: Documentation for Leadership Extraction Practices
      a.
   2. Product Data: Documentation for Low Emitting Materials
      a. Low Emitting Materials for Paints and Coatings
      b. Low Emitting Materials for Adhesives and Sealants
   3. Product Certificates: Provide the following:
      a. Environmental Product Declarations (EPD’s)

C. Informational Submittals
   1. Qualification Data: For qualified Installer.
   2. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
   3. Field quality-control reports.
   4. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

1.4 QUALITY ASSURANCE

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

B. All insulation shall be installed in accordance with National Commercial & Industrial Insulation Standards (NCIA).

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

   1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
   2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

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

1. Piping Mockups:
    a. One 10-foot section of NPS 2 straight pipe.
    b. One each of a 90-degree threaded, welded, and flanged elbow.
    c. One each of a threaded, welded, and flanged tee fitting.
    d. One NPS 2 or smaller valve, and one NPS 2-1/2 or larger valve.
    e. Four support hangers including hanger shield and insert.
    f. One threaded strainer and one flanged strainer with removable portion of insulation.
    g. One threaded reducer and one welded reducer.
    h. One pressure temperature tap.
    i. One mechanical coupling.
2. Equipment Mockups:
    a. One chilled-water pump
    b. One tank or vessel
3. Ductwork Mockups:
    a. One 10-foot section each of rectangular and round straight duct
    b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
    c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
    d. One rectangular and round transition fitting.
    e. Four support hangers for round and rectangular ductwork.
    f. Each type of damper and specialty
4. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
5. Notify Architect seven days in advance of dates and times when mockups will be constructed.
6. Obtain Architect's approval of mockups before starting insulation application.
7. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
8. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
9. Demolish and remove mockups when directed.

1.5 DELIVERY, STORAGE, AND HANDLING

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

B. Packages and standard containers of materials shall be delivered unopened to job site and shall have the manufacturer's label attached giving a complete description of the material.

C. Refer to Section 23 00 10, Subsection 3.7 for handling, protection and storage of insulation materials.

1.6 COORDINATION

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

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

C. Coordinate installation and testing of heat tracing.

1.7 DEFINITIONS

A. The term "exposed" means exposed to view in finished spaces, in equipment rooms, in fan rooms, in closets, in utility corridors, in tunnels, on roof, in storage rooms, and in other spaces as indicated.

B. The term "concealed" means concealed from view, and includes all spaces not defined as exposed.

C. The term "unconditioned" space shall mean all places where the temperature surrounding the pipe has not been conditioned consistent with conditioned spaces, and shall include mechanical equipment rooms, non-active ceiling plenums, and non-accessible chases. This term shall also include conditioned spaces where the humidity levels are allowed to rise above 70% RH.

1.8 SCHEDULING

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

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

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

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

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

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

D. Insulation shall comply with ASHRAE/IESNA 90.1, all applicable codes and requirements of the Authority having jurisdiction.

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

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

G. Calcium Silicate:

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

    a. Industrial Insulation Group (IIG); Thermo-12 Gold.
    b. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 300°F mean temperature is 0.40 Btu x in./hr. x ft. x degree F. or less.
3. Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
4. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
5. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.

H. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

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

   a. Pittsburgh Corning Corporation; Foamglas.
   b. Cell-U-Foam Corp.
   c. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 75°F mean temperature is 0.27 Btu x in./hr. x ft. x degree F. or less.

3. Block Insulation: ASTM C 552, Type I.
4. Special-Shaped Insulation: ASTM C 552, Type III.
5. Board Insulation: ASTM C 552, Type IV.
6. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.
7. Preformed Pipe Insulation with Factory-Applied ASJ-SSL: Comply with ASTM C 552, Type II, Class 2.
8. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

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

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

   a. Armacell LLC; AP Armaflex.
   b. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.
   c. Johns Manville.
   d. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 75°F mean temperature is 0.245 Btu x in./hr. x ft. x degree F. or less. Water absorption not be more than 0.2% by volume.

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

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

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

2. Thermal Conductivity (k-value) at 75°F (24°C) mean temperature is 0.29 Btu x in./hr. x ft. x degree F. (0.043 W/m x K) or less.

K. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Johns Manville; Micro-Lok.
   b. Knauf Insulation; 1000-Degree Pipe Insulation.
   c. Manson Insulation Inc.; Alley-K.
   d. Owens Corning; Fiberglas Pipe Insulation.

2. Type I, 850 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
3. Type II, 1200 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
4. Thermal Conductivity (k-value) at 75°F mean temperature is 0.23 Btu x in./hr. x ft. x degree F. or less.

L. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied ASJ complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 75 deg F is 0.27 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

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

   a. CertainTeed Corp.; CrimpWrap.
   b. Johns Manville; MicroFlex.
   c. Knauf Insulation; Pipe and Tank Insulation.
   d. Manson Insulation Inc.; AK Flex.
   e. Owens Corning; Fiberglas Pipe and Tank Insulation.

M. Phenolic:

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

   a. Kingspan Tarec Industrial Insulation NV; Koolphen K.
   b. Resolco International BV; Insul-phen.

2. Thermal Conductivity (k-value) at 75°F (24°C) mean temperature is 0.22 Btu x in./hr. x ft. x degree F. (0.031 W/m x K) or less.
3. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.

4. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
5. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
6. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.

    a. Preformed Pipe Insulation: ASJ.

N. Rigid Fiberglass: Resin bonded fibrous glass, flame retardant, factory applied all service jacket (ASJ) vapor barrier, maximum vapor permeance of .02 perm/in and puncture resistance of 50 units, maximum conductivity per 1" thickness of .23 at 75°F mean temperature. Rigid fiberglass board insulation shall conform with ASTM C 612, Type 1A or Type 1B with a density not less than ~~6~~ 3 lbs per cubic foot. The insulation shall be Johns Manville “817 SPIN-GLAS,” or approved equal.

2.2 ADHESIVES

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

B. Low Emitting Adhesives and Sealants
1. Provide Manufacturer statements that confirm the product used meets the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario.

2. Refer to Section 01 81 13.14 “Sustainable Design Requirements – LEED v4 BD+C” for additional requirements.

C. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F.

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

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    c. Mon-Eco Industries, Inc.
    d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

D. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F.

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

   a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. TremcoHenkel
   c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
   d. .

E. Phenolic Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F (minus 59 to plus 149 deg C).

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

   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
   d. .

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

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

   a. Armacell LLC.
   b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
   d. .

G. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.
d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
e. .

2. For indoor applications, adhesive shall comply with the requirements of section 01 81 13.14.

H. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.
d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

I. PVC Jacket Adhesive: Compatible with PVC jacket.

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

a. Dow Corning Corporation.
b. Johns Manville.
c. P.I.C. Plastics, Inc.
d. Speedline Corporation.
e. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2.3 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.

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

a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Henkel.
c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.
6. For indoor applications, adhesive shall comply with the requirements of section 01 81 13.14.

C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below-ambient services.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.
d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.03 metric perm) at 35-mil (0.9-mm) dry film thickness.
3. Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
4. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
5. Color: White.

D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below-ambient services.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company
c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
d. .

2. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.033 metric perm) at 30-mil (0.8-mm) dry film thickness.
3. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
4. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
5. Color: White.

E. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.

2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: 60 percent by volume and 66 percent by weight.
5. Color: White.

2.4 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.

2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3. Service Temperature Range: 0 to plus 180 deg F.
4. Color: White.
5.

2.5 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass and Phenolic Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   c. Mon-Eco Industries, Inc.
   d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
5. Color: White or gray.

B. FSK and Metal Jacket Flashing Sealants:

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

   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   c. Mon-Eco Industries, Inc.
   d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg.
5. Color: Aluminum.

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

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

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.

2.6 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: 4-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.

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

        1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
        2) ITW Insulation Systems.

6. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perm (0.007 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.

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

1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
2) ITW Insulation Systems.

7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

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

1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
2) ITW Insulation Systems.

8. Vinyl Jacket: White vinyl with a permeance of 1.3 perms (0.86 metric perms) when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.7 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Chil-Glas Number 10.
b. Owner Approved Substitution.

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for pipe.

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

a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
b. Vimasco Corporation; Elastafab 894.
c. Owner Approved Substitution.

2.8 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd.

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

a. Alpha Associates, Inc.; Alpha-Maritex 84215 and 84217/9485RW, Luben 59.
b. Owner Approved Substitution.

2.9 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

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

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

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

a. Johns Manville; Zeston.
b. P.I.C. Plastics, Inc.; FG Series.
c. Proto Corporation; LoSmoke.
d. Speedline Corporation; SmokeSafe.
e. Owner Approved Substitution.

2. Adhesive: As recommended by jacket material manufacturer and complying with the requirements of section 01 81 13.14.
3. Color: White.
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Metal Jacket:

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

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
c. RPR Products, Inc.; Insul-Mate.
d. Owner Approved Substitution.

2. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

a. Sheet and roll stock ready for shop or field sizing.
b. Finish and thickness are indicated in field-applied jacket schedules.
c. Moisture Barrier for Indoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.
d. Moisture Barrier for Outdoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.
e. Factory-Fabricated Fitting Covers:

1) Same material, finish, and thickness as jacket.
2) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
3) Tee covers.
4) Flange and union covers.
5) End caps.
6) Beveled collars.
7) Valve covers.
8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

E. Underground Direct-Buried Jacket: 125-mil- (3.2-mm-) thick vapor barrier and waterproofing membrane consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.

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

a. Pittsburgh Corning Corporation; Pittwrap.
b. Polyguard Products, Inc.; Insulrap No Torch 125.

F. Self-Adhesive Outdoor Jacket: 60-mil- (1.5-mm-) thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with stucco-embossed aluminum-foil facing.

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

a. Polyguard Products, Inc.; Alumaguard 60.

G. PVDC Jacket for Indoor Applications: 4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms (0.013 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.

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

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film.
b. ITW Insulation Systems.

H. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms (0.007 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.

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

a. Dow Chemical Company (The); Saran 560 Vapor Retarder Film.
b. ITW Insulation Systems.

I. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

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

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
b. ITW Insulation Systems.

2.10 FIELD-APPLIED DUCT INSULATION FOR TYPE I AND TYPE II KITCHEN EXHAUST

A. Type I and Type II kitchen exhaust duct shall be insulated with an approved fire rated field-applied 2-layer duct wrap system conforming to ASTM E2336 requirements.

B. Duct wrap shall be installed in strict compliance with manufacturer’s requirements, using all components from a single manufacturers.

C. Duct wrap shall be FyreWrap Elite 1.5 Duct Insulation – Grease Duct ASTM E2336 System, or approved equal.

2.11 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

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

    a. ABI, Ideal Tape Division; 428 AWF ASJ.
    b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
    c. Compac Corporation; 104 and 105.
    d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
    e. Owner Approved Substitution.

2. Width: 3 inches.
3. Thickness: 11.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

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

    a. ABI, Ideal Tape Division; 491 AWF FSK.
    b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
    c. Compac Corporation; 110 and 111.
    d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
    e. Owner Approved Substitution.

2. Width: 3 inches.
3. Thickness: 6.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

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

    a. ABI, Ideal Tape Division; 370 White PVC tape.
    b. Compac Corporation; 130.
    c. Venture Tape; 1506 CW NS.
    d. Owner Approved Substitution.

2. Width: 2 inches.
3. Thickness: 6 mils.
4. Adhesion: 64 ounces force/inch in width.

5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

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

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

a. ABI, Ideal Tape Division; 488 AWF.
b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
c. Compac Corporation; 120.
d. Venture Tape; 3520 CW.
e. Owner Approved Substitution.

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

E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

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

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
b. ITW Insulation Systems.

2. Width: 3 inches (75 mm).
3. Film Thickness: 4 mils (0.10 mm).
4. Adhesive Thickness: 1.5 mils (0.04 mm).
5. Elongation at Break: 145 percent.
6. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.

F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

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

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
b. ITW Insulation Systems.

2. Width: 3 inches (75 mm).
3. Film Thickness: 6 mils (0.15 mm).
4. Adhesive Thickness: 1.5 mils (0.04 mm).
5. Elongation at Break: 145 percent.
6. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.

2.12 SECUREMENTS

A. Bands:

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

a. ITW Insulation Systems; Gerrard Strapping and Seals.
b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
c. Owner Approved Substitution.

2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 316; 0.015 inch (0.38 mm) thick, 3/4 inch (19 mm) wide with wing seal.
3. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal or closed seal.
4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.

C. Wire: 0.062-inch (1.6-mm) soft-annealed, stainless steel.

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

a. C & F Wire.

D. Insulation Pins and Hangers:
1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following.
1) AGM Industries, Inc.; CHP-1.
2) GEMCO; Cupped Head Weld Pin.
3) Midwest Fasteners, Inc.; Cupped Head.
4) Nelson Stud Welding; CHP.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
1) AGM Industries, Inc.; RC-150.
2) GEMCO; R-150.

3) Midwest Fasteners, Inc.; WA-150.
4) Nelson Stud Welding; Speed Clips.

b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers.
2) GEMCO; Perforated Base.
3) Midwest Fasteners, Inc.; Spindle.

b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.

c. Spindle: Aluminum, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

d. Adhesive: Recommended by hanger manufacturer and complying with the requirements of section 01 81 13.14. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
1) GEMCO; Nylon Hangers.
2) Midwest Fasteners, Inc.; Nylon Insulation Hangers.

b. Baseplate: Perforated, nylon sheet, 0.030 inch (0.76 mm) thick by 1-1/2 inches (38 mm) in diameter.

c. Spindle: Nylon, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches (63 mm).

d. Adhesive: Recommended by hanger manufacturer and complying with Low Emitting Adhesives and Sealant requirements of section 01 81 13.14. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.

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

1) AGM Industries, Inc.; Tactoo Self-Adhering Insul-Hangers.
2) GEMCO; Peel & Press.

3) Hardcast, Inc.
4) Midwest Fasteners, Inc.; Self Stick.

b. Baseplate: Galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.

c. Spindle: Aluminum, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

d. Adhesive-backed base with a peel-off protective cover.

6. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

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

1) GEMCO.
2) Midwest Fasteners, Inc.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all insulation in strict accordance with the manufacturers written installation instructions.

B. All insulation work shall be performed by skilled mechanics regularly engaged in the insulation trade.

C. Properly coordinate the insulation work with the other trades so that installation is performed with a minimum of conflict.

D. Insulation shall not be applied on any piping or duct system requiring testing until testing is completed and approved by Owner's Representative.

E. Insulation shall not be applied until all systems are clean, dry, free of dirt, dust or grease.

F. The finished installation shall present a neat and acceptable appearance which includes but is not limited to: all jackets smooth, all vapor barriers sealed properly, no evidence of "ballooning" of the jackets, or sagging insulation, all valves, dampers, gauges, unions, etc. accessible. The Owner's Representative shall be the final judge of acceptance of workmanship.

G. All equipment nameplates on hot equipment shall be left uncovered. All equipment nameplates on cold equipment shall have a removable section sized to expose the nameplate. This section shall be clearly marked "NAMEPLATE".

H. If proper maintenance procedures require access to the insulated equipment removable panels, sections or covers shall be provided to accomplish this. These access devices shall be constructed in a manner to assure easy access and sturdy construction. The contractor shall assume the responsibility to coordinate all equipment requiring insulation to be either factory or field insulated.

I. Insulation and accessories shall be applied only at suitable application temperature and conditions as recommended by the manufacturer. Do not apply insulation to any surface while it is wet.

J. Insulation shall be protected from moisture and weather during storage and installation.

K. Insulation which has sustained moisture damage, torn jackets, or other damage due to improper storage or other reasons shall not be used. If evidence of this is sighted the Owner's representative reserves the right to require the insulating contractor to remove any and/or all insulation until the Owner's Representative is satisfied that there is no longer any inferior insulation installed on this project.

L. Insulation, fabric and jacketing shall be protected from damage during construction. Damage by the insulator shall be repaired without cost to the Owner. Damage by others shall be reported in writing to the contractor.

M. The insulation subcontractor is responsible for proper material storage at the work site.

N. Work performed prior to receipt of approved documents or submittals, which later proves to be incorrect or inappropriate, shall be promptly replaced by the contractor without cost to the purchaser.

O. Insulation shall not be installed until adequate access and clearances at control mechanisms, dampers, sleeves, columns and walls have been provided.

P. All insulation at handholes, access doors or other openings, and adjacent to flanges and valves shall be neatly finished where exposed to view.

Q. Where an insulated pipe or ductwork passes through a sleeve or opening in a non-rated partition, the full specified thickness of the insulation shall pass through the sleeve or opening. Where an insulated pipe or ductwork passes through a rated partition, the insulation shall be stopped at the partition. The void between the pipe and the sleeve shall be sealed with an approved fire-stopping material, and the insulation trimmed and sealed to the partition sufficient to cover the sleeve.

R. All materials, accessories and methods of installation and fabrication are subject to the Owner's Representatives inspection and approval during any phase of the work.

S. The insulation subcontractor shall prevent the accumulation of insulation debris in the buildings and on the premises of the Owner.

T. The insulation subcontractor shall be responsible for his own safety program at the work site, and shall provide instruction on safe practices for his workers assigned to the project. All employees are subject to the work rules at the job site.

U. The insulation subcontractor shall familiarize himself with the progress and execution of the job and notify the proper parties of interferences and any problems with the proper installation of his materials.

3.2 INSTALLATION

A. Duct Insulation:

1. General:

   a. Insulate or internally line all flexible duct connectors equal to or greater than adjacent insulation thickness.
   b. The tops of all diffusers shall be insulated same as connecting ductwork to prevent condensation.
   c. Duct insulation at fire dampers shall be extended over supporting angle iron and sealed to wall.

2. Rigid Fiberglass Insulation:

   a. Use boards in largest possible size to minimize seams. Do not use "scraps".
   b. Shall be installed in all non-public exposed areas up to 10’-0” above finished floor.
   c. Provide corner angles where insulation is subject to harm.
   d. All fasteners shall be non corroding.
   e. The insulation shall be applied by use of cup head weld pins. Such fasteners shall be spaced in accordance with NCIA recommendations, where NCIA standards do not address exact dimensions, cup head weld pins shall be spaced on 12" centers. Pin caps shall be covered with a round vapor seal patch that matches the jacket on the ASJ board. On cold ducts, these shall be coated so as to not cause condensation.
   f. Ducts having sharp bends shall have the insulation scored as required to conform to the curved surfaces to provide a neat and acceptable appearance when finished.
   g. Insulation edges and joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh.
   h. Generally, rigid fiberglass material will only be used in finished or exposed areas, and it is intended that the finish present a neat and uniform appearance as to color and workmanship.
   i. In finished areas, molded glass fiber insulation shall be used to insulate round ducts where commercially available sizes can be used.
   j. Fittings on round ducts in finished areas shall be covered with premolded fiberglass fitting insulators equal to Insul-Coustic where sizes are available. For sizes where premolded fittings are not available use miter-cut segments of molded pipe insulation, wired in place, with all joints sealed with adhesive and smoothed out with a coat of insulating cement.

k. On cold ducts, the fittings shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Hot ducts shall be finished in a similar manner, except the mastic need be of the weather barrier breather mastic type. Foster 46-50 Weatherite and Childers CP-10 Vi Cryl or Pittsburgh Corning 404 or Owner Approved Substitution.

3. Blanket Fiberglass Insulation:

a. Insulation shall be wrapped, with the compression no greater than stated in the manufacturer's installation instructions, on the ductwork with all circumferential joints butted and longitudinal joints lapped 2 inches and stapled. Joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Additionally secure insulation to bottom of rectangular ducts over 24 inches wide with weld pins at no more than 18 inches on center.

B. Insulation shall be butted with facing overlapping all joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Breaks, punctures, pin penetrations in facing shall be sealed with vapor barrier tape and vapor barrier coating.

C. Pipe Insulation:

1. General:

a. All locations where the insulated surface is supported by hangers, the insulation shall be protected by shields or saddles properly skimmed to maintain a smooth outer surface, and proper insulation thickness. Chilled water piping, 3" and over shall have a section of foamglas insulation installed between the pipe and shield. 3 and 4" to be 12" long, 5" and 6" to be 18" long and 8" and over, 24" long. If the possibility exists that the hanger may conduct the temperature of the conveyed medium and thus cause condensation or personal injury due to high temperature, the hanger shall also be insulated. Joints between foamglas and pipe insulation shall be properly sealed with insulation joint sealant on all longitudinal and butt joints.
b. All devices connected to or in line with the piping system shall be insulated greater than or equal to the connecting piping. This includes but is not limited to valves, air separators, expansion tanks, control valves, control devices, gauge connections, thermometer stems, chemical feed equipment, piping flexible connectors, etc. This is particularly important on ice water and refrigerant lines.
c. Insulate exterior surfaces of all anchors and guides for chilled water and dual

temperature piping systems.

d. A complete moisture and vapor barrier shall be installed wherever insulation is penetrated by hangers or other projections through insulation and in contact with cold surfaces for which a vapor seal is specified.

e. Cover fittings, flanges, unions, valves, anchors, and accessories with premolded or segmented insulation of the same thickness and material as the adjoining pipe insulation. Apply vapor barrier coating and reinforcing mesh in two coats to a minimum dry thickness of 32 mils on all below ambient piping. Where nesting size insulation is used overlap pipe insulation 2 inches or one pipe diameter. Fill voids with insulating cement and trowel smooth. Elbows shall have not less than 3 segments per elbow. Secure insulation with wire or tape until finish is applied. Blanket inserts in lieu of premolded or segmented insulation is not allowed. Cover fittings with preformed PVC fitting covers.

f. Wrap all pressure gauge taps, thermometer wells and all other penetrations through insulation with closed cell insulation tape so as to prevent condensation.

g. Seal all raw edges of insulation with vapor barrier coating or lagging adhesive.

h. For piping supported by hangers outdoors, apply a rainshield to prevent water entry.

3. Closed Cell Elastomeric:

   a. All joints shall be sealed with adhesives.
   b. Where the thickness is to be obtained by use of two layers of insulation, install with staggered joints.
   c. Finish:

      1) Concealed Indoors: No additional finish.
      2) Exposed Indoors: Provide PVC jacket over all insulation.
      3) Concealed Indoors: Provide PVC jacket over fittings fabricated from insulation sections or sheet.
      4) Outdoors: Provide aluminum pipe jacket.

4. Foamglas:

   a. Below ambient piping: All joints, both longitudinal and circumferential shall be sealed with an insulation joint sealant.
   b. Thickness shown for refrigeration pipe to be obtained by use of two layers of insulation with staggered joints.
   c. Above ambient piping finish: Weather barrier breather mastic. Foster 46-50, Childers CP-10 or Pittcote 404.
   d. Below ambient piping finish:

      1) Before PVC jacket is used, seal all insulated elbows, fittings, and valves with vapor barrier coating and reinforcing mesh.
      2) Exposed Indoors: Provide PVC jacket over all insulation that shall be sealed with an acrylic latex finish.
      3) Concealed: Provide PVC jacket over fittings fabricated from insulation sections or sheet. Provide ASJ over all other. Vapor seal ASJ with vapor barrier coating.

4) Exposed Outdoors: Provide acrylic latex finish and aluminum pipe jacket.

D. Equipment Insulation:

1. Vessel and Large Pipe Insulation:

a. Insulation shall be of the same material as the piping which serves it and it shall be layered to obtain the required thickness. Maximum of 1-1/2" thick per layer.
b. All joints shall be staggered to avoid thermal gaps.
c. Sheet size shall be as large as possible to minimize seams. Do not use "scraps".
d. Securing shall be by welded studs and/or non-corrosive banding wire. Do not weld brackets, clips or other devices to ASME coded pressure vessels or piping. Insulation pins or studs shall be as specified and installed in accordance with NCIA standards.
e. Finish shall be with PVC jacket or galvanized steel mesh wire and a finish coat of insulating cement minimum of 1/4" thick. After cement has cured apply glass lagging cloth and proper coating as directed by manufacturer. All corners shall have metal corner beads and provide acrylic latex finish.

3. Removable Covers:

a. Equipment specified to have removable covers shall have insulation as specified in Paragraph 2.4, fastened to the inside surfaces of a 20 gauge galvanized sheet metal equipment cover.
b. The covers shall be of a sectionalized design, and shall be custom-fitted around each piece of equipment. For ease of removal, joints between sections shall coincide with the splits or joints in the equipment. Joints between sections of the cover shall be held together with quick-connect trunk latches, and shall be gasketed to form a vapor-tite seal cover (for the passage of pipes, etc.) shall be provided with closed cell elastomeric collars to ensure a tight fit.
c. The box shall be fitted around each piece of equipment and split for removal to coincide with the split in the casing. The sections of the box shall be held together with quick disconnect trunk latches. Joints between box sections shall be gasketed to form a vapor seal. Void spaces in the box shall be packed with flexible fiberglass insulation. Openings around pump casing shall be provided with closed cell elastomeric collar to ensure tight fit.
d. Provide acrylic latex finish.
e. Coordinate the piping of the drain, vent, gauge, and control lines to exit through the base or back section of the removable cover. The insulation of these pipes shall be totally independent of the removable cover.
f. Pipe strainers shall also have removable covers for insulation to facilitate service and maintenance.

1.

4. Chilled Water Compression Tank and Filtering Systems: Surfaces shall be insulated

with 1 inch thick closed cell elastomeric insulation board or pipe insulation, as applicable. Finish as specified for vessel and large pipe insulation.

E. Cold Pipe Hanger Support Blocks:

1. Provide on all chilled fluid systems pipe hangers and supports.
2. Apply acrylic latex mastic filler over insulation and on ends.
3. Apply joint and penetration sealant at joint between foamglas and adjacent insulation,
4. Provide vapor barrier system to match the vapor barrier on the adjacent system.
5. Provide 20 gauge (min.) galvanized shield between the insulation and the hanger or support.

F. Weatherproof Duct Jacket:

1. Locate joints and seams to shed water.
2. All joints shall be sealed.
3. Securing shall be by non-corrosive wire banding. Maximum banding spacing 9" on center.
4. Finishing shall be with a minimum of 1/4" coat of insulating weatherproofing.
5. Provide on all ducts exposed to the weather.

G. Aluminum Pipe Jacket:

1. Provide aluminum jacket over all exposed pipe insulation located outdoors.
2. Align all seams.
3. Securing shall be with 3/4" wide draw bands. Maximum band spacing 18" on center.
4. All openings and voids shall be sealed air and water tight with metal jacketing sealant.

H. PVC Jacket:

1. Provide PVC sheet jacket over all exposed, indoor piping or insulation.
2. Provide PVC pipe jacket over all exposed, indoor foamglas or elastomeric pipe insulation.
3. Provide PVC fitting covers over all fittings fabricated from insulation sections or sheet material.
4. PVC pipe jacket shall be applied with special attention given to achieving positive seal at all longitudinal and circumferential joints using a welding solvent on the longitudinal joint as recommended by the manufacturer. Slip joints to have 4" minimum lap and no welding solvent.

I. Self Adhesive Indoor/Outdoor Jacket (Non Asphaltic):

1. Vapor barrier and waterproofing jacketing for installation over insulation located aboveground outdoors or indoors.
2. Specialized jacket with five layers of laminated aluminum and polyester film with low temperature, acrylic, pressure sensitive adhesive; outer aluminum surface coated with UV resistant coating for protection from environmental contaminants.

3. Permeance: 0.00 perm as tested by ASTM F 1249.
4. Flame Spread <25, Smoke Developed <50 tested by ASTM E-84. Aluminum finish. Embossed.

J. Glass Cloth Jacket:

1. Provide where specified.
2. Provide acrylic latex finish.

K. Flexible Acrylic Latex:

1. Apply two coats to glass cloth jacket, concealed foamglas and closed cell elastomeric insulation.
2. Refer to Division 09 for color to be used. If no instructions are given, provide a white finish.

3.3 MISCELLANEOUS ITEMS

A. General: Provide insulation of any portion of a system or piece of equipment not previously discussed where ambient operating conditions will allow condensation to occur or whose surface temperature exceeds 115°F. Insulation materials and method shall be as directed by the Designer.

B. Final Inspection: At final inspection, the finished surfaces of all exposed insulation shall be clean and without stains or blemishes. Repair and clean the insulation surfaces and, if necessary, to obtain a new appearance, shall coat discolored surfaces with off-white latex water-base semi-gloss paint or lagging adhesive, without a change in the contract price.

3.4 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. General:

1. Provide continuous unbroken vapor barrier on ducts and plenums with surface temperature below ambient.

B. Concealed supply-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

C. Concealed return-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

D. Concealed outdoor-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

E. Supply-air plenum insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. M) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. M) nominal density.

F. Return-air plenum insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) nominal density.

G. Outdoor-air plenum insulation shall be one of the following:

   1. Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

H. Exhaust-air plenum insulation shall be one of the following:

   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) nominal density.

I. Exposed outdoor-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 3 inches (50 mm) thick and nominal density.

3.5 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:

   1. None.

D. Ducts and Plenums within MER, Exposed and less than 7’-0” above finished floor (AFF)
   1. Aluminum, Smooth: 0.020 inch (0.51 mm) thick.

E. Ducts and Plenums, Exposed, other than D above:
   1. None.

3.6 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:
   1. Aluminum, Corrugated: 0.032 inch (0.81 mm) thick.
   2. Self-Adhesive Outdoor Jacket

D. Ducts and Plenums, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):

   1. Aluminum, Corrugated: 0.032 inch (0.81 mm) thick.

   2. Self-Adhesive Outdoor Jacket

E. Ducts and Plenums, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):

   1. Aluminum, Stucco Embossed with 2-1/2-Inch- (65-mm-) Deep Corrugations thick.

   2. Self-Adhesive Outdoor Jacket

3.7 INDOOR PIPING INSULATION SCHEDULE

A. Thickness shall be as follows:

B. Condensate and Equipment Drain Water below 60 Deg F:

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

      a. Flexible Elastomeric
      b. Mineral-Fiber

C. Chilled Water and Brine:

   1. Insulation shall be one of the following:
      a. Cellular glass

   2. Flexible Elastomeric insulation can be used for run-outs (maximum of 4 feet), to AHU’s and FCU’s cooling coils for pipe sizes up to NPS 4.

   3. Insulation thickness:

Piping System	Insulation Material	Pipe Size, NPS	Insulation thickness
CHW Piping (Indoor areas)	Cellular Glass	2” and smaller	1-1/2”
		2-1/2” to 20”	2”
		22” and larger	2-1/2”

Piping System	Insulation Material	Pipe Size, NPS	Insulation thickness
CHW Piping (Baggage Handling System areas, Sortation Area, Checked Baggage Resolution Areas (CBRA), and Corridors adjacent to Early Baggage Storage(EBS))	Cellular Glass	2” and smaller	1-1/2”
		2-1/2” to 8”	2”
		10” and larger	2-1/2”

D. Refrigerant:

1. Insulation shall be one of the following:
   a. Flexible Elastomeric
   b. Owner Approved Substitution

E. Engine Exhaust Piping:

1. Insulation shall be one of the following:
   a. Calcium Silicate
   b. Owner Approved Substitution

3.8 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. The minimum insulation thickness shall be 3 inches thick for pipe sizes up to and including 4 inch and a minimum 3.5 inches thick for pipe sizes 6-8 inches and larger.

B. Chilled Water and Brine:

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

   a.Cellular Glass

C. Fuel Oil Piping, Heated:

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

a. Cellular Glass: 2 inches (50 mm) thick
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick

D. Refrigerant:

1. Insulation shall be one of the following:
a. Flexible Elastomeric
b. Owner Approved Substitution

3.9 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE

A. Chilled Water, refer to Section 23 21 13.1 for Preinsulated Underground Piping System

B. Fuel Oil Piping, All Sizes, Heated: Cellular glass.

3.10 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Exposed:
1. PVC: 20 mils (0.5 mm) thick.

3.11 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Exposed:

1. PVC: 30 mils (0.8 mm) thick.
2. Aluminum, Corrugated with Z-Shaped Locking Seam: 0.040 inch (1.0 mm) thick.

3.12 EQUIPMENT INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.

B. Insulate indoor and outdoor equipment that is not factory insulated.

C. Chillers: Insulate cold surfaces on chillers, including, but not limited to, evaporator bundles, condenser bundles, suction piping, compressor inlets, tube sheets, water boxes, and nozzles with the following:
   1. Flexible Elastomeric: 1 inch (25 mm) thick.

D. Chilled-water pump insulation shall be one of the following:

   1. Cellular Glass: 3 inches (75 mm) thick.
   2. Flexible Elastomeric: 2 inch (50 mm) thick.

   3. Mineral-Fiber Board: 2 inches (50 mm) thick and 6-lb/cu. ft. (96-kg/cu. m) nominal density.

E. Chilled-water expansion/compression tank insulation shall be the following:
   1. Flexible Elastomeric: 1 inch (25 mm) thick.

F. Chilled-water air-separator insulation shall be the following:

   1. Flexible Elastomeric: 1 inch (25 mm) thick.

G. Piping system filter-housing insulation shall be one of the following:

   1. Flexible Elastomeric: 1 inch (25 mm) thick.

3.13 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Equipment, Concealed:

   1. None.

D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
   1. Aluminum, Smooth: 0.024 inch (0.61 mm) thick.

E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):

1. Aluminum, Smooth with: 0.032 inch (0.81 mm) thick.

3.14 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Equipment, Concealed:

1. None.

D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):

1. Aluminum, Corrugated with Z-Shaped Locking Seam: 0.032 inch (0.81 mm) thick.

E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):

1. Aluminum, Stucco Embossed with 2-1/2-Inch- (65-mm-) Deep Corrugations: 0.040 inch (1.0 mm) thick.

END OF SECTION 23 07 00

SECTION 23 08 00 - COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Owner's Project Requirements (OPR) and the Basis of Design (BOD) documentation are included by reference for information only.

C. Division 01 Section 01 81 13 Sustainable Design Requirements – LEED v4 BD+C for additional LEED v4 requirements related to commissioning.

D. ASHRAE standard 90.1 -2010, ASHRAE Guidelines 0-2013 (The Commissioning Process) and 1.1-2007 (The HVAC Commissioning Process) and ASHRAE Standard 202-2013 Commissioning Process for Buildings and Systems.

1.2 SUMMARY

A. This section includes commissioning process requirements for HVAC&R systems, assemblies, and equipment.

B. Related Sections:
1. Division 01 Section 01 91 13 "General Commissioning Requirements" for general commissioning process requirements.

1.3 DESCRIPTION

A. Refer to Division 01 Section 01 91 13 "General Commissioning Requirements" for the description of commissioning.

1.4 DEFINITIONS

A. Refer to Division 01 Section 01 91 13 "General Commissioning Requirements" for definitions.

1.5 SUBMITTALS

A. Refer to Division 01 Section 01 91 13 "General Commissioning Requirements" for CxA's role.

B. Refer to Division 01 Section "Submittal Procedures" for specific requirements.

C. In addition, provide the following:
1. Certificates of readiness
2. Certificates of completion of installation, prestart, and startup activities.
3. O&M manuals
4. Test reports

D. Control Drawings Submittal

1. The control drawings shall have a key to all abbreviations.
2. The control drawings shall contain populated graphic schematic depictions of the systems and each component.
3. The schematics will include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
4. Provide a full points list with at least the following included for each point:
    a. Controlled system
    b. Point abbreviation
    c. Point description
    d. Display unit
    e. Control point or set point (Yes / No)
    f. Monitoring point (Yes / No)
    g. Intermediate point (Yes / No)
    h. Calculated point (Yes / No)

1.6 QUALITY ASSURANCE

A. Test Equipment Calibration Requirements: Contractors will comply with test manufacturer's calibration procedures and intervals. Recalibrate test instruments immediately after instruments have been repaired resulting from being dropped or damaged. Affix calibration tags to test instruments. Furnish calibration records to CxA upon request.

1.7 COORDINATION

A. Refer to Division 01 Section 01 91 13 "General Commissioning Requirements" for requirements pertaining to coordination during the commissioning process.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. All standard testing equipment required to perform startup, initial checkout and functional performance testing shall be provided by the subcontractor for the equipment being tested. For example, the mechanical contractor of Division 23 shall ultimately be responsible for all standard testing equipment for the HVAC&R system and controls system in Division 23, except for equipment specific to and used by TAB in their commissioning responsibilities. A sufficient quantity of two-way radios shall be provided by each subcontractor.

B. Special equipment, tools and instruments (specific to a piece of equipment and only available from vendor) required for testing shall be included in the base bid price to the Owner and left on site, except for stand-alone data logging equipment that may be used by the CxA.

C. Proprietary test equipment and software required by any equipment manufacturer for programming and/or start-up, whether specified or not, shall be provided by the manufacturer of the equipment. Manufacturer shall provide the test equipment, demonstrate its use, and assist in the commissioning process as needed. Proprietary test equipment (and software) shall become the property of the Owner upon completion of the commissioning process.

D. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the Specifications. If not otherwise noted, the following minimum requirements apply: Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5°F and a resolution of + or - 0.1°F. Pressure sensors shall have an accuracy of + or - 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year.

PART 3 - EXECUTION

3.1 GENERAL DOCUMENTATION REQUIREMENTS

A. With assistance from the installing subcontractors, the CxA will prepare construction Verification Checklists for all commissioned components, equipment, and systems

B. Red-lined Drawings:

1. The CM at Risk and the Subcontractor will verify all equipment, systems, instrumentation, wiring and components are shown correctly on red-lined drawings.
2. Preliminary red-lined drawings must be made available to the Commissioning Team for use prior to the start of Functional Performance Testing.
3. Changes, as a result of Functional Testing, must be incorporated into the final as-built drawings, which will be created from the red-lined drawings.
4. The contracted party, as defined in the Contract Documents will create the as-built drawings.

C. Operation and Maintenance Data:

1. CM at Risk and the Subcontractor will provide a copy of O&M literature within 45 days of each submittal acceptance to the A/E for approval for use during the commissioning process by the CxA for all commissioned equipment and systems.
2. The CxA will review the O&M literature once for conformance to project requirements.
3. The CxA will receive a copy of the final approved O&M literature once corrections have been made by the CM at Risk and the Subcontractor.

D. Demonstration and Training:

1. CM at Risk and the Subcontractor will provide demonstration and training as required by the specifications.
2. A complete training plan and schedule must be submitted by the CM at Risk and the Subcontractor to the CxA a minimum of four (4) weeks prior to any training.

3. A training agenda for each training session must be submitted by the CM at Risk and the Subcontractor to the CxA, the A/E, and the OR a minimum of one (1) week prior the training session.
4. The CxA shall be notified at least 72 hours in advance of scheduled tests so that testing may be observed by the A/E, the CxA and the Owner's representative. A copy of the test record shall be provided to the CxA, the A/E and the OR.
5. Engage a Factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain specific equipment.
6. Train Owner's maintenance personnel on procedures and schedules for starting and stopping, trouble shooting, servicing, and maintaining equipment.
7. Review data in O&M Manuals.

E. Systems Manual requirements:

1. The Systems Manual is intended to be a usable information resource containing all of the information related to the systems, assemblies, and Commissioning Process in one place with indexes and cross references.
2. The CM at risk shall include final approved versions of the following information for the Systems Manual:
    a. As-Built System Schematics
    b. Verified Record Drawings
    c. Test Results (not otherwise included in Cx Record)
    d. Periodic Maintenance Information for computer maintenance management system
    e. Recommendations for recalibration frequency of sensors and actuators
    f. A list of contractors, subcontractors, suppliers, architects, and engineers involved in the project along with their contact information
    g. Training Records, Information on training provided, attendees list, and any on-going training
3. This information shall be organized and arranged by building system, such as, chilled water, heating hot water, etc.
4. Information should be provided in an electronic version to the extent possible. Legible, scanned images are acceptable for non-electronic documentation to facilitate this deliverable.

3.2 CM at RISK & SUBCONTRACTORS RESPONSIBILITIES

A. Mechanical, Controls (BAS) and TAB Contractors. The commissioning responsibilities applicable to each of the mechanical, controls and TAB contractors of Division 23 are as follows (all references apply to commissioned equipment only):

B. Perform commissioning tests at the direction of the CxA.

C. Attend coordination meetings.

D. Attend TAB and ATC coordination meetings.

E. Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection as directed by the CxA.

F. Provide information requested by the CxA for final commissioning documentation.

G. Include requirements for submittal data, operation and maintenance data, and training in each submission.

H. Prepare preliminary schedule for Mechanical system orientations and inspections, operation and maintenance manual submissions, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, testing and balancing and task completion for owner. Distribute preliminary schedule to commissioning team members.

I. Update schedule as required throughout the construction period.

J. During the startup and initial checkout process, execute the related portions of the prefunctional checklists for all commissioned equipment.

K. Assist the CxA with all verification and functional performance tests.

L. Provide measuring instruments and logging devices to record test data, and provide data acquisition equipment to record data for the complete range of testing for the required test period.

M. Gather operation and maintenance literature on all equipment, and assemble in binders as required by the specifications. Submit to A/E for approval (45) days after submittal acceptance. A/E shall issue the O & M manuals to the CxA for review of design compliance.

N. Coordinate with the CxA to provide (48) hour advance notice so that the witnessing of equipment and system start-up and testing can begin.

O. Notify the CxA and the A /E a minimum of two (2) weeks in advance of the time for start of the testing and balancing work. Attend the initial testing and balancing meeting for review of the official testing and balancing procedures.

P. Participate in, and schedule vendors and contractors to participate in the training sessions.

Q. Provide written notification to the CxA and the A /E that the following work has been completed in accordance with the contract documents, and that the equipment, systems, and sub-system are operating as required.
   1. Primary HVAC&R equipment including the CHW and HW systems including: chillers, boilers, pumps, BAS system, and all other equipment furnished under Division 23.
   2. Secondary HVAC&R equipment including all fans, air handling units, exhaust fan systems, ductwork, dampers, terminals units, insulation and all other equipment furnished under Division 23.
   3. Fire stopping in the fire rated construction, including fire and smoke damper installation, caulking, gasketing and sealing of smoke barriers.
   4. Fire detection and smoke detection devices interfaced with HVAC furnished under other divisions of the specification.

R. The equipment supplier shall document the performance of his equipment.

S. Provide a complete set of red-lined drawings to the CxA and the A/E prior to the start of Functional Performance Testing.

T. Test, Adjust and Balance Contractor

1. Attend initial commissioning coordination meeting scheduled by the Commissioning Authority.
2. Submit the site specific testing and balancing plan to the CxA and the A/E for review and acceptance.
3. Attend the testing and balancing review meeting scheduled by the CxA. Be prepared to discuss the procedures that shall be followed in testing, adjusting, and balancing the HVAC&R system.
4. At the completion of the testing and balancing work, and the submittal of the final testing and balancing report, notify the HVAC&R contractor and the CM at Risk.
5. At the completion of testing and balancing work, and the submittal of the final testing and balancing report, notify the HVAC&R Contractor and the CM at Risk.
6. Participate in verification of the testing and balancing report, which will consist of repeating measurements contained in the testing and balancing reports. Assist in diagnostic purposes when directed.

U. Provide training of the Owner’s operating staff using expert qualified personnel, as specified.

V. Equipment Suppliers

1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner, to keep warranties in force.
2. Assist in equipment testing per agreements with contractors.
3. Provide information requested by CxA regarding equipment sequence of operation and testing procedures.

W. Refer to Division 01 Section “General Commissioning Requirements” for additional contractor responsibilities.

3.3 OWNER’S RESPONSIBILITIES

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for Owner’s Responsibilities.

3.4 DESIGN PROFESSIONAL'S RESPONSIBILITIES

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for Design Professional’s Responsibilities.

3.5 CxA's RESPONSIBILITIES

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for CxA’s Responsibilities.

3.6 TESTING PREPARATION

A. Certify in writing to the CxA and the A/E that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.

B. Certify in writing to the CxA and the A/E that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

C. Certify in writing that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.

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

E. Inspect and verify the position of each device and interlock identified on checklists.

F. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.

G. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the CxA.

3.7 TESTING, ADJUSTING AND BALANCING VERIFICATION

A. Prior to performance of Testing, Adjusting and Balancing work, provide copies of reports, sample forms, checklists, and certificates to the CxA.

B. Notify the CxA at least ten (10) days in advance of testing and balancing work, and provide access for the CxA to witness testing and balancing work.

C. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the CxA.

1. The CxA will notify testing and balancing subcontractor ten (10) days in advance of the date of field verification. Notice will not include data points to be verified.
2. The testing and balancing subcontractor shall use the same instruments (by model and serial number) that were used when original data were collected.
3. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.
4. Remedy the deficiency and notify the CxA so verification of failed portions can be performed.

3.8 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the CxA.

B. Scope of HVAC&R testing shall include entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions.

C. Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

D. The CxA along with the HVAC&R contractor, TAB and ATC Subcontractor shall prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.

E. Tests will be performed using design conditions whenever possible.

F. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the CxA and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

G. The CxA may direct that set points be altered when simulating conditions is not practical.

H. The CxA may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are not practical.

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

J. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.9 HVAC&R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

A. Equipment Testing and Acceptance Procedures: Testing requirements are specified in individual Division 23 sections. Provide submittals, test data, inspector record, and certifications to the CxA.

B. HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 23 Section "Instrumentation and Control for HVAC". Assist the CxA with preparation of testing plans.

C. Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment: Test requirements are specified in Division 23 piping Sections. HVAC&R Contractor shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the CxA. Plan shall include the following:

1. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.
2. Description of equipment for flushing operations.
3. Minimum flushing water velocity.
4. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

D. HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, steam, and hydronic distribution systems; exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.

E. Vibration and Sound Tests: Provide technicians, instrumentation, tools, and equipment to test performance of vibration isolation.

F. The work included in the commissioning process involves a complete and thorough evaluation of the operation and performance of all components, systems and sub-systems. The following equipment and systems shall be evaluated:

1. Air Handling Units - Packaged
2. Air Handling Units – Modular Indoor
3. Air Terminal Units
4. Air-to-Air Energy Recovery
5. Building Automation / DDC Control System
6. Centrifugal Chillers
7. Cooling towers
8. Heat Exchangers
9. HVAC Fans
10. Hydronic Pumps
11. Particulate Air Filtration
12. Smoke Exhaust System
13. Split System A/C Units
14. Testing, Adjusting and Balancing
15. Unit Heaters
16. Unit Ventilators
17. Variable Frequency Drives (VFD)
18. Water treatment system

3.10 DEFICIENCIES/NON-CONFORMANCE, COST OF RETESTING, FAILURE DUE TO MANUFACTURER DEFECT

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for requirements pertaining to deficiencies/non-conformance, cost of retesting, or failure due to manufacturer defect.

3.11 APPROVAL

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for approval procedures.

3.12 DEFERRED TESTING

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for requirements pertaining to deferred testing.

3.13 OPERATION AND MAINTENANCE MANUALS

A. The Operation and Maintenance Manuals shall conform to Contract Documents requirements as stated in Division 01.

B. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for the AE and the CxA roles in the Operation and Maintenance Manual contribution, review and approval process.

C. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.

3.14 TRAINING OF OWNER PERSONNEL

A. Refer to Division 01 Section 01 91 13 “General Commissioning Requirements” for requirements pertaining to training. All training shall be videotaped for future use.

B. Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:

1. Provide the CM at Risk, the CxA, the A/E, and the OAR with a training plan two weeks before the planned training.
2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, all HVAC equipment (ex. pumps, chillers, cooling towers, air handling units, exhaust fans, VAV terminal units, controls and water treatment systems, etc.)
3. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
5. The appropriate trade or certified factory manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer’s representative. Practical building operating expertise, as well as in-depth knowledge of all modes of operation of the specific piece of equipment, is required. More than one party may be required to execute the training.

6. The controls & TAB contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
7. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
8. Training shall include:
   a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
   b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
   c. Discussion of relevant health and safety issues and concerns.
   d. Discussion of warranties and guarantees.
   e. Common troubleshooting problems and solutions.
   f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
   g. Discussion of any peculiarities of equipment installation or operation.
   h. The format and training agenda in The HVAC Commissioning Process, ASHRAE Guideline 1.1-2007, is recommended.
9. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.
10. The mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.
11. Training shall occur after functional testing is complete, unless approved otherwise by the Owner.

C. Controls Contractor. The controls contractor shall have the following training responsibilities:

1. Provide the CM at Risk, the CxA, the AE, and the OAR with a training plan four weeks before the planned training.
2. The controls contractor shall provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on all the capabilities of the control system.
3. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals and in all software displays. Manuals will be approved by the CxA and the AE. Copies of audiovisuals shall be delivered to the Owner.
4. The trainings will be tailored to the needs and skill-level of the trainees.

5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The Owner shall approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. There shall be two (2) training sessions:
    a. Training I. Control System. The first training shall consist of 8 hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
    b. Training II. Building Systems. The second session shall be held on-site for a period of 8 hours of actual hands-on training after the completion of system commissioning. The session shall include instruction on:
        1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with Orlando International Airport alarm and security communication systems.
        2) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing set points and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
        3) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
        4) Every screen shall be completely discussed, allowing time for questions.
        5) Use of keypad or plug-in laptop computer at the zone level.
        6) Use of remote access to the system via phone lines or networks.
        7) Setting up and changing an air terminal unit controller.
        8) Graphics generation is populated properly
        9) Point database entry and modifications
        10) Understanding DDC field panel operating programming (when applicable)

D. TAB. The TAB contractor shall have the following training responsibilities:

1. TAB shall meet for 4 hours with facility staff after completion of TAB and instruct them on the following:
   a. Go over the final TAB report, explaining the layout and meanings of each data type.
   b. Discuss any outstanding deficient items in control, ducting or design that may affect the proper delivery of air or water.
   c. Identify and discuss any terminal units, duct runs, diffusers, coils, fans and pumps that are close to or are not meeting their design capacity.
   d. Discuss any temporary settings and steps to finalize them for any areas that are not finished.
   e. Other salient information that may be useful for facility operations, relative to TAB.

END OF SECTION 23 08 00

SECTION 23 09 00 – INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERALm8

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.
   1. Summary
      a. The South Terminal Building Management System (BMS) sub-contractor is responsible to provide and install all control and monitoring devices to provide a complete system in the Airside Building (including PCA), Landside Building, Central Energy Plant (CEP), Ground Transportation Facility, Electrical Power Generation (EPG) facility, Ground Support Equipment (GSE), Checkpoint Delta and the North Terminal Maintenance Control Room. The BMS Contractor shall provide a complete system consisting of Direct Digital Control Panels (DDCPs), field I/O devices, power supplies and supportive software, to meet the written sequences of operations, as written in contract specifications. The system shall support communications to DDCP's, and provide operator interaction, data consolidation and global control functions via a Local Area Network (LAN).
      b. The BMS network connectivity shall reside on VLAN on the GOAA IT network. The BMS Contractor is responsible to coordinate VLAN and network connectivity requirements with the TMC and GOAA IT. The BMS management level network (DDC panels, workstation/servers) will utilize fiber optic cabling and pathways and outlets provided by the TMC. The TMC shall provide a surface mounted single port box outlet mounted in the DDC panels or in a compact locked panel which is conjoined to the DDC panel (panels provided by the BMS Contractor). The conjoined panels shall be keyed alike to the DDC panel.
      c. Work shall include HVAC control, energy management, alarm monitoring, point trending, point reporting and maintenance management functions. Coordinate with all site low voltage systems as specified.
      d. The project will utilize LEED EA prerequisite: Energy metering of consumption at one-month intervals and share with USGBC for a 5 year period. (Reporting shall be provided during period upon request of GOAA).
      e. All labor, material, equipment and software not specifically referred to herein or on the plans, that is required to meet the functional intent of this specification, shall be provided without additional cost to the Owner.
      f. The BMS Contractor shall be selected by the owner-CR@R based on Technical Proposal submission that meets or exceeds "BMS Contractor Installer Qualifications paragraph section 1.14."
      g. Refer to "Scope of Work" paragraph for additional information.

1.2 RELATED SECTIONS

A. Division 23 - Mechanical Section
1. 23 05 14-Variable Frequency Motor Controllers
2. 23 09 20-Refrigerant Detection and Alarm
3. 23 33 00-Air Duct Accessories
4. 23 64 16-Centrifugal Water Chillers
5. 23 64 23-Scroll Water Chillers
6. 23 65 00-Package Cooling Towers
7. 23 72 00-Air to Air Energy Recovery Units
8. 23 73 13-Modular Air Handling Units
9. 23 74 33-Dedicated Outdoor Units
10. 23 08 00-Commissioning of HVAC System
11. 23 81 23-Computer Room Air Conditioners
12. 23 81 26-Split System Air Conditioners
13. 23 82 19-Fan Coil Units
14. 23 90 00-Pre-Conditioned Air Units and Specialties

B. Division 26 - Electrical Section
1. 26 07 17-SCADA Monitoring and Control System
2. 26 05 13-Conduit
3. 26 05 19-Building Wire and Cable
4. 26 09 24-Architectural Lighting Control Systems
5. 26 27 13-Electrical Metering and Monitoring

C. Division 27
1. 27 05 00-Common Work Elements for Construction

D. Division 34
1. 34 77 13-Passenger Boarding Bridges

1.3 ABBREVIATIONS

A/C - Air Conditioning
ADA - American Disabilities Act.
AHU - Air Handling Unit
ASHRAE - American Society of Heating, Refrigeration and Air Conditioning Engineers
AMBCx: - Automated Monitoring Based Commissioning
ANSI - American National Standards Institute
AODB - Airport Operational Data Base
API - Application Programming Interface
BACnet - Building Automation Controls Network
BTL - BACnet Testing Laboratory
BIBB - BACnet Interoperability Building Block
BIM - Building Information Modeling

BMA	-	BACnet Manufacturers Association
BMS	-	Building Management System
CCDT	-	Configuration, Commissioning and Diagnostic Tool
CCP	-	Communications Control Panel
CCR	-	Central Command Room
CD-RW	-	Compact Disk with Read and Write Capability
CEP-	-	Central Energy Plant
CIBSE	-	Chartered Institution of Building Services Engineers
CM@R	-	Construction Manager at Risk
CPU	-	Central Processing Unit
DAT	-	Digital Audio Tape
DDCP	-	Direct Digital Control Panel
DDC	-	Direct Digital Control
DDR	-	Double Data Rate
DCV	-	Demand Control Ventilation
DR	-	Demand Response
EIA	-	Electronics Industries Association
EMI	-	Electro-Magnetic Interference
EMMS	-	Electrical Metering and Monitoring System
ELV	-	Extra Low Voltage
EP	-	Electric-to-Pneumatic
FAS	-	Fire Alarm System
FCU	-	Fan Coil Unit
FDD	-	Fault Detection and Diagnostics
FSD	-	Fire Smoke Damper
GOAA	-	Greater Orlando Aviation Authority
GUI	-	Graphical User Interface
GSE	-	Ground Support Equipment
HMI	-	Human Machine Interface
HVAC	-	Heating, Ventilating and Air Conditioning
HT	-	Humidity Transmitter
IBSS	-	Integrated Building Security System
IT	-	Information and Communication Technology
IDE	-	Integrated Drive Electronics (Hard Disk)
IEEE	-	Institute of Electrical and Electronic Engineers
IP	-	Internet Protocol
ISO	-	International Standards Organization
ID	-	Identification
I/O	-	Input/Output
ISA	-	Instrument Society of America (also known as International Society for Measurement and Control)
LAN	-	Local Area Network
LCD	-	Liquid Crystal Display
LEED	-	Leadership in Energy and Environmental Design
LED	-	Light Emitting Diode
LLA	-	Low Level Alarm
MCC	-	Motor Control Center
MER	-	Mechanical Equipment Room

NEMA	-	National Electric Manufacturers' Association
NFPA	-	National Fire Protection Association (US Standards)
ODBC	-	Open database Connectivity
OEM	-	Original Equipment Manufacturer
OIW	-	Operator Interface Workstation
OLE	-	Object Linking and in Embedding
OPC	-	Open Process Control
OSHA	-	Occupational Safety and Health Administration
PABX	-	Private Automatic Branch Exchange
PBB	-	Passenger Boarding Bridge
PC	-	Personal Computer
PCA	-	Pre-Conditioned Air
PCI	-	Peripheral Component Interconnect
PE	-	Pneumatic-to-Electric
PICS	-	Protocol Implementation Conformance Statement
PID	-	Proportional, Integral, Derivative
PDA	-	Personal Digital Assistant
PIM	-	I/O Point Interface Module
POT	-	Portable Operator Terminal
PTFE	-	Polytetrafluoroethylene (Teflon)
PT	-	Pressure Transmitter
RAID	-	Redundant Array of Inexpensive Disks
RAM	-	Random Access Memory
RFI	-	Radio Frequency Interference
RH	-	Relative Humidity
RTD	-	Resistance Temperature Device
RTU	-	Remote Terminal Unit
SCADA	-	Supervisory Control and Data Acquisition
SQL	-	Structured Query Language
SSPC	-	Standing Standard Project Committee (ASHRAE)
SVGA	-	Super Video Graphics Adapter
TT	-	Temperature Transmitter
TMC		Technology Master Contractor
TPM		Technical Project Manager
UC	-	Unitary Controller
UPS	-	Uninterruptible Power Supply
UL	-	Underwriters Laboratories
USGBC	-	US Green Building Council
VAV	-	Variable Air Volume
VDU	-	Video Display Unit
VPN	-	Virtual Private Network
VFD	-	Variable Frequency Drive
VLAN	-	Virtual Local Area Network
WAN	-	Wide Area Network
XIF	-	External Interface File
XML	-	Extensible Mark-up Language

1.4 DEFINITIONS

A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

C. BACnet: The Building Automation and Control Network open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135) and which is now an ISO and ANSI standard. BACnet can operate over multi-media including Ethernet, and MSTP. BACnet components shall be UL listed; and shall be fully complaint with ASHRAE Standard SSPC/135 and all other applicable codes.

D. BACnet Object: A physical or virtual point with a set of associated properties such as a temperature sensor that has properties including – name, current value, maximum/minimum values, high/low alarm levels, etc.

E. BACnet Conformance: A description of the capabilities of a device for communicating information to other BACnet devices. It is usually a set of requirements to be met in order for a device to conform to BACnet standards. There are 6 class levels of conformance for standard BACnet objects and services. The higher the conformance class level, the more features that are covered. The BACnet devices furnished under this sub-contract shall at a minimum, be conformance class 3. Preference will be given to higher conformance class of the latest controllers at time of purchase.

F. BACnet Interoperability Building Blocks (BIBBs): A BIBB defines a small portion of BACnet functionality needed to perform a particular task. BIBBs come in pairs, A and B, which reflect the client/server nature. The “A” BIBB represents the client, i.e. the device furnishing the information. The “B” BIBB represents the server, i.e. the device furnishing the information or executing the command. For 2 devices to be interoperable the “A” BIBB and the “B” BIBB must be the same.

G. BACnet/IP: The Building Automation and Control Network open protocol communication standard using Internet Protocol (IP) complying with Annex J of the ASHRAE SSPC/135 standard.

H. Binary: A two-state system where an “ON” condition is represented by a high signal level and an “OFF” condition is represented by a low signal level.

I. Building Management System (BMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities. The BMS includes the DDC subsystem, open system ports, and open protocol bus or integrators and network routers for connection to information networks. It includes components at the Field, Automation and Management Levels.

J. BMS Contractor: The Building Management System Contractor responsible for the installation of the Building Management System specified herein.

K. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.

L. Component: Any individual element of the BMS furnished under this sub-contract including hardware, software and materials.

M. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, PE and EP switches and like devices. Includes all wiring from controllers to all sensors and points specified herein and required to execute the sequence of operation. Does not include line voltage power wiring.

N. Dead band: A temperature range over which no heating or cooling energy is supplied, such as 74-78 degrees F, i.e. as opposed to single point changeover or overlap, or a range from setpoint over which no control action is taken.

O. Diagnostic Program: Machine executable instructions used to detect and isolate system and component malfunctions.

P. Direct Digital Control System: The portion of the BMS that involves the connection of microprocessor-based controllers to field level sensors and actuators. The signals received from field level instrumentation are converted from analog to digital format so that the data can be used in software logic. Control signals are determined by software logic and they are converted from digital to analog format so that the final control element can be adjusted.

Q. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more than one system.

R. Furnish: Purchase and deliver to the appropriate installing sub-contractor, complete with every appurtenance, document, commission and warranty.

S. Integration: The ability of control system components from different manufacturers connect together while providing coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator's workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, Modbus and OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer's systems.

T. Interoperability: The ability of systems from different manufacturers and of different types to share information with each other without losing any of their independent functional capabilities and without the need for complex programming.

U. Native BACnet: This term is used to imply that BACnet devices (i.e. the BMS controllers and workstation) only communicate in BACnet protocol and do not require an intermediate gateway (out of the box) for protocol conversion. The BACnet devices shall be connected on a peer-to-peer network using one of the approved LAN technologies such as Ethernet, MS/TP, or BACnet/IP.

V. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier (Management Level) networks shall provide "Peer-to-Peer" communications. Second tier (Automation Level) networks shall provide either "Peer-to-Peer", Master-Slave or Supervised Token Passing communications.

W. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

X. Operating System (OS): Software that controls the execution of computer programs and which provides scheduling, debugging, input/output controls, accounting, compilation, storage assignment, data management and related services.

Y. Open System Port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the BMS System.

Z. Operator Interface Workstation (OIW): The OIW consists of a high-level processing personal computer and peripheral I/O devices that enable access to the PC and to the entire Management Level Network. The OIW allows an operator to command, monitor, and program the system.

AA. Peer-to-Peer Communications: Communications directly between devices that operate on the same communications level of a network, without intervention from any intermediary devices such as a host computer or server.

BB. Peripheral: Input/Output equipment used to communicate with the computer and make copies of system outputs; peripherals include VDUs, printers, hard drives, disk drives and modems, etc.

CC. Portable Operator Terminal (POT): Permits portable operator interface remotely from the Operator Interface Workstation (OIW) to facilitate network management, point-to-point node commissioning, diagnostics and general operator interface with the BMS.

DD. Programmable Device: A device that does not have a pre-established built-in application. An application creation software tool is required for an application to be created and downloaded to the device.

EE. Pick Point: A pick point is a graphical display element that allows the operator to "click" the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen. Pick points shall be configured on each display screen to provide a logical user navigation system using a ladder tree hierarchy.

FF. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, and Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required and the loop shall not be subject to “Integral Windup”.

GG. Provide: The term “provide” means “provide complete in place”, that is, furnish, install, commission, test, warrant and ready for operation and use. Refer to the definition of “Furnish”.

HH. Router: A device that routes messages destined for another segment sub-net or domain of the control network. The device controls message traffic based on node address and priority. Media converters which serve as communication links between power line, twisted pair, fiber optic, coax and RF media are sometimes referred to as Routers.

II. Software: Programs that are executed by a computer-based BMS beyond the physical hardware of the computer system, encompasses any programs such as operating systems (OS), application programs, operating sequences and databases. The term “Software” in this specification shall also include all firmware provided with read-only memory as part of the BMS to meet all applicable criteria detailed to meet sequence of operations.

JJ. Unitary Controller: A controller generally designed for a specific application and for a single piece of equipment. Fully programmable unitary controllers shall be provided for this project.

KK. Virtual Private Network (VPN): This is a network that uses encryption and other technologies to provide secure communications over the Internet or an Intranet.

LL. XIF: External Interface File that contains contents of the manufacturer’s product documentation.

MM. SOAP: Simple Object Access Protocol (SOAP) is a simple extensible mark-up language (XML) - based protocol that enables applications to exchange information through a WEB Service.

1.5 BMS SYSTEM ARCHITECTURE

A. The BMS shall connect to the new TMC IT network using BACnet/IP over Ethernet. This LAN is hereafter referred to as the “Site Management Level”.

B. The Site Management Level (TMC IT network)
1. All servers, Operator Interface Workstations (OIW), Operating Systems (OS) and related applications shall reside on the management level.
2.
3. Communication Control Panels (CCPs) shall reside on the management level.
4. All Management Level components (DDCP panel, ~~workstation/servers~~, etc.) shall be support by a local ½ hour Uninterruptible Power Supply (UPS). The BMS workstations/servers shall be provided with a local two-hour UPS back-up.

5. The BMS site management level fiber optic cabling shall be provided by the TMC IT Contractor.

C. The Automation Level
1. The automation level shall comprise of Unitary Controllers (UC) for terminal equipment including VAV, FPVAV, FCU's, etc. The controllers shall be in compliance to ASHRAE SSPC/135, BACnet standards latest revision.
2. Supervisory controllers shall reside on the Automation level.
3. ~~All Automation Level components shall be support by a local Uninterruptible Power Supply (UPS)~~.

D. The Field Level
1. The field level shall include all instrumentation interfaced to the automation level controllers such as temperature, humidity, level, pressure and switches, etc.
2. It shall also include the final control elements such as the control valves, damper actuators and control relays.
3. All field level cables shall be Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit.

1.6 SCOPE OF WORK

A. Installation of Building Management System (BMS)
1. The BMS Contractor shall furnish and install a complete Building Management System (BMS) for all mechanical systems and other facility systems as included in the project documents. The BMS shall Contractor shall provide, test and commission a fully integrated BMS (software platform incorporating an integrated systems database) with the capability to interface seamlessly with other subsystems. The BMS shall allow full integration of subsystems with capability to support multi-vendor environments utilizing standard protocols and be able to integrate third-party systems using standard or subsystem vendor proprietary protocols. The BMS Contractor shall cross-reference this specification with each of the subsystem specifications and identify any gaps and/or conflicts during the bid period and documented in the Technical Proposal (Section 1.14, D. ~~at the time of bid~~. The BMS Contractor is responsible to obtaining a complete set of drawings and specifications for review for inclusion of all points, systems and values referenced in this specification. The BMS will provide the functional features as defined in Part 1-General requirements, Part 2-Products, and Part 3- Execution of these Specifications. The BMS Contractor shall provide a complete and operational system that will perform sequences of operations as verified by Owner Representative and Engineer. The BMS Contractor shall be responsible for all controls, wiring and scope detailed in Contract document M8.01.01 (BMS Responsibility Coordination Matrix).
2. The components furnished shall be the most recent products offered by the BMS manufacturer that meet the specifications. Any originally installed product (including controller hardware, operating system software, etc.) that becomes obsolete (end of shelve life-product replaced with newer product) within 5 years of project completion shall be replaced free of charge. No additional compensation shall be awarded for replacement of older generation product. If there are improved

models of any components that become available before the on-site commencement of installation then these shall be offered by the BMS Contractor to the CM@R at no additional cost to the Owner. The Owner shall have the option to accept or decline the offer. The components offered shall have been in successful operation in at least 2 similar large facility applications for a minimum of 12 months.

3. The BMS Contractor shall provide all software licenses necessary for the legal operation of the BMS. Coordinate with Owner-CM@R.
4. The BMS Contractor is responsible to coordinate all installation activities with CM@R Site Facility personnel and the Engineer by submitting a written installation schedule outlining all proposed BMS installation activities. The schedule should include the anticipated time to install new controllers and network equipment, installation of new monitoring devices and wiring, software programming, testing/commissioning, training and system acceptance.
5. Commissioning of Mechanical Systems: The BMS Contractor shall provide all labor as required to assist with the commissioning of all equipment and systems as scheduled and required by the project's Commissioning Agent.
6. In addition, the following apply:
   a. The work under this Section shall include all materials and labor to perform all work required for the installation of the BMS as specified.
   b. The drawings and Specifications are complementary to one another—meaning that what is called for on one is to be considered called for in both. Where conflicts exist between the Specifications and/or drawings, the more stringent requirement shall apply.
   c. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the BMS Contractor shall provide proper connection(s) to such equipment, including trade coordination.

B. New BACnet/IP based DDC cabinets shall be strategically installed in MER's and other locations in the facility (refer to BMS riser diagrams) to control and monitor new mechanical, electrical and plumbing equipment in the Central Energy Plant, Airside Building (including PCA), Landside Building, Ground Transportation Facility, and existing North Terminal Maintenance Control Room. The BMS shall provide a single and unified graphical user interface for all subsystems. System included (but not limited to) the following:
   1. VAV air handling units.
   2. DOAS VAV air handling units
   3. 100% outside air units
   4. VAV recirculating air handling units
   5. AHU's with fan arrays include one VFD per fan in array. Provide airflow probes for each fan in fan array.
   6. Chillers
   7. Cooling Towers (CT fan VFD's integrated with BMS via BACnet MSTP).
   8. Chiller refrigerant leak monitoring system (Furnished by mechanical and installed by BMS Contractor).
   9. PCA equipment (Airside Building). Integrated with the BMS. All PCA control, monitoring and alarm functions shall be available at the new BMS workstations in

the CEP and the North Terminal Maintenance Office. Provide colorgraphic displays, one-line drawings and floorplans resident on the BMS workstations for all PCA equipment. Refer to the specification section 239000 and the QC series Airside Concourse Mechanical drawings for equipment quantities, control/monitoring points (read/write) and alarms.

10. EMMS integrated with BMS (monitor electrical usage of lighting and plug load electrical panels). Refer to section 26 27 13. BMS Contractor shall provide colorgraphics for all power usage metering (dashboard) and one-line electrical drawings. BMS Contractor to coordinate and confirm integration requirements with system manufacturer, TMC and GOAA IT (REST API with event subscription and HTTP authentication).
    a. Building total receptacle panel KWH power usage.
    b. Building total lighting panel KWH power usage.
    c. Baggage Handling System KWH power usage.
    d. Pre-conditioned air (Main Plant) KWH power usage.
    e. Pre-conditioned air (per gate) KWH power usage.
    f. 400 Hz System (per gate) KWH power usage.
    g. SCADA system monitoring “read only” (Emergency generators, switchgear, etc.)
11. Lighting control systems (BMS integration-read/write via BACnet TCP/IP). Refer to section 26 09 23). BMS shall be programmed to send “enable-disable” request to lighting control system to override zone control manually from the BMS workstation and automatically based on information from the AODB. BMS Contractor to coordinate integration requirements with system manufacturer, TMC and GOAA IT (REST API with event subscription and HTTP authentication). Provide BMS colorgraphic screens and floorplans required for all lighting control zones.
12. BMS integration with Airport Operational Database (AODB-read only). The AODB and the BMS shall be made interoperable through the use of an open API. The BMS manufacturer and the AODB manufacturer shall provide a fully operable seamless platform through the API based integration between both systems. The API shall transfer status points from the AODB to the BMS including gate occupancy. BMS colorgraphic screens and floorplans required for all gate/area zones (occupancy status from AODB integration) including dynamic integrated graphics of lighting and HVAC (status). Refer to drawing M8.51.04. The BMS shall include the ability to control AHU and terminal zone schedules (enable-disable 1 hour-adjustable prior to scheduled occupancy based on AODB information) for occupied-unoccupied modes of operation based on information from AODB. BMS Contractor to coordinate and confirm integration requirements with system provider, TMC and GOAA IT (Information message broker).
13. Generator fuel oil system (BMS integration via Modbus).
14. Constant and variable speed pump control.
15. Variable air volume terminal boxes (BMS contractor shall furnish controls for factory installation by VAV terminal box manufacturer).
16. VAV duct damper control.
17. Miscellaneous exhaust fans.
18. CRAC units (integrated with BMS via BACnet MSTP or Modbus).
19. Split AHU.

20. Fan coil units.
21. Fan powered variable air volume boxes. BMS Contractor shall furnish controls for factory installation by VAV terminal box manufacturer.
22. VFD integration with BMS (BACnet MSTP).
23. Electric duct heating coil KWH usage monitoring via the BMS (meter provided by duct heater manufacturer-integrate with BMS via BACnet MSTP).
24. AHU electric duct heating coil KWH usage meter monitoring via the BMS (meter provided by the BMS Contractor).
25. Fire/Smoke Damper end switch monitoring (closed position) via the BMS (hardwired-Coordinate with FAS manufacturer)..
26. Chilled water BTU meters (BMS integration via Modbus protocol).
27. Pre-conditioned air system chilled water BTU meter interface with BMS.
28. Domestic water booster pump (failure alarm indication at BMS).
29. Circulating pumps (status indication at BMS).
30. Duplex sump pumps (failure alarm indication at BMS)
31. Elevator sump pump (overflow alarm indication at BMS).
32. Domestic Water Heaters (supply temperature)
33. Web based remote monitoring system (to be de-activated at the end of construction).
34. Program user interface on existing Maintenance Control Room monitor (separate icon).
35. Technical proposal (technical proposal shall be submitted, reviewed and approved prior to award and submission of shop drawings.
36. Sequence of operations: Refer to control drawings.
37. Plumbing Drip Pan Leak Detection (leak detector provided by BMS Contractor-Typical-Refer to plumbing drawings for quantity and location).
38. Pipe Insulated Containment Pipe Leak Detection System (Refer to drawing M0.00.04, Leak Detection System provided by Mechanical Contractor, BMS contractor to monitor: loss of power, common fault and leak detection-via BACnet MSTP or Modbus RTU integration~~dry contacts~~-Leak Detection Panel).
39. BMS Contractor shall participate in a low voltage testing lab (Coordinate with TMC and GOAA). Testing lab shall be set up to test the connectivity and functionality (read and write) of a sample of hardware and software with connectivity (VLAN) on the TMC network. The BMS contractor is responsible to test DDCP controllers, lighting control integration, EMMS integration and AODB integration.
40. Temporary network requirements: If TMC IT network is not operational as required for BMS testing and commissioning the BMS Contractor shall connect BMS DDC controller to temporary network provided by GOAA. GOAA shall provide temporary switches in IT closets as required. BMS Contractor shall provide all temporary server/workstations as required for pre-testing and commissioning and coordinate temporary connectivity requirements with GOAA. The BMS will require re-testing and commissioning when TMC IT network is operational. BMS Contractor shall coordinated temporary network requirements with CM@R and construction schedule.
41. BMS integration with the Passenger Boarding Bridges (PBB). All PBB operational status and alarms shall be monitored by the BMS. The following operational status and alarms shall be monitored at each PBB: Auto level alarm, anti-collision alarms, PBB on, PBB in Auto, PBB general trouble alarm, PBB in maintenance override,

(5 additional points as requested by owner). BMS Contractor to provide colorgraphics, floorplans for PBB.

C. Except as otherwise noted, the control system shall consist of all necessary Ethernet controllers, standalone digital control units, workstations (workstations/servers to be provided by GOAA, 42 inch display monitor provided by BMS Contractor), software, sensors, transducers, relays, transformers, valves, dampers, automatic damper operators, control panels, and other necessary equipment, along with a complete system of electrical interlocking wiring to fill the intent of the specification and provide for a complete and operable system. Except as otherwise specified, provide operators for equipment such as dampers if the equipment manufacturer does not provide these. Coordinate requirements with the various Contractors.

D. Provide all miscellaneous low voltage field device mounting and interconnecting wiring for all Building mechanical systems. All interlock wiring, wiring and installation of control devices associated with equipment listed below shall be provided under this contract. When the BMS is fully installed and operational, the BMS Contractor and representatives of the owner will review and check out the system-refer to System Acceptance and testing section of this document. At that time, the BMS Contractor shall demonstrate the operation of the system and prove that it complies with the intent of the drawings and specifications.

E. Provide services and manpower necessary for commissioning of the system in coordination with the HVAC Contractor, Balancing Contractor, Design Engineer, third-party commissioning agent and Owner’s representative.

F. All work performed under this section of the specifications will comply with all governing codes, laws and governing bodies. The Contractor shall obtain and pay for all necessary construction permits and licenses.

G. Provide control power transformers/power supplies for all new equipment.

H. Provide and install proper earth ground on all BMS equipment to prevent the build-up of electromagnetic voltage potential. All BMS equipment shall be EMI immune.

I. All components of the BMS at the Management level and at the BMS Automation level, except for the unitary controllers, shall be support by the Uninterruptible Power Supply (UPS). UPS provided by BMS Contractor.

J. Interface/integrate with third-party equipment as defined and specified.

K. Provide hardwire interlocks for all systems requiring interlock as noted (Fire Alarm System, Mechanical, etc.).

L. Provide system graphics for each HVAC, electrical, plumbing, and piping system. Provide scaled floor plans indicating equipment location, service, and system data as required by this specification. Graphics to incorporate integrated points communicated via multiple sources including direct protocol integration, gateways and third – party interfaces. Origin of information shall be transparent to the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BMS. Provide dynamic dashboard graphics for energy usage monitoring.

M. System Performance:
1. Graphic Display: Display graphics with minimum 20 dynamic points and current data within 5 seconds.
2. Graphic Refresh: Update graphic with minimum 20 points with current data within 5 seconds.
3. Object Command: Reaction time of less than 2 seconds between operator command of a binary object and device reaction.
4. Object Scan: Transmit change of state and change of analog value to control unit or workstation within 5 seconds.
5. Alarm Response Time: Annunciate alarm at workstation within 10 seconds from initiation. Multiple workstations must receive alarms within 5 seconds of each other.
6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical processes under control.
7. Program Execution Summary: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs every second.
8. Performance: Programmable controllers shall execute BMS PID control loops, and scan and update process values and outputs at least once per second.
9. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
    a. Water Temperature: Plus or minus 1 degF.
    b. Water Flow: Plus or minus 2 percent of full scale.
    c. Water Pressure: Plus or minus 5 percent of full scale.
    d. Space Temperature: Plus or minus 1 degF
    e. Ducted Air Temperature: Plus or minus 1 degF.
    f. Outside Air Temperature: Plus or minus 2 degF.
    g. Dew Point Temperature: Plus or minus 3 degF.
    h. Temperature Differential: Plus or minus 0.25 degF.
    i. Relative Humidity: Plus or minus 2 percent.
    j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
    k. Air Pressure (Space): Plus or minus 0.01-inch wg.
    l. Air Pressure (Ducts): Plus or minus 0.1-inch wg.

N. Provide a remote notification and monitoring system (minimum requirements):
1. BMS workstation (workstation furnished by GOAA) shall be configured to send out messages via email, phones (via speech to text technology), SMS, text messaging-cellular, mobile handsets).
2. There should be no limit to the number of points (analog or digital), that can be configured to remote notification of alarm condition and no limit to the amount of devices which can receive messages from the BMS.

3. On a per point message, system can be configured to send messages to an individual or group and shall be configured to send different messages to different to different remote devices based on alarm message priority level.
4. Remote devices may be scheduled as to when they receive messages from the system to account for the operator work schedules.
5. System must be configured to send messages to an escalation list so that if the first device does not respond, the message is sent to the next device after a configurable time has elapsed. Message detail shall be configurable on a per user basis.
6. During a “flood” of alarms, remote notification messages shall have the ability to optimize several alarms into an individual remote notification message.
7. BMS workstation shall have the ability to send manual messages allowing an operator to type a message to be sent immediately.
8. BMS workstation shall have a feature to send a “heartbeat” message to periodically notify users that they have normal communication with the system.
9. Notification and monitoring system shall have the capability to be de-activated at the end of construction. Owner will have capability to re-activate system as needed via command at the BMS workstation.
10. BMS Contractor shall coordinate, confirm and implement remote notification and responder requirements with GOAA. GOAA to provide BMS Contractor contact information of responders for alarm/programming.

O. Provide the following support for all components furnished under this sub-contract:
1. Warranty and service during the defects liability period.
2. Submittals, samples and record documentation.
3. Comprehensive commissioning and testing services.
4. Detailed theoretical and practical training services for the BMS Supervisors and Operators.
5. BMS equipment coordination with other site Specialists (Fire Alarm, etc.).
6. Comprehensive and complete interoperability documentation and method statement for all third-party systems.
7. Comprehensive PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.

P. The BMS must comply with GOAA’s IT and IT Security policies and standards including enhanced security to provide authentication, authorization, network security monitoring, intrusion detection/prevention, network flow behavioral analysis and intrusion response capabilities. Normal BMS network traffic shall be base lined and a GOAA’s endpoint and network tools and products used to detect an alert on anomalous network traffic patterns or potential network intrusions. BMS shall provide a method to respond to detected anomalous events by blocking access. Each network connection shall be monitored, analyzed for malicious activity and blocked if required. BMS Contractor shall provide detailed description of network cyber security provisions included for this project in the Technical Proposal Section 1.14, D.

1.7 SYSTEM DESCRIPTION

A. In accordance to the scope of work, the system shall also provide a graphical, web-based, operator interface that allows for instant access to any system through a standard browser. The PC-based programming workstations, operator workstations (workstations furnished by GOAA) and microcomputer controllers of modular design providing distributed processing capability and allowing future expansion of both input/output points and processing control functions. For this project the system shall consist of the following components:

1. Administration and Programming Workstation(s) for commissioning as required to meet project schedule. Temporary workstations provided by BMS Contractor.
2. Operator Workstations (furnished by GOAA).
3. Ethernet-based Network Router and/or Network Server Controller
4. Network controllers shall be tested and certified by the BACnet Testing Laboratory (BTL) as Network Server Controller (B-BC).

B. ~~The Local Area Network (LAN) shall be either a 10 or a 100 Mpbs Ethernet network supporting BACnet, Modbus, Java, XML, HTTP and Cobra IIOP for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Network server controllers, user workstations and a local host computer.~~

C. The system shall enable an open architecture that utilizes ANSI/ASHRAE Standard 135-2007, BACnet functionality to assure interoperability between all system components. Native support for the ANSI/ASHRAE Standard 135-2007, BACnet protocol are required to assure that the project is fully supported by the HVAC open protocols to reduce future building maintenance, upgrade and expansion costs.

D. The software tools required for network management of the ANSI/ASHRAE Standard 135-2008, BACnet protocol must be provided with the system. Drawings are diagrammatic only. Equipment and labor not specifically referred to herein or on the plans and are required to meet the functional intent, shall be provided without additional cost to the owner. Minimum BACnet compliance is Level 4, with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet IP or MS/TP.

E. The system shall support Modbus TCP and RTU protocols natively, and not require the use of gateways.

F. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the approved manufacturers local field office.

G. Provide the Commissioning, configuration and diagnostic tool (CCDT), color display personnel computer, software, and interfaces to provide uploading/downloading of High Point Count Controllers, Unitary Controllers, and VAV controllers monitoring all BACnet objects, monitoring overrides of all controller physical input/output points and editing of controller resident time schedules.

H. The system shall provide the capability to provide software on site server AMBCx (automated monitoring based commissioning) system. The AMBCx system shall be able to interface directly with the project BMS and energy/performance metering system to provide information on HVAC, electrical, metering and lighting systems that are being controlled. BMS Contractor shall provide equipment, software, installation labor, programming, assist Cx in functional testing, training and documentation during implementation and warranty period. Provide training as per Section 1.20. The BMS Contractor will be responsible for firmware maintenance, FDD database maintenance and upgrades and collected BMS data maintenance and integrity. The AMBCx system provided shall satisfy FDD, building analytics and analysis for all major mechanical, electrical and energy systems included in the scope of this specification. The AMBCx shall analyze a combination of hard-wired (analog and digital I/O) and virtual points (setpoints, calculated variables) in a system using real-time and historical time-series data to the following as a minimum:

1. Determine the stability of control devices (valves/actuators/speed drives)
2. Determine the degree of error above reasonable thresholds.
3. Compare sensor readings to setpoint and flag out-of-range errors from faulty sensors.
4. Compare outputs (controllers) setpoints to actual conditions to find failed devices.
5. Calculate and report on energy consumption for systems under BMS control.
6. Diagnose flow measurement systems to ensure readings are in range of expectations.
7. Categorize faults according to various priorities (energy, comfort and system maintenance impact).
8. Identify simultaneous heating and cooling in a system and subsystem.
9. Ensure ventilation rates are adequate (testing minimum outdoor air volume settings).
10. Report CEP efficiency through efficiency measurement.
11. Optimize air filter replacement by monitoring changes in filter pressure drop.
12. Monitor chiller evaporator and condenser tube bundle pressure drops for degradation of performance.
13. System shall be monitored from the North Terminal BMS workstation and the CEP. BMS Contractor shall install, test and train owner employees on its use and capability.
14. BMS Contractor shall provide a detailed description of feature, functionality and training of AMBCx in Technical Proposal Section 1.14, D.

1.8 COORDINATION WITH OTHER TRADES

A. Contractors, Sub-contractors, Employees

1. It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project will be delivered in the best possible condition and in the shortest time. The BMS Contractor will coordinate with other Trade Contractors regarding the location and size of pipes, equipment, fixtures, conduit, ducts, openings, switches, outlets, structural, architectural features and so forth, in order to eliminate any delays in the progress of the job.

2. Any task related to the BMS turnkey installation that is not clearly identified in this document as being the responsibility of another trade shall be the responsibility of the BMS Contractor.

B. Coordination with Owner & Engineer
1. The BMS Contractor shall cooperate with Owner and the Engineer when performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of existing on-site documentation, if applicable to further determine the nature and extent of BMS work.

1.9 BMS EXPANSION

A. Network architecture and software shall allow unlimited expandability by the addition of new sub networks and associated routers, gateways and controllers, etc.

B. Each BMS as installed shall be capable to be expandable, at minimum to incorporate the following in addition to the above:
1. A minimum of 50% percent additional hardware (field) point modules (each type analog, digital, inputs and outputs) with the addition of CCP, DDCP and UC.
2. A minimum of 200 percent additional system graphics diagrams and point programming in addition to those required to meet these specifications.
3. A minimum of 8 additional Operator Interface Workstations (OIW).
4. A minimum of 2 additional communication interfaces to other low voltage building systems to those integrated under this contract.

C. Subsequent to the potential expansion cited in “B” above, the BMS performance shall not be degraded in any manner and shall meet all performance criteria detailed in these specifications.

D. Terminal equipment controller sub-networks shall be configured and designed at 75% capacity to allow for future expansion.

1.10 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
1. Each control device labeled with setting or adjustable range of control.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Shop drawings shall be AutoCAD generated, minimum 11 X 17 inches. Drawings shall include diagrams, mounting instructions, installation procedures, equipment details and software descriptions for all aspects of the system to be installed. In

addition to the drawings, the Contractor shall furnish a CD containing the identical information.

2. Shop drawings shall include a riser diagram depicting locations of all controllers and workstations, with associated network wiring. Also included shall be individual schematics of each mechanical system showing all connected points with reference to their associated controller. Typicals will be allowed where appropriate.
3. Software submittals shall contain narrative descriptions of sequences of operation, program listings, point lists, and a complete description of the graphics, reports, alarms and configuration to be furnished with the workstation software. Information shall be submitted electronically. Diagrams shall be on a minimum of 11” by 17” foldouts.
4. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
5. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.
6. Details of control panel faces, including controls, instruments, and labeling.
7. Submit shop drawings of all control field panels for review and approval before fabrication.
8. Written description of sequence of operation.
9. Schedule of dampers including size, leakage, construction data, and flow characteristics.
10. Schedule of valves including leakage, construction data, and flow characteristics. Submit valve calculations for each valve for Engineer’s approval.
11. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
12. Listing of connected data points, including connected control unit and input device (Excel format for BIM requirements).
13. Submit graphic samples of actual resolution for a 42 inch flat screen monitor (colorized) as a minimum, for each major monitored system, indicating all data (connected and calculated) point addresses, and operator notations as specified. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
14. Provide Table of Contents for Devices’ data Sheets.
15. Submit electronic transmittal submittal data and shop drawings to the Engineer for review and approval prior to ordering or fabrication of the equipment. The Contractor, prior to submitting, shall check all documents for accuracy.
16. The Engineer will make corrections, if required, and return to the Contractor. The Contractor will then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the Engineer and the submittals are fully approved.

C. Samples: For each color required, of each type of thermostat cover.

D. Software and Firmware Operational Documentation: Include the following:
1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files or as per current GOAA standards.
3. Device address list.
4. Printout of software application and graphic screens.

5. Software license required by and installed for BMS workstations and control systems.

E. Software Upgrade Kit: For Owner to use in modifying software to suit future monitoring and control revisions. Coordinate and confirm requirements with GOAA.

F. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

G. Maintenance Data: For systems to include in maintenance manuals as specified. Include the following:
1. Maintenance instructions and lists of spare parts for each type of control device.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

H. Qualification Data:
1. General: Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

I. <u>Contract Closeout Submittals</u>: All manuals shall be <u>100 percent custom written for this project</u>. Closeout documents will include all as-built software and hardware revision documentation, including a step-by-step, `easy to read' decision tree diagram, which would lead facility operating personnel to specific manual sections for operating procedures, maintenance procedures, and diagnostic/trouble-shooting procedures. All manuals will be subject to the approval of Owner and Engineer prior to the warranty period, and shall provide as a minimum:
1. Project Record Documents for:
    a. Electronic As-Built Drawings in AutoCAD and or BIM Format, including the following:
        1) System architecture drawing.
        2) As-Built Riser Diagram.
        3) Layout drawing for each control panel.
        4) Wiring diagram for individual components.
        5) System flow diagram for each controlled system.
        6) Instrumentation list for each controlled system.
        7) Sequence of control.
        8) Binding map.
        9) IP address, network, MAC port openings provided by GOAA and documented in BMS as-builts.
    b. Final software database (electronic). Includes PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.
    c. Complete program listing with section and line by line comments.

d. Color coding, labeling, and other identification for point to point wiring.

2. Operation and Maintenance Documentation for:
   a. Operation and maintenance manuals for each system component.
   b. List of recommended system spare parts.
3. Information common to the entire system shall be provided. This shall include but not be limited to the following:
   a. Product manuals for the key software tasks.
   b. Operating the system.
   c. Administrating the system.
   d. Engineering the operator workstation.
   e. Application programming.
   f. Engineering the network.
   g. Setting up the web server.
   h. Report creation.
   i. Graphics creation.
   j. All other engineering tasks.
   k. System Architecture Diagram.
   l. List of recommended maintenance tasks associated with the system servers, operator workstations, data servers, web servers and web clients.
   m. Define the task.
   n. Recommend a frequency for the task.
   o. Reference the product manual that includes instructions on executing the task.
   p. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
   q. Licenses, guarantees, and warranty documents for equipment and systems.
   r. Submit one copy for each building, plus two extra copies.
4. Test Data for:
   a. All final system field test data to of temperature, humidity, air flow measurement, room differential pressure, etc. shall be provided in a standalone document to the Owner.
5. Warranty Documentation for:
   a. Materials, manufactured units, equipment and components.
   b. Software.
   c. Auxiliary system equipment.

1.11 WARRANTY AND SERVICES DURING THE WARRANTY PERIOD

A. Material and Labor:

1. The Control System shall be free from defects in material and workmanship under normal use and service. If within five years from the date of project acceptance by the Owner any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the BMS Contractor free of charge. The warranty period for all components of the BMS and their installation shall be five years following the date of project substantial completion and beneficial use as demonstrated to the Owner.

2. Updates to hardware, firmware, and software shall be installed for a period of 5 years with no additional cost to the owner. Updates shall be installed within 60 days of availability.
3. The temperature control contractor shall provide a 5-year extended warranty and preventative maintenance agreement for the temperature control system, as part of the original bid. Any manufacturing defects arising during this extended warranty period shall be corrected without cost to the Owner. The preventative maintenance agreement shall include a minimum of quarterly service visits, include defective parts replacement and commence upon date of project acceptance by the Owner of the temperature control system installation.
4. This agreement shall include 2 hours on-site response for items deemed critical by the airport and 4 hour response for items deemed non-critical emergency on-site service response as part of the warranty period coverage.
5. The temperature control contractor shall provide a manufacturer's scope description as per owner provided scope of maintenance services of the extended warranty/preventative maintenance agreement, as part of the temperature control submittal (Preventive and corrective maintenance program shall be given thru the purchasing department similar to the current North Terminal Contract Specifications) . This agreement shall contain manufacturer's standard schedules of service procedures, work task definitions, and recommended frequencies of performance. The preventative maintenance agreement shall include the temperature control system and its peripherals as specified in this section. This agreement shall include the provision and installation of all manufacturer's standard Host software and product firmware upgrades released during the term of this agreement. The temperature control submittal will not be approved without the warranty/preventative maintenance agreement. There will be no charge to the customer for preventative maintenance of the control system during the extended warranty period.

B. Any material furnished by the BMS contractor which is defective or fails during normal operation of the system, shall be remedied (replaced or repaired) immediately within 2 hours on-site for items deemed critical by the airport and 4 hours for non-critical items by the BMS Contractor at no additional cost to the Owner, during the period prior to the period prior to the start of the warranty, and during the warranty period.

C. Repair work shall only be undertaken at times approved by the Owner.

D. Repair work shall not include routine maintenance during the start of Defects Liability Period.

E. Work to troubleshoot and identify the cause of the BMS system or component failure shall begin immediately and shall continue until repaired to the satisfaction of the Site Engineer and Employer.

F. Any software upgrades and new software programs that become standard product offerings from the BMS Contractor and/or BMS equipment vendors during the Defects Liability Period (Warranty) shall be brought to the attention of the Owner and made available at no additional cost. If at my time during ‘the Defects Liability Period, software patches that correct ‘software errors becomes available the Owner shall be notified immediately and they shall be made available to the Owner at no additional cost. Owner shall be provided with a back-up copy of software package, with compiled and un-compiled read/write capability. Ownership of the original software shall be turned over to owner at their request within 30 calendar days.

1.12 CODES, PERMITS AND APPROVAL

A. All work shall conform to the following Codes and Standards, where applicable:
1. Local Electrical Codes.
2. National Fire Protection Association (NFPA) Standards, as specified.
3. National Electrical Code (NEC)
4. Underwriters Laboratories (UL) listing and labels, as specified.
5. American National Standards Institute (ANSI).
6. National Electric Manufacturers' Association (NEMA).
7. Building Automation and Control Network (BACnet) open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135).
8. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
9. American Society of Mechanical Engineers (ASME).
10. Air Movement and Control Association (AMCA).
11. Institute of Electrical and Electronic Engineers (IEEE).
12. American Standard Code for Information Interchange (ASCII).
13. Electronics Industries Association (EIA).
14. Occupational Safety and Health Administration (OSHA).
15. American Society for Testing and Materials (ASTM).
16. State Energy Code.
17. State Building Code and applicable local Building Code.
18. ANSI/TIA/EIA-862, Building Automation Systems Cabling Standards for Commercial Building.
19. NFPA 92A and 92B/UL 864/UUKL Smoke Purge Control Equipment.

B. Obtain all required permits and inspection certificates. All permits and certificates shall be made available to the Owner.

C. The latest requirements of all national, county, municipal and other authorities having jurisdiction shall be met.

D. Work shall be performed in compliance with Owner’s insurance underwriter & requirements. GOAA to confirm and provide requirements in bid package if applicable.

E. All electrical equipment, devices and components and their installation shall comply with the latest edition of the IEEE Wiring and all associated addenda.

F. Interior enclosures shall be, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.

G. The BMS Contractor shall only offer equipment that meets UL 916 requirements and all electrical components shall be UL listed and shall carry the UL label.

H. The BMS shall be listed and manufactured to ISO 9001 and ISO 9002 standards.

I. All electrical work shall conform to the requirements detailed in the electrical specifications. Where there is any conflict between the requirements of the different project trade sub-contract documents, statutes, codes, regulations, local ordinances and any requirement of an agency having jurisdiction over the project, the most stringent requirement shall apply unless determined otherwise by the Owner, Advise the Engineer of any discrepancy or conflicts between the various requirements for the project.

J. Equipment, devices and materials shall be immune against Electro-Magnetic interferences and shall conform to all performance requirements of' the specifications when exposed to the following interferences:
1. Project lighting, telephone and elevator equipment.
2. AM signals as generated from transmitters.
3. VHF and UHF signals as generated by external or internal portable or fixed transmitters.
4. Electrical noise on the building power system, both spurious and harmonies.
5. The installations shall not radiate signals that cause interference that hinder the correct operation of the Owner's on-site equipment.
6. The BMS and all individual electrical equipment, devices and components shall comply with the requirements of the Federal Communication Commission (FCC) rules and regulations Part 15, sub part J and all other applicable codes and statutes with respect to the radiation and conduction of radio frequency interference.

1.13 SCHEDULE

A. Complete site requirements of the BMS sub-contract in accordance with the project program and prior to the scheduled Substantial Completion date for each phase.

B. Attend project meetings as requested by the CM@R..

C. Provide to the CM@R a schedule indicating the sequence of work, durations of individual tasks, delivery dates for all material, devices and equipment and detail any interface that must be coordinated with any other Specialists.

D. Provide written status reports at required intervals in an electronic format acceptable to the Engineer. An updated schedule of work shall be included in each status report.

E. Comply with, the Project Construction Schedule. Provide additional staffing or work overtime as required to comply with the Project Schedule so as not to interfere with other on-site Specialists in their effort to comply with the Overall Project Schedule. Confirm, prior to tender submittal that all equipment, devices, material and services proposed are available and will be delivered accordingly to comply with the Overall Project Schedule.

F. Provide written Request 'For Information (RFI) notices to the Engineer when specific information or clarification of the specifications is required. Request For Information notices shall be provided at least two (2) weeks prior to the need for the information to the Engineer.

1.14 BMS CONTRACTOR INSTALLER QUALIFICATIONS

A. The BMS Contractor shall:
   1. Have a local staff (minimum of 4 factory certified, badged technicians, within 25 miles of the project site, of trained personnel capable of giving instructions and providing routine and emergency maintenance on the BMS, including all components and software/firmware and all other elements of the BMS.
   2. Have a proven record of experience in 'the supply and installation of equivalent systems over a minimum period of ten (10) years in the local Central Florida area.
   3. Have comprehensive local service and support facilities for the total BMS that shall be capable of responding to emergency calls within 2 hours on-site response for items deemed critical by the airport and 4 hours on-site for non-critical items, 7 days a week (Inclusive of holidays and weekends).
   4. Maintain local, or have approved local sub-contracted access to, supplies of essential expendable parts.
   5. Undertake to maintain necessary project staff and maintenance personnel as per the Owner's requirements.

B. The BMS Contractor shall have a minimum of ten years' experience with the complete, turnkey installation of Building Management Systems of similar size and technical complexity. The BMS Contractor shall provide a list of five comparable projects that have Building Management Systems with the features as specified for this project. These projects must be on-line and functional.

C. The BMS Contractor shall employ specialists in the field of Building Management Systems including: Programming, Engineering, Field Supervision, and Installation. Specialists shall have a minimum of five years of experience with Building Management Systems.

D. Technical Proposal: Prepare electronic copy of a detailed technical proposal including:

   1. Table of Contents. Executive Summary.
   2. Description of Central Florida branch office overall capabilities, number of employees and key resumes of project personnel.
   3. Provide list of all large aviation and other projects (include project square footage) completed by manufacturer and local office of Enterprise BMS installations with an integrated systems database of various subsystems utilizing a converged IT network .. Submit list of aviation project owner references and phone numbers.
   4. Submit a point by point line by line statement of compliance with the specification and the BMS Contract drawings. The statement shall consist of a list of all numbered paragraphs in specification section 230900. Where the proposed system complies fully, such shall indicate by placing the word "comply" opposite the paragraph number. Where the proposed system does not comply or

accomplishes the stated function in a manner different from the described, a full description of the deviation shall be provided. Where a full description of the deviation is not provided, it shall be assumed that the system does not comply with the paragraph in question. BMS Contractor shall cross reference the specification and drawings with each of the subsystem specifications and document any gaps in the compliance section of the Technical Proposal. The BMS bidder shall submit a signed certificate stating that the BMS bidder has read the performance, function, BMS system architecture, sequence of operations, etc. and understands them and the technical proposal shall comply with all parts of the specification.

5. Provide a written guarantee of how long (years) the system proposed will be a standard product and backed by ongoing parts and hardware availability and factory trained field support. Written guarantee shall include statement that any originally installed product (including controller hardware, operating system, software, etc) that becomes obsolete (end of shelf life) during the project construction period or five years after completion shall be replaced free of charge.
6. Unit pricing schedule as described in Section 1.16.
7. Technical data sheets of all DDC controllers and hardware. Include technical data sheets of all proposed control devices as specified in section 2.25.
8. .
9. Proposed system architecture drawing for all buildings showing all major system DDC controllers and typical terminal control systems for different applications.
10. Provide description and sample of BMS GUI colorgraphics including one-lines, floor plans.
11. Provide detailed description and sample GUI for the "Dashboard" animated colorgraphics for LEED metering. Description shall include format, sample colorgraphics, reports, web access capabilities, etc.
12. Proposed implementation plan narrative describing how installation will be accomplished as per project schedule and testing and commissioning methodology without disruption to GOAA operations.
13. Description of vendors AMBCx system product and software offering.
14. Description of BMS provider's cybersecurity data provisions including authentication, network security monitoring, intrusion detection, network flow behavioral analysis, device profiling and intrusion response capabilities. Description shall include how system firewalls or data security provisions shall detect alerts on anomalous network traffic patterns or potential network intrusions and block access. BMS Contractor to describe validation process and comprehensive testing between BMS manufacturer and core IP network manufacturer.
15. Description of remote monitoring capabilities.
16. Branch office support and training capabilities.

1.15 HEALTH AND SAFETY

A. Work shall comply with the requirements of Occupational Safety and Health Administration (OSHA), the Health and Safety requirements for the project and with all of the daily Health and Safety instructions given by the General Contractor.

1.16

A.

1.17 DELIVERY, STORAGE AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

B. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage.

C. Deliver, store, protect, and handle products to site under provisions of the contract Documents. Coordinate all site delivers with Construction project Manager.

D. Accept products on-site and verify any damage equipment. Damage equipment shall be re-ordered/replaced immediately without cost to the Owner.

E. Protect products from construction operations, dust, and debris, by storing materials inside, protected from weather in a conditioned space.

F. System Software: Update to latest version of software prior to final commissioning. .

1.18 QUALITY ASSURANCE

A. General
1. The Building Management System (BMS) herein specified shall be fully integrated and installed as a complete package by the Building Management System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system.
2. The Building Management System Contractor shall be a factory owned or authorized representative branch office that is regularly engaged in the engineering, programming, installation and service of Building Management Systems of similar size and complexity.
3. The BMS Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect/Engineer.

B. Products
1. The Building Management System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Management

Systems, and shall be the manufacturer's latest standard of design. DDCP, CCP and UC system components shall be latest (current) production products.

2. All other equipment shall be the products of the BMS manufacturers or of an approved manufacturer regularly engaged in production of specialized Building Management System materials or equipment.

C. ISO-9001

1. The manufacturer of the Building Management System shall provide documentation supporting compliance with ISO-9001 (Model of Quality Assurance in Design/Development, Production, Installation, and Servicing). Product Literature provided by the BMS manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar. Manufacturers delivering products that do not comply with the ISO-9001 certification requirement shall provide the following information to assure that quality systems are in place and are equivalent to the ISO-9001 standard:
   a. Marketing Specification Standards
   b. Design File Standards
   c. Manufacturing Test Standards
   d. Calibration Standards
   e. Quality System Standards
   f. Quality System Procedures
   g. Documented management commitment that all employees participate in quality programs
   h. Training Procedures
   i. Methods by which corrective actions are taken for problems identified within the factory process.

D. Quality Assurance Program

1. The BMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements:
   a. The BMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is to be responsible for the management of the program.
   b. The Quality Assurance Manager shall provide or maintain:
      1) Documentation of training for employees—including office, field, and subcontractors—on the Quality Assurance Program.
      2) Written verification that each worker on the project has read the Specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
      3) A detailed audit trail for all Quality Assurance issues, including: problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.
   c. Each individual team member shall be responsible for identifying and reporting Quality Assurance problems and for assisting, as requested by the Quality Assurance Manager, in the resolution thereof.

E. Each point in the system shall be tested for both hardware and software functionality. In addition, each mechanical and electrical system under control of the BMS~~BAS~~ will be tested against the appropriate sequence of operation specified herein. Successful completion of the system test shall constitute the beginning of the warranty period. A written report will be submitted to the owner indicating that the installed system functions in accordance with the plans and specifications.

F. The BMS Contractor shall commission and set in operating condition all major equipment and systems, such as the chilled water, and all air handling systems, in the presence of the equipment manufacturer's representatives, as applicable, and the Owner and Architect's representatives.

G. The BMS Contractor shall provide a technician for manpower and engineering services required to assist the HVAC Contractor and Balancing Contractor in testing, adjusting, and balancing all systems in the building. The BMS~~BAS~~ Contractor shall coordinate all requirements to provide a complete air balance with the Balancing Contractor and shall include all labor and materials in his contract.

H. Startup Testing shall be performed for each task on the startup test checklist, which shall be initialed by the technician and dated upon test was completion along with any recorded data such as voltages, offsets or tuning parameters. Any deviations from the submitted installation plan shall also be recorded.

I. Required elements of the startup testing include:
1. Measurement of voltage sources, primary and secondary
2. Verification of proper controller power wiring.
3. Verification of component inventory when compared to the submittals.
4. Verification of labeling on components and wiring.
5. Verification of connection integrity and quality (loose strands and tight connections).
6. Verification of bus topology, grounding of shields and installation of termination devices.
7. Verification of point checkout.
8. Each I/O device is landed per the submittals and functions per the sequence of control.
9. Analog sensors are properly scaled and a value is reported
10. Binary sensors have the correct normal position and the state is correctly reported.
11. Analog outputs have the correct normal position and move full stroke when so commanded.
12. Binary outputs have the correct normal state and respond appropriately to energize/de-energize commands.
13. Documentation of analog sensor calibration (measured value, reported value and calculated offset).
14. Documentation of Loop tuning (sample rate, gain and integral time constant).

J. A performance verification test shall also be completed for the operator interaction with the system. Test elements shall be written to require the verification of all operator interaction tasks including, but not limited to the following.
1. Graphics navigation.

2. Trend data collection and presentation.
3. Alarm handling, acknowledgement and routing.
4. Time schedule editing.
5. Application parameter adjustment.
6. Manual control.
7. Report execution.
8. Automatic backups.
9. Web Client access.

K. A Startup Testing Report and a Performance Verification Testing Report shall be provided upon test completion

L. Governing Code Compliance
   1. The BMS Contractor shall comply with all current governing codes ordinances and regulations as specified within these specifications, including UL, NFPA, the local Building Code, local Electrical Code and so forth.

M. FCC Regulation
   1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference and Subpart J, governing Class A Computing Devices and be so labeled.

1.19 COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.

B. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

C. Coordinate equipment with Division 26 Section "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.

D. Coordinate equipment with Division 26 Section "Panelboards" to achieve compatibility with starter coils and annunciation devices.

E. Coordinate equipment with Division 26 Section “Emergency Generators” to achieve compatibility with monitoring of system.

1.20 TRAINING

A. The BMS Contractor shall provide both on-site and classroom training to the Owner’s representative and maintenance personnel per the following description:

B. On-site training shall consist of a minimum of (40) hours of hands-on instruction geared at the operation and maintenance of the systems. The curriculum shall include:

1. System Overview
2. System Software and Operation
3. System access
4. Software features overview
5. Changing setpoints and other attributes
6. Scheduling
7. Editing programmed variables
8. Displaying color graphics
9. Running reports
10. Workstation maintenance
11. Viewing application programming
12. Operational sequences including start-up, shutdown, adjusting and balancing.
13. Equipment maintenance.

C. All training sessions will be recorded via video and turned over to GOAA for future reference. Refer to Sections 01 91 13 – General Commissioning Requirements and 23 08 00 – Commissioning of HVAC Systems.

PART 2 - PRODUCTS

2.1 APPROVED SYSTEM MANUFACTURERS

A. General: Subject to compliance with requirements, provide products by the manufacturer specified:
   1. Siemens Industries – Desigo Product-PXCM (Peer to Peer, standalone modular BACnet IP DDC controller)
   2. Johnson Controls Inc. (JCI) – Metasys NAE's (Peer to Peer, standalone modular BACnet IP controller)
   3. Honeywell Inc. – EBI Excel 5000 Product/Excel 500 Controller
   4. Schneider Electric.-Smart Struxure system.
   5. Automated Logic Corporation-WebCTRL
   6. Trane Tracer SC with standalone modular BACnet IP DDC SC controllers
   7. Carrier Corporation

2.2 EQUIPMENT AND MATERIAL – GENERAL

A. When a Specific reference to a manufacturer of a product is made, and the term "equal and approved" is used, substitutions of a product by another manufacturer will be allowed, but the substituted product must conform to all specified requirements and be pre-approved prior to installation via written notification as part of submittal process. The Engineer's determination on the acceptability of substitutes shall be final. Approved substituted equipment shall conform to available space requirements. Substituted equipment that does not conform to the available space requirements shall be replaced or required modifications shall be made at no additional cost to the Owner.

B. All equipment and materials shall be new and without any defect.

C. Hazardous Materials Notification: In the event no product or material is available that does not contain asbestos, PCB, or other hazardous material; as determined by the Engineer, a written application shall be made by the BMS Contractor to the Engineer providing all relevant details concerning a proposed product or material that contains hazardous material prior to installation.

D. Asbestos and PCB Certification: After completion of installation, but prior to Substantial Completion, the BMS Contractor shall certify in writing that products and materials installed, and processes used, do not contain asbestos or polychlorinated biphenyls (PCB).

2.3 PERFORMANCE CERTIFICATION

A. The BMS Contractor shall certify in writing with the tender submittal that all components proposed for this project comply with all of the following requirements:
1. Complete and thorough testing has proven that performance shall not be affected when the building electrical distribution system experiences disturbances of the type and magnitude normally encountered in buildings of this nature.
2. An independent testing laboratory has verified that the VAV terminal unit unitary controller meets the performance requirements detailed in these specifications. If so required by the Construction Manager, the testing laboratory shall test a project VAV terminal unit complete with the BMS unitary controller and the BMS Contractor shall demonstrate that the VAV terminal unit UC can meet all of the requirements for monitoring and control accuracy and can undertake all of the sequences of operation associated with the VAV as detailed in these specifications. The independent testing laboratory test report is to be submitted with the shop drawings.
3. Provide power line disturbance tests involving the cycling of mains voltage that will show that all BMS components operate satisfactorily when voltage drops to 75% or less of the nominal mains voltage and normal operation resumed when the voltage returned to less than 85% of the normal mains voltage. Following these brownout conditions, BMS components shall be free of any stress and/or damage, and shall operate normally with no data at the PC, CCP, DDCP and/or UC lost or corrupted.

B. The BMS Contractor shall certify in writing with the tender submittal that all components are free of date related problems.

2.4 AMBIENT CONDITIONS

A. Provide equipment, devices and materials for interior and exterior applications that shall be capable of withstanding and operating satisfactory in, at a minimum, at the following ambient conditions:
   1. BMS central hardware (processors, console, and peripherals): 50 deg F to 100 deg F 10 percent to 90 percent RH.
   2. Indoor hardware: 32 deg F to 120 deg F, 10 percent to 90 percent RH.
   3. Outdoor hardware: -30 deg F to 150 deg F, 0 percent to 100 percent RH.

2.5 SPARE PARTS

A. Submit spare parts for each different item of equipment furnished. Data to include a complete list of each supplier and product by part number, a list of parts and supplies that are either normally furnished at extra cost with the purchase of the equipment or specified hereinafter as “Extra Materials” to be furnished as part of the sub-contract.

B. Submit a list of additional items recommended by the manufacturer to assure efficient operation for a period of 790 days at the particular installation. The foregoing shall not relieve the BMS Contractor of any responsibilities during the BMS Warranty Period.

2.6 EXTRA MATERIALS

A. Provide special hardware and software tools required for maintenance.

2.7 LABELING

A. Provide labeling for all DDC controllers, gateways, routers, hubs, field level components, panels and enclosures, etc., Labeling shall meet, at minimum, the following requirements:
   1. Plastic laminated label that shall be affixed to the panel or enclosure with rivets or permanent adhesive.
   2. Lettering 6mm (0.25 inch) high that sharply contracts the background color.
   3. Consistent throughout the project.
   4. Indicated on the record (close-out) documentation.

B. Provide labeling of all cabling and containment. Labeling shall meet, at minimum, the following requirements:
   1. Identified with permanent tag or self-adhesive label within the panel.
   2. Cross referenced on the associated record (close-out) documentation and laminated record drawing within the panel enclosure.
   3. The BMS Contractor shall provide labeling for all cable furnished and installed by the BMS Contractor.

2.8 PANEL AND ENCLOSURES

A. Install equipment (servers, printers, routers, etc.) in a secure, lockable Hoffmann enclosure, suitable for mounting peripheral equipment and data network equipment. Enclosure will be free-standing, with a minimum height of 4.5 foot from finish floor.

B. Servers shall be installed physically separate from each other.

C.

D. Provide panels and enclosures for all components of the BMS except where it is specifically identified within these contract documents that the enclosure shall be furnished by another trade. Panels and enclosures shall meet, at minimum, the following requirements:
1. Painted steel panels with locking door. All panels shall be lockable with the same key.
2. Ventilated to prevent excessive heat buildup, where required.
3. Field cabling shall be terminated on a separate panel mounted terminal strip for. interconnection to controller and I/O point modules wire terminals. Provide cable support.
4. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal or replacement.
5. Panel or enclosure shall be suitable rated for the environment for which it is to be installed, Interior enclosures shall he, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.
6. Panel or enclosures shall have 25% spare space for future addition of BMS controllers.

E. Panels and enclosures shall only be located as indicate on the drawings and at Engineer approved locations.

F. The BMS Contractor shall coordinate with the trade furnishing the motor starters and variable frequency drives to provide an interface terminal strip (for BMS Contractor use) in a dedicated external enclosure or may be a compartment within the motor starter enclosure. Refer to the sub-contract documents for the trade furnishing the motor starter and the variable frequency drive controllers for the details of the enclosure. DDC controllers shall not be located in the MCC panels.

2.9 CONDUIT AND FITTING

A. The BMS Contractor shall provide conduit and fittings as necessary for a fully functioning system as detailed in these specifications.

B. Flexible metallic rustproof conduit shall be provided for the final one (1) meter before connection from a non-vibrating location to equipment subject to vibration or movement. Flexible metallic conduit shall be provided for between the last 300mm and the last l000mm of connection to field instrumentation, relays and final control elements as necessary to facilitate the removal of devices without the disconnection or the bending of the non-flexible conduit. Watertight conduit to be provided where appropriate.

C. Conduit shall be securely mounted in accordance with IEEE Regulations and shall be concealed in all, areas to which the public have access.

D. Conduit shall run parallel or perpendicular to the building lines and shall be installed in a workmanlike manner. Avoid obstructions and crossovers where possible.

E. Conduit shall be installed such that any condensation in the conduit cannot run into BMS equipment. Where necessary conduit shall enter enclosures from the bottom or shall be sloped up to the enclosure.

F. Junction and pull boxes shall be securely fastened to the conduit and be accessible where required by code or where necessary to facilitate the pulling of cables.

G. Coordinate installation of conduit with building structure and other trades.

H. Containment shall be provided, for all BMS cable. .

I. Signal wiring and cables shall be installed in minimum sized raceways and/or electric metallic tubing (EMT) where required by local code authorities.

J. Following shall be minimum approved raceways for their specific application (no exceptions):
  1. EMT: All interior building locations.
  2. Rigid Conduit: Building exterior.
  3. Plenum rated cable freely run in concealed ceiling plenums is not acceptable for any applications on this project.
  4. Refer to Division 26 specification for strict project electrical requirements.

K. Refer to electrical specification 26 00 00 series for all wiring, conduit and installation requirements.

2.10 CABLE – COPPER

A. Provide all cables for the BMS Automation and Field levels, including all cables to interconnect the BMS Management level devices and the BMS Management level Network as detailed in these specifications. Cables shall meet, at minimum, the following requirements:
  1. Minimum 98% conductivity copper.
  2. Stranded conductors.
  3. Proper impedance for the application as recommended by the BMS component manufacturer.
  4. Monitoring and control cable shall be screen #18 AWG (1.02362 mm) or larger dependent on the application.
  5. LAN cable shall be screened #24 AWG (0.51054 mm) CAT 6 or twisted pair as identified elsewhere in these documents.

6. All monitoring and control cable shall be screened with the screen earthed at the CCP, DDCP, UC or control panel end only so as to avoid earth loops.
7. Continuous runs without splices.
8. Identification of each end at the termination point. Field identification of all BMS cables shall correspond to the record drawings.
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked. Use unique color schemes for easy identification and prevention of inadvertent splicing of cabling. If there no conflict with existing color schemes, the color for exposed cable shall be purple.

B. Power wiring shall be sized in accordance with the applicable codes and shall be a minimum of # 12 AWG (1.62814 mm) stranded copper. The Electrical contractor shall provide all power cable and containment and shall terminate the dedicated power cable at a power outlet nearest to the BMS component to be powered. The BMS Contractor shall be responsible to provide final power terminations (120VAC and 24 VAC) to all devices, DDC panels, terminal box controllers, control valves, etc. The Electrical contractor shall terminate the power cable at the MCC/distribution board as applicable. The BMS Contractor shall coordinate all BMS equipment power requirements at all BMS equipment locations with the Electrical contractor.

C. The BMS Contractor shall provide all step-down transformers (120VAC and 3 phase primary step down to 24VAC) as required for all devices and controllers.

D. The BMS Contractor shall provide power connection and step-down transformers from FCU and FPVAV terminal box motors to 24 VAC terminal equipment controllers.

E. All field level cables shall be Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit as specified in Division 26.

F. Terminations shall be mechanically and electrically secure. Twist type wire nuts shall not be acceptable. Insulated tinned copper lugs shall be provided.

G. Cable within panels or enclosures shall be installed in wiring guides.

H. .All wiring terminations from field devices and within field panels shall be terminated at panel terminal strips and shall be marked by identification tags on each end of the cable at each terminal strip. All termination strips shall be labeled.

I. Cable run in conduit in vertically shall have means of cable support, at minimum, every 3 m.

J. Cables shall comply with all applicable codes including, but not limited to, the IEEE wiring regulations latest edition and the electrical sub-contract documents. Where there is a conflict between any codes, standards, ordinances, regulations or the requirements of the jurisdiction having authority, the most stringent requirements shall apply. BMS Contractor shall provide cable testing report prior to and after installation.

2.11 NOT USED

2.12 UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. The BMS contractor shall provide local uninterruptible power (1/2 hour rated) for all BMS ~~components, such as~~ CCP and, DDCP panels. ,~~ routers, gateways, field instrumentation, final control elements etc., as necessary to ensure continuous monitoring and control by the BMS and the associated satellite OIW of all equipment that operates on emergency power~~. The BMS shall monitor a trouble alarm from each DDC panel UPS. BMS Contractor to provide 2 hour rated UPS for all new workstations located in CEP and the North Terminal Maintenance Control Room. The BMS shall monitor a trouble alarm from each workstation and server UPS.

2.13 NOT USED

2.14 OPERATOR INTERFACE WORKSTATIONS (OIW)

A. Refer to Contract drawings for locations & quantities.

B. The OIW shall comprise of a PC and associated peripheral operator I/O devices.

C. The OIW PC, shall have a Microsoft Windows 10 Professional 64-bit operating system or the latest version of this software at the time of implementation. The workstations and server shall be furnished by GOAA. The BMS Contractor shall be responsible to coordinate workstation and server hardware and microprocessor features and requirements with GOAA. The BMS Contractor is responsible to provide, install and test all software on GOAA furnished equipment required for a “turnkey” installation.

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D. Universal power supply – sine wave type, with sufficient backup battery capacity to last through a 60 minute power failure.

E. Provide an alarm to uniquely identify a PC communication failure. One way that this might be accomplished is by using a watchdog timer at a DDC controller.

F. Following an extended power failure, all PCs shall return to a fully operational status without operator intervention within two (2) minutes of the return of mains power. Software changes, including modifications to database(s), shall not be lost in a power failure.

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G. The following peripheral I/O devices shall be provided by BMS Contractor at each OIW:
1. Keyboard and mouse.
2. Two – 42-inch diagonal (minimum) 4K, Industrial-grade, Black colored frame, Flat panel LCD video display units.
3. Report printer
4. Alarm printer

H. The BMS OIW at each location shall have one (l) Report Printer and one (1) Alarm Printer. Where there are multiple OIW at one location, Report and Alarm printers shall be networked such that they are available to each OIW.

I. The operator interfaces for the Operator Interface Workstation (OIW) and the Portable Operator Terminal (POT) shall be the same.

2.15 PERIPHERAL OPERATOR I/O DEVICES

A. Printers: General
1. The operator shall able to direct the hardcopy output to any printer. The BMS Contractor shall set up the system such that all BMS generated messages such alarms, returns to normal, etc. are directed to the appropriate alarm printers and all BMS automatically generated and operator requested reports are output to the appropriate report printer.
2. The printers at one location shall be accessible from any OIW such that an operator at one location can generate a hardcopy message at any other location.

B. Report Printers:
1. The report printer shall meet, at minimum, the following specifications:
   a. Minimum print speed of twelve pages per minute black and three pages per minute color. Slower speed printers shall not be acceptable when printing in normal quality.
   b. Scalable fonts.
   c. Single or double bin paper trays, capable of printing A3 size (297mm x 420mm) and A4 size (210 mm x 297 mm).

d. Page feed and page discharge controls.
e. Color and black and white printing capacity without changing ink or toner cartridges.
f. 1200 dpi black and white and 60 x 300 dpi color.
g. LaserJet technology.

C. Keyboard:
1. Provide a keyboard for operator access at each OIW and data server location. This shall be in addition to any other operator input device such as a mouse.
2. The keyboard shall be in a standard typewriter (QWERTY) configuration with a full alphanumeric standard ASCII character set and with additional dedicated keys for other functions associated with the BMS such as print screen. Keyboard shall be wireless. Provide batteries sufficient for 24 months operation.

D. Mouse:
1. Provide a mouse at each OIW and data server and configure the system such that cursor control can be undertaken from both the keyboard and mouse as selected by the operator.
2. Mouse shall be wireless. Provide batteries sufficient for 24 months operation.

2.16 PORTABLE OPERATOR'S TERMINAL (POT)

A. The POTs devices shall not be used by the BMS Contractor for commissioning the BMS or for any other purpose and shall be delivered new to the Owner immediately prior to BMS acceptance testing. Provide one (1) unit.

B. Provide a jack at each DDC controller and at each mechanical and electrical room for the plug connection of the POT. Provide two spare cables for plug connection for each POT. The operator shall be able to communicate with the BMS via the POT using the same operator interface as that at any OIW PC.

C. The POT shall meet, at minimum, the following requirements:
1. Microsoft Windows 10 Professional 64-bit operating system or the latest version of this software at the time of implementation.
2. Intel Core i7 motherboard, 16 Gigabyte RAM memory capability.
3. Minimum Processor speed of 3.0 GHz.
4. 1 – 512 Gigabyte M.2 SSD.
5. 1 Terabyte SATA hard disk.
6. 16 Gigabytes DDR4 2133MHz SDRAM memory (2 x 8GB).
7. 100/1000 Mbps Ethernet adapter.
8. 17 inch minimum touch screen display (1920 x 1080 resolution).
9. Internal analog 56Kbps modem.
10. Multi DVD burner drive (interchangeable).
11. Microsoft Intelli-mouse.
12. Integral power supplies which shall be suitably used for the service.
13. Full size integral QWERTY keyboard with full ASCII character set.
14. Weight, including carrying case, not to exceed 7.0 lbs.

15. Provide a carrying case designed specifically for the POT that ensures adequate protection.
16. POT shall be powered by a rechargeable battery and shall also be powered by a 120 Vac, nominal 60 Hz source. Provide batteries adequate for a minimum of 4 hours of operation.

D. When connected to the BMS Automation Level at the DDC controllers or at a network data port, the POT shall be able to undertake all of the control and monitoring functions that can be performed at the OIW. One of the POT shall be used to configure the system components.

E. All POTs shall be the latest model at the time of purchase and shall be from a recognized manufacturer of PCs. Purchase of the POTs shall be delayed until the latest time possible without causing a delay in the BMS installation schedule in order to ensure that it is state-of-art and is based on the latest proven technology prior to purchasing. All POTs shall be suitable for rugged and continuous operation.

F. The operator interfaces for the Operator Interface Workstation (OIW) and the Portable Operator Terminal (POT) shall be the same.

2.17 SYSTEM SOFTWARE

A. General
1. All necessary software to form a complete operating system as described in this specification shall be provided.
2. The software programs specified in this section shall be provided as an integral part of the DDC controller and shall not be dependent upon any higher level computer for execution.

B. Control Software Description:
1. Pre-Tested Control Algorithms: The DDC controllers shall have the ability to perform the following pre-tested control algorithms:
   a. Two Position Control
   b. Proportional Control
   c. Proportional plus Integral Control
   d. Proportional, Integral, plus Derivative Control
   e. Automatic Control Loop Tuning
2. Equipment Cycling Protection: Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
3. Heavy Equipment Delays: The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
4. Power fail Motor Restart: Upon the resumption of normal power, the DDC 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. (i.e. - Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System).

5. Sequential Start: Provide sequential start for all equipment. After a power failure, and after restoration of normal power, equipment shall start per a predetermined sequence as programmed via the BMS.

C. Energy Management Applications: DDC controllers shall have the ability to perform any or all of the following energy management routines:
   1. Time-of-Day Scheduling.
   2. Calendar Based Scheduling.
   3. Holiday Scheduling.
   4. Temporary Schedule Overrides.
   5. Optimal Start/Optimal Stop.
   6. Night Setback Control.
   7. Peak Demand Limiting.
   8. Energy Usage & Demand.
   9. Fan Speed/CFM Control.
   10. Heating/Cooling Interlock.
   11. Supply Air Reset.
   12. Chilled Water Reset.
   13. Condenser Water Reset.
   14. Chiller Sequencing.

D. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in the Execution portion of this specification.

E. Custom Process Programming Capability: DDC controllers shall be able to execute custom, job-specific processes defined by the operator, to automatically perform calculations and special control routines.
   1. Process Inputs and Variables: It shall be possible to use any of the following in a custom process:
      a. Any system-measured point data or status.
      b. Any calculated data.
      c. Any results from other processes.
      d. User-Defined Constants.
      e. Arithmetic functions (+,-,*, /, square root, exponential, etc.).
      f. Boolean logic operators (and, or, exclusive or, etc.).
      g. On-delay/Off-delay/One-shot timers.
   2. Process Triggers: Custom processes may be triggered based on any combination of the following:
      a. Time interval.
      b. Time of day.
      c. Date.
      d. Other processes.
      e. Time programming.
      f. Events (e.g., point alarms).
      g. Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System (FAS).

F. Dynamic Data Access: A single process shall be able to incorporate measured or calculated data from any and all other DDC controllers on the local area network. In addition, a single process shall be able to issue commands to points in any and all other DDC panels on the local area network.

G. Advisory/Message Generation: Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device, buffer the information in a follow-up file, or cause the execution of a dial-up connection to a remote device such as a printer.

H. Custom Process Documentation: The custom control programming feature shall be self-documenting. All interrelationships defined by this feature shall be documented via graphical flowcharts and English language descriptors.

I. Alarm Management: Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each DDC controller shall perform distributed independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall the DDC's ability to report alarms be affected by either operator activity at a PC Workstation or local I/O device, or communications with other panels on the network. Each analog input shall have associated alarm and pre-alarm (warning) levels that are software adjustable. Provide a minimum of one high alarm, one high warning alarm, one low alarm and one low warning alarm level per analog input.

1. Point Change Report Description: All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
2. Prioritization: The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Each DDC shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point as well as be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.
3. Report Routing: Alarm reports, messages, and files will be directed to a user-defined list of operator devices or PC disk files used for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.
4. Alarm Messages: In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a minimum 65-character alarm message to more fully describe the alarm condition or direct operator response. Each standalone DDC shall be capable of storing a library of at least 250 Alarm Messages which are assignable to any number of points in the panel.
5. Auto-Dial Alarm Management: In Dial-up applications, only critical alarms shall initiate a call to a remote operator device. In all other cases, call activity shall be minimized by time-stamping and saving reports until an operator scheduled time, a manual request, or until the buffer space is full. The alarm buffer must store a minimum of 50 alarms.
6. Transaction Logging: Operator commands and system events shall be automatically logged to disk in Personal Computer industry standard database

format. Operator commands initiated from Direct-connected workstations, dial-up workstations, and local DDC panel Network Terminal devices shall all be logged to this transaction file. This data shall be available at the Operator Interface Workstation (OIW). Facility shall be provided to allow the user to search the transaction file using standard database query techniques, including searching by dates, operator name, data point name, etc. In addition, this transaction file shall be accessible with standard third party database and spreadsheet packages.

J. Historical Data and Trend Analysis: A variety of historical data collection utilities shall be provided to automatically sample, store, and display system data in all of the following ways:
   1. Continuous Point Histories: Standalone DDC's shall store Point History Files for all analog and binary inputs and outputs. The Point History routine shall continuously and automatically sample the value of all analog inputs at half hour intervals. Samples for all points shall be stored for the past 24 hours to allow the user to immediately analyze equipment performance and all problem-related events for the past day. Point History Files for binary input or output points and analog output points shall include a continuous record of the last ten status changes or commands for each point.
   2. Control Loop Performance Trends: Standalone DDC's shall also provide high resolution sampling capability in one-second increments for verification of control loop performance.
   3. Extended Sample Period Trends: Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting operator-specified performance data over extended periods of time. Sample intervals of 1 minute to 2 hours shall be provided. Each standalone DDC shall have a dedicated buffer for trend data, and shall be capable of storing a minimum of 5000 data samples. The system shall have the capability of trending and storing all data points.
   4. Data Storage and Archiving: Trend data shall be stored at the Standalone DDC's, and uploaded to hard disk storage when archival is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers become full. All trend data shall be available in disk file format compatible with Third Party personal computer applications.

K. Runtime Totalization: Standalone DDC panels shall automatically accumulate and store runtime hours for binary input and output points as specified in the Execution portion of this specification.
   1. The Totalization routine shall have a sampling resolution of one minute or less.
   2. The user shall have the ability to define a warning limit for Runtime Totalization. Unique, user-specified messages shall be generated when the limit is reached.

L. Analog/Pulse Totalization: Standalone DDC's shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.
   1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g. KWH, gallons, KBTU, tons. etc.).
   2. The Totalization routine shall have a sampling resolution of one minute or less.

3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

M. Event Totalization: Standalone DDC panels shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly, or monthly basis.
   1. The Event Totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.
   2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

N. Operator Interface Workstation (OIW) Software (resident on each operating workstation):
   1. Operator Interface Software – General
      a. An integrated software package shall be used as the operator interface program.
      b. All Inputs, Outputs, Setpoints, and all other parameters as defined within Part 3, shown on the design drawings, or required as part of the system software, shall be displayed for operator viewing and modification from the operator interface software.
      c. The operator workstation software shall provide context-sensitive help menus and instructions for each operation and/or application currently being performed.
      d. All controller software operating parameters shall be displayed for the operator to view/modify from the operator workstation. These include: setpoints, alarm limits, time delays, PID tuning constants, run-times, point statistics, schedules, and so forth.
      e. The operation of the control system shall be independent of the operator workstation, which shall be used for operator communications only. Systems that rely on the operator workstation to provide supervisory control over controller execution of the sequences of operations or system communications shall not be acceptable.
   2. Alarms
      a. Each workstation shall receive and process alarms sent to it by the control system. The alarm management portion of the operator workstation software shall, at the minimum, provide the following functions:
         1) Log date and time of alarm occurrence.
         2) Generate a “Pop-Up” window informing an operator that an alarm has been received.
         3) Allow an operator, with the appropriate security level, to acknowledge, delete, or disable an alarm.
         4) Provide an audit trail for alarms by recording operator acknowledgment, deletion, or disabling of an alarm. The audit trail shall include the name of the operator, the alarm, the action taken on the alarm, and a time/date stamp.
         5) Record all alarms received at an operator’s workstation to that workstation’s hard drive.
         6) Allow the operators to view/manage the alarm data archived to hard disk. Selection of a single menu item or tool bar button shall allow the user to acknowledge, disable, delete, or print the selected alarm.

b. Alarms shall be generated by the operator workstation for any controller that is “Off-Line” and is not communicating, or that does not have an active control program loaded.
c. Changes made to alarm setpoints from the Operator Workstation shall directly modify the controller alarm management database.
d. Selection of a single menu item or tool bar button shall print any displayed alarm report on the system printer for use as a building management and diagnostics tool.

3. Reports
   a. Reports shall be generated and directed to one of the following: workstation displays, printers, or disk. As a minimum, the system shall provide the following reports:
      1) All points in the network.
      2) All points in a specific controller.
      3) A listing of a user-defined group of points in the network. There shall be no limit to the number of user-defined groups
      4) All points currently in alarm.
      5) All points in hardware override.
      6) All disabled points.
      7) All weekly schedules.
      8) All or selected point attributes, including, but not limited to:
         a) Values
         b) Setpoints
         c) Alarm Limits
         d) Statistics
         e) Run Times
      9) All programmed holidays and associated schedules.
      10) All disabled alarms.
      11) All active, unacknowledged alarms.
      12) All active, acknowledged alarms.
      13) Any and all other controller operating parameters.
   b. Reports shall be provided for specific point types, for each logical point group, for user-defined groups, or for the entire facility without restriction due to the hardware configuration of the control system or communications network.
   c. The system shall allow for the creation of custom report point groups that shall be capable of including points from multiple controllers. Systems limiting point report displays to only a single controller’s point database shall not be accepted.
   d. The number of custom reports or display groups shall be limited by the amount of available system memory.
   e. Selection of a single menu item, tool bar item, or tool bar button shall print any displayed report on the system printer for use as a building management and diagnostics tool.

4. Schedules
   a. A spreadsheet-type schedule input form for time-of-day scheduling and override scheduling of building operations shall be provided. At a minimum, the following spreadsheet types shall be provided:

1) Weekly schedules, by system.
2) Temporary override schedules, by system.
3) Special “Only Active If Today Is A Holiday” schedules, by system.
4) Monthly calendars.
5) Holiday scheduling system, including the ability to define floating holidays.

b. Weekly schedules shall be provided for each piece of equipment with a specific time use schedule. Each schedule shall include columns for each day of the week, as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting use and non-use times into appropriate information blocks on the spreadsheet.

c. It shall be possible to define one or more master holiday schedules to allow the operator to define in one location the holidays for all associated schedules. Systems requiring the operator to change holiday definitions on a schedule by schedule basis shall not be accepted.

d. Standard weekly schedules shall be inactive on a holiday. The system shall allow the user to include in a schedule group a schedule that will only be active if today is a holiday.

e. In addition, temporary override schedules may be inserted into schedule groups for modifying operating schedules. After overrides have been executed, the original schedule will automatically be restored.

f. Schedules shall be provided for each system or sub-system in the facility. Each schedule shall include all commandable points residing within the system. Each point may have a unique schedule of operation relative to the system use schedule, allowing for sequential starting and control of equipment within the system. Scheduling and rescheduling of points shall be accomplished easily via the system schedule spreadsheets.

g. Monthly calendars for a 12-month period shall be provided that allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device or keyboard, and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

h. Changes to schedules made from the Operator Workstation shall directly modify the controller schedule database. Systems that require permanent schedule changes to be made with a program editor shall not be acceptable.

i. Formatted schedule displays shall be provided for each system. These shall include all schedule data and associated parameters.

j. Selection of a single menu item or tool bar button shall print any displayed schedule on the system printer for use as a building management and diagnostics tool.

5. User Interface:

a. The BMS~~BAS~~ workstation software shall allow the creation of a custom, browser-style interface linked to the user when logging into any workstation. Additionally, it shall be possible to create customized workspaces that can be assigned to user groups. This interface shall support the creation of “hot-spots” that the user may link to view/edit any object in the system or run any object editor or configuration tool contained in the software. Furthermore, this interface must be able to be configured to become a user's "PC Desktop" – with all the links that a user needs to run other applications. This, along with the Windows user security capabilities, will enable a system administrator to setup workstation accounts that not only limit the capabilities of the user within the BMS~~BAS~~ software, but may also limit what a user can do on the PC and/or LAN/WAN. This might be used to ensure, for example, that the user of an alarm monitoring workstation is unable to shutdown the active alarm viewer and/or unable to load software onto the PC.

b. System shall be able to automatically switch between displayed metric vs. imperial units based on the workstation localization.

6. Password
   a. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display, and database manipulation capabilities as he or she deems appropriate for each user, based on an assigned password.
   b. Each user shall have the following: a user name (12 characters minimum); a password (12 characters minimum).
   c. The system shall not allow each user to change his or her user name or password.
   d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
   e. A minimum of 256 unique passwords, including user initials, shall be supported.
   f. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
   g. The system shall automatically generate a report of log-on/log-off and system activity for each user. Any action that results in a change in the operation or configuration of the control system shall be recorded, including: modification of point values, schedules or history collection parameters, and all changes to the alarm management system, including the acknowledgment and deletion of alarms.
   h. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving the operator workstation logged on.
7. Screen Manager - The BMS workstation shall be provided with a screen management application that allows the user to activate, close, and simultaneously manipulate a minimum of 16 windows across a minimum of 3 physical screens.
8. Graphical User Interface (GUI) Software
   a. Operating System: The GUI shall run on the latest Microsoft Windows operating system.
   b. The GUI shall employ browser-like functionality for ease of navigation. It shall include a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. In addition, menu-pull downs, and toolbars shall employ buttons, commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC

Control System and basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.

c. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:
   1) Graphic screens shall be developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.
   2) Graphic screens shall have the capability to contain objects for text, real-time values, animation, color spectrum objects, logs, graphs, HTML5 or XML document links, schedule objects, hyperlinks to other URL's, and links to other graphic screens.
   3) Graphics shall support layering and each graphic object shall be configurable for assignment to a layer. A minimum of six layers shall be supported.
   4) Modifying common application objects, such as schedules, calendars, and set points shall be accomplished in a graphical manner.
   5) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
   6) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
   7) Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
   8) Adjustments to analog objects, such as set points, shall be done by right-clicking the selected object and using a graphical slider to adjust the value. No entry of text shall be required.

d. System Configuration. At a minimum, the GUI shall permit the operator to perform the following tasks, with proper password access:
   1) Create, delete or modify control strategies.
   2) Add/delete objects to the system.
   3) Tune control loops through the adjustment of control loop parameters.
   4) Enable or disable control strategies.
   5) Generate hard copy records or control strategies on a printer.
   6) Select points to be alarmable and define the alarm state.
   7) Select points to be trended over a period of time and initiate the recording of values automatically.

e. Symbol library – The BMS system shall be provided with a very complete symbol library containing all of the basic symbols used to represent HVAC, Fire, and Security components of a typical BMS system.

f. Symbols shall be able to be added to any graphic display being constructed by simply dragging the symbol from the library to the graphic under construction.

g. Creating symbols – The user shall be able to add any number of new symbols to the symbol library. Symbol generation shall include all of the abilities described for the graphic editor.

9. Historical trending and data collection
   a. Each Network Controller shall store trend and point history data for all analog and digital inputs and outputs, as follows:
      1) Any point, physical or calculated, may be designated for trending. Three methods of collection shall be allowed: Defined time interval, upon a change of value and whenever a value is out of range.
      2) Each network controller shall have a dedicated RAM-based buffer for trend data, and shall store 10,000 samples for each physical point and software variable, including an individual sample time/date stamp. Points may be assigned to multiple history trends with different collection parameters.
   b. Trend and change of value data shall be stored within the controller and then uploaded to the trend database(s). Uploads shall occur based upon one of the following: user-defined interval, manual command, or when the trend buffers are full.
   c. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in Microsoft Access, SQL, HTML or XML database format.
   d. To enable users to easily access stored data, the system shall provide the capability to store historical data in more than one file system (i.e., removable media, separate hard drives, or a remote network file system).
   e. Provide the capability to perform statistical functions on the historical database without having to design special queries. On a specified data interval, provide functions for calculating:
      1) Average.
      2) Arithmetic mean.
      3) Maximum/minimum values.
      4) Range – difference between minimum and maximum values.
      5) Standard deviation.
      6) Sum of all values.
      7) Variance.

10. Trend data viewing and analysis
   a. Provide a trend viewing utility that shall have access to all database points.
   b. Provide database access through an Open Database Connectivity (ODBC) interface – a standard Application Programming Interface (API) for accessing data from relational databases. Client applications can reside within a Windows 10 Professional.
   c. It shall be possible to retrieve any historical database point for use in displays and reports by specifying the point name.
   d. The trend viewing utility shall have the capability to view up to 100 data sources at one time in a tabular or graphical format.
   e. Graphic displays shall be able to be single or stacked graphs with on-line selectable display characteristics, such as ranging, color, and plot style.
   f. It shall be possible to display trend data in histogram (X-Y plots) format as well as area and bar graphs.

g. Display magnitude and units shall both be selectable by the operator at any time without reconfiguring the processing or collection of data. This is a zoom capability.
h. Display magnitude shall automatically be scaled to show full graphic resolution of the data being displayed. This function shall also be operator selectable.
i. The display range shall consist of magnitude and units fields. The units are seconds, minutes, hours, days, and months.
j. Provide a wild card capability when specifying a display range for data retrieval within the historical database. Wild carding will allow the user to easily specify relative time based date ranges for the retrieval of data.
k. A time-offset capability shall be available to assist in a user’s analysis. The offset visually shifts the data being displayed to allow a user to concurrently view information without having to scroll the display.
l. The system shall be capable of printing a hard copy record of the trends as they are displayed on the workstation.

O. Energy Usage Dashboard Graphical User Interface:
1. Provide separate “dashboard” dynamic system animation colorgraphics for the on-going accountability of building energy usage over time as required for LEED energy usage accounting (Point and click icon on building BMS navigation page for graphics and reports). Provide dynamic historical trending and totalization of each piece of equipment (energy use by each component). GUI shall totalize data for the continuous monitoring of metering equipment for constant (KWH/BTU’s via runtime) and variable motor loads, variable frequency drive operation (KWH/BTU’s, building lighting panel load (each building),, building receptacle panel load (each building), electric heaters via integration with BMS integration with the VFD). Energy usage data shall be graphically represented for each systems daily energy usage, weekly energy usage, monthly energy usage and yearly energy usage. Energy usage shall be retrievable for any day, month or year. The BMS shall collect energy meter and other energy usage data shall be totalized and recorded in 15 minute intervals (adjustable-to 1 minute). Report generation shall be via a single screen interface.

P. Integration
1. Open, Interoperable, Integrated Architectures
a. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system utilizing ANSI/ASHRAE SSPC/135 (BACnet) communication protocol in an open, interoperable system.
b. In addition, adherence to BACnet industry standard ANSI / ASHRAE SSPC/135 to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a PICS document showing the installed device’s compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet.
c. All components and controllers supplied under this contract shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.

d. The supplied system must incorporate the ability to access all data using Java enabled browsers without requiring proprietary operator interface and configuration programs. An Open Database Connectivity (ODBC), Open Process Control (OPC) DX and Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.

e. Protocols: The following standard control protocols shall be provided for Programmable Logic Controller (PLC) and Direct Digital Control (DDC) platforms for control and data acquisition:
   1) ModBus (IP, RS-485 RTU)
   2) BACNet (IP, MSTP)
   3) TCP/IP

f. A network topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network.

g. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 5 seconds for network connected user interfaces.

h. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.

2. Third Party Communication Software

a. Provide direct Protocol Integration software to allow bi-directional data communications between the BMS system and 3rd party manufacturers' control panels. The BMS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, , variable frequency drives, EMMS, , , , lighting systems, etc. Refer to Section 1.6 (Scope of Work).

b. All data required by the application shall be mapped into the Network Controller's database, and shall be transparent to the operator.

c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with BMS software features such as: Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Dial-Up and Local Area Network Communications.

d. The Building Management System shall provide any combination of third-party controllers on a single network. . Integration shall be via BACnet or Modbus. .

e. The system operator shall have the ability to verify, and diagnose communication messages and point information between third-party controllers and the BMS.

2.18 NETWORK SERVER CONTROLLERS

A. Automation Server's 1.5 (Or Equal)

1. Automation Server
2. Terminal Base AS
3. PS-24V Power Supply
4. Terminal Base Power

B. Manage multiple Automation Servers for large installations - maintaining all of the same features as the AS including alarming, scheduling, trend logging, function block, and script

C. Safely manage account and database information with fully secure integration into Windows Domain user accounting, making one less IT admin tool, and ensuring policy adherence

D. Complete audit trail records changes, time, and user to facilitate thorough post situation analysis

E. New server and workstation for the South Terminal BMS shall be located in the North Terminal Maintenance Control Room. An additional workstation for the South Terminal BMS shall located in the new Central Energy Plant (CEP). Location of workstations and server to be coordinated and confirmed with GOAA.

F. Network Router Controllers shall combine both network routing functions, control functions, and server functions into a single unit.

G. The BACnet NSC shall be classified as a “native” BACnet device, supporting the BACnet Network Server Controller (B-BC) profile. Controllers that support a lesser profile such as B-SA are not acceptable. NSCs shall be tested and certified by the BACnet Testing Laboratory (BTL) as BACnet Network Server Controllers (B-BC).

H. The Network Server Controller shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control functions over the control devices connected to the NRS.

I. They shall also be responsible for monitoring and controlling their own HVAC equipment such as an AHU or boiler.

J. They shall also contain graphics, trends, trend charts, alarm views, and other similar presentation objects that can be served to workstations or web-based interfaces. A sufficient number of NSCs shall be supplied to fully meet the requirements of this specification and the attached point list.

K. It shall be capable of executing application control programs to provide:

1. Calendar functions
2. Scheduling
3. Trending
4. Alarm monitoring and routing
5. Time synchronization by means of an Internet site including automatic synchronization

6. Native integration of Modbus controller data or BACnet controller data and Modbus controller data

L. Hardware Specifications

1. Memory:

   a. The operating system of the controller, application programs, and all other portions of the configuration database, shall be stored in non-volatile, FLASH memory. Servers/Controllers shall contain enough memory for the current application, plus required history logging, plus a minimum of 100% additional free memory.

2. Each NRC shall provide the following on-board hardware for communication:

   a. One 10/100bT Ethernet for communication to Workstations, other NRCs and onto the Internet
   b. Two RS-485 ports for communication to BACnet MSTP bus or serial Modbus (software configurable)
   c. .
   d. One Device USB port
   e. Two host USB Ports

3. The NSC shall conform to a small footprint no larger than 100W x 125H x 75D mm (3.94W x 4.92H x 2.95D in).

M. Modular Expandability:

1. The system shall employ a modular I/O design to allow expansion. Input and output capacity is to be provided through plug-in modules of various types. It shall be possible to combine I/O modules as desired to meet the I/O requirements for individual control applications.
2. One shall be able to “hot-change” (hot-swap) the I/O modules preserving the system on-line without any intervention on the software; addressing and configuration shall be automatic

N. Hardware Override Switches:

1. All digital outputs shall, ~~optionally~~, include three position manual override switches to allow selection of the ON, OFF, or AUTO output state. These switches shall be built into the unit and shall provide feedback to the controller so that the position of the override switch can be obtained through software. In addition each analog output shall be equipped with an override potentiometer to allow manual adjustment of the analog output signal over its full range, when the 3 position manual override switch is placed in the ON position.

O. Universal Input Temperatures

1. All universal inputs directly connected to the NSC via modular expansion shall be capable of using the following thermistors for use in the system without any external converters needed.

    a. 10 kohm Type I (Continuum)
    b. 10 kohm Type II (I/NET)
    c. 10 kohm Type III (Satchwell)
    d. 10 kohm Type IV (FD)
    e. Linearized 10 kohm Type V (FD w/11k shunt)
    f. Linearized 10 kohm (Satchwell)
    g. 1.8 kohm (Xenta)
    h. 1 kohm (Balco)
    i. 20 kohm (Honeywell)
    j. 2.2 kohm (Johnson)

2. In addition to the above, the system shall be capable of using the below RTD sensors, however it is not required that all universal inputs be compatible with them.

    a. PT100 (Siemens)
    b. PT1000 (Sauter)
    c. Ni1000 (Danfoss)

P. Local Status Indicator Lamps:

1. The NSC shall provide as a minimum LED indication of CPU status, Ethernet LAN status, and field bus status. For each input or output, provide LED indication of the value of the point (On/Off). The LED indication shall support software configuration to set whether the illumination of the LED corresponds to On or Off or whether the color when illuminated is Red or Green.

Q. Real Time Clock (RTC):

1. Each NSC shall include a battery-backed, real time clock, accurate to 10 seconds per day. The RTC shall provide the following: time of day, day, month, year, and day of week. Each NSC will allow for its own UTC offset, depending upon the time zone. When the time zone is set, the NSC will also store the appropriate times for daylight savings time.

R. Power Supply:

1. The 24 VDC power supply for the NSCs shall provide 30 watts of available power for the NSC and associated IO modules. The system shall support the use of more than one power supply if heavily power consuming modules are required.
2. The power supply, NSC, and I/O modules shall connect power wise and communication wise via the separate terminal base allowing for ease of replacement and no separate or loose wiring.

S. Automatic Restart After Power Failure:

1. Upon restoration of power after an outage, the NSC shall automatically and without human intervention update all monitored functions, resume operation based on current, synchronize time and status, and implement special start-up strategies as required.

T. Battery backup:

1. The NSC shall include an on-board battery to back up the controller's RAM memory. The battery shall provide accumulated backup of all RAM and clock functions for at least 30 days. In the case of a power failure, the NSC shall first try to restart from the RAM memory. If that memory is corrupted or unusable, then the NSC shall restart itself from its application program stored in its FLASH memory.

U. Software Specifications

1. The operating system of the controller, application programs, and all other portions of the configuration database such as graphics, trends, alarms, views, etc., shall be stored in non-volatile, FLASH memory. There will be no restrictions placed on the type of application programs in the system. Each NSC shall be capable of parallel processing, executing all control programs simultaneously. Any program may affect the operation of any other program. Each program shall have the full access of all I/O facilities of the processor. This execution of control function shall not be interrupted due to normal user communications including interrogation, program entry, printout of the program for storage, etc.
2. Each NSC shall have an available capacity of 4 GB of memory. This shall represent 2 GB for application and historical data and 2 GB dedicated for backup storage.

V. User Programming Language:

1. The application software shall be user programmable. This includes all strategies, sequences of operation, control algorithms, parameters, and setpoints. The source program shall be either a script-based structured text or graphical function block based and fully programmable by the user. The language shall be structured to allow for the configuration of control programs, schedules, alarms, reports, telecommunications, local displays, mathematical calculations, and histories. Users shall be able to place comments anywhere in the body of either script or function block programs.
2. Network Server Controllers that use a "canned" program method will not be accepted.

W. Control Software:

1. The NSC shall have the ability to perform the following pre-tested control algorithms:

   a. Proportional, Integral plus Derivative Control (PID)
   b. Two Position Control
   c. Digital Filter
   d. Ratio Calculator
   e. Equipment Cycling Protection

X. Mathematical Functions:

1. Each controller shall be capable of performing basic mathematical functions (+, -, *, /), squares, square roots, exponential, logarithms, Boolean logic statements, or combinations of both. The controllers shall be capable of performing complex logical statements including operators such as >, <, =, and, or, exclusive or, etc. These must be able to be used in the same equations with the mathematical operators and nested up to five parentheses deep.

Y. NSCs shall have the ability to perform any or all of the following energy management routines:

1. Time of Day Scheduling
2. Calendar Based Scheduling
3. Holiday Scheduling
4. Temporary Schedule Overrides
5. Optimal Start
6. Optimal Stop
7. Night Setback Control
8. Peak Demand Limiting
9. Temperature Compensated Duty Cycling
10. CFM Tracking
11. MER Space Pressurization Control
12. Heating/Cooling Interlock
13. Hot Water Reset
14. Chilled Water Reset
15. Condenser Water Reset
16. Chiller Sequencing

Z. History Logging:

1. Each NSC controller shall be capable of LOCALLY logging any input, output, calculated value or other system variable either over user defined time intervals ranging from 1 second to 1440 minutes or based upon a user configurable change of value. A minimum of 1000 logs, with a minimum of 100,000 records, shall be stored. Each log can record either the instantaneous, average, minimum or maximum value of the point. Logged data shall be downloadable to a higher level NSC long term archiving based upon user-defined time intervals, or manual command.
2. For extended trend logging a minimum of 1500 trends shall be capable, with a minimum number of 600,000 records within.
3. Management of a power meter replacement to ensure meter log data is accurate shall be possible in the NSC.
4. Every hardware input and output point, hosted within the NSC and attached I/O modules, shall be trended automatically without the requirement for manual creation, and each of these logs shall log values based upon a change of value and store at least 500 trend samples before replacing the oldest sample with new data.

5. The presentation of logged data shall be built into the server capabilities of the NSC Presentation can be in time stamped list formats or in a chart format with fully configurable pen colors, weights, scales and time spans.

AA. Alarm Management:

1. For each system point, alarms can be created based on high/low limits or in comparison to other point values. All alarms will be tested each scan of the NSC and can result in the display of one or more alarm messages or reports.
2. There is no limit to the number of alarms that can be created for any point
3. Alarms can be configured to be generated based upon a single system condition or multiple system conditions.
4. Alarms will be generated based on an evaluation of the alarm conditions and can be presented to the user in a fully configurable order, by priority, by time, by category, etc.
5. The alarm management system shall support the ability to create and select cause and action notes to be selected and associated with an alarm event. Checklists shall also be possible in order to present to an operator a suggested mode of troubleshooting. When acknowledging an alarm, it shall be possible to assign it to a user of the system such that the user is notified of the assignment and is made responsible for the alarm resolution.
6. Alarms must be capable of being routed to any BACnet workstation that conforms to the B-OWS device profile and uses the BACnet/IP protocol.

2.19 BMS CONTROLLERS: GENERAL

A. There shall be 3 types of BMS control panels:
1. Communications Control Panels (CCP).
2. Direct Digital Control Panels (DDCP).
3. Unitary Controllers (UC).

B. All BACnet controllers shall be based on native BACnet and shall support all applicable BIBBs from the data sharing, alarm event, schedule, trend and device manager groups. Standard BACnet object types supported by the controllers shall include:
1. Binary input and output and value.
2. Analog input, output and value.
3. Multi-state input and output.
4. Loop calendar, notification class, command, file, program, schedule, group, event enrollment and device.
5. Proprietary object types shall not be used unless specifically approved by the Engineer.

C. All Controllers shall have a minimum of 10-bit Input /Output resolution.

D. Following a loss of power the PC, CCP, DDCP and UC shall reboot in an orderly fashion and attain a normal operating status within 2 minutes of the return of power. That shall be accomplished without operator intervention.

2.20 COMMUNICATION CONTROL PANELS (CCP)

A. The Communication Control Panels shall be programmable controllers on the BMS primary LAN and shall undertake two roles:
   1. Gateway interface to third-party controllers, if the data communicated from the third party system cannot be provided in the form of BACnet Objects.

B. The CCP shall incorporate software as necessary to provide communications on the network including Network interface Cards if necessary. Additionally, if the CCP acts as a gateway, then the CCP shall incorporate all software as necessary to perform this function including any change of protocol between the networks. The BMS Contractor shall provide all third-party controller gateways and complete software/hardware documentation.

C. Communication Control Panels shall also meet the following requirements:
   1. Provide integral network communication connections.
   2. CCP shall be totally independent of any other LAN/BMS Management Level Network nodes for their operating functions.
   3. CCP failure shall not place any BMS component or any component controlled by the BMS in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a CCP shall not affect the operation of any other network node.
   4. The failure of any CCP shall be annunciated as a critical alarm at the OIW.
   5. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
   6. Each CCP shall have, at minimum, a 32 bit microprocessor.
   7. All CCP shall be powered from a UPS source, but memory shall be battery-backed RAM. Battery shall be rechargeable with a minimum life of 7 years and shall be capable of providing data retention for a minimum of 60 days.
   8. Provide a real-time clock at each CCP. The real-time clock at the CCP shall be synchronized at least once every 24 hours.
   9. Provide a hardware or software watchdog timer.
   10. Provide interoperability documentation for the CCP. All the data related to the CCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the CCP with another system in the future. This may be part of the overall interoperability documentation.
   11. The CCP shall have a port for the connection of POT.

D. The CCP shall be housed in the enclosure panels as detailed in the “Panels and Enclosures” Paragraph.

E. Diagnostics – Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

F. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.21 DIRECT DIGITAL CONTROL PANELS (DDCP)

A. The BACnet IP DDCPs shall be standalone, shall reside on the Automation Level and shall meet the following requirements:

1. DDCP controllers shall be freely programmable and shall have an I/O capability to handle major items of equipment such as air handling units.
2. DDCP shall interface via Point Interface Modules (PIM) to the field instrumentation and final control elements.
3. DDCP may be used for any equipment monitored and controlled by the BMS. A dedicated DDCP shall be provided at minimum to monitor and control the following:
    a. A Single Air Handling Unit (each AHU shall have a dedicated DDCP).
    b. Other major items of equipment.
4. The DDCP shall control its own communications so that the failure of any one node, including any PC shall not inhibit communications on the network between the remaining nodes. Provide integral network communications connections.
5. DDCP shall be totally independent of any other primary and secondary LAN nodes for their monitoring and control functions. DDCP shall monitor and control entire systems, multiple DDCP for a single system shall not be allowed.
6. Where a DDCP receives data from other nodes, such as an outdoor air temperature, which is used for a global system program strategy executed at that DDCP, then alternative control strategies shall be automatically initiated, based on operator definable default values, if there is a loss of communication of the required data.
7. DDCP failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a DDCP shall not affect the operation of any other network node.
8. The failure of any DDCP shall be annunciated as a critical alarm at the OIW.
9. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
10. Each DDCP shall have its own power supplies that shall be rated such that they will adequately accommodate all foreseeable uses of the DDCP.
11. Each DDCP shall have, at minimum, a 32 bit microprocessor.
12. All operating sequences, schedules and trend data for equipment controlled by the DDCP shall reside at the DDCP.
13. Provide each DDCP with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Provide a 10-hour minimum full function, battery support capability.
14. Provide a real-time clock, at each DDCP. The real-time clock at the DDCP shall be synchronized at least once every 24 hours.

15. The DDCP shall have a port for the connection of the POT.
16. DDCP shall be housed in enclosures that shall meet the requirements detailed in Section titled “Panels and Enclosures” of these specifications. The DDCP shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation, including any current sensing relays in the MCC panels, and the DDCP shall be by the BMS Contractor.
17. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
    a. Enable the DDCP to receive signals from the digital and analog instrumentation.
    b. Enable the DDCP to output control signals to the final control elements.
18. PIM shall be incorporated into the DDCP by one or the following methods:
    a. Plug-in type modules with specific or universal input/output capabilities.
    b. Integral to the DDCP controller board.
19. PIM shall accommodate the following point types:
    a. Analog and digital inputs.
    b. Analog and digital outputs.
    c. Pulse inputs.
20. Analog input PIM shall have a minimum 10-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.
21. Analog output PIM shall have a minimum 10-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.
22. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.
23. All PIM shall be easily exchanged and the failure of one PIM shall not affect any other PIM. Field terminations shall be such that the removal of a failed PIM shall not require the removal and reconnecting of field device cable terminations.
24. All PIM shall be such that all output points can be manually positioned via an on board on-off-auto or potentiometer dial as applicable to the individual point.
25. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.
26. DDCP mounted on vibrating equipment, such as an air handling units, shall have vibration isolation protection that ensures their satisfactory operation.
27. DDCP shall have optic-isolation or equivalent.
28. DDCP shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.
29. The BMS Contractor shall provide interoperability documentation for the DDCP. All the data related to the DDCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the DDCP with another system in the future. This may be part of the overall interoperability documentation.

2.22 UNITARY CONTROLLERS (UC) – GENERAL

A. Unitary Controllers (UC) shall be “freely programmable” controllers with pre-packaged operating sequences maintained in EEPROM or flash EPROM.

B. Unitary controllers shall reside at the BMS Automation Level.

C. Customization of “freely programmable” controllers shall be possible to the extent that variable operating parameters, such as sequences of operation, setpoints, control loop parameters, control constants, and schedules shall be changeable on-line by the OIW operator.

D. UC shall reside on a BACnet MSTP BMS LAN.

E. UC shall provide an interface via PIM to the field instrumentation and final control elements of the following types of equipment:
1. One (1) Fan Powered VAV terminal unit with or without Electric Reheat
2. One (1) Fan Coil Unit with or without Electric Reheat
3. One (1) VAV terminal unit (cooling only).
4. Up to Six (6) miscellaneous fans.
5. Up to Four (4) miscellaneous pumps.
6. Up to Two (2) self-contained A/C units.
7. Miscellaneous equipment input monitoring.

F. Panels meeting the requirements of DDCP shall control all other types of ‘equipment and systems.

G. The UC shall be a node on the primacy BMS LAN. The UC shall control its own communications so that the failure of any one node shall not inhibit communications on the network between the remaining nodes and the BMS Management Level Network.

H. UC shall be totally independent of other Management and BMS Automation Level components for their monitoring and control functions.

I. UC failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a UC shall not affect the operation of any other network node.

J. The failure of any UC shall be annunciated as a critical alarm at the OIW.

K. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.

L. UC shall be powered from the electrical service that serves the equipment monitored and controlled by the UC. The BMS Contractor shall furnish transformers suitably rated for the application. The UC shall be housed in an enclosure that provides adequate physical and electrical protection.

M. Each UC shall have, at minimum, an 8 bit microprocessor.

N. Provide each UC with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Batteries shall be rated for a 7 year life. The UC serving VAV terminal units and FCU shall not be placed on UPS power.

O. Provide a real time clock at each UC. The real-time clock at the UC shall be synchronized from the real-time clock at the BMS Network Data Servers (NDS) at least once every 24 hours.

P. UC shall be housed in enclosures that shall meet the requirements detailed in Section titled “Panels and Enclosures” of these specifications. The UC shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation and the UC shall be by the BMS Contractor.

Q. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
   1. Enable the UC to receive signals from the digital and analog instrumentation.
   2. Enable the UC to output control signals to the final control elements.

R. PIM shall accommodate the following point types:
   1. Analog and digital inputs.
   2. Analog and digital outputs.
   3. Pulse inputs.

S. Analog input PIM shall have a minimum 8-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.

T. Analog output PIM shall have a minimum 8-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.

U. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.

V. UC shall control and monitor all points associated with a system. Multiple UC shall not be used to control and monitor a single system.

W. All application programs shall reside at the UC.

X. Operating sequences for UC shall be resident at the UC. Database changes shall be undertaken from the OIW and POT. Schedules and trend data shall reside at the UC.

Y. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.

Z. UC mounted on vibrating equipment, such as on FCUs, shall have vibration isolation protection that ensures their satisfactory operation.

AA. UC shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.

BB. The BMS Contractor shall provide interoperability documentation for the UC. All the data related to the UC shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the UC with another system in the future. This may be part of the overall interoperability documentation.

2.23 VAV TERMINAL UNIT CONTROLLER (VAV - UC)

A. General: Ship VAV-UC Controllers to terminal box manufacturer's factory for controller mounting prior to shipping to site. Coordinate with Box manufacturer.

B. The VAV UC shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units.

C. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

D. The VAV UC shall be a configurable digital controller with an integral differential pressure transducer. It shall be compatible with 3 wire (incremental) and proportional damper actuators.

E. The VAV UC shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

F. Each VAV UC shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

G. The VAV UC shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

H. Each VAV UC shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

I. The VAV UC shall provide the ability to download and upload UC configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

J. UC control setpoint changes initiated over the network shall be written to UC non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

K. The VAV UC firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

L. The VAV UC shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

M. The VAV UC shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

N. .

O. The VAV UC performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The UC shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
1. Absolute temperature loop error.
2. Signed temperature loop error.
3. Absolute airflow loop error.
4. Signed airflow loop error.
5. Average damper actuator duty cycle.

P. The VAV UC shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
1. Unreliable space temperature sensor.
2. Unreliable differential pressure sensor.
3. Starved box.
4. Insufficient cooling.
5. Insufficient heating.

Q. The VAV UC shall provide a compliant interface for ASHRAE Standard 62 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

R. The VAV UC shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

S. The VAV UC shall be compatible with the U.S. EPA Energy Star Buildings recommendations for fan energy reduction via demand-based static pressure reset down to 2/3 of duct static pressure set point, “VSD 2/3 Reset.”

T. Inputs:
1. Analog inputs shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
   a. 0-10 VDC Sensors
   b. 4-20 mA Sensors
   c. 1000ohm RTDs
   d. NTC Thermistors
2. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
3. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

U. Outputs
1. Analog outputs shall provide the following control outputs:
   a. 0-10 VDC
   b. 4-20 mA
2. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
3. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

2.24 BACNET ROUTERS

A. Provide all BACnet routers as necessary to meet the requirements of these specifications.

B. BACnet routers shall be native BACnet only. Proprietary and other standard protocols shall not be provided. Routers shall be provided at necessary to connect one medium to another, e.g. BACnet/IP to BACnet MS/TP, etc.

C. The BACnet routers shall, at minimum, support BIBBs for data sharing, alarm and event management.

2.25 HVAC INPUT DEVICES

A. General Requirements
1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors
1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. General Requirements:
   a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
   b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.

c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

Point Type	Accuracy
Chilled Water	$\pm$ .5°F.
Room Temp	$\pm$ .5°F.
Duct Temperature	$\pm$ .5°F.
All Others	$\pm$ .75°F.

3. Room Temperature Sensors with Integral Display
   a. Room sensors shall be constructed for either surface or wallbox mounting. Thermistors are acceptable for space temperature monitoring
   b. Room sensors in public spaces, back of house space, service corridors, MER's, storage, IT rooms, IT closets, lounges, etc.) shall have blank faceplates.
   c. Room sensors in office areas (including occupied rooms by airline, TSA, security, airport personnel) shall have an integral LCD display and four button keypad with the following capabilities:
      1) Display room temperature.
      2) Display and adjust room comfort setpoint.
      3) Display and adjust fan operation status (if required for application).
      4) Timed override request push button with LED status for activation of after-hours operation.
4. Thermowells
   a. When thermowells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
   b. Thermowells shall be pressure rated and constructed in accordance with the system working pressure.
   c. Thermowells and sensors shall be mounted in a threadolet or 1/2" NFT saddle and allow easy access to the sensor for repair or replacement.
   d. Thermowells shall be constructed of 316 stainless steel.
5. Outside Air Sensors
   a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
   b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
   c. Temperature transmitters shall be of NEMA IV construction and rated for ambient temperatures.
6. Duct Mount Sensors
   a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.

b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.

7. Averaging Sensors
   a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
   b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
   c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Humidity Sensors
1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. The sensor shall be a solid state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
3. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
4. The humidity transmitter shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH meet the following overall accuracy, including lead loss and Analog to Digital conversion.
5. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless steel bushings.
6. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
7. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

D. Combination Humidity and Temperature Transmitter Assembly
1. Assembly shall consist of capacitive type humidity sensing element with 1000 ohm platinum RTD and a solid-state, 2-wire, 4-20mA transmitter mounted in housing suitable for outdoor installation (NEMA IV) or indoor (wall-mounted) applications. Sensing elements shall be installed in a weatherproof aspirating enclosure.
2. Assembly shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH.
3. Acceptable Manufacturers: Veris Industries or Owner Approved substitution.

E. Differential Pressure Transmitters
1. General Air and Water Pressure Transmitter Requirements:
   a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
   b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.

c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.
d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.
e. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.

2. Low Differential Water Pressure Applications (0” - 20” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) .01-20” w.c. input differential pressure range.
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra . or approved equal by Engineer.
3. Medium to High Differential Water Pressure Applications (Over 21” w.c.)
   a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
      1) Differential pressure range 10” w.c. to 300 PSI.
      2) Reference Accuracy: ±1% of full span (includes non-linearity, hysteresis, and repeatability).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
   c. Acceptable Manufacturers: Siemens Sitran, Rosemount - Model 1151 DP, Fisher Porter, or Dieterich Standard Co. - Pro-ducer series.
4. Building Differential Air Pressure Applications (-1” to +1” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra or approved equal by Engineer..
5. Low Differential Air Pressure Applications (0” to 5” w.c.)

a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
   1) (0.00 - 1.00” to 5.00”) w.c. input differential pressure ranges. (Select range appropriate for system application.)
   2) 4-20 mA output.
   3) Maintain accuracy up to 20 to 1 ratio turndown.
   4) Reference Accuracy: +0.2% of full span.
c. Acceptable Manufacturers: Setra or approved equal by Engineer.

6. Medium Differential Air Pressure Applications (5” to 21” w.c.)
   a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
      1) Zero & span: (c/o F.S. /Deg. F): .04% including linearity, hysteresis and repeatability.
      2) Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
      3) Thermal Effects: <+.033 F.S. /Deg. F. over 40°F. to 100°F. (calibrated at 70°F.).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
   c. Acceptable manufacturers: Setra or approved equal by Engineer.

F. Indoor Air Quality (CO2) Sensors- Wall and Duct Mounted
1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. Provide indoor air quality sensors to monitor Carbon Dioxide (CO2). The sensors shall be of microprocessor-based photo-acoustic type with heated stannic dioxide semiconductor.
3. The CO2 sensors shall have no more than 1% drift during the first year of operation and minimal drift thereafter so that no calibration will be required.
4. The units shall be wall or duct mounted type as indicated on plans and in the sequence of operation.
5. Wall mounted sensors shall be provided with white plastic cover, without LED indicators.
6. Duct mounted sensors shall be provided with LED indicators in a dust proof plastic housing with transparent cover.
7. The sensor shall meet the following requirements:

a.	Operating voltage:	24 VAC +/- 20%
b.	Frequency:	50/60 Hz
c.	Power consumption:	max. 6 VA
d.	CO2 measuring range:	0 – 2000 ppm

e. Tolerance: +/- 100 ppm
f. Output: 0 – 10 VAC
g. Calibration: none required
h. Permissible air velocity in duct: <26.2 Ft/s.
i. Manufacturer: Veris Industries or Owner Approved Substitution.

G. Carbon Monoxide (CO) Transmitter
1. UL listed sensor assembly suitable for N.E.C. installations (NEMA 4x enclosure).
2. Continuous carbon monoxide analysis shall be capable of measurement in the range of 0-500 part per million with 4-20mA output.
3. Minimum indicated concentration: 3ppm
4. Accuracy: +/-5% of reading.
5. Span drift: less than 5% change per year.
6. Operating temperature range: -20degC to 50 degC.
7. Humidity range (continuous): 15-90% RH non-condensing
8. Humidity range (intermittent): 0-99%RH non-condensing.
9. Stability: +/-1%
10. Repeatability: +/-2% of reading
11. Provide audible and visual alarm beacons.
12. Provide multichannel controller to monitor multiple variables in each space as required.
13. Manufacturer: Mine Safety Appliances (MSA), Sensidyne

H. Nitrogen Dioxide (NO2) Detection System:
1. Provide UL listed nitrogen dioxide sensor in NEMA 4x enclosure. Sensor to include LED display, an audible and visual alarm beacon for local alarm annunciation.
2. Minimum Indicated Concentration: 0.3ppm.
3. Repeatability: +/-2% of Reading
4. Accuracy: +/-10% of Reading.
5. Span Drift: less than 12% change per 6 months
6. Temperature Range: -20degC to 50degC
7. Humidity Range (Continuous): 15-90% RH non-condensing
8. Humidity Range (intermittent): 0-99% RH non-condensing
9. Pressure Range: Ambient atmospheric: +/-1psi
10. Sensor life: 2 years from shipping date.
11. Provide multichannel controller.
12. Manufacturer: MSA Ultimo X, Sensidyne

I. Flow and Pressure Monitoring
1. Air Flow Monitoring
a. Duct and Outside Air Flow Measuring Stations
1) Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of fundamentals, as well as in the Industrial Ventilation Handbook.
2) Each sensor assembly shall contain two individually wired, hermetically sealed bead-in-glass thermistors.

3) Probes shall be constructed of extruded, gold anodized aluminum tube. All wires within the aluminum tube shall be Kynar coated.

4) Transmitters shall include a 16-character alpha-numeric display capable of displaying airflow, temperature, system status, configuration settings, and diagnostics. The transmitter shall have the capability of field configuration and diagnostics using an on-board pushbutton interface and LCD display. The operating temperature range of the transmitter shall be installed at a location that is protected from weather and water.

Each unit shall measure the airflow rate within an accuracy of plus 2% as determined by U.S. – GSA certification tests.

The units shall have a self-generated sound rating of less than NC40, and the sound level within the duct shall not be amplified nor shall additional sound be generated.

Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork.

Where control dampers are shown as part of the airflow measuring station, opposed blade precision controlled volume dampers integral to the station and complete with actuator, pilot positioner, and linkage shall be provided. Stations shall be installed in strict accordance with the manufacturer's published requirements, and in accordance with ASME Guidelines affecting non-standard approach conditions.

5) Air flow measurement accuracy shall be ±3% of actual flow over a range of 6 to 1 capacity turndown. The probe installation shall not produce any static barrier (resistance to air flow). Provide a minimum of two (2) probes per each outdoor air intake. Follow manufacturer guidelines for installation and additional probe requirements.

6) Acceptable manufacturers: , Ebtron Gold series GP1 with standoff mounting bracket option.

b. Fan Inlet Probe Type:

1) Fan Inlet Type: Provide where indicated on the plans, airflow measuring stations of fan inlet type. Airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fan.

2) Probes shall be provided with the appropriate end support brackets for mounting in the inlet bell(s). Where fans are of dual inlet type, two sets of inlet probes must be provided. Provide inlet probes for each fan in fan array arrangements.

3) Fan inlet airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fans. Each sensor assembly shall contain individually wired hermetically sealed bead-in glass thermistors.

4) Airflow accuracy of +/-2% of reading over the entire operating range.

5) Fan inlet probes shall be Ebtron Gold series or approved equal by Engineer.

c. Space Pressurization Sensor:

1). Provide UL listed bi-directional bleed/differential pressure thermal dispersion airflow sensor in a ½ inch diameter tube. Sensor hermetically sealed bead-in glass thermistor.

2). Include all mounting kits as required.

3). NIST-traceable calibrated.

4). Accuracy: +/-2% of reading.

5). Manufacturer: Ebtron Bleed sensor assembly.

d. Static Pressure Traverse Probe

1) Duct static probes shall be provided where required to monitor duct static pressure.

2) Acceptable manufacturers: Setra or approved equal by Engineer.

2. BTU Monitoring Devices:

a. Accuracy: Temperature: Overall differential temperature: +/-0.15% over the stated range

b. Calculating nonlinearity within +/-0.05%

c. Temperature sensors: solid state matched sensors custom calibrated using NIST traceable temperature standards (1/2 inch NPT stainless steel thermowells.

d. Factory programmed for specific applications

e. Memory: Nonvolatile EEPROM memory retains all program parameters and totalized values in the event of power loss.

f. Display: Alphanumeric LCD displays total energy, total flow, energy rate, flow rate, supply temperature, return temperature, and alarm status.

g. Integrated with BMS via BACnet MSTP protocol.

h. Flow meter: Onicon F-3500.

i. Enclosure: Steel NEMA 13.

j. Power: 24 VAC

k. Manufacturer: Onicon System-10 BTU meter

3. Water Flow Monitoring Devices

a. Accuracy: +/-1% of reading from 2 to 20 ft/sec, +/-0.02 ft/sec below 2 ft/sec

b. Sensing method: Electromagnetic, no moving parts

c. Input power: 20-28 VAC 50/60 Hz

d. Liquid temperature range 15degF to 250degF

e. Operating Pressure: 400 PSI maximum

f. Pressure drop: Less than 0.1 psi at 12 ft/sec velocity

g. Materials of Construction: Wetted metal components-316L stainless steel

h. Enclosure rating: Weather-tight, NEMA 4

i. Manufacturer: Onicon F-3500

J. Status and Safety Switches

1. General Requirements

a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BMS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.

2. Current Sensing Switches
   a. The current sensing switch shall be self-powered with solid state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.
   b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.
   c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   d. Acceptable manufacturers: Veris Industries or Hawkeye
3. Leak Detection
   a. Provide Liqui-tect 410 (LT410) for leak detection application.
   b. Application: Leak spot detector.
   c. Power Input: 24 VAC, 50/60 Hz, 100mA, 3 VA
   d. Manufacturer: Liebert (Vertiv).
4. Water Flow Switches
   a. Water flow switches shall be equal to the Siemens, Johnson Controls P74, Honeywell.
5. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
   b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
   c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.
   d. The low temperature limit switch shall be equal to Johnson Controls A70, Honeywell, Siemens.

2.26 HVAC OUTPUT DEVICES

A. Actuators
1. General Requirements
   a. Damper and valve actuators shall be electric/electronic. Provide local position indicator dial on all actuators.
   b. Provide a separate actuator for each damper bank. Linkages are not allowed.
2. Electronic Damper Actuators
   a. Electronic damper actuators shall be direct shaft mount.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer’s recommendations for face velocity, differential pressure and

damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in both direction, and a gear release to allow manual positioning. Spring-return actuators with more than 7 Nm (60 in.-lb) torque capacity shall have a manual crank for this purpose.

c. Minimum Torque Requirements: 150 inch-lbs.

d. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.

e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop associated fan. Two-position actuators, as specified in sequences of operations as “quick acting,” shall move full stroke within 20 seconds. All smoke damper actuators shall be quick acting and be UL listed for smoke control service.

f. Provide normally open spring-return actuators for dampers serving all battery room locations.

g. Acceptable manufacturers: Belimo, Siemens, Honeywell or approved equal by Engineer.

3. Electronic Valve Actuators

a. Electronic valve actuators shall be manufactured by the valve manufacturer.

b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.

c. Provide electric/electronic actuators in all areas, sized by the manufacturer, of sufficient size and power to operate the valve under all conditions and to close the valve tight against 150% maximum differential pressure.

d. Valve actuators for finned tube radiation and terminal units shall be electronic, floating control, fail to last position.

e. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer’s recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.

f. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal, and may be used to parallel other actuators and provide true position indication. The feedback signal of each valve actuator (except terminal valves) shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.

g. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated equipment such as a pump, chiller, etc.

B. Control Dampers/Smoke Control Dampers

1. The BMS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the BMS Contractor or as specifically indicated on the Drawings.
2. All dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.
3. All dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.
4. Damper frames and blades shall be constructed of either stainless steel or aluminum. Maximum blade length in any section shall be 48”. Damper blades shall be 16-gauge minimum and shall not exceed six (6) inches in width. Damper frames shall be 16-gauge minimum hat channel type with corner bracing. Additional stiffening or bracing shall be provided for any section exceeding 48” in height. All damper bearings shall be made of stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals. Dampers of 48”x48” size shall not leak in excess of 6 cfm per square foot when closed against 4” w.g. static pressure when tested in accordance with AMCA Std. 500.
5. Air foil blade dampers of double skin construction with linkage out of the air stream shall be used whenever the damper face velocity exceeds 1500 FPM or system pressure exceeds 2.5” w.g., but no more than 4000 FPM or 6” w.g.
6. Acceptable manufacturers: Control Damper – Tamco, Siemens, Johnson Controls D-1300, Ruskin CD50.
7. One piece rolled blade dampers with exposed linkage may be used with face velocities of 1500 FPM or below. Acceptable manufacturers are: Johnson Controls D-1100, Ruskin CD36.
8. Multiple section dampers may be jack-shafted to allow mounting of direct connect electronic actuators. Each end of the jack shaft shall receive at least one actuator to reduce jack shaft twist.

C. VAV Duct Damper (integral flow station)

1. Provide Ebtron/Tamco AIR-IQ/GTC-PC (refer to mechanical drawings for locations).

D. Step-Down Transformers:

1. Provide and install all step-down transformers for a complete system. Transformers shall be machine tool type and shall be UL listed. Primary and secondary sides shall be fused in accordance with NEC. Transformers shall be properly sized for application and mounted in NEMA enclosure with overload circuit breaker.

2. Manufacturer: RIB or equal.

E. Control Relays

1. Control Pilot Relays
   a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
   b. Mounting bases shall be snap-mount.
   c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
   d. Contacts shall be rated for 10 amps at 120VAC.
   e. Relays shall have an integral indicator light and check button.
   f. Acceptable manufacturers: Johnson Controls, Honeywell, ASCO or Lectro.

F. Not Used

G. Control Valves (PICBV-Pressure Independent Control and Balancing Valve)

1. Provide pressure independent control valves to compensate for pressure variations, performing a continual balancing function to maintain system performance at varying loads. Valves shall be configured with one integrated valve body that incorporates chamber with adjustable Cv and a separate pressure regulating used to maintain a constant differential pressure across the control surface. Each control valve shall be individually flow tested at the factory and verified to deviate no more than +/-5% through the selected operating pressure range. A calibrated performance tag (or factory provided calibration documentation) shall be provided with each valve that verifies the flow rate in 10 degree increments up to the full rated flow. All testing shall be performed with instruments calibrated to the requirements of ANSI/ ISA-S75. 11-1985, with traceability to NIST and/or ISO standards. Control valve rangeability shall be 100:1 minimum. The valve shall be rated for pressure and temperature as required. Each control valve shall subjected to 70 psid and tested to exceed ANSI/FCI 70-2-1998 leakage rating. Class IV leakage or better is required for control valves 2 inch nominal size or less. Class III leakage or better is required for control valves large than 2 inch. The control valve bodies shall be steel or bronze. All internal parts shall be stainless steel, steel, Teflon, brass or bronze. Plastic internal parts are not acceptable. The proportional control valve actuator shall modulate from 0 to 100% design flow. The control valve and factory mounted actuator shall be rated to shut-off against 150 psi minimum. When proportional actuators are utilized the end-stroke of the actuator shall be set on-site with the software (limit control signal) at full design flow from coil or from data listed on performance tag. Torque requirements for actuator selection shall be provided by the valve manufacturer. There are shall test ports installed at the factory integral for each valve and capable of being used to measure pressure or temperature. The differential pressure between the test ports shall be used to verify proper valve operation and flow regulation.

2. For valves without factory mounted test ports provide/furnish test port assemblies on the inlet and outlet side of the pressure independent control valves for field installation. Coordinate and confirm test port and pressure independent valve manufacturer's recommended installation requirements with mechanical contractor.
3. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and mechanical schedules..
4. All valve and actuator assemblies shall be warranted by the manufacturer for no less than 5 years from the date of purchase.
5. Manufacturers:
   a. Flow Control Industries-Delta Valve (Basis of Design)
   b. Belimo PICCV
   c. Oventrop Cocon Q
   d. IMI Hydronic-TA (TA-FUSION-P)

H. Control Valves
1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer, and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure rating and connection type (sweat, screwed, or flanged) shall conform to the mechanical pipe schedule.
   a. Leakage: Control valves shall provide tight shut off in the closed position at 150 percent of maximum working pressure.
2. Chilled water control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer's recommendations for the given application. In general, valves (2 way) serving variable flow air handling unit coils shall be sized for a pressure drop equal to the actual coil pressure drop, but no less than 3 PSI. Valves for terminal reheat coils shall be sized for a 2 PSIG pressure drop, but no more than a 5 PSI drop.
3. Characteristics:
   a. Chilled Water Service: equal percentage flow characteristics, single seated type.
   b. Bypass service: linear flow characteristics. Double seated.
4. Valve action: Cooling valves normally closed, humidity control valve normally closed (spring return type).
5. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all chilled water applications, except those described hereinafter. The valve discs shall be composition type. Valve stems shall be stainless steel.
6. Characterized Ball valves shall be acceptable for fan coil units.

7. Globe valves are acceptable for use with Air Handlers. Automatic control valves for temperature control shall be fully proportioning with V-port inner guides, unless otherwise specified. Valves shall be quiet in operation and fail safe in either normally open or normally closed position in the event of control air failure. Valves shall be capable of operation in sequence when required by the sequence of operation. Size all globe control valves by the control manufacturer and guarantee they meet the heating and cooling loads as specified. Control valves shall be suitable for the system pressure conditions and shall close against the differential pressure involved.
8. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and schedules.
9. Butterfly valves shall be acceptable for modulating large flow applications greater than modulating plug valves, and for all two-position, open/close applications. In-line and/or three-way butterfly valves shall be heavy-duty pattern with a body rating comparable to the pipe rating, replaceable lining suitable for temperature of system, and a stainless steel vane. Valves for modulating service shall be sized and travel limited to 50 degrees of full open. Valves for isolation service shall be the same as the pipe. Valves in the closed position shall be bubble-tight.
10. Provide Bray Flow-Tek flanged full port ball valves for central plant modulating control valve applications. Control valves shall include feedback indicating valve position indication at BMS. Modulating control valves shall be capable of minimum of up to 1,800 starts/hour (duty cycle).
11. Provide electric high-performance butterfly motorized valves for on/off service with manually operated declutchable handwheels for overriding the operator in both emergency and normal operation. Valve body shall be carbon steel with 316 stainless disc with a stainless shaft. Valve seat material shall be teflon. All valves shall be provided with two (2) limit switches that will indicate open and close valve positions remotely at the BMS. Minimum ANSI B16.104 Shut-off Class III ANSI Pressure Class 150.~~: Class 300~~.
12. Central Plant Locations: Electric powered valves are provided and specified in the central plant equipment specifications.
13. CEP Plant Applications: manufactured by Dezurik BHP Series, Bray/McCannalok MK Series High performance butterfly motorized valves with Industrial actuators manufactured by EIM Controls (HQ series), Bray Series 70 or as approved by Engineer.
14. All automatic control valves shall be furnished by the BMS Contractor and installed by the Mechanical Contractor.

2.27 ELECTRICAL

A. Electrical Power Monitors, Single Point (Easy Install):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Consist of three split-core CTs, factory calibrated as a system, hinged at both axes with the electronics embedded inside the master CT. The transducer shall measure true (rms.RMS) power demand real power (kW) consumption (kWh). Conform to ANSI C12.1 metering accuracy standards.
3. Voltage Input: Load capacity as shown on drawings. 208-480 VAC, 60 Hz

4. Maximum Current Input: Up to 2400A
5. Performance:

    a. Accuracy: +/- 1% system from 10% to 100% of the rated current of the CT's
    b. Operating Temperature Range: 32-140°F, 122°F for 2400A.

6. Output: 4 to 20 mA, Pulse. or Modbus RTU
7. Ratings:

    a. Agency: UL508 or equivalent
    b. Transducer internally isolated to 2000 VAC.
    c. Case isolation shall be 600 VAC.

8. Basis of Design: Similar to Hawkeye Veris H80xx40 series
9. Accessories: BACnet communications gateway

B. Electrical Power Monitors, Single Point (High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), and reactive power (kVARar), and power factor (PF) per phase and total load for a single load. Factory calibrated as a system using split core CT's. Neutral voltage connection is required.
3. Voltage Input: 208-480 VAC, 60 Hz
4. Current Input: Up to 2400A
5. Performance:

    a. Accuracy: +/- 1% system from 2% to 100% of the rated current of the CT's
    b. Operating Temperature Range: 32-122°F

6. Output: Pulse, BACnet, Modbus RTU
7. Display: Backlit LCD
8. Enclosure: NEMA 1
9. Agency Rating: UL508 or equivalent
10. Basis of Design: Veris Industries H81xx00 series.

C. Electrical Power Monitors, Single Point (High Accuracy/Versatility):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), reactive power (kVAR), apparent power (kVA) and power factor (PF) per phase and total load for a single load. Available with data logging , Bi-directional (4-quadrant) metering, and pulse contact accumulator inputs.
3. Voltage Input: 90-600 VAC, 50/60 Hz, 125-300 VDC
4. Current Input: 5A – 32,000A, selectable 1/3V or 1V CT inputs
5. Performance:

    a. Accuracy shall be +/- 0.2% revenue grade
    b. Operating Temperature Range: -22-158°F

6. Output shall be BACnet
7. Display: Backlit LCD
8. Enclosure: NEMA 4x optional
9. Agency Rating: UL508, ANSI C12.20
10. Basis of Design: Veris E5xxx series.

D. Electrical Power Monitors, Multiple Point (92 loads, High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures volts, amps, power and energy for each circuit. 1/4 amp to 200 amp monitoring. 4 configurable alarm threshold registers.
3. Voltage Input: 90-277 VAC, 60 Hz
4. Current Input: 5A – 32,000A, 1/3V CT inputs
5. Performance:

   a. Accuracy: +/- 0.5% meter (split core), +/- 1% system from 1/4-100A (solid core)
   b. Operating Temperature Range: 32-140°F

6. Output: Modbus RTU
7. Agency Rating: UL508, ANSI C12.10, IEC Class 1
8. Basis of Design: Veris E3xxx series

2.28 HVAC MISCELLANEOUS DEVICES

A. Local Control Panels
1. All control panels shall be factory constructed, incorporating the BMS manufacturers standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance. Control panels shall be fully enclosed, with sub-panel, hinged door, and key-locking latch.
2. In general, the control panels shall consist of the DDC controller(s), display module, and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the control panel due to function. The display module shall be flush mounted in the panel face unless otherwise noted.
3. All I/O connections on the DDC controller shall be extended to a numbered, color-coded, and labeled terminal strip for ease of maintenance and expansion. Wiring to I/O devices shall be made from this terminal strip.
4. All other wiring in the panel, internal and external, shall be made to additional line or low voltage color-coded and labeled terminal strips. Low and line voltage wiring shall be segregated. All terminal strips and wiring shall be UL listed 300-volt service and provide adequate clearance for field wiring.
5. All wiring for every control panel shall follow a common color-coded format. All terminal strip color coding and numbering shall follow a common format. All wiring shall be neatly installed in plastic trays or tie-wrapped.
6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

B. Outside Air Damper Override Switch: Provide UL listed mushroom switch (momentary switch) with time delay relay (time delay adjustable up to one hour) with auxiliary contacts for BMS interface. Provide EN 418 compliant safety guard (safety yellow). Refer to mechanical drawings for quantity and location.

C. Power Supplies (Provide new power supplies for all new BMS control panels)
1. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75% of the rated capacity of the power supply.
2. Input: 120 VAC +10%, 60Hz.
3. Output: 24 VDC.
4. Line Regulation: +0.05% for 10% line change.
5. Load Regulation: +0.05% for 50% load change.
6. Ripple and Noise: 1 mV rms., 5-mV peak to peak.
7. An appropriately sized fuse and fuse block shall be provided and located next to the power supply.
8. A power disconnect switch shall be provided next to the power supply.

PART 3 - EXECUTION

3.1 INSTALLATION PRACTICES

A. Control System Wiring:
1. All conduit, wiring, accessories and wiring connections required for the installation of the Building Management System, as herein specified, shall be provided by the BMS ~~Sub -~~Contractor. All wiring shall comply with the requirements of applicable local and national electric codes, unless specified otherwise in this section.
2. The BMS Contractor is responsible for the installation of all low voltage control, monitoring and network wiring.
3. Power wiring 120VAC and greater shall be provided by the Electrical Sub-Contractor. BMS Contractor shall provide and coordinate all 120v power requirements with the electrical engineer of record and electrical contractor during the submittal phase. Final 120VAC terminations from Division 26 electrical power junction boxes to all BMS equipment and devices including DDC controllers, terminal equipment controllers, control valves, meters, sensors, etc. shall be provided by the BMS Contractor.
4. All system-input wiring shall be twisted shielded pair, minimum 18-gauge wire. All system analog output wiring shall be twisted shielded pair/3-wire as required, minimum 18-gauge wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24 gauge.
5. All internal panel device wiring for binary outputs and pilot relay shall be minimum 16-gauge wire.
6. All Class 2 (24VAC or less) wiring shall be installed in conduit unless otherwise specified.
   a. Class 2 wiring not installed in conduit shall be supported every 5' from the building structure utilizing metal hangers designed for this application. Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements. Exposed wiring shall only be allowed in concealed accessible locations.

7. Low voltage control wiring and 24VAC can be run in the same conduit. Power wiring 50VAC and greater must be in a separate conduit.
8. All wiring in mechanical rooms shall be in conduit. Minimum control wiring conduit size 3/4”.
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked.

B. Identification Standards
1. Controller Identification: All controllers shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
2. Panel Identification: All local control panels shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
3. Field Devices: All field devices shall be identified by a typed (not handwritten) securely attached tag label.
4. Panel Devices: All panel devices shall be identified by a typed label securely fastened to the backplane of the local control panel.
5. Raceway Identification: All the covers to junction and pull boxes of the control system raceways shall be painted blue or have identification labels stating “Control System Wiring” affixed to the covers. Labels shall be typed, not hand written.
6. Wire Identification: All low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be permanently secured to the conductor or cable and shall be typed.

C. Dedicated Digital Controller Per Major System
1. Each major system will be provided with its own dedicated BMS controller. Mechanical systems such as AHUs or Refrigeration Plant <u>shall not</u> share or be controlled from the same BMS controller.

D. Input Devices
1. All Input devices shall be installed per the manufacturer’s recommendation. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, duct smoke detectors, air flow stations, etc.
    a. Low Differential Air Pressure Applications (Under 5” w.c.) Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and Owner permanent easy-to-use connection. Provide a minimum of a NEMA 1 housing for the transmitter. Locate transmitters in accessible local control panels wherever possible. Except on VAV box applications.
    b. Medium Differential Air Pressure Applications (5” to 21” w.c.) Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
    c. Medium to High Differential Water Pressure Applications (Over 21” w.c.): Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall

be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.

d. Building Differential Air Pressure Applications (-1" to +1" w.c.): Mount pressure transmitter in the local control panel. Transmitter's exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind. The interior tip shall be inconspicuous and located within a central corridor shown on the drawings.

e. Air Flow Measuring Stations: Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork. Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.

f. Water Flow Monitoring Stations: Water Flow Monitoring Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.

g. Outside Air Humidity Sensors: Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless steel bushings.

h. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.

i. Duct Temperature Sensors: Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate. For ductwork greater in any dimension that 48 inches and/or air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor with multiple sensing points. The sensor shall be mounted to suitable supports using factory approved element holders. For large plenum applications such as mixed air temperature measurements, utilize a string of sensors mounted across the plenum to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12 foot long segment.

j. Space Temperature Sensors: Shall be mounted as per ADA or architectural requirements (coordinate height of all space devices with architect. above the finished floor. Temperature sensors installed in public areas (blank face plates) shall be provided with lockable covers to prevent tampering.Coordinate with architect and GOAA for requirements.

k. Low Temperature Limit Switches: Mount element horizontally across duct in a serpentine pattern insuring each square foot of coil is protected by 1 foot of sensor. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

l. Differential Pressure Status Switches: Provide complete installation kit including; static pressure tops, tubing, fittings and air filters. Provide appropriate scale range and differential adjustment for intended service.

m. Valve Limit Switches: Mount limit switch on valve yolk as recommended by switch manufacturer. Provide valve limit switches that will indicate both 100% Open and 100% Closed Positions.

E. Output Devices

1. All output devices shall be installed per the manufacturer's recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, etc.
2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke.
3. Control Dampers: Shall be opposed blade for modulating control of air flows. Parallel blade dampers shall be installed for two position applications.
4. Control Valves: Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI.
5. Electronic Signal Isolation Transducers: Whenever an analog output signal from the Building Management System is to be connected to an external control system as an input (such as a chiller control panel), or is to receive as an input a signal from a remote system, provide a signal isolation transducer. Signal isolation transducer shall provide ground plane isolation between systems. Signals shall provide optical isolation between systems.

3.2 TRAINING

A. General

1. The controls contractor shall provide the following training services.
2. Operator Training (provide 40 hours): Operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall demonstrate how the system accomplishes the sequence of operation.
   a. From the workstation, the operator shall demonstrate the software features of the system. As a minimum, the operator demonstrate and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.
   b. One day (8 hours) of the 40 hours will be devoted to on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations.
3. Factory training for two owner representatives in a factory training lab. This training shall be performed by a factory-certified professional trainer and, at a minimum, shall consist of:

a. Two days (16 hours) training covering basic system operation.
b. One day (16 hours) training covering system reporting and alarm management.
c. One day (16 hours) training of scheduling and point trending
4. The owner representatives shall be issued Continuing Education Credits (C.E.U.s) for the factory training.

3.3 COMMISSIONING & TESTING

A. General
1. Commissioning the Building Management System is a mandatory documented performance requirement of the selected BMS Contractor for all control systems detailed in this Specification and sequence of operations. Commissioning shall include verification of proper installation practices by the BMS Contractor and subcontractors under the BMS Contractor, point verification and calibration, system/sequence of operation verification with respect to specified operation, and network/workstation verification. Documentation shall be presented upon completion of each commissioning step and final completion to ensure proper operation of the Building Management System.
2. BMS commissioning and testing documentation is to be provided separately to the Owner.

B. Testing Requirements
1. Intent: Demonstrate to satisfaction of authorized representative that BMS is performing in accordance with specification requirements.
2. Logs of Tests: Complete logs of tests retained by Contractor for inspection and review of authorized representative at any time after testing started. Upon final completion of system tests log records submitted.
3. Witness of Tests: At time directed by authorized representative complete functional, operational test shall be performed by contractor. Test witnessed by personnel directed by authorized representative. Tests continue until functions of points, of alarms and command functions are proven to satisfaction of authorized representative.
4. Performance of Field Tests: Complete tests required at different and distinct times for various phases of construction as designated by authorized representative.
5. BMS Contractor shall provide a bench-test and mock-up system (typical DDC controller and networked typical terminal equipment controllers) set-up for GOAA review and approval six months prior to scheduled deployment. Refer to Section 1.6 Scope of Work for participation and testing equipment connectivity in low voltage testing lab.

C. Testing Procedure
1. Upon completion of the installation, the BMS Contractor shall start-up the system and perform all necessary testing and run diagnostic tests to ensure proper operation. The BMS Contractor shall be responsible for generating all software and entering all database information necessary to perform existing control sequences.

D. Testing Documentation

1. Prior to acceptance testing, BMS Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

E. Field Points Testing
   1. This step shall verify that all of the installed points receive or transmit the correct information prior to loading/activating the system software.
   2. ON/OFF commands from the workstation shall be performed in order to verify each binary output point.
   3. All binary input points are to be tested by observing a change of state upon command at PC workstation or locally in the field.
   4. All analog output points shall be tested using a command from the PC workstation to modulate the output device from minimum calibrated signal to maximum calibrated output.
   5. All analog input points are to be tested by comparing the reading obtained through the workstations to the value of an independent testing meter
   6. All two-way communication interfaces (Modbus, Bacnet, etc) tested and monitored values and commanded verified at the BMS workstation and in the field.

F. Verify that activation of site related alarms specifically identifies and notifies the Owner remote monitoring sites and selected personnel.

G. VAV box performance verification and documentation: (Perform testing if required).
   1. As part of the commissioning of the terminal unit control (UC) and air distribution system, the Contractor shall initiate an automated test where the dampers in one half of a group of boxes are stepped towards full open while the other half are stepped towards full closed. At each step, after a settling time, box airflow and damper positions will be sampled. Following the cycle, a pass/fail report indicating results shall be produced. Possible results are Pass, No change in flow between full open and full close, reverse operation, or Maximum flow not achieved. The report shall be submitted as documentation of the installation.
   2. The controls contractor shall issue a report based on a sampling of the UC calculated loop performance metrics. The report shall indicate performance criteria, include the count of conforming and non-conforming boxes, list the non-conforming boxes along with their performance data, and shall also include graphical representations of performance. The sampling shall take place after completion of Test and Balance, when design cooling and heating media have been available and occupied conditions approximated for five consecutive days.
   3. Verify that new graphics are complete and contain dynamic (real-time) information that can be viewed at both workstation locations.

H. Non-compliant Items
   1. The Contractor shall remove and replace, at its expense, all items that are not in compliance with the Specification requirements.

END OF SECTION 23 0900

SECTION 23 09 00 – INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1. Summary
   a. The South Terminal Building Management System (BMS) sub-contractor is responsible to provide and install all control and monitoring devices to provide a complete system in the Airside Building (including PCA), Landside Building, Central Energy Plant (CEP), Ground Transportation Facility, Electrical Power Generation (EPG) facility, Ground Support Equipment (GSE), Checkpoint Delta and the North Terminal Maintenance Control Room. The BMS Contractor shall provide a complete system consisting of Direct Digital Control Panels (DDCPs), field I/O devices, power supplies and supportive software, to meet the written sequences of operations, as written in contract specifications. The system shall support communications to DDCP's, and provide operator interaction, data consolidation and global control functions via a Local Area Network (LAN).
   b. The BMS network connectivity shall reside on the IT network. The BMS management level network (DDC panels, workstation/servers) will utilize fiber optic cabling and pathways and outlets provided by the IT Contractor. The IT Contractor shall provide a surface mounted single port box outlet mounted in the DDC panels or in a compact locked panel which is conjoined to the DDC panel (panels provided by the BMS Contractor). The conjoined panels shall be keyed alike to the DDC panel.
   c. Work shall include HVAC control, energy management, alarm monitoring, point trending, point reporting and maintenance management functions. Coordinate with all site low voltage systems as specified.
   d. The project will utilize LEED EA prerequisite: Energy metering of consumption at one month intervals and share with USGBC for a 5 year period.
   e. All labor, material, equipment and software not specifically referred to herein or on the plans, that is required to meet the functional intent of this specification, shall be provided without additional cost to the Owner.
   f. The BMS Contractor shall be selected by the owner-CR@R based on Technical Proposal submission that meets or exceeds "BMS Contractor Installer Qualifications paragraph section 1.14."
   g. Refer to "Scope of Work" paragraph for additional information.

1.2 RELATED SECTIONS

A. Division 23 - Mechanical Section
   1. 23 05 14-Variable Frequency Motor Controllers
   2. 23 09 20-Refrigerant Detection and Alarm
   3. 23 33 00-Air Duct Accessories
   4. 23 64 16-Centrifugal Water Chillers
   5. 23 64 23-Scroll Water Chillers
   6. 23 65 00-Package Cooling Towers
   7. 23 72 00-Air to Air Energy Recovery Units
   8. 23 73 13-Modular Air Handling Units
   9. 23 74 33-Dedicated Outdoor Units
   10. 23 08 00-Commissioning of HVAC System
   11. 23 81 23-Computer Room Air Conditioners
   12. 23 81 26-Split System Air Conditioners
   13. 23 82 19-Fan Coil Units

B. Division 26 - Electrical Section
   1. 26 07 17-SCADA Monitoring and Control System
   2. 26 05 13-Conduit
   3. 26 05 19-Building Wire and Cable
   4. 26 09 24-Architectural Lighting Control Systems
   5. 26 27 13-Electrical Metering and Monitoring

1.3 ABBREVIATIONS

A/C	-	Air Conditioning
AHU	-	Air Handling Unit
ASHRAE	-	American Society of Heating, Refrigeration and Air Conditioning Engineers
AMBCx:	-	Automated Monitoring Based Commissioning
ANSI	-	American National Standards Institute
AODB	-	Airport Operational Data Base
API	-	Application Programming Interface
BACnet	-	Building Automation Controls Network
BTL	-	BACnet Testing Laboratory
BIBB	-	BACnet Interoperability Building Block
BMA	-	BACnet Manufacturers Association
BMS	-	Building Management System
CCDT	-	Configuration, Commissioning and Diagnostic Tool
CCP	-	Communications Control Panel
CCR	-	Central Command Room
CD-RW	-	Compact Disk with Read and Write Capability
CEP-	-	Central Energy Plant
CIBSE	-	Chartered Institution of Building Services Engineers
CM@R	-	Construction Manager at Risk
CPU	-	Central Processing Unit
DAT	-	Digital Audio Tape
DDCP	-	Direct Digital Control Panel
DDC	-	Direct Digital Control
DDR	-	Double Data Rate

DCV	-	Demand Control Ventilation
DR	-	Demand Response
EIA	-	Electronics Industries Association
EMI	-	Electro-Magnetic Interference
EMMS	-	Electrical Metering and Monitoring System
ELV	-	Extra Low Voltage
EP	-	Electric-to-Pneumatic
FAS	-	Fire Alarm System
FCU	-	Fan Coil Unit
FDD	-	Fault Detection and Diagnostics
FSD	-	Fire Smoke Damper
GOAA	-	Greater Orlando Aviation Authority
GUI	-	Graphical User Interface
GSE	-	Ground Support Equipment
HMI	-	Human Machine Interface
HVAC	-	Heating, Ventilating and Air Conditioning
HT	-	Humidity Transmitter
IBSS	-	Integrated Building Security System
IT	-	Information and Communication Technology
IDE	-	Integrated Drive Electronics (Hard Disk)
IEEE	-	Institute of Electrical and Electronic Engineers
IP	-	Internet Protocol
ISO	-	International Standards Organization
ID	-	Identification
I/O	-	Input/Output
ISA	-	Instrument Society of America (also known as International Society for Measurement and Control)
LAN	-	Local Area Network
LCD	-	Liquid Crystal Display
LEED	-	Leadership in Energy and Environmental Design
LED	-	Light Emitting Diode
LLA	-	Low Level Alarm
MCC	-	Motor Control Center
MER	-	Mechanical Equipment Room
NEMA	-	National Electric Manufacturers' Association
NFPA	-	National Fire Protection Association (US Standards)
ODBC	-	Open database Connectivity
OEM	-	Original Equipment Manufacturer
OIW	-	Operator Interface Workstation
OLE	-	Object Linking and in Embedding
OPC	-	Open Process Control
OSHA	-	Occupational Safety and Health Administration
PABX	-	Private Automatic Branch Exchange
PC	-	Personal Computer
PCA	-	Pre-Conditioned Air
PCI	-	Peripheral Component Interconnect
PE	-	Pneumatic-to-Electric
PICS	-	Protocol Implementation Conformance Statement

PID	-	Proportional, Integral, Derivative
PDA	-	Personal Digital Assistant
PIM	-	I/O Point Interface Module
POT	-	Portable Operator Terminal
PTFE	-	Polytetrafluoroethylene (Teflon)
PT	-	Pressure Transmitter
RAID	-	Redundant Array of Inexpensive Disks
RAM	-	Random Access Memory
RFI	-	Radio Frequency Interference
RH	-	Relative Humidity
RTD	-	Resistance Temperature Device
RTU	-	Remote Terminal Unit
SCADA	-	Supervisory Control and Data Acquisition
SQL	-	Structured Query Language
SSPC	-	Standing Standard Project Committee (ASHRAE)
SVGA	-	Super Video Graphics Adapter
TT	-	Temperature Transmitter
UC	-	Unitary Controller
UPS	-	Uninterruptible Power Supply
UL	-	Underwriters Laboratories
USGBC	-	US Green Building Council
VAV	-	Variable Air Volume
VDU	-	Video Display Unit
VPN	-	Virtual Private Network
VFD	-	Variable Frequency Drive
WAN	-	Wide Area Network
XIF	-	External Interface File
XML	-	Extensible Mark-up Language

1.4 DEFINITIONS

A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

C. BACnet: The Building Automation and Control Network open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135) and which is now an ISO and ANSI standard. BACnet can operate over multi-media including Ethernet, and MSTP. BACnet components shall be UL listed; and shall be fully complaint with ASHRAE Standard SSPC/135 and all other applicable codes.

D. BACnet Object: A physical or virtual point with a set of associated properties such as a temperature sensor that has properties including – name, current value, maximum/minimum values, high/low alarm levels, etc.

E. BACnet Conformance: A description of the capabilities of a device for communicating information to other BACnet devices. It is usually a set of requirements to be met in order for a device to conform to BACnet standards. There are 6 class levels of conformance for standard BACnet objects and services. The higher the conformance class level, the more features that are covered. The BACnet devices furnished under this sub-contract shall at a minimum, be conformance class 3. Preference will be given to higher conformance class of the latest controllers at time of purchase.

F. BACnet Interoperability Building Blocks (BIBBs): A BIBB defines a small portion of BACnet functionality needed to perform a particular task. BIBBs come in pairs, A and B, which reflect the client/server nature. The “A” BIBB represents the client, i.e. the device furnishing the information. The “B” BIBB represents the server, i.e. the device furnishing the information or executing the command. For 2 devices to be interoperable the “A” BIBB and the “B” BIBB must be the same.

G. BACnet/IP: The Building Automation and Control Network open protocol communication standard using Internet Protocol (IP) complying with Annex J of the ASHRAE SSPC/135 standard.

H. Binary: A two-state system where an “ON” condition is represented by a high signal level and an “OFF” condition is represented by a low signal level.

I. Building Management System (BMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities. The BMS includes the DDC subsystem, open system ports, and open protocol bus or integrators and network routers for connection to information networks. It includes components at the Field, Automation and Management Levels.

J. BMS Contractor: The Building Management System Contractor responsible for the installation of the Building Management System specified herein.

K. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.

L. Component: Any individual element of the BMS furnished under this sub-contract including hardware, software and materials.

M. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, PE and EP switches and like devices. Includes all wiring from controllers to all sensors and points specified herein and required to execute the sequence of operation. Does not include line voltage power wiring.

N. Dead band: A temperature range over which no heating or cooling energy is supplied, such as 74-78 degrees F, i.e. as opposed to single point changeover or overlap, or a range from setpoint over which no control action is taken.

O. Diagnostic Program: Machine executable instructions used to detect and isolate system and component malfunctions.

P. Direct Digital Control System: The portion of the BMS that involves the connection of microprocessor-based controllers to field level sensors and actuators. The signals received from field level instrumentation are converted from analog to digital format so that the data can be used in software logic. Control signals are determined by software logic and they are converted from digital to analog format so that the final control element can be adjusted.

Q. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more than one system.

R. Furnish: Purchase and deliver to the appropriate installing sub-contractor, complete with every appurtenance, document, commission and warranty.

S. Integration: The ability of control system components from different manufacturers connect together while providing coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator's workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, Modbus and OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer's systems.

T. Interoperability: The ability of systems from different manufacturers and of different types to share information with each other without losing any of their independent functional capabilities and without the need for complex programming.

U. Native BACnet: This term is used to imply that BACnet devices (i.e. the BMS controllers and workstation) only communicate in BACnet protocol and do not require an intermediate gateway for protocol conversion. The BACnet devices shall be connected on a peer-to-peer network using one of the approved LAN technologies such as Ethernet, MS/TP, or BACnet/IP.

V. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier (Management Level) networks shall provide "Peer-to-Peer" communications. Second tier (Automation Level) networks shall provide either "Peer-to-Peer", Master-Slave or Supervised Token Passing communications.

W. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

X. Operating System (OS): Software that controls the execution of computer programs and which provides scheduling, debugging, input/output controls, accounting, compilation, storage assignment, data management and related services.

Y. Open System Port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the BMS System.

Z. Operator Interface Workstation (OIW): The OIW consists of a high-level processing personal computer and peripheral I/O devices that enable access to the PC and to the entire Management Level Network. The OIW allows an operator to command, monitor, and program the system.

AA. Peer-to-Peer Communications: Communications directly between devices that operate on the same communications level of a network, without intervention from any intermediary devices such as a host computer or server.

BB. Peripheral: Input/Output equipment used to communicate with the computer and make copies of system outputs; peripherals include VDUs, printers, hard drives, disk drives and modems, etc.

CC. Portable Operator Terminal (POT): Permits portable operator interface remotely from the Operator Interface Workstation (OIW) to facilitate network management, point-to-point node commissioning, diagnostics and general operator interface with the BMS.

DD. Programmable Device: A device that does not have a pre-established built-in application. An application creation software tool is required for an application to be created and downloaded to the device.

EE. Pick Point: A pick point is a graphical display element that allows the operator to “click” the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen. Pick points shall be configured on each display screen to provide a logical user navigation system using a ladder tree hierarchy.

FF. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, and Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required and the loop shall not be subject to “Integral Windup”.

GG. Provide: The term “provide” means “provide complete in place”, that is, furnish, install, commission, test, warrant and ready for operation and use. Refer to the definition of “Furnish”.

HH. Router: A device that routes messages destined for another segment sub-net or domain of the control network. The device controls message traffic based on node address and priority. Media converters which serve as communication links between power line, twisted pair, fiber optic, coax and RF media are sometimes referred to as Routers.

II. Software: Programs that are executed by a computer-based BMS beyond the physical hardware of the computer system, encompasses any programs such as operating systems (OS), application programs, operating sequences and databases. The term “Software” in this specification shall also include all firmware provided with read-only memory as part of the BMS to meet all applicable criteria detailed to meet sequence of operations.

JJ. Unitary Controller: A controller generally designed for a specific application and for a single piece of equipment. Fully programmable unitary controllers shall be provided for this project.

KK. Virtual Private Network (VPN): This is a network that uses encryption and other technologies to provide secure communications over the Internet or an Intranet.

LL. XIF: External Interface File that contains contents of the manufacturer's product documentation.

MM. SOAP: Simple Object Access Protocol (SOAP) is a simple extensible mark-up language (XML) - based protocol that enables applications to exchange information through a WEB Service.

1.5 BMS SYSTEM ARCHITECTURE

A. The BMS shall connect to the new IT network using BACnet/IP over Ethernet. This LAN is hereafter referred to as the "Site Management Level".

B. The Site Management Level (IT network)
   1. All servers, Operator Interface Workstations (OIW), Operating Systems (OS) and related applications shall reside on the management level.
   2.
   3. Communication Control Panels (CCPs) shall reside on the management level.
   4. All Management Level components (DDCP panel, workstation/servers,, etc.) shall be support by a local ½ hour Uninterruptible Power Supply (UPS). The BMS workstations shall be provided with a local two hour UPS back-up.
   5. The BMS site management level fiber optic cabling shall be provided by the IT Contractor.

C. The Automation Level
   1. The automation level shall comprise of Unitary Controllers (UC) for terminal equipment including VAV, FPVAV, FCU's, etc. The controllers shall be in compliance to ASHRAE SSPC/135, BACnet standards latest revision.
   2. Supervisory controllers shall reside on the Automation level.
   3. All Automation Level components shall be support by a site or local Uninterruptible Power Supply (UPS).

D. The Field Level
   1. The field level shall include all instrumentation interfaced to the automation level controllers such as temperature, humidity, level, pressure and switches, etc.
   2. It shall also include the final control elements such as the control valves, damper actuators and control relays.
   3. All field level cables shall Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit.

1.6 SCOPE OF WORK

A. Installation of Building Management System (BMS)

1. The BMS Contractor shall furnish and install a complete Building Management System (BMS) for all mechanical systems and other facility systems as included in the project documents. The BMS shall Contractor shall provide, test and commission a fully integrated BMS (software platform incorporating an integrated systems database) with the capability to interface seamlessly with other subsystems. The BMS shall allow full integration of subsystems with capability to support multi-vendor environments utilizing standard protocols and be able to integrate third-party systems using standard or subsystem vendor proprietary protocols. The BMS Contractor shall cross-reference this specification with each of the subsystem specifications and identify any gaps and/or conflicts at the time of bid. The BMS Contractor is responsible to obtaining a complete set of drawings and specifications for review for inclusion of all points, systems and values referenced in this specification. The BMS will provide the functional features as defined in Part 1-General requirements, Part 2-Products, and Part 3- Execution of these Specifications. The BMS Contractor shall provide a complete and operational system that will perform sequences of operations as verified by Owner Representative and Engineer.
2. The components furnished shall be the most recent products offered by the BMS manufacturer that meet the specifications. Any product (including controller hardware, operating system software, etc.) that is replaced by a new product or software or becomes obsolete during the project construction period or two years after completion shall be replaced free of charge. No additional compensation shall be awarded for replacement of older generation product. If there are improved models of any components that become available before the on-site commencement of installation then these shall be offered by the BMS Contractor to the CM@R at no additional cost to the Owner. The Owner shall have the option to accept or decline the offer. The components offered shall have been in successful operation in at least 2 similar large facility applications for a minimum of 12 months.
3. The BMS Contractor shall provide all software licenses necessary for the legal operation of the BMS. Coordinate with Owner-CM@R.
4. The BMS Contractor is responsible to coordinate all installation activities with General Contractor Site Facility personnel and the Engineer by submitting a written installation schedule outlining all proposed BMS installation activities. The schedule should include the anticipated time to install new controllers and network equipment, , installation of new monitoring devices and wiring, software programming, testing/commissioning, training and system acceptance.
5. <u>Commissioning of Mechanical Systems:</u> The BMS Contractor shall provide all labor as required to assist with the commissioning of all equipment and systems as scheduled and required by the project's Commissioning Agent.
6. In addition, the following apply:
    a. The work under this Section shall include all materials and labor to perform all work required for the installation of the BMS as specified.
    b. The drawings and Specifications are complementary to one another—meaning that what is called for on one is to be considered called for in both.

Where conflicts exist between the Specifications and/or drawings, the more stringent requirement shall apply.

c. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the BMS Contractor shall provide proper connection(s) to such equipment, including trade coordination.

B. New BACnet/IP based DDC cabinets shall be strategically installed in MER's and other locations in the facility (refer to BMS riser diagrams) to control and monitor new mechanical, electrical and plumbing equipment in the Central Energy Plant, Airside Building (including PCA), Landside Building, Ground Transportation Facility, and existing North Terminal Maintenance Control Room. The BMS shall provide a single and unified graphical user interface for all subsystems. System included (but not limited to) the following:

1. VAV air handling units.
2. DOAS VAV air handling units
3. 100% outside air units
4. VAV recirculating air handling units
5. AHU's with fan arrays include one VFD per fan in array. Provide airflow probes for each fan in fan array.
6. Chillers
7. Cooling Towers (CT fan VFD's integrated with BMS via BACnet MSTP).
8. Chiller refrigerant leak monitoring system (Furnished by mechanical and installed by BMS Contractor).
9. PCA equipment (Airside Building). Integrated with the BMS. All PCA control, monitoring and alarm functions shall be available at the new BMS workstations in the CEP and the North Terminal Maintenance Office.
10. EMMS integrated with BMS (monitor electrical usage of lighting and plug load electrical panels). Refer to section 26 27 13. BMS Contractor to coordinate and confirm integration requirements with system manufacturer (REST API with event subscription and HTTP authentication).
    a. Building total receptacle panel KWH power usage.
    b. Building total lighting panel KWH power usage.
    c. Baggage Handling System KWH power usage.
    d. Pre-conditioned air (Main Plant) KWH power usage.
    e. Pre-conditioned air (per gate) KWH power usage.
    f. 400 Hz System (per gate) KWH power usage.
    g. SCADA system monitoring "read only" (Emergency generators, switchgear, etc.)
11. Lighting control systems (BMS integration-read/write via BACnet TCP/IP). Refer to section 26 09 23). BMS shall be programmed to send "enable-disable" request to lighting control system to override zone control manually from the BMS workstation and automatically based on information from the AODB. BMS Contractor to coordinate integration requirements with system manufacturer (REST API with event subscription and HTTP authentication).
12. BMS integration with Airport Operational Database (AODB-read only). The AODB and the BMS shall be made interoperable through the use of an open API. The BMS manufacturer and the AODB manufacturer shall provide a fully operable

seamless platform through the API based integration between both systems. The API shall transfer status points from the AODB to the BMS including gate occupancy. The BMS shall include the ability to control AHU and terminal zone schedules for occupied-unoccupied modes of operation based on information from AODB. BMS Contractor to coordinate and confirm integration requirements with system provider (REST API with event subscription and HTTP authentication).

13. Fuel oil system (BMS integration via Modbus).
14. Constant and variable speed pump control.
15. Variable air volume terminal boxes (BMS contractor shall furnish controls for factory installation by VAV terminal box manufacturer).
16. VAV duct damper control.
17. Miscellaneous exhaust fans.
18. CRAC units (integrated with BMS via BACnet MSTP or Modbus).
19. Split AHU.
20. Fan coil units.
21. Fan powered variable air volume boxes. BMS Contractor shall furnish controls for factory installation by VAV terminal box manufacturer.
22. VFD integration with BMS (BACnet MSTP).
23. Electric duct heating coil KWH usage monitoring via the BMS (meter provided by duct heater manufacturer-integrate with BMS via BACnet MSTP).
24. AHU electric duct heating coil KWH usage meter monitoring via the BMS (meter provided by the BMS Contractor).
25. Fire/Smoke Damper end switch monitoring (closed position) via the BMS (hardwired or via integration-Coordinate with FAS manufacturer). Refer to mechanical drawings for quantity and location.
26. Chilled water BTU meters (BMS integration via Modbus protocol).
27. Pre-conditioned air system chilled water BTU meter interface with BMS.
28. Domestic water booster pump (failure alarm indication at BMS).
29. Circulating pumps (status indication at BMS).
30. Duplex sump pumps (failure alarm indication at BMS)
31. Elevator sump pump (overflow alarm indication at BMS).
32. Domestic Water Heaters (supply temperature)
33. Web based remote monitoring system (to be de-activated at the end of construction).
34. Program user interface on existing Maintenance Control Room monitor (separate icon).
35. Technical proposal (technical proposal shall be submitted, reviewed and approved prior to award and submission of shop drawings.
36. Sequence of operations: Refer to control drawings.
37. Plumbing Drip Pan Leak Detection (leak detector provided by BMS Contractor-Typical-Refer to plumbing drawings for quantity and location).
~~36.~~38. Pipe Insulated Containment Pipe Leak Detection System (Refer to drawing M0.00.04, Leak Detection System provided by Mechanical Contractor, BMS contractor to monitor: loss of power, common fault and leak detection-via dry contacts-Leak Detection Panel).

C. Except as otherwise noted, the control system shall consist of all necessary Ethernet controllers, standalone digital control units, workstations, software, sensors, transducers, relays, transformers, valves, dampers, automatic damper operators, control panels, and other necessary equipment, along with a complete system of electrical interlocking wiring to fill the intent of the specification and provide for a complete and operable system. Except as otherwise specified, provide operators for equipment such as dampers if the equipment manufacturer does not provide these. Coordinate requirements with the various Contractors.

D. Provide all miscellaneous low voltage field device mounting and interconnecting wiring for all Building mechanical systems. All interlock wiring, wiring and installation of control devices associated with equipment listed below shall be provided under this contract. When the BMS is fully installed and operational, the BMS Contractor and representatives of the owner will review and check out the system-refer to System Acceptance and testing section of this document. At that time, the BMS Contractor shall demonstrate the operation of the system and prove that it complies with the intent of the drawings and specifications.

E. Provide services and manpower necessary for commissioning of the system in coordination with the HVAC Contractor, Balancing Contractor, Design Engineer and Owner's representative.

F. All work performed under this section of the specifications will comply with all governing codes, laws and governing bodies. If the drawings and/or specifications are in conflict with governing codes, the Contractor, with guidance from the engineer, shall submit a proposal with appropriate modifications to the project to meet code restrictions. If this specification and associated drawings exceed governing code requirements the specification will govern. The Contractor shall obtain and pay for all necessary construction permits and licenses.

G. Provide control power transformers/power supplies for all new equipment.

H. Provide and install proper earth ground on all BMS equipment to prevent the build-up of electromagnetic voltage potential. All BMS equipment shall be EMI immune.

I. All components of the BMS at the Management level and at the BMS Automation level, except for the unitary controllers, shall be support by the Uninterruptible Power Supply (UPS).

J. Interface/integrate with third-party equipment as defined and specified.

K. Provide hardwire interlocks for all systems requiring interlock as noted (Fire Alarm System, Mechanical, etc.).

L. Provide system graphics for each HVAC, electrical, plumbing, and piping system. Provide scaled floor plans indicating equipment location, service, and system data as required by this specification. Graphics to incorporate integrated points communicated via multiple sources including direct protocol integration, gateways and third – party interfaces. Origin of information shall be transparent to the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BMS. Provide dynamic dashboard graphics for energy usage monitoring.

M. Provide communication network amplification devices as required whenever device quantity and/or network wiring standard limitations length are exceeded.

N. System Performance:
   1. Graphic Display: Display graphics with minimum 20 dynamic points and current data within 5 seconds.
   2. Graphic Refresh: Update graphic with minimum 20 points with current data within 5 seconds.
   3. Object Command: Reaction time of less than 2 seconds between operator command of a binary object and device reaction.
   4. Object Scan: Transmit change of state and change of analog value to control unit or workstation within 5 seconds.
   5. Alarm Response Time: Annunciate alarm at workstation within 10 seconds from initiation. Multiple workstations must receive alarms within 5 seconds of each other.
   6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical processes under control.
   7. Program Execution Summary: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs every second.
   8. Performance: Programmable controllers shall execute BMS PID control loops, and scan and update process values and outputs at least once per second.
   9. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
      a. Water Temperature: Plus or minus 1 degF.
      b. Water Flow: Plus or minus 2 percent of full scale.
      c. Water Pressure: Plus or minus 5 percent of full scale.
      d. Space Temperature: Plus or minus 1 degF
      e. Ducted Air Temperature: Plus or minus 1 degF.
      f. Outside Air Temperature: Plus or minus 2 degF.
      g. Dew Point Temperature: Plus or minus 3 degF.
      h. Temperature Differential: Plus or minus 0.25 degF.
      i. Relative Humidity: Plus or minus 2 percent.
      j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
      k. Air Pressure (Space): Plus or minus 0.01-inch wg.
      l. Air Pressure (Ducts): Plus or minus 0.1-inch wg.

O. Provide a remote notification and monitoring system:
   1. BMS workstation shall be configured to send out messages via email, phones (via speech to text technology), SMS, text messaging-cellular, mobile handsets).
   2. There should be no limit to the number of points (analog or digital), that can be configured to remote notification of alarm condition and no limit to the amount of devices which can receive messages from the BMS.
   3. On a per point message, system can be configured to send messages to an individual or group and shall be configured to send different messages to different to different remote devices based on alarm message priority level.
   4. Remote devices may be scheduled as to when they receive messages from the system to account for the operator work schedules.

5. System must be configured to send messages to an escalation list so that if the first device does not respond, the message is sent to the next device after a configurable time has elapsed. Message detail shall be configurable on a per user basis.
6. During a “flood” of alarms, remote notification messages shall have the ability to optimize several alarms into an individual remote notification message.
7. BMS workstation shall have the ability to send manual messages allowing an operator to type a message to be sent immediately.
8. BMS workstation shall have a feature to send a “heartbeat” message to periodically notify users that they have normal communication with the system.
9. Notification and monitoring system shall have the capability to be de-activated at the end of construction. Owner will have capability to re-activate system as needed via command at the BMS workstation.

P. Provide the following support for all components furnished under this sub-contract:
1. Warranty and service during the defects liability period.
2. Submittals, samples and record documentation.
3. Comprehensive commissioning and testing services.
4. Detailed theoretical and practical training services for the BMS Supervisors and Operators.
5. BMS equipment coordination with other site Specialists (Fire Alarm, etc.).
6. Comprehensive and complete interoperability documentation and method statement for all third-party systems.
7. Comprehensive PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.

Q. Add alternate:

The BMS shall be provided with data security provisions and firewalls (3rd party software) including enhanced security to provide authentication, authorization (network authorization rules shall follow the industry best practices), network security monitoring, intrusion detection network flow behavioral analysis and intrusion response capabilities. Normal BMS network traffic shall be base lined and a method used to detect an alert on anomalous network traffic patterns or potential network intrusions. BMS shall provide a method to respond to detected anomalous events by blocking access. Each network connection shall be monitored, analyzed for malicious activity and blocked if required. BMS Contractor shall provide detailed description of network cyber security provisions included for this project in the Technical Proposal Section 1.14, D.

1.7 SYSTEM DESCRIPTION

A. In accordance to the scope of work, the system shall also provide a graphical, web-based, operator interface that allows for instant access to any system through a standard browser. The BMS Contractor shall provide PC-based programming workstations, operator workstations and microcomputer controllers of modular design providing distributed processing capability, and allowing future expansion of both input/output points and processing control functions. For this project the system shall consist of the following components:

1. Administration and Programming Workstation(s)
2. Web-based Operator Workstations
3. Ethernet-based Network Router and/or Network Server Controller
4. Network controllers shall be tested and certified by the BACnet Testing Laboratory (BTL) as Network Server Controller (B-BC).

B. The Local Area Network (LAN) shall be either a 10 or a 100 Mpbs Ethernet network supporting BACnet, Modbus, Java, XML, HTTP and Cobra IIOP for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Network server controllers, user workstations and a local host computer.

C. The system shall enable an open architecture that utilizes ANSI/ASHRAE Standard 135-2007, BACnet functionality to assure interoperability between all system components. Native support for the ANSI/ASHRAE Standard 135-2007, BACnet protocol are required to assure that the project is fully supported by the HVAC open protocols to reduce future building maintenance, upgrade and expansion costs.

D. The software tools required for network management of the ANSI/ASHRAE Standard 135-2008, BACnet protocol must be provided with the system. Drawings are diagrammatic only. Equipment and labor not specifically referred to herein or on the plans and are required to meet the functional intent, shall be provided without additional cost to the owner. Minimum BACnet compliance is Level 4, with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet IP or MS/TP.

E. The system shall support Modbus TCP and RTU protocols natively, and not require the use of gateways.

F. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the approved manufacturers local field office.

G. Provide the Commissioning, configuration and diagnostic tool (CCDT), color display personnel computer, software, and interfaces to provide uploading/downloading of High Point Count Controllers, Unitary Controllers, and VAV controllers monitoring all BACnet objects, monitoring overrides of all controller physical input/output points and editing of controller resident time schedules.

H. The system shall have the capability to provide a middleware on site server AMBCx (automated monitoring based commissioning) system. The AMBCx system shall be able to interface directly with the project BMS and energy/performance metering system to provide information on HVAC, electrical, metering and lighting systems that are being controlled. BMS Contractor shall provide equipment, software, installation labor, programming, assist Cx in functional testing, training and documentation. The BMS Contractor shall be responsible for firmware maintenance, FDD database maintenance and upgrades and collected BMS data maintenance and integrity. The AMBCx system provided shall be able to satisfy FDD, building analytics and analysis for all major mechanical, electrical and energy systems included in the scope of this specification. The AMBCx shall be able to analyze a combination of hard-wired (analog and digital

I/O) and virtual points (setpoints, calculated variables) in a system using real-time and historical time-series data to the following as a minimum:

1. Determine the stability of control devices (valves/actuators/speed drives)
2. Determine the degree of error above reasonable thresholds.
3. Compare sensor readings to setpoint and flag out-of-range errors from faulty sensors.
4. Compare outputs (controllers) setpoints to actual conditions to find failed devices.
5. Calculate and report on energy consumption for systems under BMS control.
6. Diagnose flow measurement systems to ensure readings are in range of expectations.
7. Categorize faults according to various priorities (energy, comfort and system maintenance impact).
8. Identify simultaneous heating and cooling in a system and subsystem.
9. Ensure ventilation rates are adequate (testing minimum outdoor air volume settings).
10. Report CEP efficiency through efficiency measurement.
11. Optimize air filter replacement by monitoring changes in filter pressure drop.
12. Monitor chiller evaporator and condenser tube bundle pressure drops for degradation of performance.
13. System shall be monitored from the North Terminal BMS workstation and the CEP. BMS Contractor shall install, test and train owner employees on its use and capability.
14. BMS Contractor shall provide a detailed description of features and functionality of AMBCx in Technical Proposal Section 1.14, D.

1.8 COORDINATION WITH OTHER TRADES

A. Contractors, Sub-contractors, Employees

1. It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project will be delivered in the best possible condition and in the shortest time. The BMS Contractor will coordinate with other Trade Contractors regarding the location and size of pipes, equipment, fixtures, conduit, ducts, openings, switches, outlets, structural, architectural features and so forth, in order to eliminate any delays in the progress of the job.
2. Any task related to the BMS turnkey installation that is not clearly identified in this document as being the responsibility of another trade shall be the responsibility of the BMS Contractor.

B. Coordination with Owner & Engineer

1. The BMS Contractor shall cooperate with Owner and the Engineer when performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of existing on-site documentation, if applicable to further determine the nature and extent of BMS work.

1.9 BMS EXPANSION

A. Network architecture shall allow unlimited expandability by the addition of new sub networks and associated routers, gateways and controllers, etc.

B. Each BMS as installed shall be capable to be expandable, at minimum to incorporate the following in addition to the above:
   1. A minimum of 50% percent additional hardware (field) point modules (each type analog, digital, inputs and outputs) with the addition of CCP, DDCP and UC.
   2. A minimum of 200 percent additional system graphics diagrams and point programming in addition to those required to meet these specifications.
   3. A minimum of 8 additional Operator Interface Workstations (OIW).
   4. A minimum of 2 additional communication interfaces to other low voltage building systems to those integrated under this contract.

C. Subsequent to the potential expansion cited in “B” above, the BMS performance shall not be degraded in any manner and shall meet all performance criteria detailed in these specifications.

1.10 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
   1. Each control device labeled with setting or adjustable range of control.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   1. Shop drawings shall be AutoCAD generated, minimum 11 X 17 inches. Drawings shall include diagrams, mounting instructions, installation procedures, equipment details and software descriptions for all aspects of the system to be installed. In addition to the drawings, the Contractor shall furnish a CD containing the identical information.
   2. Shop drawings shall include a riser diagram depicting locations of all controllers and workstations, with associated network wiring. Also included shall be individual schematics of each mechanical system showing all connected points with reference to their associated controller. Typicals will be allowed where appropriate.
   3. Software submittals shall contain narrative descriptions of sequences of operation, program listings, point lists, and a complete description of the graphics, reports, alarms and configuration to be furnished with the workstation software. Information shall be submitted electronically. Diagrams shall be on 11” by 17” foldouts.
   4. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
   5. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.

6. Details of control panel faces, including controls, instruments, and labeling.
7. Submit shop drawings of all control field panels for review before fabrication.
8. Written description of sequence of operation.
9. Schedule of dampers including size, leakage, construction data, and flow characteristics.
10. Schedule of valves including leakage, construction data, and flow characteristics. Submit valve calculations for each valve for Engineer’s approval.
11. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
12. Listing of connected data points, including connected control unit and input device.
13. Submit graphic samples of actual resolution for a 20 inch flat screen monitor (colorized) as a minimum, for each major monitored system, indicating all data (connected and calculated) point addresses, and operator notations as specified. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
14. Provide Table of Contents for Devices’ data Sheets.
15. Submit electronic transmittal submittal data and shop drawings to the Engineer for review prior to ordering or fabrication of the equipment. The Contractor, prior to submitting, shall check all documents for accuracy.
16. The Engineer will make corrections, if required, and return to the Contractor. The Contractor will then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the Engineer and the submittals are fully approved.

C. Samples: For each color required, of each type of thermostat cover.

D. Software and Firmware Operational Documentation: Include the following:
1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
3. Device address list.
4. Printout of software application and graphic screens.
5. Software license required by and installed for BMS workstations and control systems.

E. Software Upgrade Kit: For Owner to use in modifying software to suit future monitoring and control revisions.

F. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

G. Maintenance Data: For systems to include in maintenance manuals as specified. Include the following:
1. Maintenance instructions and lists of spare parts for each type of control device.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.

4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

H. Qualification Data:
1. General: Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

I. Contract Closeout Submittals: All manuals shall be 100 percent custom written for this project. Closeout documents will include all as-built software and hardware revision documentation, including a step-by-step, `easy to read' decision tree diagram, which would lead facility operating personnel to specific manual sections for operating procedures, maintenance procedures, and diagnostic/trouble-shooting procedures. All manuals will be subject to the approval of Owner and Engineer prior to the warranty period, and shall provide as a minimum:
1. Project Record Documents for:
   a. Electronic As-Built Drawings in AutoCAD Format, including the following:
      1) System architecture drawing.
      2) As-Built Riser Diagram.
      3) Layout drawing for each control panel.
      4) Wiring diagram for individual components.
      5) System flow diagram for each controlled system.
      6) Instrumentation list for each controlled system.
      7) Sequence of control.
      8) Binding map.
   b. Final software database (electronic). Includes PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.
   c. Complete program listing with section and line by line comments.
   d. Color coding, labeling, and other identification for point to point wiring.
2. Operation and Maintenance Documentation for:
   a. Operation and maintenance manuals for each system component.
   b. List of recommended system spare parts.
3. Information common to the entire system shall be provided. This shall include but not be limited to the following:
   a. Product manuals for the key software tasks.
   b. Operating the system.
   c. Administrating the system.
   d. Engineering the operator workstation.
   e. Application programming.
   f. Engineering the network.
   g. Setting up the web server.
   h. Report creation.
   i. Graphics creation.
   j. All other engineering tasks.
   k. System Architecture Diagram.
   l. List of recommended maintenance tasks associated with the system servers, operator workstations, data servers, web servers and web clients.

m. Define the task.
n. Recommend a frequency for the task.
o. Reference the product manual that includes instructions on executing the task.
p. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
q. Licenses, guarantees, and warranty documents for equipment and systems.
r. Submit one copy for each building, plus two extra copies.

4. Test Data for:
   a. All final system field test data to of temperature, humidity, air flow measurement, room differential pressure, etc. shall be provided in a standalone document to the Owner.
5. Warranty Documentation for:
   a. Materials, manufactured units, equipment and components.
   b. Software.
   c. Auxiliary system equipment.

1.11 WARRANTY AND SERVICES DURING THE WARRANTY PERIOD

A. Material and Labor:
1. The Control System shall be free from defects in material and workmanship under normal use and service. If within five years from the date of project acceptance by the Owner any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the BMS Contractor free of charge. The warranty period for all components of the BMS and their installation shall be five years following the date of project acceptance by the Owner.
2. Updates to hardware, firmware, and software shall be installed for a period of 5 years with no additional cost to the owner. Updates shall be installed within 60 days of availability. BMS Contractor shall include 2 hours on-site response for items deemed critical by the airport and 4 hour response for items deemed non-critical emergency response as part of warranty period coverage.
3. The temperature control contractor shall provide a 5 year extended warranty and preventative maintenance agreement for the temperature control system, as part of the original bid. Any manufacturing defects arising during this extended warranty period shall be corrected without cost to the Owner. The preventative maintenance agreement shall include a minimum of quarterly service visits, include defective parts replacement and commence upon date of project acceptance by the Owner of the temperature control system installation.
4. This agreement shall include 2 hours on-site response for items deemed critical by the airport and 4 hour response for items deemed non-critical emergency on-site service response.
5. The temperature control contractor shall provide a manufacturer's scope description as per owner provided scope of maintenance services of the extended warranty/preventative maintenance agreement, as part of the temperature control submittal (Preventive and corrective maintenance program shall be given thru the purchasing department similar to the current North Terminal Contract Specifications) . This agreement shall contain manufacturer's standard schedules

of service procedures, work task definitions, and recommended frequencies of performance. The preventative maintenance agreement shall include the temperature control system and its peripherals as specified in this section. This agreement shall include the provision and installation of all manufacturer's standard Host software and product firmware upgrades released during the term of this agreement. The temperature control submittal will not be approved without the warranty/preventative maintenance agreement. There will be no charge to the customer for preventative maintenance of the control system during the extended warranty period.

B. Any material furnished by the BMS contractor which is defective or fails during normal operation of the system, shall be remedied (replaced or repaired) immediately within 2 hours on-site for items deemed critical by the airport and 4 hours for non-critical items by the BMS Contractor at no additional cost to the Owner, during the period prior to the issue of the certificate of completion, and during the warranty period.

C. Repair work shall only be undertaken at times approved by the Owner.

D. Repair work shall not include routine maintenance during the Defects Liability Period.

E. Respond and be on site within 2 hour on-site for items deemed critical by the airport and 4 hours for non-critical items of the Site Engineer and/or Owner placing a system trouble call for items of an immediate nature (e.g. failed component, non-functioning controller, etc.).

F. Response to warranty calls made by the Site Engineer and/or Owner shall be within 2 hours on-site for items deemed critical by the airport and 4 hours for non-critical items..

G. Work to troubleshoot and identify the cause of the BMS system or component failure shall begin immediately and shall continue until repaired to the satisfaction of the Site Engineer and Employer.

H. Any software upgrades and new software programs that become standard product offerings from the BMS Contractor and/or BMS equipment vendors during the Defects Liability Period (Warranty) shall be brought to the attention of the Owner and made available at no additional cost. If at my time during ‘the Defects Liability Period, software patches that correct ‘software errors becomes available the Owner shall be notified immediately and they shall be made available to the Owner at no additional cost. Owner shall be provided with a back-up copy of software package, with compiled and un-compiled read/write capability. Ownership of the original software shall be turned over to owner at their request within 30 calendar days.

1.12 CODES, PERMITS AND APPROVAL

A. All work shall conform to the following Codes and Standards, where applicable:
1. Local Electrical Codes.
2. National Fire Protection Association (NFPA) Standards, as specified.
3. National Electrical Code (NEC)
4. Underwriters Laboratories (UL) listing and labels, as specified.
5. American National Standards Institute (ANSI).
6. National Electric Manufacturers' Association (NEMA).
7. Building Automation and Control Network (BACnet) open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135).
8. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
9. American Society of Mechanical Engineers (ASME).
10. Air Movement and Control Association (AMCA).
11. Institute of Electrical and Electronic Engineers (IEEE).
12. American Standard Code for Information Interchange (ASCII).
13. Electronics Industries Association (EIA).
14. Occupational Safety and Health Administration (OSHA).
15. American Society for Testing and Materials (ASTM).
16. State Energy Code.
17. State Building Code and applicable local Building Code.
18. ANSI/TIA/EIA-862, Building Automation Systems Cabling Standards for Commercial Building.
19. NFPA 92A and 92B/UL 864/UUKL Smoke Purge Control Equipment.

B. Obtain all required permits and inspection certificates. All permits and certificates shall be made available to the Owner.

C. The latest requirements of all national, county, municipal and other authorities having jurisdiction shall be met.

D. Work shall be performed in compliance with Owner’s insurance underwriter & requirements.

E. All electrical equipment, devices and components and their installation shall comply with the latest edition of the IEEE Wiring and all associated addenda.

F. Interior enclosures shall be, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.

G. The BMS Contractor shall only offer equipment that meets UL 916 requirements and all electrical components shall be UL listed and shall carry the UL label.

H. The BMS shall be listed and manufactured to ISO 9001 and ISO 9002 standards.

I. All work shall conform to the requirements detailed in the electrical specifications. Where there is any conflict between the requirements of the different project trade sub-contract documents, statutes, codes, regulations, local ordinances and any requirement of an agency having jurisdiction over the project, the most stringent requirement shall apply unless determined otherwise by the Owner, Advise the Engineer of any discrepancy or conflicts between the various requirements for the project.

J. Equipment, devices and materials shall be immune against Electro-Magnetic interferences and shall conform to all performance requirements of' the specifications when exposed to the following interferences:
1. Project lighting, telephone and elevator equipment.
2. AM signals as generated from transmitters.
3. VHF and UHF signals as generated by external or internal portable or fixed transmitters.
4. Electrical noise on the building power system, both spurious and harmonies.
5. The installations shall not radiate signals that cause interference that hinder the correct operation of the Owner's on-site equipment.
6. The BMS and all individual electrical equipment, devices and components shall comply with the requirements of the Federal Communication Commission (FCC) rules and regulations Part 15, sub part J and all other applicable codes and statutes with respect to the radiation and conduction of radio frequency interference.

1.13 SCHEDULE

A. Complete site requirements of the BMS sub-contract in accordance with the project program and prior to the scheduled Substantial Completion date for each phase.

B. Attend project meetings as requested by the General Contractor.

C. Provide to the General Contractor a schedule indicating the sequence of work, durations of individual tasks, delivery dates for all material, devices and equipment and detail any interface that must be coordinated with any other Specialists.

D. Provide written status reports at required intervals in an electronic format acceptable to the Engineer. An updated schedule of work shall be included in each status report.

E. Comply with, the Project Construction Schedule. Provide additional staffing or work overtime as required to comply with the Project Schedule so as not to interfere with other on-site Specialists in their effort to comply with the Overall Project Schedule. Confirm, prior to tender submittal that all equipment, devices, material and services proposed are available and will be delivered accordingly to comply with the Overall Project Schedule.

F. Provide written Request 'For Information (RFI) notices to the Engineer when specific information or clarification of the specifications is required. Request For Information notices shall be provided at least two (2) weeks prior to the need for the information to the Engineer.

1.14 BMS CONTRACTOR INSTALLER QUALIFICATIONS

A. The BMS Contractor shall:

1. Have a local staff (minimum of 4 factory certified, badged technicians, within 25 miles of the project site, of trained personnel capable of giving instructions and providing routine and emergency maintenance on the BMS, including all components and software/firmware and all other elements of the BMS.
2. Have a proven record of experience in ‘the supply and installation of equivalent systems over a minimum period of ten (10) years in the local Central Florida area.
3. Have comprehensive local service and support facilities for the total BMS that shall be capable of responding to emergency calls within 2 hours on-site response for items deemed critical by the airport and 4 hours on-site for non-critical items, 7 days a week (Inclusive of holidays and weekends).
4. Maintain local, or have approved local sub-contracted access to, supplies of essential expendable parts.
5. Undertake to maintain necessary project staff and maintenance personnel as per the Owner’s requirements.

B. The BMS Contractor shall have a minimum of ten years experience with the complete, turnkey installation of Building Management Systems of similar size and technical complexity. The BMS Contractor shall provide a list of five comparable projects that have Building Management Systems with the features as specified for this project. These projects must be on-line and functional.

C. The BMS Contractor shall employ specialists in the field of Building Management Systems including: Programming, Engineering, Field Supervision, and Installation. Specialists shall have a minimum of five years of experience with Building Management Systems.

D. Technical Proposal: Prepare electronic copy of a detailed technical proposal including:

1. Table of Contents. Executive Summary.
2. Description of Central Florida branch office overall capabilities, number of employees and key resumes of project personnel.
3. Provide list of all large aviation and other projects (include project square footage) completed by manufacturer and local office of Enterprise BMS installations with an integrated systems database of various subsystems utilizing a converged IT network .. Submit list of aviation project owner references and phone numbers.
4. Submit a point by point line by line statement of compliance with the specification and the BMS Contract drawings. The statement shall consist of a list of all numbered paragraphs in specification section 230900. Where the proposed system complies fully, such shall indicate by placing the word “comply” opposite the paragraph number. Where the proposed system does not comply or accomplishes the stated function in a manner different from the described, a full description of the deviation shall be provided. Where a full description of the deviation is not provided, it shall be assumed that the system does not comply with the paragraph in question. The BMS bidder shall submit a signed certificate stating that the BMS bidder has read the performance, function, BMS system architecture,

sequence of operations, etc. and understands them and the technical proposal shall comply with all parts of the specification.

5. Provide a written guarantee of how long (years) the system proposed will be a standard product and backed by ongoing parts and hardware availability and factory trained field support. Written guarantee shall include statement that any product that is replaced with a new product or becomes obsolete during the project construction period or two years after completion shall be replaced free of charge.
6. Unit pricing schedule as described in Section 1.16.
7. Technical data sheets of all DDC controllers and hardware.
8. Software and programming manuals.
9. Proposed system architecture drawing for all buildings showing all major system DDC controllers and typical terminal control systems for different applications.
10. Provide description and sample of BMS GUI colorgraphics including one-lines, floor plans.
11. Provide detailed description and sample GUI for the “Dashboard” animated colorgraphics for LEED metering. Description shall include format, sample colorgraphics, reports, web access capabilities, etc.
12. Proposed implementation plan narrative describing how installation will be accomplished as per project schedule and testing and commissioning methodology without disruption to GOAA operations.
13. Description of vendors AMBCx system product and software offering.
14. Description of BMS provider’s cybersecurity data provisions including authentication, network security monitoring, intrusion detection, network flow behavioral analysis, device profiling and intrusion response capabilities. Description shall include how system firewalls or data security provisions shall detect alerts on anomalous network traffic patterns or potential network intrusions and block access. BMS Contractor to describe validation process and comprehensive testing between BMS manufacturer and core IP network manufacturer.
15. Description of remote monitoring capabilities.
16. Branch office support and training capabilities.

1.15 HEALTH AND SAFETY

A. Work shall comply with the requirements of Occupational Safety and Health Administration (OSHA), the Health and Safety requirements for the project and with all of the daily Health and Safety instructions given by the General Contractor.

1.16 UNIT PRICES

A. The BMS Contractor is to provide a tender price for the complete BMS. In addition, the BMS Contractor shall provide unit prices for all items and equipment installed (unit price to include wiring and programming) under the contract in sufficient details to enable additions and deletions to the contract to be priced by the Owner.

B. Central Equipment:
1. Network Data Servers $_____________ ea.

2. BMS Workstation (CPU, Video Display, Printers) $_____________ ea.
3. DDCP with 100 I/O points $___________ea.
4. CCP $_______________ea.

C. Bi-directional communication Interfaces:
1. Modbus $_____________ ea.
2. BACnet $_____________ ea.

D. Field Points: Provide unit prices for the following:
1. Analog input point. $_____________ ea.
2. Analog output point. $_____________ ea.
3. Digital input point. $_____________ ea.
4. Digital output point. $______________ ea.
5. Conduit and wiring for above points between device and BMS panel. $___________ per ft.
6. Direct digital control units and all necessary appurtenances to permit attachment of control devices included above:
a. $______________ per sq.ft.
b. $______________ per sq.ft.
c. $______________ per sq.ft.
d. $_______________ ea.

E. Cat 6 Trunk wiring for transmission of data, including conduit $_______________ per first 100 ft. $______________ per additional ft.

F. Field Devices: Furnish and install (not including wiring or DDC input/output):
1. Duct-mounted RTD Type transmitters $________ea.
2. Liquid insertion RTD Type transmitters and wells $________ea.
3. Duct-mounted static pressure transmitters $________ea.
4. Duct-mounted high temperature thermostats $________ea.
5. Low temperature thermostats (freeze protection) $________ea.
6. Duct-mounted relative humidity transmitter $________ea.
7. Wall-mounted relative humidity transmitter $________ea.
8. Differential pressure transmitter (water) $________ea.
9. Water flow measuring element and transmitter $________ea.
10. Current sensing relays $________ea
11. Outside airflow measuring station $___________ea.
12. BTU meter $_________ea
13. Space pressurization sensor $_________ea.

G. Valves and Actuators
1. Automatic Louvered Dampers with Actuators: Furnished only: $
2. Smoke Dampers with Actuators: Furnished only: $

3. Automatic Valves with Actuators: Furnished only: $
4. 1/2 in. $__________ per valve
5. 3/4 in. $__________ per valve
6. 1 in. $__________ per valve
7. 1-1/2 in. $__________ per valve

8. 2 in. $__________ per valve 2-1/2 in. $__________ per valve
9. 3 in. $__________ per valve
10. 4 in. $__________ per valve

H. Motorized Valves with Actuators, Limit Switches: Furnished only:
1. 6 in. $__________ per valve
2. 8 in. $__________ per valve
3. 10 in. $__________ per valve
4. 12 in. $__________ per valve
5. 14 in. $__________ per valve
6. 16 in. $__________ per valve
7. 18 in. $__________ per valve
8. 20 in. $__________ per valve
9. 24 in. $__________per valve

I. Variable Air Volume Terminal Unit Controllers (cooling only) (Direct Digital Control): Furnish and provide DDC controller, programming, actuator, flow sensing element, temperature sensor, power transformer as shown on contract drawings. Devices factory mounted and wired at terminal unit manufacturer or field mounted. Furnish and install space sensor and associated control wiring and power to DDC unit. $__________ per unit (factory mounted) $___________per unit (field mounted)

J. Variable Air Volume Terminal Unit Controllers (with electric reheat coil) (Direct Digital Control): Furnish and provide DDC controller, programming, actuator, flow sensing element, temperature sensor, power transformer as shown on controls drawings. Devices factory mounted and wired at terminal unit manufacturer or field mounted. Furnish and install space sensor and associated control wiring and power wiring to DDC unit. $__________per unit (factory mounted) $___________per unit (field mounted)

K. Fan-Powered Terminal Unit Controllers (Direct Digital Control): Furnish only DDC controller, programming, actuator, flow sensing element, current sensor, and power transformer. Devices factory mounted and wired at terminal unit manufacturer or field mounted. Furnish and install space sensor and associated control wiring and power and control wiring to DDC. $______per unit (factory mounted) $______per unit (field mounted)

L. Fan Coil Unit Terminal Controllers (cooling only) (Direct Digital Control): Provide DDC controller, programming, actuators, control valves (furnished), fan control and miscellaneous sensors and points as shown on controls drawings. $___________per unit (field installed)

M. Fan Coil Unit Terminal Controllers (heating and cooling) (Direct Digital Control): Provide DDC controller, programming, actuators, control valves (furnished), fan and electric heater control and miscellaneous points as shown on controls drawings. $______per unit (field installed).

N. Variable flow AHU pretreated outside air and return fan Direst Digital Control: Provide DDC controller, programming, actuators, control valves (furnished), sensors and miscellaneous points shown on control drawings. $_______per unit (field installed).

O. Variable flow AHU dedicated outside air system (DOAS) Direct Digital Control: Provide DDC controller, programming, actuator, control valves (furnished), sensors and miscellaneous points shown on control drawings. $________per unit (field installed).

P. 100% outside air unit (tenant make-up air unit-airside) Direct Digital Control: Provide DDC controller, programming, actuator, control valves (furnished), sensors and miscellaneous points shown on controls drawings. $________per unit (field installed).

Q. Packaged air conditioning unit (chilled water) Direct Digital Control: Provide DDC controller programming, actuators, control valves (furnished), sensors and miscellaneous points shown on control drawings. $_______per unit (field installed).

R. Packaged air conditioning units with dual chilled water (DX coil) Direct Digital Control: Provide DDC controller, programming, actuators, control valves (furnished), sensors, and miscellaneous points shown on control drawings. $________per unit (field installed).

S. General exhaust fan with HEPA filter Direct Digital Control: Provide DDC controller, programming, actuators, and miscellaneous points shown on control drawings. $_____per unit (field installed).

T. Provide separate line item unit price for an AMBCx (Automated Monitoring Based Commissioning) system. Provide price for on-site middleware server configurations.

1.17 DELIVERY, STORAGE AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

B. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage.

C. Deliver, store, protect, and handle products to site under provisions of the contract Documents. Coordinate all site delivers with Construction project Manager.

D. Accept products on-site and verify any damage equipment. Damage equipment shall be re-ordered/replaced immediately without cost to the Owner.

E. Protect products from construction operations, dust, and debris, by storing materials inside, protected from weather in a conditioned space.

F. System Software: Update to latest version of software at Project completion.

1.18 QUALITY ASSURANCE

A. General

1. The Building Management System (BMS) herein specified shall be fully integrated and installed as a complete package by the Building Management System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system.
2. The Building Management System Contractor shall be a factory owned or authorized representative branch office that is regularly engaged in the engineering, programming, installation and service of Building Management Systems of similar size and complexity.
3. The BMS Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect/Engineer.

B. Products

1. The Building Management System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Management Systems, and shall be the manufacturer's latest standard of design. DDCP, CCP and UC system components shall be latest (current) production products.
2. All other equipment shall be the products of the BMS manufacturers or of an approved manufacturer regularly engaged in production of specialized Building Management System materials or equipment.

C. ISO-9001

1. The manufacturer of the Building Management System shall provide documentation supporting compliance with ISO-9001 (Model of Quality Assurance in Design/Development, Production, Installation, and Servicing). Product Literature provided by the BMS manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar. Manufacturers delivering products that do not comply with the ISO-9001 certification requirement shall provide the following information to assure that quality systems are in place and are equivalent to the ISO-9001 standard:
   a. Marketing Specification Standards
   b. Design File Standards
   c. Manufacturing Test Standards
   d. Calibration Standards
   e. Quality System Standards
   f. Quality System Procedures
   g. Documented management commitment that all employees participate in quality programs
   h. Training Procedures
   i. Methods by which corrective actions are taken for problems identified within the factory process.

D. Quality Assurance Program

1. The BMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements:

a. The BMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is to be responsible for the management of the program.

b. The Quality Assurance Manager shall provide or maintain:
   1) Documentation of training for employees—including office, field, and subcontractors—on the Quality Assurance Program.
   2) Written verification that each worker on the project has read the Specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
   3) A detailed audit trail for all Quality Assurance issues, including: problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.

c. Each individual team member shall be responsible for identifying and reporting Quality Assurance problems and for assisting, as requested by the Quality Assurance Manager, in the resolution thereof.

E. Each point in the system shall be tested for both hardware and software functionality. In addition, each mechanical and electrical system under control of the BAS will be tested against the appropriate sequence of operation specified herein. Successful completion of the system test shall constitute the beginning of the warranty period. A written report will be submitted to the owner indicating that the installed system functions in accordance with the plans and specifications.

F. The BMS Contractor shall commission and set in operating condition all major equipment and systems, such as the chilled water, and all air handling systems, in the presence of the equipment manufacturer's representatives, as applicable, and the Owner and Architect's representatives.

G. The BMS Contractor shall provide a technician for manpower and engineering services required to assist the HVAC Contractor and Balancing Contractor in testing, adjusting, and balancing all systems in the building. The BAS Contractor shall coordinate all requirements to provide a complete air balance with the Balancing Contractor and shall include all labor and materials in his contract.

H. Startup Testing shall be performed for each task on the startup test checklist, which shall be initialed by the technician and dated upon test was completion along with any recorded data such as voltages, offsets or tuning parameters. Any deviations from the submitted installation plan shall also be recorded.

I. Required elements of the startup testing include:
   1. Measurement of voltage sources, primary and secondary
   2. Verification of proper controller power wiring.
   3. Verification of component inventory when compared to the submittals.
   4. Verification of labeling on components and wiring.
   5. Verification of connection integrity and quality (loose strands and tight connections).

6. Verification of bus topology, grounding of shields and installation of termination devices.
7. Verification of point checkout.
8. Each I/O device is landed per the submittals and functions per the sequence of control.
9. Analog sensors are properly scaled and a value is reported
10. Binary sensors have the correct normal position and the state is correctly reported.
11. Analog outputs have the correct normal position and move full stroke when so commanded.
12. Binary outputs have the correct normal state and respond appropriately to energize/de-energize commands.
13. Documentation of analog sensor calibration (measured value, reported value and calculated offset).
14. Documentation of Loop tuning (sample rate, gain and integral time constant).

J. A performance verification test shall also be completed for the operator interaction with the system. Test elements shall be written to require the verification of all operator interaction tasks including, but not limited to the following.
1. Graphics navigation.
2. Trend data collection and presentation.
3. Alarm handling, acknowledgement and routing.
4. Time schedule editing.
5. Application parameter adjustment.
6. Manual control.
7. Report execution.
8. Automatic backups.
9. Web Client access.

K. A Startup Testing Report and a Performance Verification Testing Report shall be provided upon test completion

L. Governing Code Compliance
1. The BMS Contractor shall comply with all current governing codes ordinances and regulations as specified within these specifications, including UL, NFPA, the local Building Code, local Electrical Code and so forth.

M. FCC Regulation
1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference and Subpart J, governing Class A Computing Devices and be so labeled.

1.19 COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.

B. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

C. Coordinate equipment with Division 26 Section "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.

D. Coordinate equipment with Division 26 Section "Panelboards" to achieve compatibility with starter coils and annunciation devices.

E. Coordinate equipment with Division 26 Section “Emergency Generators” to achieve compatibility with monitoring of system.

1.20 TRAINING

A. The BMS Contractor shall provide both on-site and classroom training to the Owner’s representative and maintenance personnel per the following description:

B. On-site training shall consist of a minimum of (40) hours of hands-on instruction geared at the operation and maintenance of the systems. The curriculum shall include:

1. System Overview
2. System Software and Operation
3. System access
4. Software features overview
5. Changing setpoints and other attributes
6. Scheduling
7. Editing programmed variables
8. Displaying color graphics
9. Running reports
10. Workstation maintenance
11. Viewing application programming
12. Operational sequences including start-up, shutdown, adjusting and balancing.
13. Equipment maintenance.

C. All training sessions will be recorded via video and turned over to GOAA for future reference. Refer to Sections 01 91 13 – General Commissioning Requirements and 23 08 00 – Commissioning of HVAC Systems.

PART 2 - PRODUCTS

2.1 APPROVED SYSTEM MANUFACTURERS

A. General: Subject to compliance with requirements, provide products by the manufacturer specified:
1. Siemens Industries – Desigo Product-PXCM (Peer to Peer, standalone modular BACnet IP DDC controller)
2. Johnson Controls Inc. (JCI) – Metasys NAE’s (Peer to Peer, standalone modular BACnet IP controller)

3. Honeywell Inc. – EBI Excel 5000 Product/Excel 500 Controller
4. Schneider Electric.-Smart Struxure system.
5. Automated Logic Corporation-WebCTRL
6. Trane Tracer SC with standalone modular BACnet IP DDC SC controllers
7. Carrier Corporation

2.2 EQUIPMENT AND MATERIAL – GENERAL

A. When a Specific reference to a manufacturer of a product is made, and the term “equal and approved” is used, substitutions of a product by another manufacturer will be allowed, but the substituted product must conform to all specified requirements. The Engineer’s determination on the acceptability of substitutes shall be final. Approved substituted equipment shall conform to available space requirements. Substituted equipment that does not conform to the available space requirements shall be replaced or required modifications shall be made at no additional cost to the Owner.

B. All equipment and materials shall be new and without any defect.

C. Hazardous Materials Notification: In the event no product or material is available that does not contain asbestos, PCB, or other hazardous material; as determined by the Engineer, a written application shall be made by the BMS Contractor to the Engineer providing all relevant details concerning a proposed product or material that contains hazardous material prior to installation.

D. Asbestos and PCB Certification: After completion of installation, but prior to Substantial Completion, the BMS Contractor shall certify in writing that products and materials installed, and processes used, do not contain asbestos or polychlorinated biphenyls (PCB).

2.3 PERFORMANCE CERTIFICATION

A. The BMS Contractor shall certify in writing with the tender submittal that all components proposed for this project comply with all of the following requirements:
   1. Complete and thorough testing has proven that performance shall not be affected when the building electrical distribution system experiences disturbances of the type and magnitude normally encountered in buildings of this nature.
   2. An independent testing laboratory has verified that the VAV terminal unit unitary controller meets the performance requirements detailed in these specifications. If so required by the Construction Manager, the testing laboratory shall test a project VAV terminal unit complete with the BMS unitary controller and the BMS Contractor shall demonstrate that the VAV terminal unit UC can meet all of the requirements for monitoring and control accuracy and can undertake all of the sequences of operation associated with the VAV as detailed in these specifications. The independent testing laboratory test report is to be submitted with the shop drawings.

3. Provide power line disturbance tests involving the cycling of mains voltage that will show that all BMS components operate satisfactorily when voltage drops to 75% or less of the nominal mains voltage and normal operation resumed when the voltage returned to less than 85% of the normal mains voltage. Following these brownout conditions, BMS components shall be free of any stress and/or damage, and shall operate normally with no data at the PC, CCP, DDCP and/or UC lost or corrupted.

B. The BMS Contractor shall certify in writing with the tender submittal that all components are free of date related problems.

2.4 AMBIENT CONDITIONS

A. Provide equipment, devices and materials for interior and exterior applications that shall be capable of withstanding and operating satisfactory in, at a minimum, at the following ambient conditions:
   1. BMS central hardware (processors, console, and peripherals): 50 deg F to 100 deg F 10 percent to 90 percent RH.
   2. Indoor hardware: 32 deg F to 120 deg F, 10 percent to 90 percent RH.
   3. Outdoor hardware: -30 deg F to 150 deg F, 0 percent to 100 percent RH.

2.5 SPARE PARTS

A. Submit spare parts for each different item of equipment furnished. Data to include a complete list of each supplier and product by part number, a list of parts and supplies that are either normally furnished at extra cost with the purchase of the equipment, or specified hereinafter as “Extra Materials” to be furnished as part of the sub-contract.

B. Submit a list of additional items recommended by the manufacturer to assure efficient operation for a period of 790 days at the particular installation. The foregoing shall not relieve the BMS Contractor of any responsibilities during the BMS Warranty Period.

2.6 EXTRA MATERIALS

A. Provide special hardware and software tools required for maintenance.

2.7 LABELING

A. Provide labeling for all DDC controllers, gateways, routers, hubs, field level components, panels and enclosures, etc., Labeling shall meet, at minimum, the following requirements:
   1. Plastic laminated label that shall be affixed to the panel or enclosure with rivets or permanent adhesive.
   2. Lettering 6mm (0.25 inch) high that sharply contracts the background color.
   3. Consistent throughout the project.

4. Indicated on the record (close-out) documentation.

B. Provide labeling of all cabling and containment. Labeling shall meet, at minimum, the following requirements:
   1. Identified with permanent tag or self-adhesive label within the panel.
   2. Cross referenced on the associated record (close-out) documentation and laminated record drawing within the panel enclosure.
   3. The BMS Contractor shall provide labeling for all cable furnished and installed by the BMS Contractor.

2.8 PANEL AND ENCLOSURES

A. Install equipment (servers, printers, routers, etc.) in a secure, lockable Hoffmann enclosure, suitable for mounting peripheral equipment and data network equipment. Enclosure will be free-standing, with a minimum height of 4.5 foot from finish floor.

B. Servers shall be installed physically separate from each other.

C.

D. Provide panels and enclosures for all components of the BMS except where it is specifically identified within these contract documents that the enclosure shall be furnished by another trade. Panels and enclosures shall meet, at minimum, the following requirements:
   1. Painted steel panels with locking door. All panels shall be lockable with the same key.
   2. Ventilated to prevent excessive heat buildup, where required.
   3. Field cabling shall be terminated on a terminal strip. Provide cable support.
   4. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal or replacement.
   5. Panel or enclosure shall be suitable rated for the environment for which it is to be installed, Interior enclosures shall he, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.
   6. Panel or enclosures shall have 25% spare space for future addition of BMS controllers.

E. Panels and enclosures shall only be located as indicate on the drawings and at Engineer approved locations.

F. The BMS Contractor shall coordinate with the trade furnishing the motor starters and variable frequency drives to provide an interface terminal strip (for BMS Contractor use) in a dedicated external enclosure or may be a compartment within the motor starter enclosure. Refer to the sub-contract documents for the trade furnishing the motor starter and the variable frequency drive controllers for the details of the enclosure. DDC controllers shall not be located in the MCC panels.

2.9 CONDUIT AND FITTING

A. The BMS Contractor shall provide conduit and fittings as necessary for a fully functioning system as detailed in these specifications.

B. Flexible metallic rustproof conduit shall be provided for the final one (1) meter before connection from a non-vibrating location to equipment subject to vibration or movement. Flexible metallic conduit shall be provided for between the last 300mm and the last l000mm of connection to field instrumentation, relays and final control elements as necessary to facilitate the removal of devices without the disconnection or the bending of the non-flexible conduit. Watertight conduit to be provided where appropriate.

C. Conduit shall be securely mounted in accordance with IEEE Regulations and shall be concealed in all, areas to which the public have access.

D. Conduit shall run parallel or perpendicular to the building lines and shall be installed in a workmanlike manner. Avoid obstructions and crossovers where possible.

E. Conduit shall be installed such that any condensation in the conduit cannot run into BMS equipment. Where necessary conduit shall enter enclosures from the bottom or shall be sloped up to the enclosure.

F. Junction and pull boxes shall be securely fastened to the conduit and be accessible where required by code or where necessary to facilitate the pulling of cables.

G. Coordinate installation of conduit with building structure and other trades.

H. Containment shall be provided, for all BMS cable. .

I. Signal wiring and cables shall be installed in minimum sized raceways and/or electric metallic tubing (EMT) where required by local code authorities.

J. Following shall be minimum approved raceways for their specific application (no exceptions):
   1. EMT: All interior building locations.
   2. Rigid Conduit: Building exterior.
   3. Plenum rated cable freely run in concealed ceiling plenums is not acceptable for any applications on this project.
   4. Refer to Division 26 specification for strict project electrical requirements.

K. Refer to electrical specification 26 00 00 series for all wiring, conduit and installation requirements.

2.10 CABLE – COPPER

A. Provide all cables for the BMS Automation and Field levels, including all cables to interconnect the BMS Management level devices and the BMS Management level

Network as detailed in these specifications. Cables shall meet, at minimum, the following requirements:

1. Minimum 98% conductivity copper.
2. Stranded conductors.
3. Proper impedance for the application as recommended by the BMS component manufacturer.
4. Monitoring and control cable shall be screen #18 AWG (1.02362 mm) or larger dependent on the application.
5. LAN cable shall be screened #24 AWG (0.51054 mm) CAT 6 or twisted pair as identified elsewhere in these documents.
6. All monitoring and control cable shall be screened with the screen earthed at the CCP, DDCP, UC or control panel end only so as to avoid earth loops.
7. Continuous runs without splices.
8. Identification of each end at the termination point. Field identification of all BMS cables shall correspond to the record drawings.
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked. Use unique color schemes for easy identification and prevention of inadvertent splicing of cabling. If there no conflict with existing color schemes, the color for exposed cable shall be purple.

B. Power wiring shall be sized in accordance with the applicable codes and shall be a minimum of # 12 AWG (1.62814 mm) stranded copper. The Electrical contractor shall provide all power cable and containment and shall terminate the dedicated power cable at a power outlet nearest to the BMS component to be powered. The BMS Contractor shall be responsible to provide final power terminations (120VAC and 24 VAC) to all devices, DDC panels, terminal box controllers, control valves, etc. The Electrical contractor shall terminate the power cable at the MCC/distribution board as applicable. The BMS Contractor shall coordinate all BMS equipment power requirements at all BMS equipment locations with the Electrical contractor.

C. The BMS Contractor shall provide all step down transformers (120VAC and 3 phase primary step down to 24VAC) as required for all devices and controllers.

D. The BMS Contractor shall provide power connection and step down transformers from FCU and FPVAV terminal box motors to 24 VAC terminal equipment controllers.

E. All field level cables shall be Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit as specified in Division 26.

F. Terminations shall be mechanically and electrically secure. Twist type wire nuts shall not be acceptable. Insulated tinned copper lugs shall be provided.

G. Cable within panels or enclosures shall be installed in wiring guides.

H. .All wiring terminations from field devices and within field panels shall be terminated at panel terminal strips and shall be marked by identification tags on each end of the cable at each terminal strip. All termination strips shall be labeled.

I. Cable run in conduit in vertically shall have means of cable support, at minimum, every 3 m.

J. Cables shall comply with all applicable codes including, but not limited to, the IEEE wiring regulations latest edition and the electrical sub-contract documents. Where there is a conflict between any codes, standards, ordinances, regulations or the requirements of the jurisdiction having authority, the most stringent requirements shall apply.

2.11 NOT USED

2.12 UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. The BMS contractor shall provide local uninterruptible power (1/2 hour rated) for all BMS components, such as CCP, DDCP, routers, , gateways, field instrumentation, final control elements etc., as necessary to ensure continuous monitoring and control by the BMS and the associated satellite OIW of all equipment that operates on emergency power. The BMS shall monitor a trouble alarm from each DDC panel UPS. BMS Contractor to provide 2 hour rated UPS for new workstations located in CEP and the North Terminal Maintenance Control Room.

2.13 NOT USED

2.14 OPERATOR INTERFACE WORKSTATIONS (OIW)

A. Refer to Contract drawings for locations & quantities.

B. The OIW shall comprise of a PC and associated peripheral operator I/O devices.

C. The OIW PC, shall have a Microsoft Windows 10 Professional 64-bit operating system or the latest version of this software at the time of implementation. Provide OIW with the following minimum requirements:
1. Single Processor Intel Core i7 processor, 6th generation (4 cores).
2. Motherboard with minimum of:
    a. 3 - PCIe 3.0/2.0 x16; 1 - PCIe 2.0 x16; 2 – PCIe 3.0 x1 slots.
    b. 1 – SATA Express port; 8 – SATA 6Gb/s ports.
    c. 2 – USB 3.1; 6 – USB 3.0; 6 – USB 2.0 ports
    d. Flash BIOS support.
    e. Support for Raid 0, 1, 5, 10.
    f. 128 Gigabyte RAM memory capability (8 x DIMM slots).
    g. 1 – gigabit LAN Controller.
    h. 8-Channel High Definition Audio CODEC.
3. Minimum Processor speed of 4.0 GHz with CPU fan/heat sinks.
4. One 512 GB SSD Drive
5. Two - 4 Terabyte hard disks in RAID 1 configuration.
6. 32 Gigabyte DDR4-2133 SDRAM memory (2 – 16GB DIMMS).

7. 100/1000 Mbps Ethernet adapter.
8. 8 gigabyte GDDR5 PCI Express video adapter with 7680 x 4320 maximum resolution and multi-monitor support.
9. Blu-Ray RW drive.
10. Real time software or hardware clock.
11. Standard ATX Tower Case with minimum of 4 external and 5 Internal drive bays, 750 watt or greater capacity rated power supplies, internal cooling fans and external keyboard lock.
12. All necessary mounting hardware and cables for all components.

D. Universal power supply – sine wave type, with sufficient backup battery capacity to last through a 60 minute power failure.

E. Provide an alarm to uniquely identify a PC communication failure. One way that this might be accomplished is by using a watchdog timer at a DDC controller.

F. Following an extended power failure, all PCs shall return to a fully operational status without operator intervention within two (2) minutes of the return of mains power. Software changes, including modifications to database(s), shall not be lost in a power failure.

G. All PC shall be the latest model at the time of purchase and shall be from a recognized manufacturer of PCs. Purchase of the PC shall be delayed until the latest time possible without causing a delay in the BMS installation schedule in order to ensure that it is state-of-art and is based on the latest proven technology prior to purchasing. All PCs shall be suitable for rugged and continuous operation.

H. The following peripheral I/O devices shall be provided at each OIW:
1. Keyboard and mouse.
2. Two – 40-inch diagonal (minimum) 4K, Industrial-grade, Black colored frame, Flat panel LCD video display units.
3. Report printer
4. Alarm printer

I. The BMS OIW at each location shall have one (I) Report Printer and one (1) Alarm Printer. Where there are multiple OIW at one location, Report and Alarm printers shall be networked such that they are available to each OIW.

J. The operator interfaces for the Operator Interface Workstation (OIW) and the Portable Operator Terminal (POT) shall be the same.

2.15 PERIPHERAL OPERATOR I/O DEVICES

A. Printers: General
1. The operator shall able to direct the hardcopy output to any printer. The BMS Contractor shall set up the system such that all BMS generated messages such alarms, returns to normal, etc. are directed to the appropriate alarm printers and

all BMS automatically generated and operator requested reports are output to the appropriate report printer.

2. The printers at one location shall be accessible from any OIW such that an operator at one location can generate a hardcopy message at any other location.

B. Report Printers:
   1. The report printer shall meet, at minimum, the following specifications:
      a. Minimum print speed of twelve pages per minute black and three pages per minute color. Slower speed printers shall not be acceptable when printing in normal quality.
      b. Scalable fonts.
      c. Single or double bin paper trays, capable of printing A3 size (297mm x 420mm) and A4 size (210 mm x 297 mm).
      d. Page feed and page discharge controls.
      e. Color and black and white printing capacity without changing ink or toner cartridges.
      f. 1200 dpi black and white and 60 x 300 dpi color.
      g. LaserJet technology.

C. Keyboard:
   1. Provide a keyboard for operator access at each OIW and data server location. This shall be in addition to any other operator input device such as a mouse.
   2. The keyboard shall be in a standard typewriter (QWERTY) configuration with a full alphanumeric standard ASCII character set and with additional dedicated keys for other functions associated with the BMS such as print screen. Keyboard shall be wireless. Provide batteries sufficient for 24 months operation.

D. Mouse:
   1. Provide a mouse at each OIW and data server and configure the system such that cursor control can be undertaken from both the keyboard and mouse as selected by the operator.
   2. Mouse shall be wireless. Provide batteries sufficient for 24 months operation.

2.16 PORTABLE OPERATOR'S TERMINAL (POT)

A. The POTs devices shall not be used by the BMS Contractor for commissioning the BMS or for any other purpose and shall be delivered new to the Owner immediately prior to BMS acceptance testing. Provide one (1) unit.

B. Provide a jack at each DDC controller and at each mechanical and electrical room for the plug connection of the POT. Provide two spare cables for plug connection for each POT. The operator shall be able to communicate with the BMS via the POT using the same operator interface as that at any OIW PC.

C. The POT shall meet, at minimum, the following requirements:
   1. Microsoft Windows 10 Professional 64-bit operating system or the latest version of this software at the time of implementation.
   2. Intel Core i7 motherboard, 16 Gigabyte RAM memory capability.

3. Minimum Processor speed of 3.0 GHz.
4. 1 – 512 Gigabyte M.2 SSD.
5. 1 Terabyte SATA hard disk.
6. 16 Gigabytes DDR4 2133MHz SDRAM memory (2 x 8GB).
7. 100/1000 Mbps Ethernet adapter.
8. 17 inch minimum touch screen display (1920 x 1080 resolution).
9. Internal analog 56Kbps modem.
10. Multi DVD burner drive (interchangeable).
11. Microsoft Intelli-mouse.
12. Integral power supplies which shall be suitably used for the service.
13. Full size integral QWERTY keyboard with full ASCII character set.
14. Weight, including carrying case, not to exceed 7.0 lbs.
15. Provide a carrying case designed specifically for the POT that ensures adequate protection.
16. POT shall be powered by a rechargeable battery and shall also be powered by a 120 Vac, nominal 60 Hz source. Provide batteries adequate for a minimum of 4 hours of operation.

D. When connected to the BMS Automation Level at the DDC controllers or at a network data port, the POT shall be able to undertake all of the control and monitoring functions that can be performed at the OIW. One of the POT shall be used to configure the system components.

E. All POTs shall be the latest model at the time of purchase and shall be from a recognized manufacturer of PCs. Purchase of the POTs shall be delayed until the latest time possible without causing a delay in the BMS installation schedule in order to ensure that it is state-of-art and is based on the latest proven technology prior to purchasing. All POTs shall be suitable for rugged and continuous operation.

F. The operator interfaces for the Operator Interface Workstation (OIW) and the Portable Operator Terminal (POT) shall be the same.

2.17 SYSTEM SOFTWARE

A. General
1. All necessary software to form a complete operating system as described in this specification shall be provided.
2. The software programs specified in this section shall be provided as an integral part of the DDC controller and shall not be dependent upon any higher level computer for execution.

B. Control Software Description:
1. Pre-Tested Control Algorithms: The DDC controllers shall have the ability to perform the following pre-tested control algorithms:
   a. Two Position Control
   b. Proportional Control
   c. Proportional plus Integral Control
   d. Proportional, Integral, plus Derivative Control

e. Automatic Control Loop Tuning
2. Equipment Cycling Protection: Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
3. Heavy Equipment Delays: The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
4. Power fail Motor Restart: Upon the resumption of normal power, the DDC 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. (i.e. - Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System).
5. Sequential Start: Provide sequential start for all equipment. After a power failure, and after restoration of normal power, equipment shall start per a predetermined sequence as programmed via the BMS.

C. Energy Management Applications: DDC controllers shall have the ability to perform any or all of the following energy management routines:
1. Time-of-Day Scheduling.
2. Calendar Based Scheduling.
3. Holiday Scheduling.
4. Temporary Schedule Overrides.
5. Optimal Start/Optimal Stop.
6. Night Setback Control.
7. Peak Demand Limiting.
8. Energy Usage & Demand.
9. Fan Speed/CFM Control.
10. Heating/Cooling Interlock.
11. Supply Air Reset.
12. Chilled Water Reset.
13. Condenser Water Reset.
14. Chiller Sequencing.

D. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in the Execution portion of this specification.

E. Custom Process Programming Capability: DDC controllers shall be able to execute custom, job-specific processes defined by the operator, to automatically perform calculations and special control routines.
1. Process Inputs and Variables: It shall be possible to use any of the following in a custom process:
a. Any system-measured point data or status.
b. Any calculated data.
c. Any results from other processes.
d. User-Defined Constants.
e. Arithmetic functions (+,-,*, /, square root, exponential, etc.).
f. Boolean logic operators (and, or, exclusive or, etc.).
g. On-delay/Off-delay/One-shot timers.

2. Process Triggers: Custom processes may be triggered based on any combination of the following:
   a. Time interval.
   b. Time of day.
   c. Date.
   d. Other processes.
   e. Time programming.
   f. Events (e.g., point alarms).
   g. Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System (FAS).

F. Dynamic Data Access: A single process shall be able to incorporate measured or calculated data from any and all other DDC controllers on the local area network. In addition, a single process shall be able to issue commands to points in any and all other DDC panels on the local area network.

G. Advisory/Message Generation: Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device, buffer the information in a follow-up file, or cause the execution of a dial-up connection to a remote device such as a printer.

H. Custom Process Documentation: The custom control programming feature shall be self-documenting. All interrelationships defined by this feature shall be documented via graphical flowcharts and English language descriptors.

I. Alarm Management: Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each DDC controller shall perform distributed independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall the DDC's ability to report alarms be affected by either operator activity at a PC Workstation or local I/O device, or communications with other panels on the network. Each analog input shall have associated alarm and pre-alarm (warning) levels that are software adjustable. Provide a minimum of one high alarm, one high warning alarm, one low alarm and one low warning alarm level per analog input.
   1. Point Change Report Description: All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
   2. Prioritization: The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Each DDC shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point as well as be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.
   3. Report Routing: Alarm reports, messages, and files will be directed to a user-defined list of operator devices or PC disk files used for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.

4. Alarm Messages: In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a minimum 65-character alarm message to more fully describe the alarm condition or direct operator response. Each standalone DDC shall be capable of storing a library of at least 250 Alarm Messages which are assignable to any number of points in the panel.
5. Auto-Dial Alarm Management: In Dial-up applications, only critical alarms shall initiate a call to a remote operator device. In all other cases, call activity shall be minimized by time-stamping and saving reports until an operator scheduled time, a manual request, or until the buffer space is full. The alarm buffer must store a minimum of 50 alarms.
6. Transaction Logging: Operator commands and system events shall be automatically logged to disk in Personal Computer industry standard database format. Operator commands initiated from Direct-connected workstations, dial-up workstations, and local DDC panel Network Terminal devices shall all be logged to this transaction file. This data shall be available at the Operator Interface Workstation (OIW). Facility shall be provided to allow the user to search the transaction file using standard database query techniques, including searching by dates, operator name, data point name, etc. In addition, this transaction file shall be accessible with standard third party database and spreadsheet packages.

J. Historical Data and Trend Analysis: A variety of historical data collection utilities shall be provided to automatically sample, store, and display system data in all of the following ways:
1. Continuous Point Histories: Standalone DDC’s shall store Point History Files for all analog and binary inputs and outputs. The Point History routine shall continuously and automatically sample the value of all analog inputs at half hour intervals. Samples for all points shall be stored for the past 24 hours to allow the user to immediately analyze equipment performance and all problem-related events for the past day. Point History Files for binary input or output points and analog output points shall include a continuous record of the last ten status changes or commands for each point.
2. Control Loop Performance Trends: Standalone DDC’s shall also provide high resolution sampling capability in one-second increments for verification of control loop performance.
3. Extended Sample Period Trends: Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting operator-specified performance data over extended periods of time. Sample intervals of 1 minute to 2 hours shall be provided. Each standalone DDC shall have a dedicated buffer for trend data, and shall be capable of storing a minimum of 5000 data samples. The system shall have the capability of trending and storing all data points.
4. Data Storage and Archiving: Trend data shall be stored at the Standalone DDC’s, and uploaded to hard disk storage when archival is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers become full. All trend data shall be available in disk file format compatible with Third Party personal computer applications.

K. Runtime Totalization: Standalone DDC panels shall automatically accumulate and store runtime hours for binary input and output points as specified in the Execution portion of this specification.
    1. The Totalization routine shall have a sampling resolution of one minute or less.
    2. The user shall have the ability to define a warning limit for Runtime Totalization. Unique, user-specified messages shall be generated when the limit is reached.

L. Analog/Pulse Totalization: Standalone DDC's shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.
    1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g. KWH, gallons, KBTU, tons. etc.).
    2. The Totalization routine shall have a sampling resolution of one minute or less.
    3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

M. Event Totalization: Standalone DDC panels shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly, or monthly basis.
    1. The Event Totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.
    2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

N. Operator Interface Workstation (OIW) Software:
    1. Operator Interface Software – General
        a. An integrated software package shall be used as the operator interface program.
        b. All Inputs, Outputs, Setpoints, and all other parameters as defined within Part 3, shown on the design drawings, or required as part of the system software, shall be displayed for operator viewing and modification from the operator interface software.
        c. The operator workstation software shall provide context-sensitive help menus and instructions for each operation and/or application currently being performed.
        d. All controller software operating parameters shall be displayed for the operator to view/modify from the operator workstation. These include: setpoints, alarm limits, time delays, PID tuning constants, run-times, point statistics, schedules, and so forth.
        e. The operation of the control system shall be independent of the operator workstation, which shall be used for operator communications only. Systems that rely on the operator workstation to provide supervisory control over controller execution of the sequences of operations or system communications shall not be acceptable.
    2. Alarms
        a. Each workstation shall receive and process alarms sent to it by the control system. The alarm management portion of the operator workstation software shall, at the minimum, provide the following functions:
            1) Log date and time of alarm occurrence.

2) Generate a "Pop-Up" window informing an operator that an alarm has been received.
3) Allow an operator, with the appropriate security level, to acknowledge, delete, or disable an alarm.
4) Provide an audit trail for alarms by recording operator acknowledgment, deletion, or disabling of an alarm. The audit trail shall include the name of the operator, the alarm, the action taken on the alarm, and a time/date stamp.
5) Record all alarms received at an operator's workstation to that workstation's hard drive.
6) Allow the operators to view/manage the alarm data archived to hard disk. Selection of a single menu item or tool bar button shall allow the user to acknowledge, disable, delete, or print the selected alarm.

b. Alarms shall be generated by the operator workstation for any controller that is "Off-Line" and is not communicating, or that does not have an active control program loaded.
c. Changes made to alarm setpoints from the Operator Workstation shall directly modify the controller alarm management database.
d. Selection of a single menu item or tool bar button shall print any displayed alarm report on the system printer for use as a building management and diagnostics tool.

3. Reports
a. Reports shall be generated and directed to one of the following: workstation displays, printers, or disk. As a minimum, the system shall provide the following reports:
1) All points in the network.
2) All points in a specific controller.
3) A listing of a user-defined group of points in the network. There shall be no limit to the number of user-defined groups
4) All points currently in alarm.
5) All points in hardware override.
6) All disabled points.
7) All weekly schedules.
8) All or selected point attributes, including, but not limited to:
a) Values
b) Setpoints
c) Alarm Limits
d) Statistics
e) Run Times
9) All programmed holidays and associated schedules.
10) All disabled alarms.
11) All active, unacknowledged alarms.
12) All active, acknowledged alarms.
13) Any and all other controller operating parameters.

b. Reports shall be provided for specific point types, for each logical point group, for user-defined groups, or for the entire facility without restriction due to the hardware configuration of the control system or communications network.

c. The system shall allow for the creation of custom report point groups that shall be capable of including points from multiple controllers. Systems limiting point report displays to only a single controller's point database shall not be accepted.
d. The number of custom reports or display groups shall be limited by the amount of available system memory.
e. Selection of a single menu item, tool bar item, or tool bar button shall print any displayed report on the system printer for use as a building management and diagnostics tool.

4. Schedules
   a. A spreadsheet-type schedule input form for time-of-day scheduling and override scheduling of building operations shall be provided. At a minimum, the following spreadsheet types shall be provided:
      1) Weekly schedules, by system.
      2) Temporary override schedules, by system.
      3) Special "Only Active If Today Is A Holiday" schedules, by system.
      4) Monthly calendars.
      5) Holiday scheduling system, including the ability to define floating holidays.
   b. Weekly schedules shall be provided for each piece of equipment with a specific time use schedule. Each schedule shall include columns for each day of the week, as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting use and non-use times into appropriate information blocks on the spreadsheet.
   c. It shall be possible to define one or more master holiday schedules to allow the operator to define in one location the holidays for all associated schedules. Systems requiring the operator to change holiday definitions on a schedule by schedule basis shall not be accepted.
   d. Standard weekly schedules shall be inactive on a holiday. The system shall allow the user to include in a schedule group a schedule that will only be active if today is a holiday.
   e. In addition, temporary override schedules may be inserted into schedule groups for modifying operating schedules. After overrides have been executed, the original schedule will automatically be restored.
   f. Schedules shall be provided for each system or sub-system in the facility. Each schedule shall include all commandable points residing within the system. Each point may have a unique schedule of operation relative to the system use schedule, allowing for sequential starting and control of equipment within the system. Scheduling and rescheduling of points shall be accomplished easily via the system schedule spreadsheets.
   g. Monthly calendars for a 12-month period shall be provided that allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device or keyboard, and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

h. Changes to schedules made from the Operator Workstation shall directly modify the controller schedule database. Systems that require permanent schedule changes to be made with a program editor shall not be acceptable.
i. Formatted schedule displays shall be provided for each system. These shall include all schedule data and associated parameters.
j. Selection of a single menu item or tool bar button shall print any displayed schedule on the system printer for use as a building management and diagnostics tool.

5. User Interface:
   a. The BAS workstation software shall allow the creation of a custom, browser-style interface linked to the user when logging into any workstation. Additionally, it shall be possible to create customized workspaces that can be assigned to user groups. This interface shall support the creation of "hot-spots" that the user may link to view/edit any object in the system or run any object editor or configuration tool contained in the software. Furthermore, this interface must be able to be configured to become a user's "PC Desktop" – with all the links that a user needs to run other applications. This, along with the Windows user security capabilities, will enable a system administrator to setup workstation accounts that not only limit the capabilities of the user within the BAS software, but may also limit what a user can do on the PC and/or LAN/WAN. This might be used to ensure, for example, that the user of an alarm monitoring workstation is unable to shutdown the active alarm viewer and/or unable to load software onto the PC.
   b. System shall be able to automatically switch between displayed metric vs. imperial units based on the workstation localization.

6. Password
   a. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display, and database manipulation capabilities as he or she deems appropriate for each user, based on an assigned password.
   b. Each user shall have the following: a user name (12 characters minimum); a password (12 characters minimum).
   c. The system shall not allow each user to change his or her user name or password.
   d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
   e. A minimum of 256 unique passwords, including user initials, shall be supported.
   f. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
   g. The system shall automatically generate a report of log-on/log-off and system activity for each user. Any action that results in a change in the operation or configuration of the control system shall be recorded, including: modification of point values, schedules or history collection parameters, and

all changes to the alarm management system, including the acknowledgment and deletion of alarms.

h. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving the operator workstation logged on.

7. Screen Manager - The BMS workstation shall be provided with a screen management application that allows the user to activate, close, and simultaneously manipulate a minimum of 16 windows across a minimum of 3 physical screens.

8. Graphical User Interface (GUI) Software
   a. Operating System: The GUI shall run on the latest Microsoft Windows operating system..
   b. The GUI shall employ browser-like functionality for ease of navigation. It shall include a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. In addition, menu-pull downs, and toolbars shall employ buttons, commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC Control System and basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.
   c. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:
      1) Graphic screens shall be developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.
      2) Graphic screens shall have the capability to contain objects for text, real-time values, animation, color spectrum objects, logs, graphs, HTML5 or XML document links, schedule objects, hyperlinks to other URL's, and links to other graphic screens.
      3) Graphics shall support layering and each graphic object shall be configurable for assignment to a layer. A minimum of six layers shall be supported.
      4) Modifying common application objects, such as schedules, calendars, and set points shall be accomplished in a graphical manner.
      5) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
      6) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
      7) Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
      8) Adjustments to analog objects, such as set points, shall be done by right-clicking the selected object and using a graphical slider to adjust the value. No entry of text shall be required.
   d. System Configuration. At a minimum, the GUI shall permit the operator to perform the following tasks, with proper password access:

1) Create, delete or modify control strategies.
2) Add/delete objects to the system.
3) Tune control loops through the adjustment of control loop parameters.
4) Enable or disable control strategies.
5) Generate hard copy records or control strategies on a printer.
6) Select points to be alarmable and define the alarm state.
7) Select points to be trended over a period of time and initiate the recording of values automatically.

e. Symbol library – The BMS system shall be provided with a very complete symbol library containing all of the basic symbols used to represent HVAC, Fire, and Security components of a typical BMS system.

f. Symbols shall be able to be added to any graphic display being constructed by simply dragging the symbol from the library to the graphic under construction.

g. Creating symbols – The user shall be able to add any number of new symbols to the symbol library. Symbol generation shall include all of the abilities described for the graphic editor.

9. Historical trending and data collection

a. Each Network Controller shall store trend and point history data for all analog and digital inputs and outputs, as follows:

1) Any point, physical or calculated, may be designated for trending. Three methods of collection shall be allowed: Defined time interval, upon a change of value and whenever a value is out of range.
2) Each network controller shall have a dedicated RAM-based buffer for trend data, and shall store 10,000 samples for each physical point and software variable, including an individual sample time/date stamp. Points may be assigned to multiple history trends with different collection parameters.

b. Trend and change of value data shall be stored within the controller and then uploaded to the trend database(s). Uploads shall occur based upon one of the following: user-defined interval, manual command, or when the trend buffers are full.

c. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in Microsoft Access, SQL, HTML or XML database format.

d. To enable users to easily access stored data, the system shall provide the capability to store historical data in more than one file system (i.e., removable media, separate hard drives, or a remote network file system).

e. Provide the capability to perform statistical functions on the historical database without having to design special queries. On a specified data interval, provide functions for calculating:

1) Average.
2) Arithmetic mean.
3) Maximum/minimum values.
4) Range – difference between minimum and maximum values.
5) Standard deviation.
6) Sum of all values.
7) Variance.

10. Trend data viewing and analysis
    a. Provide a trend viewing utility that shall have access to all database points.
    b. Provide database access through an Open Database Connectivity (ODBC) interface – a standard Application Programming Interface (API) for accessing data from relational databases. Client applications can reside within a Windows 10 Professional.
    c. It shall be possible to retrieve any historical database point for use in displays and reports by specifying the point name.
    d. The trend viewing utility shall have the capability to view up to 100 data sources at one time in a tabular or graphical format.
    e. Graphic displays shall be able to be single or stacked graphs with on-line selectable display characteristics, such as ranging, color, and plot style.
    f. It shall be possible to display trend data in histogram (X-Y plots) format as well as area and bar graphs.
    g. Display magnitude and units shall both be selectable by the operator at any time without reconfiguring the processing or collection of data. This is a zoom capability.
    h. Display magnitude shall automatically be scaled to show full graphic resolution of the data being displayed. This function shall also be operator selectable.
    i. The display range shall consist of magnitude and units fields. The units are seconds, minutes, hours, days, and months.
    j. Provide a wild card capability when specifying a display range for data retrieval within the historical database. Wild carding will allow the user to easily specify relative time based date ranges for the retrieval of data.
    k. A time-offset capability shall be available to assist in a user’s analysis. The offset visually shifts the data being displayed to allow a user to concurrently view information without having to scroll the display.
    l. The system shall be capable of printing a hard copy record of the trends as they are displayed on the workstation.

O. Energy Usage Dashboard Graphical User Interface:
1. Provide separate “dashboard” dynamic system animation colorgraphics for the on-going accountability of building energy usage over time as required for LEED energy usage accounting (Point and click icon on building BMS navigation page for graphics and reports). Provide dynamic historical trending and totalization of each piece of equipment (energy use by each component). GUI shall totalize data for the continuous monitoring of metering equipment for constant (KWH/BTU’s via runtime) and variable motor loads, variable frequency drive operation (KWH/BTU’s, building lighting panel load (each building),, building receptacle panel load (each building), electric heaters via integration with BMS integration with the VFD). Energy usage data shall be graphically represented for each systems daily energy usage, weekly energy usage, monthly energy usage and yearly energy usage. Energy usage shall be retrievable for any day, month or year. The BMS shall collect energy meter and other energy usage data shall be totalized and recorded in 15 minute intervals (adjustable-to 1 minute). Report generation shall be via a single screen interface.

P. Integration
1. Open, Interoperable, Integrated Architectures
a. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system utilizing ANSI/ASHRAE SSPC/135 (BACnet) communication protocol in an open, interoperable system.
b. In addition, adherence to BACnet industry standard ANSI / ASHRAE SSPC/135 to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a PICS document showing the installed device's compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet.
c. All components and controllers supplied under this contract shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.
d. The supplied system must incorporate the ability to access all data using Java enabled browsers without requiring proprietary operator interface and configuration programs. An Open Database Connectivity (ODBC), Open Process Control (OPC) DX and Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.
e. Protocols: The following standard control protocols shall be provided for Programmable Logic Controller (PLC) and Direct Digital Control (DDC) platforms for control and data acquisition:
1) ModBus (IP, RS-485 RTU)
2) BACNet (IP, MSTP)
3) TCP/IP
f. A network topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network.
g. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation <u>shall not exceed 5 seconds for network connected user interfaces</u>.
h. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.
2. Third Party Communication Software
a. Provide direct Protocol Integration software to allow bi-directional data communications between the BMS system and 3rd party manufacturers' control panels. The BMS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, boilers, variable frequency drives, power monitoring system, fire alarm, access control, lighting systems, etc.
b. All data required by the application shall be mapped into the Network Controller's database, and shall be transparent to the operator.

c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with BMS software features such as: Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Dial-Up and Local Area Network Communications.

d. The Building Management System shall provide any combination of third-party controllers on a single network. A minimum of 100 third-party controllers shall be supported on a single network. Integration shall be via RS-232, RS-485 or Modbus technologies.

e. The system operator shall have the ability to verify, and diagnose communication messages and point information between third-party controllers and the BMS.

2.18 NETWORK SERVER CONTROLLERS

A. Automation Server's 1.5 (Or Equal)

1. Automation Server
2. Terminal Base AS
3. PS-24V Power Supply
4. Terminal Base Power

B. Manage multiple Automation Servers for large installations - maintaining all of the same features as the AS including alarming, scheduling, trend logging, function block, and script

C. Safely manage account and database information with fully secure integration into Windows Domain user accounting, making one less IT admin tool, and ensuring policy adherence

D. Complete audit trail records changes, time, and user to facilitate thorough post situation analysis

E. New Server's North and South Complex

F. Network Router Controllers shall combine both network routing functions, control functions, and server functions into a single unit.

G. The BACnet NSC shall be classified as a "native" BACnet device, supporting the BACnet Network Server Controller (B-BC) profile. Controllers that support a lesser profile such as B-SA are not acceptable. NSCs shall be tested and certified by the BACnet Testing Laboratory (BTL) as BACnet Network Server Controllers (B-BC).

H. The Network Server Controller shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control functions over the control devices connected to the NRS.

I. They shall also be responsible for monitoring and controlling their own HVAC equipment such as an AHU or boiler.

J. They shall also contain graphics, trends, trend charts, alarm views, and other similar presentation objects that can be served to workstations or web-based interfaces. A sufficient number of NSCs shall be supplied to fully meet the requirements of this specification and the attached point list.

K. It shall be capable of executing application control programs to provide:

1. Calendar functions
2. Scheduling
3. Trending
4. Alarm monitoring and routing
5. Time synchronization by means of an Internet site including automatic synchronization
6. Native integration of Modbus controller data or BACnet controller data and Modbus controller data

L. Hardware Specifications

1. Memory:

   a. The operating system of the controller, application programs, and all other portions of the configuration database, shall be stored in non-volatile, FLASH memory. Servers/Controllers shall contain enough memory for the current application, plus required history logging, plus a minimum of 100% additional free memory.

2. Each NRC shall provide the following on-board hardware for communication:

   a. One 10/100bT Ethernet for communication to Workstations, other NRCs and onto the Internet
   b. Two RS-485 ports for communication to BACnet MSTP bus or serial Modbus (software configurable)
   c. .
   d. One Device USB port
   e. Two host USB Ports

3. The NSC shall conform to a small footprint no larger than 100W x 125H x 75D mm (3.94W x 4.92H x 2.95D in).

M. Modular Expandability:

1. The system shall employ a modular I/O design to allow expansion. Input and output capacity is to be provided through plug-in modules of various types. It shall be possible to combine I/O modules as desired to meet the I/O requirements for individual control applications.

2. One shall be able to "hot-change" (hot-swap) the I/O modules preserving the system on-line without any intervention on the software; addressing and configuration shall be automatic

N. Hardware Override Switches:

1. All digital outputs shall, optionally, include three position manual override switches to allow selection of the ON, OFF, or AUTO output state. These switches shall be built into the unit and shall provide feedback to the controller so that the position of the override switch can be obtained through software. In addition each analog output shall be equipped with an override potentiometer to allow manual adjustment of the analog output signal over its full range, when the 3 position manual override switch is placed in the ON position.

O. Universal Input Temperatures

1. All universal inputs directly connected to the NSC via modular expansion shall be capable of using the following thermistors for use in the system without any external converters needed.

a. 10 kohm Type I (Continuum)
b. 10 kohm Type II (I/NET)
c. 10 kohm Type III (Satchwell)
d. 10 kohm Type IV (FD)
e. Linearized 10 kohm Type V (FD w/11k shunt)
f. Linearized 10 kohm (Satchwell)
g. 1.8 kohm (Xenta)
h. 1 kohm (Balco)
i. 20 kohm (Honeywell)
j. 2.2 kohm (Johnson)

2. In addition to the above, the system shall be capable of using the below RTD sensors, however it is not required that all universal inputs be compatible with them.

a. PT100 (Siemens)
b. PT1000 (Sauter)
c. Ni1000 (Danfoss)

P. Local Status Indicator Lamps:

1. The NSC shall provide as a minimum LED indication of CPU status, Ethernet LAN status, and field bus status. For each input or output, provide LED indication of the value of the point (On/Off). The LED indication shall support software configuration to set whether the illumination of the LED corresponds to On or Off or whether the color when illuminated is Red or Green.

Q. Real Time Clock (RTC):

1. Each NSC shall include a battery-backed, real time clock, accurate to 10 seconds per day. The RTC shall provide the following: time of day, day, month, year, and day of week. Each NSC will allow for its own UTC offset, depending upon the time zone. When the time zone is set, the NSC will also store the appropriate times for daylight savings time.

R. Power Supply:

1. The 24 VDC power supply for the NSCs shall provide 30 watts of available power for the NSC and associated IO modules. The system shall support the use of more than one power supply if heavily power consuming modules are required.
2. The power supply, NSC, and I/O modules shall connect power wise and communication wise via the separate terminal base allowing for ease of replacement and no separate or loose wiring.

S. Automatic Restart After Power Failure:

1. Upon restoration of power after an outage, the NSC shall automatically and without human intervention update all monitored functions, resume operation based on current, synchronize time and status, and implement special start-up strategies as required.

T. Battery backup:

1. The NSC shall include an on-board battery to back up the controller's RAM memory. The battery shall provide accumulated backup of all RAM and clock functions for at least 30 days. In the case of a power failure, the NSC shall first try to restart from the RAM memory. If that memory is corrupted or unusable, then the NSC shall restart itself from its application program stored in its FLASH memory.

U. Software Specifications

1. The operating system of the controller, application programs, and all other portions of the configuration database such as graphics, trends, alarms, views, etc., shall be stored in non-volatile, FLASH memory. There will be no restrictions placed on the type of application programs in the system. Each NSC shall be capable of parallel processing, executing all control programs simultaneously. Any program may affect the operation of any other program. Each program shall have the full access of all I/O facilities of the processor. This execution of control function shall not be interrupted due to normal user communications including interrogation, program entry, printout of the program for storage, etc.
2. Each NSC shall have an available capacity of 4 GB of memory. This shall represent 2 GB for application and historical data and 2 GB dedicated for backup storage.

V. User Programming Language:

1. The application software shall be user programmable. This includes all strategies, sequences of operation, control algorithms, parameters, and setpoints. The source program shall be either a script-based structured text or graphical function block

based and fully programmable by the user. The language shall be structured to allow for the configuration of control programs, schedules, alarms, reports, telecommunications, local displays, mathematical calculations, and histories. Users shall be able to place comments anywhere in the body of either script or function block programs.

2. Network Server Controllers that use a “canned” program method will not be accepted.

W. Control Software:

1. The NSC shall have the ability to perform the following pre-tested control algorithms:

   a. Proportional, Integral plus Derivative Control (PID)
   b. Two Position Control
   c. Digital Filter
   d. Ratio Calculator
   e. Equipment Cycling Protection

X. Mathematical Functions:

1. Each controller shall be capable of performing basic mathematical functions (+, -, *, /), squares, square roots, exponential, logarithms, Boolean logic statements, or combinations of both. The controllers shall be capable of performing complex logical statements including operators such as >, <, =, and, or, exclusive or, etc. These must be able to be used in the same equations with the mathematical operators and nested up to five parentheses deep.

Y. NSCs shall have the ability to perform any or all of the following energy management routines:

1. Time of Day Scheduling
2. Calendar Based Scheduling
3. Holiday Scheduling
4. Temporary Schedule Overrides
5. Optimal Start
6. Optimal Stop
7. Night Setback Control
8. Peak Demand Limiting
9. Temperature Compensated Duty Cycling
10. CFM Tracking
11. MER Space Pressurization Control
12. Heating/Cooling Interlock
13. Hot Water Reset
14. Chilled Water Reset
15. Condenser Water Reset
16. Chiller Sequencing

Z. History Logging:

1. Each NSC controller shall be capable of LOCALLY logging any input, output, calculated value or other system variable either over user defined time intervals ranging from 1 second to 1440 minutes or based upon a user configurable change of value. A minimum of 1000 logs, with a minimum of 100,000 records, shall be stored. Each log can record either the instantaneous, average, minimum or maximum value of the point. Logged data shall be downloadable to a higher level NSC long term archiving based upon user-defined time intervals, or manual command.
2. For extended trend logging a minimum of 1500 trends shall be capable, with a minimum number of 600,000 records within.
3. Management of a power meter replacement to ensure meter log data is accurate shall be possible in the NSC.
4. Every hardware input and output point, hosted within the NSC and attached I/O modules, shall be trended automatically without the requirement for manual creation, and each of these logs shall log values based upon a change of value and store at least 500 trend samples before replacing the oldest sample with new data.
5. The presentation of logged data shall be built into the server capabilities of the NSC Presentation can be in time stamped list formats or in a chart format with fully configurable pen colors, weights, scales and time spans.

AA. Alarm Management:

1. For each system point, alarms can be created based on high/low limits or in comparison to other point values. All alarms will be tested each scan of the NSC and can result in the display of one or more alarm messages or reports.
2. There is no limit to the number of alarms that can be created for any point
3. Alarms can be configured to be generated based upon a single system condition or multiple system conditions.
4. Alarms will be generated based on an evaluation of the alarm conditions and can be presented to the user in a fully configurable order, by priority, by time, by category, etc.
5. The alarm management system shall support the ability to create and select cause and action notes to be selected and associated with an alarm event. Checklists shall also be possible in order to present to an operator a suggested mode of troubleshooting. When acknowledging an alarm, it shall be possible to assign it to a user of the system such that the user is notified of the assignment and is made responsible for the alarm resolution.
6. Alarms must be capable of being routed to any BACnet workstation that conforms to the B-OWS device profile and uses the BACnet/IP protocol.

2.19 BMS CONTROLLERS: GENERAL

A. There shall be 3 types of BMS control panels:
   1. Communications Control Panels (CCP).
   2. Direct Digital Control Panels (DDCP).

3. Unitary Controllers (UC).

B. All BACnet controllers shall be based on native BACnet and shall support all applicable BIBBs from the data sharing, alarm event, schedule, trend and device manager groups. Standard BACnet object types supported by the controllers shall include:
1. Binary input and output and value.
2. Analog input, output and value.
3. Multi-state input and output.
4. Loop calendar, notification class, command, file, program, schedule, group, event enrollment and device.
5. Proprietary object types shall not be used unless specifically approved by the Engineer.

C. All Controllers shall have a minimum of 10-bit Input /Output resolution.

D. Following a loss of power the PC, CCP, DDCP and UC shall reboot in an orderly fashion and attain a normal operating status within 2 minutes of the return of power. That shall be accomplished without operator intervention.

2.20 COMMUNICATION CONTROL PANELS (CCP)

A. The Communication Control Panels shall be programmable controllers on the BMS primary LAN and shall undertake two roles:
1. Gateway interface to third-party controllers, if the data communicated from the third party system cannot be provided in the form of BACnet Objects.

B. The CCP shall incorporate software as necessary to provide communications on the network including Network interface Cards if necessary. Additionally, if the CCP acts as a gateway, then the CCP shall incorporate all software as necessary to perform this function including any change of protocol between the networks. The BMS Contractor shall provide all third-party controller gateways and complete software/hardware documentation.

C. Communication Control Panels shall also meet the following requirements:
1. Provide integral network communication connections.
2. CCP shall be totally independent of any other LAN/BMS Management Level Network nodes for their operating functions.
3. CCP failure shall not place any BMS component or any component controlled by the BMS in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a CCP shall not affect the operation of any other network node.
4. The failure of any CCP shall be annunciated as a critical alarm at the OIW.
5. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
6. Each CCP shall have, at minimum, a 32 bit microprocessor.

7. All CCP shall be powered from a UPS source, but memory shall be battery-backed RAM. Battery shall be rechargeable with a minimum life of 7 years and shall be capable of providing data retention for a minimum of 60 days.
8. Provide a real-time clock at each CCP. The real-time clock at the CCP shall be synchronized at least once every 24 hours.
9. Provide a hardware or software watchdog timer.
10. Provide interoperability documentation for the CCP. All the data related to the CCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the CCP with another system in the future. This may be part of the overall interoperability documentation.
11. The CCP shall have a port for the connection of POT.

D. The CCP shall be housed in the enclosure panels as detailed in the “Panels and Enclosures” Paragraph.

E. Diagnostics – Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

F. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.21 DIRECT DIGITAL CONTROL PANELS (DDCP)

A. The BACnet IP DDCPs shall be standalone, shall reside on the Automation Level and shall meet the following requirements:
1. DDCP controllers shall be freely programmable and shall have an I/O capability to handle major items of equipment such as air handling units.
2. DDCP shall interface via Point Interface Modules (PIM) to the field instrumentation and final control elements.
3. DDCP may be used for any equipment monitored and controlled by the BMS. A dedicated DDCP shall be provided at minimum to monitor and control the following:
    a. A Single Air Handling Unit (each AHU shall have a dedicated DDCP).
    b. Other major items of equipment.
4. The DDCP shall control its own communications so that the failure of any one node, including any PC shall not inhibit communications on the network between the remaining nodes. Provide integral network communications connections.
5. DDCP shall be totally independent of any other primary and secondary LAN nodes for their monitoring and control functions. DDCP shall monitor and control entire systems, multiple DDCP for a single system shall not be allowed.
6. Where a DDCP receives data from other nodes, such as an outdoor air temperature, which is used for a global system program strategy executed at that DDCP, then alternative control strategies shall be automatically initiated, based on operator definable default values, if there is a loss of communication of the required data.
7. DDCP failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or

discomfort to building occupants and operations staff. The failure of a DDCP shall not affect the operation of any other network node.

8. The failure of any DDCP shall be annunciated as a critical alarm at the OIW.
9. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
10. Each DDCP shall have its own power supplies that shall be rated such that they will adequately accommodate all foreseeable uses of the DDCP.
11. Each DDCP shall have, at minimum, a 32 bit microprocessor.
12. All operating sequences, schedules and trend data for equipment controlled by the DDCP shall reside at the DDCP.
13. Provide each DDCP with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Provide a 10-hour minimum full function, battery support capability.
14. Provide a real-time clock, at each DDCP. The real-time clock at the DDCP shall be synchronized at least once every 24 hours.
15. The DDCP shall have a port for the connection of the POT.
16. DDCP shall be housed in enclosures that shall meet the requirements detailed in Section titled “Panels and Enclosures” of these specifications. The DDCP shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation, including any current sensing relays in the MCC panels, and the DDCP shall be by the BMS Contractor.
17. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
    a. Enable the DDCP to receive signals from the digital and analog instrumentation.
    b. Enable the DDCP to output control signals to the final control elements.
18. PIM shall be incorporated into the DDCP by one or the following methods:
    a. Plug-in type modules with specific or universal input/output capabilities.
    b. Integral to the DDCP controller board.
19. PIM shall accommodate the following point types:
    a. Analog and digital inputs.
    b. Analog and digital outputs.
    c. Pulse inputs.
20. Analog input PIM shall have a minimum 10-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.
21. Analog output PIM shall have a minimum 10-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.
22. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.
23. All PIM shall be easily exchanged and the failure of one PIM shall not affect any other PIM. Field terminations shall be such that the removal of a failed PIM shall not require the removal and reconnecting of field device cable terminations.
24. All PIM shall be such that all output points can be manually positioned via an on board on-off-auto or potentiometer dial as applicable to the individual point.

25. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.
26. DDCP mounted on vibrating equipment, such as an air handling units, shall have vibration isolation protection that ensures their satisfactory operation.
27. DDCP shall have optic-isolation or equivalent.
28. DDCP shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.
29. The BMS Contractor shall provide interoperability documentation for the DDCP. All the data related to the DDCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the DDCP with another system in the future. This may be part of the overall interoperability documentation.

2.22 UNITARY CONTROLLERS (UC) – GENERAL

A. Unitary Controllers (UC) shall be “freely programmable” controllers with pre-packaged operating sequences maintained in EEPROM or flash EPROM.

B. Unitary controllers shall reside at the BMS Automation Level.

C. Customization of “freely programmable” controllers shall be possible to the extent that variable operating parameters, such as sequences of operation, setpoints, control loop parameters, control constants, and schedules shall be changeable on-line by the OIW operator.

D. UC shall reside on a BACnet MSTP BMS LAN.

E. UC shall provide an interface via PIM to the field instrumentation and final control elements of the following types of equipment:
1. One (1) Fan Powered VAV terminal unit with or without Electric Reheat
2. One (1) Fan Coil Unit with or without Electric Reheat
3. One (1) VAV terminal unit (cooling only).
4. Up to Six (6) miscellaneous fans.
5. Up to Four (4) miscellaneous pumps.
6. Up to Two (2) self-contained A/C units.
7. Miscellaneous equipment input monitoring.

F. Panels meeting the requirements of DDCP shall control all other types of ‘equipment and systems.

G. The UC shall be a node on the primacy BMS LAN. The UC shall control its own communications so that the failure of any one node shall not inhibit communications on the network between the remaining nodes and the BMS Management Level Network.

H. UC shall be totally independent of other Management and BMS Automation Level components for their monitoring and control functions.

I. UC failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a UC shall not affect the operation of any other network node.

J. The failure of any UC shall be annunciated as a critical alarm at the OIW.

K. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.

L. UC shall be powered from the electrical service that serves the equipment monitored and controlled by the UC. The BMS Contractor shall furnish transformers suitably rated for the application. The UC shall be housed in an enclosure that provides adequate physical and electrical protection.

M. Each UC shall have, at minimum, an 8 bit microprocessor.

N. Provide each UC with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Batteries shall be rated for a 7 year life. The UC serving VAV terminal units and FCU shall not be placed on UPS power.

O. Provide a real time clock at each UC. The real-time clock at the UC shall be synchronized from the real-time clock at the BMS Network Data Servers (NDS) at least once every 24 hours.

P. UC shall be housed in enclosures that shall meet the requirements detailed in Section titled “Panels and Enclosures” of these specifications. The UC shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation and the UC shall be by the BMS Contractor.

Q. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
   1. Enable the UC to receive signals from the digital and analog instrumentation.
   2. Enable the UC to output control signals to the final control elements.

R. PIM shall accommodate the following point types:
   1. Analog and digital inputs.
   2. Analog and digital outputs.
   3. Pulse inputs.

S. Analog input PIM shall have a minimum 8-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.

T. Analog output PIM shall have a minimum 8-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.

U. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.

V. UC shall control and monitor all points associated with a system. Multiple UC shall not be used to control and monitor a single system.

W. All application programs shall reside at the UC.

X. Operating sequences for UC shall be resident at the UC. Database changes shall be undertaken from the OIW and POT. Schedules and trend data shall reside at the UC.

Y. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.

Z. UC mounted on vibrating equipment, such as on FCUs, shall have vibration isolation protection that ensures their satisfactory operation.

AA. UC shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.

BB. The BMS Contractor shall provide interoperability documentation for the UC. All the data related to the UC shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the UC with another system in the future. This may be part of the overall interoperability documentation.

2.23 VAV TERMINAL UNIT CONTROLLER (VAV - UC)

A. General: Ship VAV-UC Controllers to terminal box manufacturer’s factory for controller mounting prior to shipping to site. Coordinate with Box manufacturer.

B. The VAV UC shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units.

C. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

D. The VAV UC shall be a configurable digital controller with an integral differential pressure transducer. It shall be compatible with 3 wire (incremental) and proportional damper actuators.

E. The VAV UC shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

F. Each VAV UC shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

G. The VAV UC shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

H. Each VAV UC shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

I. The VAV UC shall provide the ability to download and upload UC configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

J. UC control setpoint changes initiated over the network shall be written to UC non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

K. The VAV UC firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

L. The VAV UC shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

M. The VAV UC shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

N. The VAV UC shall be capable of direct electronic connection to a balancing hood. Connection shall be through a port located on the room sensor, or directly at the controller. As an alternative, software balancing tools shall be provided that will run in a hand-held device. The balancing tools shall allow adjustment of airflow setpoints and parameters, and provide permanent upload of the values entered to the UC. The Palm Pilot shall connect to the terminal unit through the room sensor port.

O. The VAV UC performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The UC shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
   1. Absolute temperature loop error.
   2. Signed temperature loop error.
   3. Absolute airflow loop error.
   4. Signed airflow loop error.
   5. Average damper actuator duty cycle.

P. The VAV UC shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
   1. Unreliable space temperature sensor.
   2. Unreliable differential pressure sensor.
   3. Starved box.
   4. Insufficient cooling.
   5. Insufficient heating.

Q. The VAV UC shall provide a compliant interface for ASHRAE Standard 62 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

R. The VAV UC shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

S. The VAV UC shall be compatible with the U.S. EPA Energy Star Buildings recommendations for fan energy reduction via demand-based static pressure reset down to 2/3 of duct static pressure set point, "VSD 2/3 Reset."

T. Inputs:
   1. Analog inputs shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
      a. 0-10 VDC Sensors
      b. 4-20 mA Sensors
      c. 1000ohm RTDs
      d. NTC Thermistors
   2. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input "bouncing."
   3. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

U. Outputs
   1. Analog outputs shall provide the following control outputs:
      a. 0-10 VDC
      b. 4-20 mA
   2. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
   3. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

2.24 BACNET ROUTERS

A. Provide all BACnet routers as necessary to meet the requirements of these specifications.

B. BACnet routers shall be native BACnet only. Proprietary and other standard protocols shall not be provided. Routers shall be provided at necessary to connect one medium to another, e.g. BACnet/IP to BACnet MS/TP, etc.

C. The BACnet routers shall, at minimum, support BIBBs for data sharing, alarm and event management.

2.25 HVAC INPUT DEVICES

A. General Requirements
1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors
1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. General Requirements:
a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.
c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

Point Type	Accuracy
Chilled Water	$\pm$ .5°F.
Room Temp	$\pm$ .5°F.
Duct Temperature	$\pm$ .5°F.
All Others	$\pm$ .75°F.

3. Room Temperature Sensors with Integral Display
a. Room sensors shall be constructed for either surface or wallbox mounting. Thermistors are acceptable for space temperature monitoring
b. Room sensors in public spaces, back of house space, service corridors, MER’s, storage, IT rooms, IT closets, lounges, etc.) shall have blank faceplates.
c. Room sensors in office areas (including occupied rooms by airline, TSA, security, airport personnel) shall have an integral LCD display and four button keypad with the following capabilities:
1) Display room temperature.
2) Display and adjust room comfort setpoint.
3) Display and adjust fan operation status (if required for application).
4) Timed override request push button with LED status for activation of after-hours operation.
4. Thermowells

a. When thermowells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
b. Thermowells shall be pressure rated and constructed in accordance with the system working pressure.
c. Thermowells and sensors shall be mounted in a threadolet or 1/2” NFT saddle and allow easy access to the sensor for repair or replacement.
d. Thermowells shall be constructed of 316 stainless steel.

5. Outside Air Sensors
   a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
   b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
   c. Temperature transmitters shall be of NEMA IV construction and rated for ambient temperatures.
6. Duct Mount Sensors
   a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
   b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
   c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.
7. Averaging Sensors
   a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
   b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
   c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Humidity Sensors
   1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
   2. The sensor shall be a solid state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
   3. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
   4. The humidity transmitter shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH meet the following overall accuracy, including lead loss and Analog to Digital conversion.
   5. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless steel bushings.

6. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
7. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

D. Combination Humidity and Temperature Transmitter Assembly
1. Assembly shall consist of capacitive type humidity sensing element with 1000 ohm platinum RTD and a solid-state, 2-wire, 4-20mA transmitter mounted in housing suitable for outdoor installation (NEMA IV) or indoor (wall-mounted) applications. Sensing elements shall be installed in a weatherproof aspirating enclosure.
2. Assembly shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH.
3. Acceptable Manufacturers: Veris Industries or Owner Approved substitution.

E. Differential Pressure Transmitters
1. General Air and Water Pressure Transmitter Requirements:
   a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
   b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
   c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.
   d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.
   e. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.

2. Low Differential Water Pressure Applications (0" - 20" w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) .01-20" w.c. input differential pressure range.
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra . or approved equal by Engineer.
3. Medium to High Differential Water Pressure Applications (Over 21" w.c.)
   a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
      1) Differential pressure range 10" w.c. to 300 PSI.
      2) Reference Accuracy: ±1% of full span (includes non-linearity, hysteresis, and repeatability).

b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

c. Acceptable Manufacturers: Siemens Sitran, Rosemount - Model 1151 DP, Fisher Porter, or Dieterich Standard Co. - Pro-ducer series.

4. Building Differential Air Pressure Applications (-1” to +1” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra or approved equal by Engineer..

5. Low Differential Air Pressure Applications (0” to 5” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) (0.00 - 1.00” to 5.00”) w.c. input differential pressure ranges. (Select range appropriate for system application.)
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Setra or approved equal by Engineer.

6. Medium Differential Air Pressure Applications (5” to 21” w.c.)
   a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
      1) Zero & span: (c/o F.S. /Deg. F): .04% including linearity, hysteresis and repeatability.
      2) Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
      3) Thermal Effects: <+.033 F.S. /Deg. F. over 40°F. to 100°F. (calibrated at 70°F.).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped

and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

c. Acceptable manufacturers: Setra or approved equal by Engineer.

F. Indoor Air Quality (CO_2) Sensors- Wall and Duct Mounted

1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. Provide indoor air quality sensors to monitor Carbon Dioxide (CO_2). The sensors shall be of microprocessor-based photo-acoustic type with heated stannic dioxide semiconductor.
3. The CO_2 sensors shall have no more than 1% drift during the first year of operation and minimal drift thereafter so that no calibration will be required.
4. The units shall be wall or duct mounted type as indicated on plans and in the sequence of operation.
5. Wall mounted sensors shall be provided with white plastic cover, without LED indicators.
6. Duct mounted sensors shall be provided with LED indicators in a dust proof plastic housing with transparent cover.
7. The sensor shall meet the following requirements:
   a. Operating voltage: 24 VAC +/- 20%
   b. Frequency: 50/60 Hz
   c. Power consumption: max. 6 VA
   d. CO_2 measuring range: 0 – 2000 ppm
   e. Tolerance: +/- 100 ppm
   f. Output: 0 – 10 VAC
   g. Calibration: none required
   h. Permissible air velocity in duct: <26.2 Ft/s.
   i. Manufacturer: Veris Industries or Owner Approved Substitution.

G. Carbon Monoxide (CO) Transmitter

1. UL listed sensor assembly suitable for N.E.C. installations (NEMA 4x enclosure).
2. Continuous carbon monoxide analysis shall be capable of measurement in the range of 0-500 part per million with 4-20mA output.
3. Minimum indicated concentration: 3ppm
4. Accuracy: +/-5% of reading.
5. Span drift: less than 5% change per year.
6. Operating temperature range: -20degC to 50 degC.
7. Humidity range (continuous): 15-90% RH non-condensing
8. Humidity range (intermittent): 0-99%RH non-condensing.
9. Stability: +/-1%
10. Repeatability: +/-2% of reading
11. Provide audible and visual alarm beacons.
12. Provide multichannel controller to monitor multiple variables in each space as required.
13. Manufacturer: Mine Safety Appliances (MSA), Sensidyne

H. Nitrogen Dioxide (NO_2) Detection System:

1. Provide UL listed nitrogen dioxide sensor in NEMA 4x enclosure. Sensor to include LED display, an audible and visual alarm beacon for local alarm annunciation.

2. Minimum Indicated Concentration: 0.3ppm.
3. Repeatability: +/-2% of Reading
4. Accuracy: +/-10% of Reading.
5. Span Drift: less than 12% change per 6 months
6. Temperature Range: -20degC to 50degC
7. Humidity Range (Continuous): 15-90% RH non-condensing
8. Humidity Range (intermittent): 0-99% RH non-condensing
9. Pressure Range: Ambient atmospheric: +/-1psi
10. Sensor life: 2 years from shipping date.
11. Provide multichannel controller.
12. Manufacturer: MSA Ultimo X, Sensidyne

I. Flow and Pressure Monitoring
   1. Air Flow Monitoring
      a. Duct and Outside Air Flow Measuring Stations
         1) Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of fundamentals, as well as in the Industrial Ventilation Handbook.
         2) Each sensor assembly shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
         3) Probes shall be constructed of extruded, gold anodized aluminum tube. All wires within the aluminum tube shall be Kynar coated.
         4) Transmitters shall include a 16-character alpha-numeric display capable of displaying airflow, temperature, system status, configuration settings, and diagnostics. The transmitter shall have the capability of field configuration and diagnostics using an on-board pushbutton interface and LCD display. The operating temperature range of the transmitter shall be installed at a location that is protected from weather and water.

            Each unit shall measure the airflow rate within an accuracy of plus 2% as determined by U.S. – GSA certification tests.

            The units shall have a self-generated sound rating of less than NC40, and the sound level within the duct shall not be amplified nor shall additional sound be generated.

            Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork.

            Where control dampers are shown as part of the airflow measuring station, opposed blade precision controlled volume dampers integral to the station and complete with actuator, pilot positioner, and linkage shall be provided. Stations shall be installed in strict accordance with the manufacturer's published requirements, and in accordance with ASME Guidelines affecting non-standard approach conditions.

5) Air flow measurement accuracy shall be ±3% of actual flow over a range of 6 to 1 capacity turndown. The probe installation shall not produce any static barrier (resistance to air flow). Provide a minimum of two (2) probes per each outdoor air intake. Follow manufacturer guidelines for installation and additional probe requirements.
6) Acceptable manufacturers: , Ebtron Gold series GP1 with standoff mounting bracket option.

b. Fan Inlet Probe Type:
1) Fan Inlet Type: Provide where indicated on the plans, airflow measuring stations of fan inlet type. Airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fan.
2) Probes shall be provided with the appropriate end support brackets for mounting in the inlet bell(s). Where fans are of dual inlet type, two sets of inlet probes must be provided. Provide inlet probes for each fan in fan array arrangements.
3) Fan inlet airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fans. Each sensor assembly shall contain individually wired hermetically sealed bead-in glass thermistors.
4) Airflow accuracy of +/-2% of reading over the entire operating range.
5) Fan inlet probes shall be Ebtron Gold series or approved equal by Engineer.

c. Space Pressurization Sensor:
1). Provide UL listed bi-directional bleed/differential pressure thermal dispersion airflow sensor in a ½ inch diameter tube. Sensor hermetically sealed bead-in glass thermistor.
2). Include all mounting kits as required.
3). NIST-traceable calibrated.
4). Accuracy: +/-2% of reading.
5). Manufacturer: Ebtron Bleed sensor assembly.

d. Static Pressure Traverse Probe
1) Duct static probes shall be provided where required to monitor duct static pressure.
2) Acceptable manufacturers: Setra or approved equal by Engineer.

2. BTU Monitoring Devices:
a. Accuracy: Temperature: Overall differential temperature: +/-0.15% over the stated range
b. Calculating nonlinearity within +/-0.05%
c. Temperature sensors: solid state matched sensors custom calibrated using NIST traceable temperature standards (1/2 inch NPT stainless steel thermowells.
d. Factory programmed for specific applications
e. Memory: Nonvolatile EEPROM memory retains all program parameters and totalized values in the event of power loss.
f. Display: Alphanumeric LCD displays total energy, total flow, energy rate, flow rate, supply temperature, return temperature, and alarm status.
g. Integrated with BMS via BACnet MSTP protocol.
h. Flow meter: Onicon F-3500.

i. Enclosure: Steel NEMA 13.
j. Power: 24 VAC
k. Manufacturer: Onicon System-10 BTU meter

3. Water Flow Monitoring Devices
   a. Accuracy: +/-1% of reading from 2 to 20 ft/sec, +/-0.02 ft/sec below 2 ft/sec
   b. Sensing method: Electromagnetic, no moving parts
   c. Input power: 20-28 VAC 50/60 Hz
   d. Liquid temperature range 15degF to 250degF
   e. Operating Pressure: 400 PSI maximum
   f. Pressure drop: Less than 0.1 psi at 12 ft/sec velocity
   g. Materials of Construction: Wetted metal components-316L stainless steel
   h. Enclosure rating: Weather-tight, NEMA 4
   i. Manufacturer: Onicon F-3500

J. Status and Safety Switches
1. General Requirements
   a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BMS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.
2. Current Sensing Switches
   a. The current sensing switch shall be self-powered with solid state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.
   b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.
   c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   d. Acceptable manufacturers: Veris Industries or Hawkeye
3. Leak Detection
   a. Provide Liqui-tect 410 (LT410) for leak detection application.
   b. Application: Leak spot detector.
   c. Power Input: 24 VAC, 50/60 Hz, 100mA, 3 VA
   d. Manufacturer: Liebert (Vertiv).
4. Water Flow Switches
   a. Water flow switches shall be equal to the Siemens, Johnson Controls P74, Honeywell.
5. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
   b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across

duct in accordance with manufacturers recommended installation procedures.

c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.

d. The low temperature limit switch shall be equal to Johnson Controls A70, Honeywell, Siemens.

2.26 HVAC OUTPUT DEVICES

A. Actuators

1. General Requirements
   a. Damper and valve actuators shall be electric/electronic. Provide local position indicator dial on all actuators.
   b. Provide a separate actuator for each damper bank. Linkages are not allowed.
2. Electronic Damper Actuators
   a. Electronic damper actuators shall be direct shaft mount.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer's recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in both direction, and a gear release to allow manual positioning. Spring-return actuators with more than 7 Nm (60 in.-lb) torque capacity shall have a manual crank for this purpose.
   c. Minimum Torque Requirements: 150 inch-lbs.
   d. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
   e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop associated fan. Two-position actuators, as specified in sequences of operations as "quick acting," shall move full stroke within 20 seconds. All smoke damper actuators shall be quick acting and be UL listed for smoke control service.
   f. Provide normally open spring-return actuators for dampers serving all battery room locations.

g. Acceptable manufacturers: Belimo, Siemens, Honeywell or approved equal by Engineer.

3. Electronic Valve Actuators
   a. Electronic valve actuators shall be manufactured by the valve manufacturer.
   b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
   c. Provide electric/electronic actuators in all areas, sized by the manufacturer, of sufficient size and power to operate the valve under all conditions and to close the valve tight against 150% maximum differential pressure.
   d. Valve actuators for finned tube radiation and terminal units shall be electronic, floating control, fail to last position.
   e. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer's recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.
   f. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal, and may be used to parallel other actuators and provide true position indication. The feedback signal of each valve actuator (except terminal valves) shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
   g. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated equipment such as a pump, chiller, etc.

B. Control Dampers/Smoke Control Dampers
   1. The BMS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the BMS Contractor or as specifically indicated on the Drawings.
   2. All dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.
   3. All dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.
   4. Damper frames and blades shall be constructed of either stainless steel or aluminum. Maximum blade length in any section shall be 48". Damper blades shall be 16-gauge minimum and shall not exceed six (6) inches in width. Damper frames

shall be 16-gauge minimum hat channel type with corner bracing. Additional stiffening or bracing shall be provided for any section exceeding 48” in height. All damper bearings shall be made of stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals. Dampers of 48”x48” size shall not leak in excess of 6 cfm per square foot when closed against 4” w.g. static pressure when tested in accordance with AMCA Std. 500.

5. Air foil blade dampers of double skin construction with linkage out of the air stream shall be used whenever the damper face velocity exceeds 1500 FPM or system pressure exceeds 2.5” w.g., but no more than 4000 FPM or 6” w.g.
6. Acceptable manufacturers: Control Damper – Tamco, Siemens, Johnson Controls D-1300, Ruskin CD50.
7. One piece rolled blade dampers with exposed linkage may be used with face velocities of 1500 FPM or below. Acceptable manufacturers are: Johnson Controls D-1100, Ruskin CD36.
8. Multiple section dampers may be jack-shafted to allow mounting of direct connect electronic actuators. Each end of the jack shaft shall receive at least one actuator to reduce jack shaft twist.

C. VAV Duct Damper (integral flow station)

1. Provide Ebtron/Tamco AIR-IQ/GTC-PC (refer to mechanical drawings for locations).

D. Step-Down Transformers:

1. Provide and install all step down transformers for a complete system. Transformers shall be machine tool type and shall be UL listed. Primary and secondary sides shall be fused in accordance with NEC. Transformers shall be properly sized for application and mounted in NEMA enclosure with overload circuit breaker.

2. Manufacturer: RIB or equal.

E. Control Relays
1. Control Pilot Relays
   a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
   b. Mounting bases shall be snap-mount.
   c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
   d. Contacts shall be rated for 10 amps at 120VAC.
   e. Relays shall have an integral indicator light and check button.
   f. Acceptable manufacturers: Johnson Controls, Honeywell, ASCO or Lectro.

F. Not Used

G. Control Valves (PICBV-Pressure Independent Control and Balancing Valve)

1. Provide pressure independent control valves to compensate for pressure variations, performing a continual balancing function to maintain system performance at varying loads. Valves shall be configured with one integrated valve body that incorporates chamber with adjustable Cv and a separate pressure regulating used to maintain a constant differential pressure across the control surface. Each control valve shall be

individually flow tested at the factory and verified to deviate no more than +/-5% through the selected operating pressure range. A calibrated performance tag (or factory provided calibration documentation) shall be provided with each valve that verifies the flow rate in 10 degree increments up to the full rated flow. All testing shall be performed with instruments calibrated to the requirements of ANSI/ ISA-S75. 11-1985, with traceability to NIST and/or ISO standards. Control valve rangeability shall be 100:1 minimum. The valve shall be rated for pressure and temperature as required. Each control valve shall subjected to 70 psid and tested to exceed ANSI/FCI 70-2-1998 leakage rating. Class IV leakage or better is required for control valves 2 inch nominal size or less. Class III leakage or better is required for control valves large than 2 inch. The control valve bodies shall be steel or bronze. All internal parts shall be stainless steel, steel, Teflon, brass or bronze. Plastic internal parts are not acceptable. The proportional control valve actuator shall modulate from 0 to 100% design flow. The control valve and factory mounted actuator shall be rated to shut-off against 150 psi minimum. When proportional actuators are utilized the end-stroke of the actuator shall be set on-site with the software (limit control signal) at full design flow from coil or from data listed on performance tag. Torque requirements for actuator selection shall be provided by the valve manufacturer. There are shall test ports installed at the factory integral for each valve and capable of being used to measure pressure or temperature. The differential pressure between the test ports shall be used to verify proper valve operation and flow regulation.

2. For valves without factory mounted test ports provide/furnish test port assemblies on the inlet and outlet side of the pressure independent control valves for field installation. Coordinate and confirm test port and pressure independent valve manufacturer’s recommended installation requirements with mechanical contractor.
3. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and mechanical schedules..
4. All valve and actuator assemblies shall be warranted by the manufacturer for no less than 5 years from the date of purchase.
5. Manufacturers:
    a. Flow Control Industries-Delta Valve (Basis of Design)
    b. Belimo PICCV
    c. Oventrop Cocon Q
    d. IMI Hydronic-TA (TA-FUSION-P)

H. Control Valves

1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer, and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure rating and connection type (sweat, screwed, or flanged) shall conform to the mechanical pipe schedule.

   a. Leakage: Control valves shall provide tight shut off in the closed position at 150 percent of maximum working pressure.
2. Chilled water control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer's recommendations for the given application. In general, valves (2 way) serving variable flow air handling unit coils shall be sized for a pressure drop equal to the actual coil pressure drop, but no less than 3 PSI. Valves for terminal reheat coils shall be sized for a 2 PSIG pressure drop, but no more than a 5 PSI drop.
3. Characteristics:
   a. Chilled Water Service: equal percentage flow characteristics, single seated type.
   b. Bypass service: linear flow characteristics. Double seated.
4. Valve action: Cooling valves normally closed, humidity control valve normally closed (spring return type).
5. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all chilled water applications, except those described hereinafter. The valve discs shall be composition type. Valve stems shall be stainless steel.
6. Characterized Ball valves shall be acceptable for fan coil units.
7. Globe valves are acceptable for use with Air Handlers. Automatic control valves for temperature control shall be fully proportioning with V-port inner guides, unless otherwise specified. Valves shall be quiet in operation and fail safe in either normally open or normally closed position in the event of control air failure. Valves shall be capable of operation in sequence when required by the sequence of operation. Size all globe control valves by the control manufacturer and guarantee they meet the heating and cooling loads as specified. Control valves shall be suitable for the system pressure conditions and shall close against the differential pressure involved.
8. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and schedules.
9. Butterfly valves shall be acceptable for modulating large flow applications greater than modulating plug valves, and for all two-position, open/close applications. In-line and/or three-way butterfly valves shall be heavy-duty pattern with a body rating comparable to the pipe rating, replaceable lining suitable for temperature of system, and a stainless steel vane. Valves for modulating service shall be sized and travel limited to 50 degrees of full open. Valves for isolation service shall be the same as the pipe. Valves in the closed position shall be bubble-tight.
10. Provide Bray Flow-Tek flanged full port ball valves for central plant modulating control valve applications. Control valves shall include feedback indicating valve position indication at BMS. Modulating control valves shall be capable of minimum of up to 1,800 starts/hour (duty cycle).
11. Provide electric high performance butterfly motorized valves for on/off service with manually operated declutchable handwheels for overriding the operator in both emergency and normal operation. Valve body shall be carbon steel with 316 stainless disc with a stainless shaft. Valve seat material shall be teflon. All valves shall be provided with two (2) limit switches that will indicate open and close valve positions remotely at the BMS. Minimum ANSI B16.104 Shut-off Class: Class 300.

12. Central Plant Locations: Electric powered valves are provided and specified in the central plant equipment specifications.
13. CEP Plant Applications: manufactured by Dezurik BHP Series, Bray/McCannalok MK Series High performance butterfly motorized valves with Industrial actuators manufactured by EIM Controls (HQ series), Bray Series 70 or as approved by Engineer.

2.27 ELECTRICAL

A. Electrical Power Monitors, Single Point (Easy Install):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Consist of three split-core CTs, factory calibrated as a system, hinged at both axes with the electronics embedded inside the master CT. The transducer shall measure true (rms.RMS) power demand real power (kW) consumption (kWh). Conform to ANSI C12.1 metering accuracy standards.
3. Voltage Input: Load capacity as shown on drawings. 208-480 VAC, 60 Hz
4. Maximum Current Input: Up to 2400A
5. Performance:
   a. Accuracy: +/- 1% system from 10% to 100% of the rated current of the CT's
   b. Operating Temperature Range: 32-140°F, 122°F for 2400A.
6. Output: 4 to 20 mA, Pulse. or Modbus RTU
7. Ratings:
   a. Agency: UL508 or equivalent
   b. Transducer internally isolated to 2000 VAC.
   c. Case isolation shall be 600 VAC.
8. Basis of Design: Similar to Hawkeye Veris H80xx40 series
9. Accessories: BACnet communications gateway

B. Electrical Power Monitors, Single Point (High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), and reactive power (kVARar), and power factor (PF) per phase and total load for a single load. Factory calibrated as a system using split core CT's. Neutral voltage connection is required.
3. Voltage Input: 208-480 VAC, 60 Hz
4. Current Input: Up to 2400A
5. Performance:
   a. Accuracy: +/- 1% system from 2% to 100% of the rated current of the CT's
   b. Operating Temperature Range: 32-122°F
6. Output: Pulse, BACnet, Modbus RTU

7. Display: Backlit LCD
8. Enclosure: NEMA 1
9. Agency Rating: UL508 or equivalent
10. Basis of Design: Veris Industries H81xx00 series.

C. Electrical Power Monitors, Single Point (High Accuracy/Versatility):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), reactive power (kVAR), apparent power (kVA) and power factor (PF) per phase and total load for a single load. Available with data logging , Bi-directional (4-quadrant) metering, and pulse contact accumulator inputs.
3. Voltage Input: 90-600 VAC, 50/60 Hz, 125-300 VDC
4. Current Input: 5A – 32,000A, selectable 1/3V or 1V CT inputs
5. Performance:

    a. Accuracy shall be +/- 0.2% revenue grade
    b. Operating Temperature Range: -22-158°F

6. Output shall be BACnet
7. Display: Backlit LCD
8. Enclosure: NEMA 4x optional
9. Agency Rating: UL508, ANSI C12.20
10. Basis of Design: Veris E5xxx series.

D. Electrical Power Monitors, Multiple Point (92 loads, High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures volts, amps, power and energy for each circuit. 1/4 amp to 200 amp monitoring. 4 configurable alarm threshold registers.
3. Voltage Input: 90-277 VAC, 60 Hz
4. Current Input: 5A – 32,000A, 1/3V CT inputs
5. Performance:

    a. Accuracy: +/- 0.5% meter (split core), +/- 1% system from 1/4-100A (solid core)
    b. Operating Temperature Range: 32-140°F

6. Output: Modbus RTU
7. Agency Rating: UL508, ANSI C12.10, IEC Class 1
8. Basis of Design: Veris E3xxx series

2.28 HVAC MISCELLANEOUS DEVICES

A. Local Control Panels

1. All control panels shall be factory constructed, incorporating the BMS manufacturers standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance.

Control panels shall be fully enclosed, with sub-panel, hinged door, and key-locking latch.

2. In general, the control panels shall consist of the DDC controller(s), display module, and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the control panel due to function. The display module shall be flush mounted in the panel face unless otherwise noted.
3. All I/O connections on the DDC controller shall be extended to a numbered, color-coded, and labeled terminal strip for ease of maintenance and expansion. Wiring to I/O devices shall be made from this terminal strip.
4. All other wiring in the panel, internal and external, shall be made to additional line or low voltage color-coded and labeled terminal strips. Low and line voltage wiring shall be segregated. All terminal strips and wiring shall be UL listed 300-volt service and provide adequate clearance for field wiring.
5. All wiring for every control panel shall follow a common color-coded format. All terminal strip color coding and numbering shall follow a common format. All wiring shall be neatly installed in plastic trays or tie-wrapped.
6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

B. Outside Air Damper Override Switch: Provide UL listed mushroom switch (momentary switch) with time delay relay (time delay adjustable up to one hour) with auxiliary contacts for BMS interface. Provide EN 418 compliant safety guard (safety yellow). Refer to mechanical drawings for quantity and location.

C. Power Supplies (Provide new power supplies for all new BMS control panels)
1. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75% of the rated capacity of the power supply.
2. Input: 120 VAC +10%, 60Hz.
3. Output: 24 VDC.
4. Line Regulation: +0.05% for 10% line change.
5. Load Regulation: +0.05% for 50% load change.
6. Ripple and Noise: 1 mV rms., 5-mV peak to peak.
7. An appropriately sized fuse and fuse block shall be provided and located next to the power supply.
8. A power disconnect switch shall be provided next to the power supply.

PART 3 - EXECUTION

3.1 INSTALLATION PRACTICES

A. Control System Wiring:
1. All conduit, wiring, accessories and wiring connections required for the installation of the Building Management System, as herein specified, shall be provided by the BMS Sub -Contractor. All wiring shall comply with the requirements of applicable local and national electric codes, unless specified otherwise in this section.
2. The BMS Contractor is responsible for the installation of all low voltage control, monitoring and network wiring.

3. Power wiring 120VAC and greater shall be provided by the Electrical Sub-Contractor.
4. All system-input wiring shall be twisted shielded pair, minimum 18-gauge wire. All system analog output wiring shall be twisted shielded pair/3-wire as required, minimum 18-gauge wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24 gauge.
5. All internal panel device wiring for binary outputs and pilot relay shall be minimum 16-gauge wire.
6. All Class 2 (24VAC or less) wiring shall be installed in conduit unless otherwise specified.
   a. Class 2 wiring not installed in conduit shall be supported every 5' from the building structure utilizing metal hangers designed for this application. Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements. Exposed wiring shall only be allowed in concealed accessible locations.
7. Low voltage control wiring and 24VAC can be run in the same conduit. Power wiring 50VAC and greater must be in a separate conduit.
8. All wiring in mechanical rooms shall be in conduit. Minimum control wiring conduit size 3/4".
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked.

B. Identification Standards
1. Controller Identification: All controllers shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
2. Panel Identification: All local control panels shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
3. Field Devices: All field devices shall be identified by a typed (not handwritten) securely attached tag label.
4. Panel Devices: All panel devices shall be identified by a typed label securely fastened to the backplane of the local control panel.
5. Raceway Identification: All the covers to junction and pull boxes of the control system raceways shall be painted blue or have identification labels stating "Control System Wiring" affixed to the covers. Labels shall be typed, not hand written.
6. Wire Identification: All low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be permanently secured to the conductor or cable and shall be typed.

C. Dedicated Digital Controller Per Major System
1. Each major system will be provided with its own dedicated BMS controller. Mechanical systems such as AHUs or Refrigeration Plant shall not share or be controlled from the same BMS controller.

D. Input Devices
1. All Input devices shall be installed per the manufacturer's recommendation. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, duct smoke detectors, air flow stations, etc.

a. Low Differential Air Pressure Applications (Under 5” w.c.) Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and Owner permanent easy-to-use connection. Provide a minimum of a NEMA 1 housing for the transmitter. Locate transmitters in accessible local control panels wherever possible. Except on VAV box applications.

b. Medium Differential Air Pressure Applications (5” to 21” w.c.) Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.

c. Medium to High Differential Water Pressure Applications (Over 21” w.c.): Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.

d. Building Differential Air Pressure Applications (-1” to +1” w.c.): Mount pressure transmitter in the local control panel. Transmitter’s exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind. The interior tip shall be inconspicuous and located within a central corridor shown on the drawings.

e. Air Flow Measuring Stations: Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork. Stations shall be installed in strict accordance with the manufacturer’s published requirements, and with ASME Guidelines affecting non-standard approach conditions.

f. Water Flow Monitoring Stations: Water Flow Monitoring Stations shall be installed in strict accordance with the manufacturer’s published requirements, and with ASME Guidelines affecting non-standard approach conditions.

g. Outside Air Humidity Sensors: Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless steel bushings.

h. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.

i. Duct Temperature Sensors: Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate. For ductwork greater in any dimension that 48 inches and/or air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor with multiple sensing points. The sensor shall be mounted to suitable supports using factory approved element holders. For large plenum applications such as mixed air temperature measurements, utilize a string of sensors mounted across the plenum to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12 foot long segment.

j. Space Temperature Sensors: Shall be mounted at 60” above the finished floor. Temperature sensors installed in public areas shall be provided with lockable covers to prevent tampering.

k. Low Temperature Limit Switches: Mount element horizontally across duct in a serpentine pattern insuring each square foot of coil is protected by 1 foot of sensor. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

l. Differential Pressure Status Switches: Provide complete installation kit including; static pressure tops, tubing, fittings and air filters. Provide appropriate scale range and differential adjustment for intended service.

m. Valve Limit Switches: Mount limit switch on valve yolk as recommended by switch manufacturer. Provide valve limit switches that will indicate both 100% Open and 100% Closed Positions.

E. Output Devices

1. All output devices shall be installed per the manufacturer’s recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, etc.
2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke.
3. Control Dampers: Shall be opposed blade for modulating control of air flows. Parallel blade dampers shall be installed for two position applications.
4. Control Valves: Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI.
5. Electronic Signal Isolation Transducers: Whenever an analog output signal from the Building Management System is to be connected to an external control system as an input (such as a chiller control panel), or is to receive as an input a signal from a remote system, provide a signal isolation transducer. Signal isolation transducer shall provide ground plane isolation between systems. Signals shall provide optical isolation between systems.

3.2 TRAINING

A. General

1. The controls contractor shall provide the following training services.
2. Operator Training (provide 40 hours): Operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall demonstrate how the system accomplishes the sequence of operation.

a. From the workstation, the operator shall demonstrate the software features of the system. As a minimum, the operator demonstrate and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.
b. One day (8 hours) of the 40 hours will be devoted to on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations.

3. Factory training for two owner representatives in a factory training lab. This training shall be performed by a factory-certified professional trainer and, at a minimum, shall consist of:
   a. Two days (16 hours) training covering basic system operation.
   b. One day (16 hours) training covering system reporting and alarm management.
   c. One day (16 hours) training of scheduling and point trending
4. The owner representatives shall be issued Continuing Education Credits (C.E.U.s) for the factory training.

3.3 COMMISSIONING & TESTING

A. General
1. Commissioning the Building Management System is a mandatory documented performance requirement of the selected BMS Contractor for all control systems detailed in this Specification and sequence of operations. Commissioning shall include verification of proper installation practices by the BMS Contractor and subcontractors under the BMS Contractor, point verification and calibration, system/sequence of operation verification with respect to specified operation, and network/workstation verification. Documentation shall be presented upon completion of each commissioning step and final completion to ensure proper operation of the Building Management System.
2. BMS commissioning and testing documentation is to be provided separately to the Owner.

B. Testing Requirements
1. Intent: Demonstrate to satisfaction of authorized representative that BMS is performing in accordance with specification requirements.
2. Logs of Tests: Complete logs of tests retained by Contractor for inspection and review of authorized representative at any time after testing started. Upon final completion of system tests log records submitted.
3. Witness of Tests: At time directed by authorized representative complete functional, operational test shall be performed by contractor. Test witnessed by personnel directed by authorized representative. Tests continue until functions of points, of alarms and command functions are proven to satisfaction of authorized representative.
4. Performance of Field Tests: Complete tests required at different and distinct times for various phases of construction as designated by authorized representative.

C. Testing Procedure
   1. Upon completion of the installation, the BMS Contractor shall start-up the system and perform all necessary testing and run diagnostic tests to ensure proper operation. The BMS Contractor shall be responsible for generating all software and entering all database information necessary to perform existing control sequences.

D. Testing Documentation
   1. Prior to acceptance testing, BMS Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

E. Field Points Testing
   1. This step shall verify that all of the installed points receive or transmit the correct information prior to loading/activating the system software.
   2. ON/OFF commands from the workstation shall be performed in order to verify each binary output point.
   3. All binary input points are to be tested by observing a change of state upon command at PC workstation or locally in the field.
   4. All analog output points shall be tested using a command from the PC workstation to modulate the output device from minimum calibrated signal to maximum calibrated output.
   5. All analog input points are to be tested by comparing the reading obtained through the workstations to the value of an independent testing meter
   6. All two-way communication interfaces (Modbus, Bacnet, etc) tested and monitored values and commanded verified at the BMS workstation and in the field.

F. Verify that activation of site related alarms specifically identifies and notifies the Owner remote monitoring sites and selected personnel.

G. VAV box performance verification and documentation: (Perform testing if required).
   1. As part of the commissioning of the terminal unit control (UC) and air distribution system, the Contractor shall initiate an automated test where the dampers in one half of a group of boxes are stepped towards full open while the other half are stepped towards full closed. At each step, after a settling time, box airflow and damper positions will be sampled. Following the cycle, a pass/fail report indicating results shall be produced. Possible results are Pass, No change in flow between full open and full close, reverse operation, or Maximum flow not achieved. The report shall be submitted as documentation of the installation.
   2. The controls contractor shall issue a report based on a sampling of the UC calculated loop performance metrics. The report shall indicate performance criteria, include the count of conforming and non-conforming boxes, list the non-conforming boxes along with their performance data, and shall also include graphical representations of performance. The sampling shall take place after completion of Test and Balance, when design cooling and heating media have been available and occupied conditions approximated for five consecutive days.
   3. Verify that new graphics are complete and contain dynamic (real-time) information that can be viewed at both workstation locations.

H. Non-compliant Items

1. The Contractor shall remove and replace, at its expense, all items that are not in compliance with the Specification requirements.

END OF SECTION 23 0900

SECTION 23 09 20 - REFRIGERANT DETECTION AND ALARM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes refrigerant monitors and notification appliances.

1.3 DEFINITIONS

A. LCD: Liquid-crystal display.

B. LED: Light-emitting diode.

C. PIR: Photoacoustic infrared.

1.4 SUBMITTALS

A. Product Data:

1. For each type of refrigerant monitor, include refrigerant sensing range in ppm, temperature and humidity range, alarm outputs, display range, furnished specialties, installation requirements, and electric power requirement.

B. Shop Drawings:

1. Air-Sampling Tubing: Size, routing, and termination including elevation above finished floor.
2. Wiring Diagrams: Power, signal, and control wiring.

C. Coordination Drawings: Include machinery-room layout showing location of monitoring devices and air-sampling tubing with filter/inlet locations in relation to refrigerant equipment.

D. Product Certificates: For monitoring devices signed by product manufacturer.

E. Field quality-control test reports.

F. Operation and Maintenance Data: For refrigerant monitoring equipment to include in emergency, operation, and maintenance manuals.

1.5 COORDINATION

A. Coordinate refrigerant detection and alarm system with refrigerant contained in refrigeration equipment for compatibility.

1.6 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. One calibration kit including clean air calibration gas bottle for zero calibration and specific refrigerant calibration gas for span calibration, minimum 58-L capacity, pressure regulator, and tubing.

PART 2 - PRODUCTS

2.1 PIR REFRIGERANT MONITOR

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

1. Chillgard Refrigerant Monitors; MSA; Instrument Division.
2. Haloguard Monitors; Thermal Gas Systems, Inc.
3. Owner approved substitution.

B. Description: Sensor shall be factory tested, calibrated, and certified to continuously measure and display the specific gas concentration and shall be capable of indicating, alarming, and automatically activating ventilation system.

C. ASHRAE: Monitoring system shall comply with ASHRAE 15 and ASHRAE 147.

D. Performance:

1. Refrigerant to Be Monitored: R-134a.
2. Range: 0 to 1000 ppm.
3. Sensitivity:
    a. Minimum Detectability: 1 ppm.
    b. Accuracy: 0 to 50 ppm; plus or minus 1 ppm. 51 to 1000 ppm; plus or minus 10 percent of reading.
    c. Repeatability: Plus or minus 1 percent of full scale.
    d. Response: Maximum 10 seconds per sample.
    e. Detection Level Set Points:
        1) Detection Level 1: 1 ppm.

2) Detection Level 2: 10 ppm (adjustable).
3) Detection Level 3: 50 ppm (adjustable).

4. Operating Temperature: 32 to 104 deg F.
5. Relative Humidity: 20 to 95 percent, noncondensing over the operating temperature range. Compensate sensor for relative humidity.

E. Input/Output Features:

1. Maximum Power Input: 120-V ac, 60 Hz, 75 W.
2. Number of Air-Sampling Points: Eight.
3. Air-Sampling Point Inlet Filter: 0.10-micron filter element for each sampling point.
4. Air-Sampling Point Analog Output: 0- to 10-V dc into 2k ohms, or 4- to 20-mA into 1k ohms matched to sensor output.
5. Alarm Relays: Minimum 4 relays at a minimum of 5-A resistive load each.
6. Alarm Set Points: Displayed and adjustable through keypad on front of meter.
7. Alarm Silence Switch: Mount in the front panel of the monitor to stop audible and visual notification appliances, but alarm LED remains illuminated.
8. Alarm Manual Reset: Momentary-contact push button in the front panel of the monitor stops audible and visual notification appliances, extinguishes alarm LED, and returns monitor to detection mode at current detection levels.
9. Display: Alphanumeric LCD, LED indicating lights for each detection level; acknowledge switch and test switch mounted on front panel; alarm status LEDs and service fault/trouble LEDs.
10. Audible Output: Minimum 75 dB at 10 feet.
11. Visible Output: Strobe light.
12. Sensor Analog Output: 0- to 10-V dc into 2k ohms, or 4- to 20-mA into 1k ohms.
13. Serial Output: RS-232 or RS-485 compatible with HVAC controls.
14. Enclosure: NEMA 250, Type 12 , with locking quarter-turn latch and key.

2.2 MONITOR ALARM SEQUENCE

A. Detection Level 1: Notify HVAC control workstation of detection in the refrigeration equipment room on a rise or fall of refrigerant concentration to this level. Start ventilation system at low speed to allow occupancy by maintenance technicians to identify leaks. Cycle blue strobe lights.

B. Detection Level 2: Notify the HVAC control workstation of the detection in the refrigeration equipment room on a rise or fall of refrigerant concentration to this level. Run ventilation system at high speed on a rise in concentration to this level, and change to low speed on a reduction in concentration below this level. Operate the ventilation system at high speed for a minimum of five minutes. Cycle amber strobe lights.

C. Detection Level 3: Notify the HVAC control workstation of the detection in the refrigeration equipment room on a rise or fall of refrigerant concentration to this level. Sound alarm horns and cycle red strobe lights inside and outside refrigeration equipment room. Terminate operation of any combustion-process equipment located in the refrigeration equipment room. Provide manual reset for this detection level.

D. Sensor Fault/Trouble: Notify HVAC control workstation of fault/trouble detection in monitor.

2.3 NOTIFICATION APPLIANCES

A. Horns: Comply with UL 464; electric-vibrating-polarized type, listed by a qualified testing agency with provision for housing the operating mechanism behind a grille. Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet from the horn.

B. Visible Alarm Devices: Comply with UL 1971; three color xenon strobe lights, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate. The words "REFRIGERANT DETECTION" printed in minimum 1/2-inch- high letters on the lens. Rated light output is 110 candela.

2.4 AIR-SAMPLING TUBING

A. Annealed-Temper Copper Tubing: ASTM B 88, Type L.

B. Polyethylene Tubing: ASTM D 2737, flame-retardant, nonmetallic tubing rated for ambient temperature range of 10 to 150 deg F.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with ASHRAE 15 and ASHRAE 147.

B. Install air-sampling inlets, or diffusion type monitors in pits, tunnels, or trenches in machinery room that are accessible to personnel.

C. Floor mount diffusion-type monitor, sensor/transmitters, or air-sampling inlets on slotted channel frame 12 to 18 inches above the floor in a location near the refrigerant source or between the refrigerant source and the ventilation duct inlet.

D. Wall mount air-sampling multiple-point monitors with top of unit 60 inches above finished floor.

E. Run air-sampling tubing from monitor to air-sampling point, in size as required by monitor manufacturer. Install tubing with maximum unsupported length of 36 inches, for tubing exposed to view. Terminate air-sampling tubing at sampling point with filter recommended by monitor manufacturer.

F. Install air-sampling tubing with sufficient slack and flexible connections to allow for vibration of tubing and movement of equipment.

G. Purge air-sampling tubing with dry, oil-free compressed air before connecting to monitor.

H. Number-code or color-code air-sampling tubing for future identification and service of air-sampling multiple-point monitors.

I. Extend air-sampling tubing from exhaust part of multiple-point monitors to outside.

J. Install warning signs, labels, and nameplates to identify detection devices according to Division 23 Section "Identification for HVAC Piping and Equipment."

K. Place warning signs inside and outside each door to the refrigeration equipment room. Sample wording: "AUDIBLE AND VISUAL ALARM SOUNDING INDICATES REFRIGERANT DETECTION."

L. Audible Alarm-Indicating Devices: Install at each entry door to refrigeration equipment room, and position not less than 6 inches below the ceiling. Install horns on flush-mounted back boxes with the device-operating mechanism concealed behind a grille.

M. Visible Alarm-Indicating Devices: Install adjacent to each alarm horn at each entry door to refrigeration equipment room, and position at least 6 inches below the ceiling.

N. Maintenance - System shall require no periodic adjustments other than checking against a clean air source every 6 months. Span calibration frequency shall be no more than once every 12 months. Changes in External Zero Filters and Line Filters are unacceptable. Internal Sample Filters should be visually checked every 6 to 12 months and replaced if needed.

3.2 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections and prepare test reports.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

C. Perform tests and inspections and prepare test reports.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Tests and Inspections:

1. Inspect field-assembled components, equipment installation, and electrical connections for compliance with requirements.
2. Test and adjust controls and safeties.
3. Test Reports: Prepare a written report to record the following:

a. Test procedures used.
b. Test results that comply with requirements.
c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.

E. Repair or replace malfunctioning units and retest as specified above.

3.3 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain refrigerant detection devices and SCBA equipment. Refer to requirements in Division 01 Section "Demonstration and Training."

END OF SECTION 23 09 20

SECTION 23 11 13 - FACILITY FUEL - OIL PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 WORK INCLUDED

A. Hydrostatic Tank Leak Detection System with Remote Electronic Panel.

B. Inventory Control and Leak Detection System for Underground Tank System.

C. Liquid Level Indicator.

D. Vent Cap.

E. Fill or Sounding Line Cap.

F. Fuel Oil Pump.

G. Manhole and Cover.

H. Fuel Filter.

I. Dual or Single Slip Tank Fitting.

J. Overflow Prevention Valve.

K. Piping Requirements.

L. Double Poppet Foot Valve

M. Ball Valve

N. Motorized Fuel Valve

O. Hand Fuel Pump

P. Backpressure Regulating Valve

1.3 QUALITY ASSURANCE

A. General:

1. NFPA 30 - Flammable Combustible Liquid Code.
2. NFPA 30A – Automotive and Marine Service Station Code
3. NFPA 31 - Standard for the Installation of Oil Burning Equipment, for oil piping materials and components, oil piping installations, and inspection, and testing of fuel oil piping systems.
4. Standard Mechanical Code, 2010 Edition.
5. UL 343 - "Standard for Pumps for Oil Burning Appliances", for oil transfer pumps.
6. UL 567 - "Pipe Connections for Flammable and Combustible Liquids and LP-Gas".
7. General Services Administration, Public Building Service Guide Specification, PBS: 1568.
8. ANSI B31.4 - Liquid Petroleum Transportation Piping System.
9. All equipment and installation shall conform to FDEP regulations Chapter 62-761.
10. All equipment shall be on the FDEP approved list.

1.4 SUBMITTALS

A. Product data for the following products:

1. Inventory control and monitoring system.
2. Oil transfer pumps. Include performance curves, electrical characteristics, and specified accessories.
3. Oil piping specialties.

B. Wiring diagrams detailing wiring for power and control systems; differentiating between manufacturer-installed wiring and field-installed wiring.

C. Maintenance data for oil transfer equipment, for inclusion in Operating and Maintenance Manual specified in Division 1.

1.5 FEDERAL DEMONSTRATION OF FINANCIAL RESPONSIBILITY

A. Supplier of the Underground Storage Tank shall provide evidence of financial responsibility in accordance with State and Federal requirements.

1.6 NOTIFICATION

A. The mechanical subcontractor, on behalf of the Owner, shall obtain a permit, the required inspections and certificate of use in accordance with the provisions of the local

AHJ prior to beginning installation.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Hydrostatic Tank Leak Detection System with Remote Electronic Panel:

1. Veeder Root.
2. Owner approved substitution.

B. Inventory Control and Detection System:

1. E.J. Ward.
2. Owner approved substitution.

C. Liquid Level Indicator:

1. Veeder Root.
2. Owner approved substitution.

D. Vent Cap:

1. OPW Model 23 (basis of design)
2. Morrison Brothers Company Figure 354.
3. Preferred Utilities Manufacturing Company Model 332 Breather Cap.
4. Owner approved substitution.

E. Fill or Sounding Line Cap:

1. OPW.
2. Owner approved substitution.

F. Prepackaged Fuel-Oil Pump Set:

1. Simplex, Inc.
2. Owner approved substitution.

G. Manhole and Cover:

1. OPW, Pomeco Composite.
2. Owner approved substitution.

H. Fuel Filter:

1. ~~General Filter.~~Racor, Division of Parker Hannifin Corporation.

~~2. Fuel Flo.~~
~~3.~~2. Owner approved substitution.

I. Dual or Single Slip Tank Fitting:

1. General Tanks.
2 Owner approved substitution.

J. Overflow Prevention Valve:

1. OPW Fueling Components Division.
2. Owner approved substitution.

K. Double Poppet Foot Valve

1. OPW Model 86 (basis of design)
2. Morrison Brothers Company Figure 335A.
3. Preferred Utilities Manufacturing Company Model 22.
4. Owner approved substitution.

L. Hand Fuel Pump

1. Fill-Rite FR112 (basis of design)
2. Owner approved substitution.

M. Backpressure Regulating Valve

1. Watts LFF116 (basis of design)
2. Owner approved substitution.

N. Motorized Fuel Valve

1. ASCO AH2E/V710 (basis of design)
2. Owner approved substitution.

O. Ball Valve

1. Nibco Model T-585-70 (basis of design)
2. Apollo Model 77F
3. Jamesbury Model 2000.
4. Owner approved substitution.

2.2 DIESEL FUEL OIL PIPING SYSTEM

A. General: Piping and equipment shall be located as shown on the drawings. Coordinate piping with outside utilities. Provide valves and specialties as indicated.

B. Piping Material: The following schedule covers materials unless specifically noted otherwise.

1. Above ground piping

a. Black steel pipe, Schedule 40.
b. Copper tube, Type K, hard drawn.

2. Below ground piping

a. All secondary-containment piping shall be an FDEP-approved engineered containment system. Supply and return carrier pipes shall be protected from the exterior environment by one (1) secondary containment. The system supplier shall have at least 5 years of experience in the manufacture of secondary contained pipe systems. All straight sections, fittings and other accessories shall be factory prefabricated to job dimensions. Secondary-containment joints completed at the factory shall be 100 percent air-tested. The containment shall be drainable, dryable and air pressure testable. Contractor fabricated systems, whether built on-site or off-site, shall not be acceptable.
b. The secondary containment shall not be exposed to pressures that exceed the maximum for the selected containment material. When product pipe design pressures exceed the maximum allowable pressure for the secondary containment, then either a control system activated by the leak detection alarm station relay or a pressure relief valve shall be utilized. When the leak detection/location system is used, the normally energized alarm station relay shall de-energize and break the control circuit, which will de-activate the control relays for valves and/or pumps that supply pressure in the carrier pipe.
c. The secondary containment manufacturer shall supply a complete design submittal including layout drawings, catalog sheets, material data and pipe stress and end load calculations in accordance with ANSI B31.3 latest edition. The calculations shall be stamped by a registered professional engineer.
d. Carrier pipe supply and return shall be standard weight carbon steel, ASTM A-53 Grade B ERW or seamless. All joints shall be butt welded for sizes 2½ inches and greater, and socket or butt welded for 2 inches and below. Where possible, straight sections shall be supplied in 40-foot random lengths with 6 inches of piping exposed at each end for field joint fabrication.
e. The secondary containment shall be epoxy fiberglass as manufactured by Ameron 3000A or A.O. Smith Red Thread II.
f. Support spacing shall be determined by the manufacturer based on pipe diameter, pipe materials, and operating temperature of the product pipes. In all cases pipes within the secondary containment shall be supported at not more than 10-foot intervals. These supports shall be .250" thick steel plate

with a .134" thick band tack welded to plate to eliminate point loading the fiberglass jacket and designed to allow for continuous airflow and drainage of the secondary containment in place. No plastic type supports will be allowed.

g. End seals and other subassemblies shall be designed and factory prefabricated to prevent the ingress of moisture into the system. All subassemblies shall be designed to allow for complete draining of the secondary containment.

h. The field closure shall be made with a split fiberglass closure sleeve of the same diameter and thickness as the containment pipe. The sleeve shall be sealed and bonded to the containment pipe with double hand lay-ups over all seams.

i. Pipe Protection: Underground carrier piping shall be factory coated with an epoxy coating. Field application kits shall be furnished for the contractor to apply to any field joints.

C. Valves: All valves used in the fuel oil piping system shall be 125 psi SWP, 200 psi WOG.

D. Containment Pipe Monitoring Well: Provide a containment pipe monitoring well for each containment pipe system. The well shall consist of a factory-fabricated 4 inch deep waterproof sump on the bottom of the containment pipe with a 2 inch test well. The test well shall cut slots 0.02 inches wide and 1/4 inch apart from the bottom cap to within 1 inch from the top of the pipe. The well shall be provided with a watertight seal at the top of the containment pipe and shall extend up to within 2 inches below finish grade. The top of the test well shall be provided with a removable cap. A minimum 8 inch cast iron frame and cover shall be installed above the test well for access. The top of the access shall be set 2 inches above the finished grade and shall be surrounded with a 24 inch diameter by 4 inches thick concrete pad. The top of the concrete pad shall slope down away from the cover to prevent water from entering the access area.

2.3 UNDERGROUND FUEL OIL STORAGE TANK

A. Tank Data: Provide the equipment, labor and materials necessary to furnish and install the petroleum storage tanks utilizing three (3) underground 40,000 gallons Permatank double-wall tanks with a steel primary tank and a 100mil FRP secondary tank. Interstitial space between the tank layers shall remain dry. Provide tank tappings for fuel fill, vent, fuel return, pump inlet, interstitial space probe, and fuel gauge. Provide a manhole of minimum diameter 22 inch with ladder. Provide lifting lugs manufactured as part of the tank, and provide the manufacturers' complete installation assembly including restraining straps, turnbuckles and clamps. Tank shall have U.L.-58 certification with attached plate. Extend fuel fill line to the remote fuel fill station (specified elsewhere), and also to grade in a valve box or steel column, and terminate with a steel collar and a lid marked "fuel". Tank shall withstand an internal test pressure of 5 psig and an external load of H-20 and a hydrostatic pressure of flooded underground installation to seven feet deep.

1. Manufacturer:

    a. General Industries, Permatank, Goldsboro, NC
    b. Modern Welding

B. Underground Fuel Monitoring System: The underground fuel monitoring system shall be capable of performing remote monitoring, diagnostics, inventory and testing for up to eight separate fuel tanks. The microprocessor-controlled system shall generate reports which include fuel volume, weight, height, temperature, ullage, temperature-compensated fuel volume, and time and date. The system shall, both on demand and at adjustable intervals, perform diagnostic leak detection tests in compliance with Federal EPA regulations 40 CFR Part 280. The fuel monitoring console shall be UL listed for the application.

1. Console: The remote wall-mounted console panel shall have a two-line, 24-character liquid crystal display for inventory, leak detection and alarm information. A 24-button panel keypad shall be provided for programming, operating pre-set functions, and reporting, and shall have alarm, warning, and power LED's and internal audible warning horn with alarm acknowledgement switch.
2. Printer: Console shall include an integral printer with cover and built-in take-up spool for hard-copy documentation of inventory, leak detection and alarm information. Furnish three extra printer paper rolls with the console.
3. Monitoring Probes: Provide software, capacitance-type probe, and control wiring to perform the inventory in-tank monitoring.
4. Performance Criteria: The system shall be capable of measuring and reporting fuel status, based on a nominal 40,000 gallon tank, to within plus or minus 15 gallons of temperature-compensated fuel volume; fuel temperature to plus or minus 1.5 degrees F.; time accurate to plus or minus 1 minute/month; and leak detection of 0.1 gallon per hour or greater. History reports of the past ten deliveries, plus an alarm history, shall be retained and accessed via the console keypad. Alarms shall warn of leaks, overfill, high level, high water level, low inventory, and theft.
5. Alarm Monitoring: Provide alarm probes, software, console hardware module, and control wiring to perform the following alarming features:

    a. Two-wire interstitial probe to sense fuel or water between the dual-wall fuel tank (1 sensor).
    b. A ground water sensor with well cap, sensor well cap, locking handle, float and perforated PVC monitoring well housing. Sensor shall detect 1/10 of an inch of product on the water table and shall alert upon loss of water table height (2 sensors, located on alternate sides of tank).
    c. Sump sensor to detect liquid in the sump (1 sensor).
    d. Vapor sensor and well to detect hydrocarbons and water underground (2 sensors, alternating sides).
6. Relay Output Module: Provide a relay output module with four form "C" NO/NC 2 amp 120 VAC relays, for interconnection of external output to the BMS system for the following program module alarm points:

a. Leak detection alarm
b. Low inventory alarm
c. Overfill alarm
d. Spare

7. Manufacturer and Model Number:

a. Automatic Tank Gauge: Veeder-Root TLS-350
b. Tank Monitoring and Leak Detection System: Omntec, OEL 8000
c. Liquid Leak Detection: Perm Alert, PAL-AT

2.4 DAY TANK

A. Provide an inline fuel filter/water separator, Racor Model 1000FH or equal, as shown on generator day tank fuel supply line.

2.5 REMOTE FUEL FILL STATION

A. Provide a multi-tank fuel filling station to deliver fuel to three (3) main fuel tanks. Fuel filling station shall be expandable to serve a future total of six (6) tanks. The fuel fill station shall be FDEP-approved and a factory-packaged system as manufactured by Simplex, Inc., Automatic FuelPort model AFP-3/6, Springfield, IL.

B. Construction: the fuel filling station shall be freestanding, pad-mountable design, with lockable full weatherproof enclosure and 20-gallon spill containment sump. Fuel filling station shall include a 3” quick-disconnect hose coupling for fuel delivery vehicle connection and all accessories and controls as described below.

C. Components: the fuel filling station shall include the following primary components:

1. Level transmitters and electrically-operated shut-off valves for installation at three (3) main fuel tanks.

2. Shut-off ball valves, installed on outlet of the fuel fill station.

3. Check valve

4. Spill sump drain valve.

5. Ground stud.

D. A UL508 fuel level controller and alarm indicator panel for monitoring of fuel tanks. Controller shall include:

1. 95% visual alarm

2. tank leak alarm with sensor included

3. digital level indicator, scaled in percent.

4. audible alarm horn activated by alarms above

5. power available indicator

6. control power on/off switch.

7. valve open/close pushbuttons

8. NEMA 3R control enclosure

2.5 FUEL TRANSFER PUMP

A. Provide a diesel fuel-oil transfer pump set consisting of a prepackaged system designed and coordinated to transfer fuel from main fuel-oil tanks to generator day tanks. The fuel transfer pump shall provide controls and alarm indications as described in this section.

B. Pump set shall be as manufactured by Simplex, Inc., Series SKS, Springfield, Illinois.

C. Performance:

1. All control panels shall be UL508 Listed. Controls shall include automatic triplex pump lead/lag controls with lead pump alternate sequence.

2. Triplex fuel transfer pump set shall be capable of providing a 150gpm flow rate at 50psi discharge pressure.

D. Construction:

1. The fuel transfer pump set shall be a skid-style, steel construction, designed for floor mounting indoors. The skid base shall include a drip pan to contain fuel leaks.

2. All components specified herein shall be assembled and pre-wired at the place of manufacture.

E. Components: The fuel transfer pump set shall include the following primary components:

1. Separate power supply connection points for power input to controls and electric motors. Both power circuits shall be 460Vac, 3-phase.

2. Triplex pumps shall be direct-driven, positive displacement, internal gear type with mechanical shaft seal, and cast-iron housing.

3. Motors shall be TEFC construction, continuous duty at 40ºC, 1725 RPM, 460Vac, 3-phase, 60 hertz, 1.15 service factor.

4. Triplex pump controller and tank monitor to provide automatic lead/lag pump operation as well as pump monitoring and tank level indication.

5. Additional accessories to provide a complete and functional system shall include:

a. Check valve

b. Door-mounted disconnect switch

c. Shutoff ball valves on inlet and outlet.

d. Pressure relief valve (set at 65psi).

e. Duplex fuel strainer on inlet.

f. Pressure and vacuum gauges on each pump, with isolation hand valve.

g. Loss of flow sensor/alarm, for activation of lag pump.

h. Containment sump with leak sensor.

i. Pump inlet/outlet manifolds, flanged type.

j. Back-pressure regulating valve (supplied loose for field installation between FOS and FOR piping) to maintain stable system pressure.

6. The control section shall provide the following functions, indications and alarms:

   a. Tank selection feature, for control of supply/return fuel from three (3) bulk storage tanks. This tank selection feature shall be expandable to a future total of six (6) tanks.

   b. Pump control switch for Manual-Off-Automatic operation.

   c. Lead pump running.

   d. Lag pump running.

   e. Power available.

   f. Loss of flow alarm.

   g. Sump leak alarm.

   h. Tank normal fuel level.

i. Tank low fuel level.

j. Tank high fuel level.

k. Tank leak alarm.

2.6 DAY TANK

B. Fire Pump Day Tank: The day tank shall be included as part of the fire pump installation.

C. Generator Day Tank: The day tank shall be included as part of the standby engine generator. Refer to electrical sections.

2.7 VENT CAP

A. The vent cap shall meet the following requirements:
   i) Vent cap shall be of the 2" size or as indicated on the Drawings.
   ii) The vent cap shall be constructed of an aluminum body and provided with a 40-mesh brass wire screen. The cap shall extend outward with drains designed to deter rainwater entry.
   iii) The vent cap must comply with NFPA – 30 requirements.
   iv) The vent cap shall be open atmospheric type

2.8 DOUBLE POPPET FOOT VALVE

A. The double poppet foot valve shall meet the following requirements:
   i) The double poppet foot valve shall be of the 2" size or as indicated on the Drawings.
   ii) The double poppet foot valve shall be constructed of an bronze body, provided with two (2) flat brass poppets with lapped-in seats, and provided with a 20-mesh monel or stainless steel wire screen. The Double Poppet Foot Valve shall provide double protection against the loss of pump prime.

2.9 MOTORIZED FUEL VALVE

A. The Motorized Fuel Valve shall meet the following requirements:
   i) The motorized fuel valve shall be of the 3" size or as indicated on the Drawings.
   ii) The motorized fuel valve shall be of aluminum construction, watertight type valve body. The motorized actuator shall be a two position, normally closed, slow motion (14 second), electric actuator; the ball and stem shall be of Type 316 stainless steel; and the seats and seals of TFE.
   iii) Motorized fuel valves shall be rated to 125 psi.

2.10 HAND FUEL PUMP

A. The Hand Fuel Pump shall meet the following requirements:
   i) The hand fuel pump shall be of the 2" size or as indicated on the Drawings.
   ii) The hand fuel pump shall be of aluminum body, cast iron rotor, built-in check valve and strainer, and lockable.

iii) The hand fuel pump shall be UL listed.
iv) The hand fuel pump shall provide 10 gallons of flow per 100 revolutions.

2.11 BACKPRESSURE REGULATING VALVE

A. The Backpressure Regulating Valve shall meet the following requirements:
   i) The backpressure regulating valve shall be of the 2” size or as indicated on the Drawings.
   ii) The backpressure regulating valve shall be constructed of an iron body globe valve, provided with pressure regulating trim. The backpressure regulating valve shall provide protection against excessive pressure in the fuel piping (set at 50 psi).

2.12 BALL VALVE

A. The ball valve shall meet the following requirements:
   i) The ball valve shall be of the 2” size or as indicated on the Drawings.
   ii) The ball valve shall be manually actuated, bronze, resilient seated, full port, threaded two-piece bolted body type valves. The body and cap shall be of bronze, ASTM 62; the ball and stem shall be of Type 316 stainless steel; and the seats and seals of TFE. The valve handles shall be lockable. Provide a stainless steel lock with each valve. The valves shall have full floating ball and shall be non-lubricated. Valve seats shall be easily accessible and replaceable.
   iii) Ball valves shall be rated to 125 psi.

2.13 FUEL-OIL LEAK DETECTION SYSTEM FOR INDOOR SPACES

A. Furnish a complete leak early-detection and location system consisting of a microprocessor based monitoring unit, sensor cables, system layout map and auxiliary equipment required to provide continuous monitoring of the sensing string(s) for leaks (growing and multiple), shorts and breaks. If any of these conditions should occur at any point along the cable, an alarm shall sound, type of condition and location shall be clearly identified. Systems that lose accuracy or alarm due to build-up of dust, dirt or other dry contaminants shall not be acceptable.
B. The system shall monitor for leaks around indoor day tanks, fuel transfer pumps, and generator sets.
C. Manufacturer: The system shall be the PAL-AT Leak Detection and Location System manufactured by PermAlert, Niles, Illinois, (847)-966-2190. The manufacturer shall have at least ten years’ experience in supplying leak detection systems.
D. Approvals: The system shall be UL Listed (USA and Canada), CE certified.
E. Performance:
   1. The Leak Detection System shall locate the point of origin of the first liquid leak or fault within 0.6% of the sensor string length, or 6 feet, whichever is greater. The system shall identify the type of alarm leak/break/short as well as the location. The system shall be able to monitor (detect and locate) with up to 100' of cable wetted without significant inaccuracy in location.
   2. Sensing String Length: The system shall be capable of monitoring up to 3,000 feet of cable per sensor string from a single monitoring unit.
   3. The system shall be capable of monitoring (detecting and locating) for initial leaks, growing leaks and multiple leaks on the sensor cable.

4. The system shall be capable of identifying the location of breaks and shorts on the cable. When either of these faults occurs, an alarm shall sound and a display visible on the front of the monitoring unit shall clearly indicate the type of fault.
5. The system shall be capable of detecting hydrocarbon only.
6. The system shall provide Modbus TCP and Modbus RTU output and dry contact relays for remote indication of an alarm condition.
7. The system shall record significant events in nonvolatile memory. A minimum of 900 events shall be stored. When the memory becomes full, the recorded events shall be deleted from memory on a FIFO basis. Each recorded event shall include the time and date that the event occurred. Archives shall be retrievable through the communication ports.
8. The system shall continuously provide positive indication that it is monitoring the sensing string and the status of the sensing string. The system clock shall provide the time and date on the LCD of the monitoring panel. The system clock shall be programmable by the user. A time and date indication shall be included for all events recorded in memory.
9. The monitoring unit shall be microprocessor based and capable of monitoring up to 3,000 feet of sensing string per cable.
10. The monitoring unit shall indicate when fuel/oil contacts the sensor cable by sounding an alarm, actuating output relays, and displaying a message that states a leak has been detected and shows the location of that leak on the sensing string.
11. The monitoring unit shall be enclosed in a Type 12 (IP52) enclosure.
12. The sensor cables shall be suitable for use with the monitoring unit. The sensor cables shall be of coaxial construction consisting of an insulated copper center conductor, a suitable spacer material, and an insulated outer braid with a protective overbraid.
13. Cable on flat surfaces shall have hold down clips every 8 feet and cable identification tags every 50 feet.
14. Cable shall be designed to detect hydrocarbons only and have a center core that allows hydrocarbon penetration.

F. Installation

1. The system shall be installed per the manufacturer's recommended installation procedures. All local, state and federal codes and requirements shall be followed. The system shall be installed by properly trained personnel.
2. A location map shall be provided with the system by the installing contractor; indicating the "As Installed" system configuration and sensing string layout. Footage along the cable shall be provided as references to locate leaks.

G. Field Test of System

1. Tests shall be performed to demonstrate the ability of the system to detect and locate breaks, and shorts on the sensor string. The cable shall be shorted with the alarm and location verified.
2. The contractor will provide manufacturer's technical assistance for contractor, training, installation inspection, start up and owner operating and maintenance training. Contractor is to follow the manufacturer’s instructions for installation.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all items in strict accordance with the manufacturers written installation instructions.

B. Marker tape should be installed above fuel oil supply, return and vent pipes. Locate tape 6" below finished grade.

C. Suction Line and Return Line: Shall be installed on site by the contractor.

D. Complete all work listed in the manufacturer's checklist and obtain a certificate of use in accordance with Code.

3.2 GENERAL

A. Installation: The design drawings are generally diagrammatic. Every bend, off-set, elbow or other fitting which is required, may not be shown for the piping installation. Careful coordination of the work is necessary to avoid conflicts.

B. Piping: Run all piping parallel or perpendicular to building lines unless otherwise indicated.

C. Dielectric Connections: Provide dielectric unions between dissimilar metals and at connections to the tank and all equipment. Do not use steel and copper piping in the same system without isolation.

D. Pipe reductions on horizontal piping shall be made with eccentric reducers. Top of piping shall be flat for venting. The bottom of vent and return lines shall be flat for drainage.

E. Prohibited Fittings: Screwed bushings are prohibited, except where available space prevents use of reducing couplings.

3.3 FUEL OIL PIPING

A. General: Above-grade fuel oil piping shall be rigidly supported at all locations. Care shall be taken in installing piping where damage could occur due to normal maintenance of the area in and around the fuel oil system.

B. Equipment Connection: Flexible fuel oil supply and return piping connections at the standby engine generator shall be provided by the generator manufacturer.

C. Containment Pipe: Join piping in accordance with manufacturers recommendations.

3.4 UNDERGROUND FUEL OIL STORAGE TANK

A. Installation: Install the underground tank in strict compliance with the manufacturer's recommendations. Provide ballast and backfill, of composition (pea gravel or crushed gravel) and compaction as required by the manufacturer.

B. Fuel Monitoring System: Install the fuel monitoring system in strict compliance with the manufacturer's recommendations. Install the drywells, dry sumps, modifications to insert the interstitial probes, etc. as necessary to provide the manufacturer's recommended sensing location and installation.

3.5 UNDERGROUND PIPING

A. Installation: Minimum cover for exterior underground piping is thirty- six inches unless otherwise indicated. Install piping as recommended by the manufacturer.

B. Identification Tape: Place color coded 6 inch wide 0.004 inch thickness polyethylene printed plastic identification tape directly above all underground piping systems approximately 12 inch below finished grade. Tapes shall be continuously printed with "CAUTION" in large bold letters. Printed second line with type of service below (i.e., fuel oil supply).

3.6 CONTAINMENT PIPE MONITORING WELL

A. The bottom of the containment pipe shall slope down toward the monitoring well. If slope cannot be maintained, more than one monitoring well shall be provided.

3.7 TESTS

A. Piping: Piping shall be disconnected from tank and equipment prior to testing. Piping shall be tested at 5 psig air pressure for a period of four hours.

B. Fuel Tank Monitoring System: Provide a factory personnel from the manufacturer to perform test, check and start-up. Perform a 2-hour instructional seminar for the Owner's representatives on the use of the fuel monitoring system.

C. Tank Warranty: Provide manufacturer’s standard 1-year warranty against defects in workmanship and manufacture, and also provide a 30-year warranty for the tank, as provided by the Steel Tank Institute.

3.8 ADDITIONAL REQUIREMENTS

A. Inventory Control and Tank Leak Detection System with Remote Electronic Panel:

1. Install in accordance with manufacturers written installation instructions.
2. Locate remote panel as indicated on drawings.
3. Provide 115 V power supply to console from adjacent 115 V source provided by Division 26. Coordinate electrical service and control monitoring interface with electrical and controls sub-contractors.
4. Provide necessary conduit and accessories for low voltage connection to probes. See Division 26 for material specification.

B. Liquid Level Indicator:

1. Install in location as indicated on drawings.
2. Transmission tubing shall be installed in 3/4" conduit with sweep ells or long radius bends.

C. Vent Cap: Install as indicated on drawings.

D. Fill or Sounding Line Cap:

1. Set cap in concrete slab, as detailed on drawings. Slab shall be crowned to assure water will run away from the cap.
2. Label cap for proper usage, i.e., "Sounding Line", "Fill Cap".

E. Fuel Oil Pump:

1. Install pump with containment sump.

F. Manhole and Cover: Install as indicated on drawings.

G. Fuel Filter: Install as indicated on drawings.

H. Dual or Single Slip Tank Fittings: Install as indicated on drawings.
I. Overflow Prevention Valve: Install in accordance with manufacturer's written instructions.

J.

END OF SECTION 23 11 13

SECTION 23 21 13 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Chilled-water piping.
2. Condenser-water piping.
3. Makeup-water piping.
4. Condensate-drain piping.
5. Blowdown-drain piping.
6. Air-vent piping.
7. Safety-valve-inlet and -outlet piping

B. Related Sections include the following:

1. Division 1 Section 01 35 46: “Indoor Air quality Management”
2. Division 1 Section 01 74 23: “Final Cleaning”
3. Division 1 Section 01 81 13.14: “Sustainable Design Requirements - LEED V4 BD+C.
4. Division 23 Section "Hydronic Pumps" for pumps, motors, and accessories for hydronic piping.
5. Division 23 Section “HVAC Piping Insulation”.
6. Division 23 Sections “General Duty Valves For HVAC Piping”.
7. Division 23 Section “HVAC Water treatment”.
8. Division 23 Section “Vibration Controls for HVAC Piping and Equipment”.

C. Abbreviations

1. PTFE: Polytetrafluoroethylene.
2. DWV: Drain-Waste-Vent piping system.
3. RTRP: Reinforced Thermosetting Resin Pipe
4. RTRF: Reinforced Thermosetting Resin Fitting

1.3 SUBMITTALS

A. Action Submittals

1. Product Data: Submit manufacturer's standard technical product data indicating conformance to the stipulated reference specifications, construction materials, dimensions, construction details, and test and operating pressures. Submit manufacturer's product data on the following:
   a. Pipe materials.
   b. Unions and flanges, including gaskets, nuts, and bolts.
   c. Welding fittings.
   d. Sleeves and packings.
   e. Plastic pipe and fittings with solvent cement.
   f. RTRP and RTRF with adhesive.
   g. Pressure-seal fittings.
   h. Air control devices.
   i. Chemical treatment.
   j. Grooved-joint couplings and fittings

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 "Sustainable Design Requirements – LEED V4 BD+C".
1. Product Data: Documentation for Leadership Extraction Practices in the following:
   a. Leadership Extraction Practices for Recycled Content
2. Product Data: Documentation for Low Emitting Materials
   a. Low Emitting Materials for Paints and Coatings
   b. Low Emitting Materials for Adhesives and Sealants
3. Product Certificates: Provide the following:
   a. Environmental Product Declarations (EPD's)
   b. Corporate Sustainability Reporting (CSR's)
   c. Health Product Declarations (HPD's)

C. Delegated-Design Submittal:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
2. Locations of pipe anchors and alignment guides and expansion joints and loops.
3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

D. Shop Drawings: Provide piping layout drawings, drawn to a scale of not less than 1/4 inch to 1 ft. showing the proposed layout of piping system including valves, fittings, equipment, pumps, hangers, grading, high points, low points, drain points, guides, anchors, ball joints, and expansion devices. Piping below 3 inches show single line, all 3 inches and above show double line. Coordination Drawings: Show double line at 3/8 inch to 1 ft. Calculations required for stressed piping at anchors. Provide shop drawings for the following locations:

1. Refrigeration rooms.
2. Cooling towers.
3. Air handling equipment rooms.
4. Pipe shafts.
5. Cooling coils.
6. Refrigeration machines
7. All floor plans and roof plans.

E. Schedules:

1. Submit schedule of pipe type and rating for each system.

F. Informational Submittals
1. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved. Submit shop drawings for piping systems drawn at a minimum scale of ¼ inch per foot to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:
   a. Architectural and structural backgrounds with room names and numbers, including but not limited to plans, sections, suspended ceiling components, elevations, details and structural members.
   b. Fabrication and erection dimensions.
   c. Arrangements and sectional views.
   d. Details, including complete information for making connections to equipment.
   e. Descriptive names of equipment.
   f. Modifications and options to standard equipment required by Contract Documents.
   g. Suspended ceiling components.
   h. Other building services.
   i. Structural members.
2. Qualification Data: For Installer.
3. Welding certificates.
4. Field quality-control reports.
5. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

G. General: Provide shop drawing and manufacturer's data sheet for the following items:

1. Manufacturers Literature:

a. Complete design and construction data for dielectric unions and flanges.
b. Complete design and construction data for grooved mechanical fittings and couplings for steel piping systems.
c. Complete design and construction data for grooved mechanical fittings and couplings for copper piping systems.
d. Manufacturer's data on piping and fittings used, with an indication of each specific application

2. Performance Data: Submit a copy of the Welding Procedure Specification with the Procedure Qualification Record and certificates of the welders and welding operators required by Section IX of the ASME Boiler and Pressure Vessel Code.

3. Installation Data:

a. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for steel pipe.
b. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for copper pipe.
c. UL approval number, installation materials, and procedures for pipe penetrations of fire-rated walls and floor.

1.4 QUALITY ASSURANCE

A. Codes and Standards: Provide piping conforming to the requirements of the following:

1. American Society of Mechanical Engineers (ASME):

a. B16.1: Cast iron pipe flanges and flanged fittings Class 25, 125, 250, and 800.
b. B16.4: Cast iron threaded fittings Classes 125 and 250.
c. B16.3: Malleable iron threaded fittings.
d. B16.5: Pipe flanges and flanged fittings.
e. B16.9: Factory-made wrought steel buttwelding fittings.
f. B16.1: Forged steel fittings, socket-welding and threaded.
g. B16.18: Cast copper alloy solder joint pressure fittings.
h. B16.22: Wrought copper and copper alloy solder joint pressure fittings.
i. B16.39: Malleable iron threaded pipe unions Classes 150, 250, and 300.
j. B31: Code for pressure piping.
k. B31.1: Power piping.

2. Installation of piping shall conform to the requirements of ASME B31.1 “Power Piping.”
3. American Society for Testing and Materials (ASTM):

a. A 53: Standard specification for pipe, steel, black and hot-dipped, zinc-coated welded seamless.
b. A 106: Standard specification for seamless carbon steel pipe for high-temperature service.
c. A 126: Standard specification for gray iron castings for flanges, and pipe fittings.
d. A 193/A 193M: Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service.
e. A 194/A 194M: Standard specification for carbon and alloy steel nuts for bolts for high-pressure and high-temperature service.
f. A 216/A 216M: Standard specification for steel castings, carbon, suitable for fusion welding for high-temperature service.
g. A 276: Standard specification for stainless and heat-resisting steel bars and shapes.
h. A 307: Standard specification for carbon steel bolts and studs, 60,000 psi tensile strength.
i. B 88: Standard specification for seamless copper water tube.

B. Codes and Standards: Provide hydronic specialties conforming to the requirements of the following:

1. Published specifications' standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section.
2. Comply with all applicable national, state, and local codes and refer to Section "General Provisions" for mechanical for additional Reference Standards.
3. In addition, comply with all standards or associations as specified herein including, but not limited to, the following, as applicable:

a. American Society for Mechanical Engineers (ASME).
b. American Society for Testing and Materials (ASTM).
c. American National Standards Institute (ANSI).

C. Installer Qualifications:

1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

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

E. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

F. To assure uniformity and compatibility of piping components in grooved piping systems, all grooved products utilized shall be supplied by the same manufacturer. Grooving tools shall be designed, manufactured and supplied by the same manufacturer as the grooved components

1. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability

2. Grooved steel pipe (in applicable sizes to the tools current capability) shall be produced using the Victaulic RG5200i fully automated grooving tool that provides groove traceability documents, corresponding identification marks on the pipe, and confirmation that all critical dimensions fall into the required tolerance range as listed by the tool manufacturer

3. Inspection Requirement for Grooved Piping Systems:

a. A manufacturer's factory trained representative (a direct employee of the manufacturer) shall periodically visit the job site and review the installation for best practices. This shall be at the expense of the installing contractor. The installing Contractor shall correct any identified deficiencies

b. Product that has been examined and has not met the visual inspection criteria for proper installation must be corrected and re-examined by Inspection Services prior to the completion of the project. Any product that has not been corrected or was not examined will not be considered as part of the successful completion of Inspection Services. Any products that require a torque per written manufacturer's installation instructions shall be verified as torqued with a properly-certified torque wrench

c. At the completion of system inspection, a report shall be provided to the project team and a limited-term installation warranty may be provided to the Owner covering inspected joints.

1.5 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the applicable standards and codes listed in paragraph entitled "Code Compliance" in Section 23 00 10.

B. Quality and Weight: The quality and weight of materials shall comply with requirements and specifications of the appropriate standards of the American Society of Testing and Materials, American National Standards Institute, American Society of Mechanical Engineers, and the American Welding Society.

C. Piping System: All pressurized piping systems shall conform to ASME B31.9, Code for Pressure Piping, Building Services Piping.

D. Welder Certification: Welders shall be tested and certified within the last 2 years by the National Certified Pipe Welding Bureau or recognized testing agency acceptable to the Designer. Competent certified welders shall perform all welding operations. Each welder shall possess a stamp to identify his work and shall stamp each weld. A copy of the certification shall be available at the jobsite for each welder.

E. Welding Installation: Welding shall be in accordance with the welding procedures and requirements set forth in "Welding of Pipe Joints" of the "Code for Pressure Piping" in the American Welding Society Welding handbook. Pipe welding shall comply with the provisions of the latest revision of the applicable code, whether ASME Boiler and Pressure Vessel Code, ANSI Code for Pressure Piping, or state or local requirements as may supersede these codes.

F. Brazing: Brazing of copper tubing shall be in accordance with the standards of the American Welding Society, the Copper Development Association Copper Tube Handbook instructions on brazing, and ASME Boiler code Section IX.

G. Soldering: Soldering of copper tubing shall be done in accordance with the Copper Development Association, Copper Tube Handbook instructions on Joining and Forming Copper Tube, Soldered Joints.

H. Grooving: Pipe grooving shall be in accordance with manufacturer’s most current written operating instructions and shall include direct manufacturer field training

PART 2 - PRODUCTS

2.1 PRODUCT, GENERAL

A. Recycled Content of Steel Products: Post-consumer recycled content plus one-half of pre-consumer recycled content not less than 25%.

B. Recycled Content of Copper Products: Post-consumer recycled content plus on-half of pre-consumer recycled content not less than 25%.

C. Refer to Section 01 81 13.14 “Sustainable Design Requrements – LEED v4 BD+C” for additional information and requirements for recycled content. Provide material cost data specific to this material.

D. Environmental Product Disclosure: Provide an Environmental Product Declarations (EPD) that conforms with one of the followings:
   1. Product specific declarations in accordance to ISO 1404
   2. Environmental Product Declarations conforming to ISO 14025, 14040, 14044 and EN 15804 or ISO 21930.
   3. Industry Wide Product Specific Type III EPD Third Party Certification.

2.2 PERFORMANCE REQUIREMENTS

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

   1. Chilled-Water Piping: 150 psig at 200 deg F.
   2. Condenser-Water Piping: 150 psig at 150 deg F
   3. Makeup-Water Piping: 80 psig at 150 deg F.
   4. Condensate-Drain Piping: 150 deg F
   5. Blowdown-Drain Piping: 200 deg F
   6. Air-Vent Piping: 200 deg F.
   7. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.3 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type K.

B. DWV Copper Tubing: ASTM B 306, Type DWV.

C. Grooved, Mechanical-Joint, Wrought-Copper Fittings: ASME B16.22.

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

      a. Victaulic Company.
      b. Owner approved Substitution.

   2. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.

3. Grooved-End-Tube Couplings: Rigid pattern unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves, prelubricated EPDM gasket rated for minimum 250 deg F (121 deg C) for use with housing, and steel bolts and nuts. Housing shall be cast with offsetting, angle-pattern bolt pads with keys matching pipe and fitting grooves to provide system rigidity upon visual metal-to-metal pad contact without a torque requirement

D. Copper or Bronze Pressure-Seal Fittings:

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

   a. Viega, LLC
   b. Owner approved Substitution.

2. Housing: Copper.
3. O-Rings and Pipe Stops: EPDM.
4. Tools: Manufacturer's special tools.
5. Minimum 200-psig working-pressure rating at 250 deg F.

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

2.4 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; electric resistance welded (ERW) and seamless (S), Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

H. Grooved Mechanical-Joint Fittings and Couplings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Victaulic Company.
    b. Owner approved Substitution.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron;; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or ASTM A234, Grade WPB steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

3. Couplings: Ductile- -iron housing and EPDM gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

    a. Rigid Type: Housings 12” and smaller shall be cast with offsetting, angle-pattern bolt pads to provide system rigidity and support and hanging in accordance with ASME B31.1 and B31.9 upon visual metal-to-metal pad contact without a torque requirement.
        1) 2” through 12”: Installation-Ready, for direct installation with-out field disassembly, with grade EHP gasket rated to +250 deg F / 120 deg C. Victaulic Style 107N.
        2) 14” and larger: AGS Style W07 with wide-width groove and lead-in chamfer.

    b. Flexible Type: Use in locations where thermal stress relief are required such as expansion loops or piping offsets. In lieu of each flexible connector at major equipment, three (3) flexible couplings may be used for vibration attenuation and shall be placed in close proximity to the vibrating source.
        1) 2” through 8”: Installation-Ready, for direct installation without field disassembly, with grade EHP gasket rated to +250 deg F / 120 deg C. Victaulic Style 177N.
        2) 10” and 12”: Standard rigid coupling with Grade “E” EPDM gasket rated to +230F. Victaulic Style 77.
        3) 14” and larger: AGS Style W177 with wide-width groove and lead-in chamfer.

4. Factory-Assembled Pump Drops;

a. Factory assembled grooved end drop for pipe sizes 3” through 12”. Orange enamel coated assembly, consisting of a Class 150 flange for pump connection, required elbow and reducers, valves, specialties, and pipe spool with thermometer and pressure ports. (Butterfly valves used in assemblies shall have a pressure responsive seat and stem offset from the disc centerline to provide complete 360-degree circumferential seating. Assembly is installation-ready, with flexible couplings to accommodate vibration attenuation and stress relief. Assembly rated for working pressure to 300-psig.

1). Grooved end vibration pump discharge drop with tri-service valve assembly consisting of a spring-actuated check [Venturi-Check] valve and butterfly valve. Victaulic Series 380 or Owner approved Substitution

2). Grooved end vibration pump suction drop consisting of a suction diffuser with stainless steel basket and diffuser and Class 150 flange for pump connection, and butterfly valve. Victaulic Series 381 or Owner approved Substitution

3). Grooved end vibration pump suction drop consisting of a 90-degree base elbow, Wye pattern strainer with stainless steel perforated metal basket, and butterfly valve. Victaulic Series 382 or Owner approved Substitution.

5. Factory-Fabricated Header:

a. Factory-fabricated grooved end header [manifold] all-in-one assembly for fluid distribution. Header shall consist of an ASTM A53, Grade B, standard weight pipe spool with required outlet connections. Grooved ends roll grooved to Victaulic [OGS] [AGS] dimensions, with enamel coating or galvanized to project requirements. Victaulic or Owner approved Substitute

I. Steel Pressure-Seal Fittings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Viega LLC.
   b. Owner Approved substitution.

2. Housing: Steel.
3. O-Rings and Pipe Stop: EPDM.
4. Tools: Manufacturer's special tool.
5. Minimum 300-psig working-pressure rating at 230 deg F.

2.5 Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.6 PLASTIC PIPE AND FITTINGS

A. CPVC Plastic Pipe: ASTM F 441/F 441M, with wall thickness as indicated in "Piping Applications" Article.

1. CPVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe.

B. PVC Plastic Pipe: ASTM D 1785, with wall thickness as indicated in "Piping Applications" Article.

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

2.7 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

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

D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

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

G. Solvent Cements for Joining Plastic Piping:

1. CPVC Piping: ASTM F 493.

    a. CPVC solvent cement shall have a VOC content of 490 g/L or less.
    b. Adhesive primer shall have a VOC content of 550 g/L or less.
    c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method v1.1 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

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

    a. PVC solvent cement shall have a VOC content of 510 g/L or less.
    b. Adhesive primer shall have a VOC content of 550 g/L or less.
    c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

H. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.8 TRANSITION FITTINGS

A. Plastic-to-Metal Transition Fittings:

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

    a. Charlotte Pipe and Foundry Company.
    b. IPEX USA LLC.
    c. KBI (King Bros. Industries).
    d. Viega LLC.

2. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.

B. Plastic-to-Metal Transition Unions:

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

    a. Charlotte Pipe and Foundry Company.
    b. IPEX USA LLC.
    c. KBI (King Bros. Industries).
    d. NIBCO INC.

2. Brass or copper end, solvent-cement-joint end of material and wall thickness to match plastic pipe material, rubber gasket, and threaded union.

2.9 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Capitol Manufacturing Company.
   b. Central Plastics Company.
   c. Hart Industries International, Inc.
   d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
   e. Zurn Industries, LLC.

2. Description:

   a. Standard: ASSE 1079.
   b. Pressure Rating: 125 psig minimum at 180 deg F.
   c. End Connections: Viega Pro-Press or Owner approved substitution.

C. Dielectric Flanges:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Capitol Manufacturing Company.
   b. Central Plastics Company.
   c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
   d. Zurn Industries, LLC.

2. Description:

   a. Standard: ASSE 1079.
   b. Factory-fabricated, bolted, companion-flange assembly.
   c. Pressure Rating: 125 psig minimum at 180 deg F.
   d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

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

   a. Advance Products & Systems, Inc.
   b. Calpico, Inc.
   c. Central Plastics Company.
   d. Pipeline Seal and Insulator, Inc.

2. Description:

   a. Nonconducting materials for field assembly of companion flanges.
   b. Pressure Rating: 150 psig.
   c. Gasket: Neoprene or phenolic.
   d. Bolt Sleeves: Phenolic or polyethylene.
   e. Washers: Phenolic with steel backing washers.

E. Dielectric Nipples:

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

   a. Elster Perfection Corporation.
   b. Grinnell Mechanical Products.
   c. Matco - Norca.
   d. Precision Plumbing Products, Inc.
   e. Victaulic Company.

2. Description:

   a. Standard: IAPMO PS 66.
   b. Electroplated steel nipple, complying with ASTM F 1545 or unlined copper-silicone body.
   c. Pressure Rating: 300 psig at 225 deg F.
   d. End Connections: Male threaded or grooved.
   e. Lining: Inert and noncorrosive, propylene.

2.10 MECHANICAL SLEEVE SEALS

A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

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

   a. Advance Products & Systems, Inc.

b. Calpico, Inc.
c. Metraflex Co.
d. Pipeline Seal and Insulator, Inc.

2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
3. Pressure Plates: Carbon steel. Include two for each sealing element.
4. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.11 SLEEVES

A. Galvanized-Steel Sheet: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

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

C. Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

D. Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.

1. Under deck Clamp: Clamping ring with set screws.

E. Molded PVC: Permanent, with nailing flange for attaching to wooden forms.

F. PVC Pipe: ASTM D 1785, Schedule 40.

G. Molded PE: Reusable, PE, tapered-cup shaped and smooth-outer surface with nailing flange for attaching to wooden forms.

2.12 ESCUTCHEONS

A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.

B. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

C. One-Piece, Cast-Brass Type: With set screw.

1. Finish: Polished chrome-plated.

D. Split-Casting, Cast-Brass Type: With concealed hinge and set screw.

1. Finish: Polished chrome-plated.

E. One-Piece, Stamped-Steel Type: With set screw and chrome-plated finish.

F. Split-Plate, Stamped-Steel Type: With concealed hinge, set screw, and chrome-plated finish.

G. One-Piece, Floor-Plate Type: Cast-iron floor plate.

H. Split-Casting, Floor-Plate Type: Cast brass with concealed hinge and set screw.

2.13 BYPASS CHEMICAL FEEDER

A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Chilled-water piping, aboveground, NPS 2 and smaller, shall be the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered joints. Viega Pro-Press fittings or Owner approved substitution pressure-seal joints.

B. Chilled-water piping, aboveground, NPS 2-1/2 to 4, shall be any of the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints. Viega Pro-Press fittings or Owner approved substitution pressure-seal joints.

C. Chilled-water piping, aboveground, NPS 5 to 12, shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

D. Chilled-water piping, aboveground, NPS 14 and larger, shall be any of the following:

1. ~~Schedule 40~~Standard Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. ~~Schedule 40~~Standard Schedule steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

E. Chilled-water piping installed belowground and within slabs shall be the following:

1. Pre-insulated piping system as specified in section 23 21 13.15.

F. Condenser-water piping, aboveground, NPS 4 and smaller, shall be any of the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints. Piping shall be painted green.

G. Condenser-water piping, aboveground, NPS 6 to 12 ~~and larger~~, shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
3. Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

H. Condenser-water piping, aboveground, NPS 14 and larger, shall be any of the following:

1. Standard Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Standard Schedule steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
3. Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

~~H.~~I. Underground condenser-water piping shall be black steel with three coats of epoxy paint.

~~I.~~J. Makeup-water piping installed aboveground shall be the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints.

~~J.~~K. Condensate-Drain Piping: Type K annealed-temper copper tubing, wrought-copper Viega Pro-Press fittings, or Owner approved substitution or Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

~~K.~~L. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

~~L.~~M. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

~~M.~~N. Underground Petroleum Products Piping Additional Requirements:

1. Provide a pipe system, complete with all piping, tools, and accessories for a proper and safe installation, in accordance with the current EPA regulations, to prevent contamination of ground in the event of a rupture or leak in fluid carrier pipe.
2. Provide a 'Marker Tape', located 6" below finished grade, above all underground petroleum products piping.
3. The piping system shall be compatible with Section 23 11 13 - Fuel Storage Tank and Accessories.
4. Provide filter fabric barrier at bottom of piping excavation for containment in event of pipe leak.
5. Piping shall be in accordance with FDEP Chapter 62-761.

3.2 PIPING INSTALLATIONS

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

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

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

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

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, ball valve, and short threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage. Ball valve and threaded nipple with cap: Up to 6 inches pipe use NPS 3/4 and 8 inches and larger pipe use NPS 1-1/2.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," Section 230523.14 "Check Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

U. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

Y. Install strainers on inlet side of each control valve, pressure-reducing valve, solenoid valve, pump, and elsewhere as indicated.

Z. Install no piping in elevator machine rooms, electric rooms and closets, and telephone rooms and closets, other than the piping serving the air conditioning equipment in the respective room. Install drain pan for the length of the piping in the room.

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges.

D. Dielectric Fittings for NPS 5 and Larger: Use dielectric flange kits.

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.

B. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
~~4. Spring hangers to support vertical runs.~~
~~5.~~4. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
~~6.~~5. Supports of wire, rope, wood, chain, strap, perforated bar or any other makeshift device will not be permitted.
~~7.~~6. Minimum spacing and minimum rod diameter shall comply with latest edition of MSS SP-58.

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

1. NPS 3/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 7 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
4. NPS 1-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
5. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
6. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 1/2 inch.
7. NPS 3: Maximum span, 12 feet; minimum rod size, 1/2 inch.
8. NPS 4: Maximum span, 14 feet; minimum rod size, 5/8 inch.
9. NPS 6: Maximum span, 17 feet; minimum rod size, 3/4 inch.
10. NPS 8: Maximum span, 19 feet; minimum rod size, 3/4 inch.
11. NPS 10: Maximum span, 20 feet; minimum rod size, 7/8 inch.
12. NPS 12: Maximum span, 23 feet; minimum rod size, 7/8 inch.
13. NPS 14: Maximum span, 25 feet; minimum rod size, 1 inch.
14. NPS 16: Maximum span, 27 feet; minimum rod size, 1 inch.
15. NPS 18: Maximum span, 28 feet; minimum rod size, 1-1/4 inches.
16. NPS 20 and Larger: Maximum span, 30 feet; minimum rod size, 1-1/4 inches.

E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 6 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
4. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
5. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
6. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 1/2 inch.
7. NPS 3: Maximum span, 10 feet; minimum rod size, 1/2 inch.
8. NPS 4: Maximum span, 12 feet; minimum rod size, 1/2 inch.
9. NPS 6: Maximum span, 14 feet; minimum rod size, 5/8 inch.
10. NPS 8: Maximum span, 16 feet; minimum rod size, 3/4 inch.
11. NPS 10: Maximum span, 18 feet; minimum rod size, 3/4 inch.
12. NPS 12: Maximum span, 19 feet; minimum rod size, 3/4 inch.

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

G. Support vertical runs at roof, at each floor.

1. Base Elbow Support: Provide bearing plate on structural support, similar to F&S Manufacturing Corp. Fig. 720.
2. Provide guides at every third floor but not to exceed:

a. 25 ft. for piping to 2 inches.
b. 36 ft. for piping 2-1/2 inches to 12 inches.
c. 50 ft. for piping 14 inches and larger.

3. Top Support: Provide special hanger or saddle in horizontal connection and make provisions for expansion.
4. Intermediate Supports: Steel pipe clamp at floor. Bolt and weld to pipe with extension ends bearing on structural steel or bearing plates.
5. For multiple pipes, coordinate guides bearing plates and accessory steel.

3.5 PIPE JOINT CONSTRUCTION

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

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

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

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

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.
4. PVC Nonpressure Piping: Join according to ASTM D 2855.

I. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid or flexible, grooved-end-pipe couplings. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by the grooved coupling manufacturer. Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove. A factory-trained field representative shall provide on-site training for contractor's field personnel in the use of grooving tools, application of groove, and installation of grooved piping products. Representative shall be a direct employee of the grooved system manufacturer. A distributor representative is not qualified for this site service. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products at no additional charges.

J. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.7 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.

2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Installation: Pipe and fittings shall be installed as specified in this section unless specific installation instructions are provided in the individual sections covering the piping system. Install each run with a minimum of joints and couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated using reducing fittings. Align piping at connections within 1/16 inch misalignment tolerance.

C. Routing and Placement: Piping shall be run without traps or pockets and pitched a minimum 1 inch per 40 feet in the direction of flow, unless indicated or required to be pitched steeper. Grade piping so that air in the mains and risers will be carried up and discharged at venting points. Coordinate installation with structural features, and with other piping, equipment and the work of other trades. All piping shall be installed as close to the structure overhead as possible.

D. Prohibited Installation: Do not run piping through transformer vaults, elevator equipment rooms, other electrical or electronic equipment spaces and enclosures. Do not run piping over electrical panels. Where pipe joints or valves in water lines occur within two feet in horizontal directions from electrical panels or equipment, provide drip pans sized to afford protection. Pans shall be 20-gauge galvanized steel with edges turned up 2-1/2 inches on all sides, reinforced with galvanized steel angles or by rolling edges over 1/4-inch diameter steel wire. Provide a drain with 3/4-inch flange and pipe to nearest floor drain, and support the pan assemblies as required to prevent sagging or swaying.

E. Interior Piping: Interior piping shall be run parallel to the walls and ceilings; avoid diagonal runs. Provide a minimum 6-inch clearance between walls and horizontal piping.

F. Exterior Piping: Exterior piping (above and below grade) shall essentially be routed and located as indicated on the drawings; however, actual placement shall be verified by confirming exact location of structures and other utilities in the field and by careful layout prior to execution of the work.

G. Insulated Piping: Pipe requiring insulation shall be installed with sufficient clearances to permit proper application of insulation.

H. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's design pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

I. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 23 21 13

SECTION 23 21 13 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Glycol-water piping.
2. Chilled-water piping.
3. Condenser water piping.
4. Condensate-drain piping.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved. Submit shop drawings for piping systems drawn at a minimum scale of ¼ inch per foot to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:

1. Architectural and structural backgrounds with room names and numbers, including but not limited to plans, sections, suspended ceiling components, elevations, details and structural members.
2. Fabrication and erection dimensions.
3. Arrangements and sectional views.
4. Details, including complete information for making connections to equipment.
5. Descriptive names of equipment.
6. Modifications and options to standard equipment required by Contract Documents.

B. Qualification Data: For Installer.

C. Welding certificates.

D. Field quality-control reports.

E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

F. General: Provide shop drawing and manufacturer's data sheet for the following items:

1. Manufacturers Literature:

   a. Complete design and construction data for dielectric unions and flanges.
   b. Complete design and construction data for grooved mechanical fittings and couplings for steel piping systems.
   c. Complete design and construction data for grooved mechanical fittings and couplings for copper piping systems.
   d. Manufacturer's data on piping and fittings used, with an indication of each specific application

2. Performance Data: Submit a copy of the Welding Procedure Specification with the Procedure Qualification Record and certificates of the welders and welding operators required by Section IX of the ASME Boiler and Pressure Vessel Code.

3. Installation Data:

   a. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for steel pipe.
   b. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for copper pipe.
   c. UL approval number, installation materials, and procedures for pipe penetrations of fire-rated walls and floor.

1.4 QUALITY ASSURANCE

A. Installer Qualifications:

   1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

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

C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

   1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

1.5 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the applicable standards and codes listed in paragraph entitled "Code Compliance" in Section 23 00 10.

B. Quality and Weight: The quality and weight of materials shall comply with requirements and specifications of the appropriate standards of the American Society of Testing and Materials, American National Standards Institute, American Society of Mechanical Engineers, and the American Welding Society.

C. Piping System: All pressurized piping systems shall conform to ASME B31.9, Code for Pressure Piping, Building Services Piping. All piping systems with services exceeding 250°F. 160 psig and steam and condensate exceeding 15 psig shall meet ASME B13.9, Power Piping.

D. Welder Certification: Welders shall be tested and certified within the last 2 years by the National Certified Pipe Welding Bureau or recognized testing agency acceptable to the Designer. Competent certified welders shall perform all welding operations. Each welder shall possess a stamp to identify his work and shall stamp each weld. A copy of the certification shall be available at the jobsite for each welder.

E. Welding Installation: Welding shall be in accordance with the welding procedures and requirements set forth in "Welding of Pipe Joints" of the "Code for Pressure Piping" in the American Welding Society Welding handbook. Pipe welding shall comply with the provisions of the latest revision of the applicable code, whether ASME Boiler and Pressure Vessel Code, ANSI Code for Pressure Piping, or state or local requirements as may supersede these codes.

F. Brazing: Brazing of copper tubing shall be in accordance with the standards of the American Welding Society, the Copper Development Association Copper Tube Handbook instructions on brazing, and ASME Boiler code Section IX.

G. Soldering: Soldering of copper tubing shall be done in accordance with the Copper Development Association, Copper Tube Handbook instructions on Joining and Forming Copper Tube, Soldered Joints.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

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

1. Glycol-Water Piping: 150 psig @ 200 deg F.
2. Chilled-Water Piping: 150 psig at 200 deg F.
3. Condenser Water Piping: 150 psig at 200 deg F.

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.

B. Grooved, Mechanical-Joint, Wrought-Copper Fittings: ASME B16.22.

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

a. Anvil International, Inc.
b. Star Pipe Products.
c. Victaulic Company.

2. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.
3. Grooved-End-Tube Couplings: Rigid pattern unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves, prelubricated EPDM gasket rated for minimum 230 deg F (110 deg C) for use with housing, and steel bolts and nuts.

C. Copper or Bronze Pressure-Seal Fittings:

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

   a. Viega
   b. Owner approved Substitution

2. Housing: Copper.
3. O-Rings and Pipe Stops: EPDM.
4. Tools: Manufacturer's special tools.
5. Minimum 200-psig working-pressure rating at 250 deg F.

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

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

D. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

E. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

G. Grooved Mechanical-Joint Fittings and Couplings:

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

   a. Anvil International, Inc.
   b. Star Pipe Products.
   c. Victaulic Company.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or

ASTM A 106/A 106M, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

3. Couplings: Ductile- or malleable-iron housing and EPDM gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

2.4 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

D. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

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

2.5 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

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

a. Viega Pro-Press
b. Owner approved substitution

2. Description:

a. Standard: ASSE 1079.
b. Pressure Rating: 125 psig minimum at 180 deg F.
c. End Connections: Viega Pro-Press or Owner approved substitution.

C. Dielectric Flanges:

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

a. Viega Pro-Press
b. Owner Approved Substitution

2. Description:

a. Standard: ASSE 1079.
b. Factory-fabricated, bolted, companion-flange assembly.
c. Pressure Rating: 125 psig minimum at 180 deg F.
d. End Connections: Viega Pro-Press or Owner approved substitution.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Glycol and Chilled-water piping, aboveground, NPS 2 and smaller, shall be the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

B. Glycol and Chilled-water piping, aboveground, NPS 2-1/2 to 4 shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

C. Glycol and Chilled-water piping, aboveground, 6 and larger, shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

D. Condenser-water piping, aboveground, NPS 4 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints. Piping shall be painted green.

E. Condenser-water piping, aboveground, NPS 6 and larger, shall be the following:

1. Piping shall be Schedule 40 black steel; Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

F. Condensate-Drain Piping: Type K, annealed-temper copper tubing, wrought-copper fittings, and soldered joints and ¾" elastomeric insulation.

G. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

3.2 PIPING INSTALLATIONS

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

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

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

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

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Section 230523.01 "Valves for PCA Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.

U. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

V. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges.

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices.

B. Comply with requirements in Section 23 05 48 "Vibration Controls for HVAC" for equipment isolation.

3.5 PIPE JOINT CONSTRUCTION

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

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

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

H. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

I. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 23 05 19 "Meters and Gages for HVAC Piping."

3.7 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Installation: Pipe and fittings shall be installed as specified in this section unless specific installation instructions are provided in the individual sections covering the piping system. Install each run with a minimum of joints and couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated using reducing fittings. Align piping at connections within 1/16 inch misalignment tolerance.

C. Routing and Placement: Piping shall be run without traps or pockets and pitched a minimum 1 inch per 40 feet in the direction of flow, unless indicated or required to be pitched steeper. Grade piping so that air in the mains and risers will be carried up and discharged at venting points. Coordinate installation with structural features, and with other piping, equipment and the work of other trades. All piping shall be installed as close to the structure overhead as possible.

D. Prohibited Installation: Do not run piping through transformer vaults, elevator equipment rooms, other electrical or electronic equipment spaces and enclosures. Do not run piping over electrical panels. Where pipe joints or valves in water lines occur within two feet in horizontal directions from electrical panels or equipment, provide drip pans sized to afford protection. Pans shall be 20-gauge galvanized steel with edges turned up 2-1/2 inches on all sides, reinforced with galvanized steel angles or by rolling edges over 1/4-inch diameter steel wire. Provide a drain with

3/4-inch flange and pipe to nearest floor drain, and support the pan assemblies as required to prevent sagging or swaying.

E. Interior Piping: Interior piping shall be run parallel to the walls and ceilings; avoid diagonal runs. Provide a minimum 6 inch clearance between walls and horizontal piping.

F. Exterior Piping: Exterior piping (above and below grade) shall essentially be routed and located as indicated on the drawings; however, actual placement shall be verified by confirming exact location of structures and other utilities in the field and by careful layout prior to execution of the work.

G. Insulated Piping: Pipe requiring insulation shall be installed with sufficient clearances to permit proper application of insulation.

H. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

I. Perform the following before operating the system:

1. Open manual valves fully.
2. Set makeup pressure-reducing valves for required system pressure.
3. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type).
4. Set temperature controls so all coils are calling for full flow.

END OF SECTION 23 21 13

SECTION 23 21 13 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Glycol-water piping.
2. Chilled-water piping.
3. Condenser water piping.
4. Condensate-drain piping.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved. Submit shop drawings for piping systems drawn at a minimum scale of ¼ inch per foot to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:

1. Architectural and structural backgrounds with room names and numbers, including but not limited to plans, sections, suspended ceiling components, elevations, details and structural members.
2. Fabrication and erection dimensions.
3. Arrangements and sectional views.
4. Details, including complete information for making connections to equipment.
5. Descriptive names of equipment.
6. Modifications and options to standard equipment required by Contract Documents.

B. Qualification Data: For Installer.

C. Welding certificates.

D. Field quality-control reports.

E. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

F. General: Provide shop drawing and manufacturer's data sheet for the following items:

1. Manufacturers Literature:

   a. Complete design and construction data for dielectric unions and flanges.
   b. Complete design and construction data for grooved mechanical fittings and couplings for steel piping systems.
   c. Complete design and construction data for grooved mechanical fittings and couplings for copper piping systems.
   d. Manufacturer's data on piping and fittings used, with an indication of each specific application

2. Performance Data: Submit a copy of the Welding Procedure Specification with the Procedure Qualification Record and certificates of the welders and welding operators required by Section IX of the ASME Boiler and Pressure Vessel Code.

3. Installation Data:

   a. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for steel pipe.
   b. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for copper pipe.
   c. UL approval number, installation materials, and procedures for pipe penetrations of fire-rated walls and floor.

1.4 QUALITY ASSURANCE

A. Installer Qualifications:

   1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

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

C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

   1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

1.5 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the applicable standards and codes listed in paragraph entitled "Code Compliance" in Section 23 00 10.

B. Quality and Weight: The quality and weight of materials shall comply with requirements and specifications of the appropriate standards of the American Society of Testing and Materials, American National Standards Institute, American Society of Mechanical Engineers, and the American Welding Society.

C. Piping System: All pressurized piping systems shall conform to ASME B31.9, Code for Pressure Piping, Building Services Piping. All piping systems with services exceeding 250°F. 160 psig and steam and condensate exceeding 15 psig shall meet ASME B13.9, Power Piping.

D. Welder Certification: Welders shall be tested and certified within the last 2 years by the National Certified Pipe Welding Bureau or recognized testing agency acceptable to the Designer. Competent certified welders shall perform all welding operations. Each welder shall possess a stamp to identify his work and shall stamp each weld. A copy of the certification shall be available at the jobsite for each welder.

E. Welding Installation: Welding shall be in accordance with the welding procedures and requirements set forth in "Welding of Pipe Joints" of the "Code for Pressure Piping" in the American Welding Society Welding handbook. Pipe welding shall comply with the provisions of the latest revision of the applicable code, whether ASME Boiler and Pressure Vessel Code, ANSI Code for Pressure Piping, or state or local requirements as may supersede these codes.

F. Brazing: Brazing of copper tubing shall be in accordance with the standards of the American Welding Society, the Copper Development Association Copper Tube Handbook instructions on brazing, and ASME Boiler code Section IX.

G. Soldering: Soldering of copper tubing shall be done in accordance with the Copper Development Association, Copper Tube Handbook instructions on Joining and Forming Copper Tube, Soldered Joints.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

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

1. Glycol-Water Piping: 150 psig @ 200 deg F.
2. Chilled-Water Piping: 150 psig at 200 deg F.
3. Condenser Water Piping: 150 psig at 200 deg F.

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.

B. Grooved, Mechanical-Joint, Wrought-Copper Fittings: ASME B16.22.

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

a. Anvil International, Inc.
b. Star Pipe Products.
c. Victaulic Company.

2. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.
3. Grooved-End-Tube Couplings: Rigid pattern unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves, prelubricated EPDM gasket rated for minimum 230 deg F (110 deg C) for use with housing, and steel bolts and nuts.

C. Copper or Bronze Pressure-Seal Fittings:

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

    a. Viega
    b. Owner approved Substitution

2. Housing: Copper.
3. O-Rings and Pipe Stops: EPDM.
4. Tools: Manufacturer's special tools.
5. Minimum 200-psig working-pressure rating at 250 deg F.

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

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

D. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

E. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

G. Grooved Mechanical-Joint Fittings and Couplings:

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

    a. Anvil International, Inc.
    b. Star Pipe Products.
    c. Victaulic Company.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or

ASTM A 106/A 106M, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

3. Couplings: Ductile- or malleable-iron housing and EPDM gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

2.4 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

D. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

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

2.5 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

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

a. Viega Pro-Press
b. Owner approved substitution

2. Description:

a. Standard: ASSE 1079.
b. Pressure Rating: 125 psig minimum at 180 deg F.
c. End Connections: Viega Pro-Press or Owner approved substitution.

C. Dielectric Flanges:

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

a. Viega Pro-Press
b. Owner Approved Substitution

2. Description:

a. Standard: ASSE 1079.
b. Factory-fabricated, bolted, companion-flange assembly.
c. Pressure Rating: 125 psig minimum at 180 deg F.
d. End Connections: Viega Pro-Press or Owner approved substitution.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Glycol and Chilled-water piping, aboveground, NPS 2 and smaller, shall be the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

B. Glycol and Chilled-water piping, aboveground, NPS 2-1/2 to 4 shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

C. Glycol and Chilled-water piping, aboveground, 6 and larger, shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

D. Condenser-water piping, aboveground, NPS 4 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints. Piping shall be painted green.

E. Condenser-water piping, aboveground, NPS 6 and larger, shall be the following:

1. Piping shall be Schedule 40 black steel; Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

F. Condensate-Drain Piping: Type K, annealed-temper copper tubing, wrought-copper fittings, and soldered joints and ¾” elastomeric insulation.

G. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

3.2 PIPING INSTALLATIONS

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

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

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

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

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Section 230523.01 "Valves for PCA Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.

U. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

V. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges.

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices.

B. Comply with requirements in Section 23 05 48 "Vibration Controls for HVAC" for equipment isolation.

3.5 PIPE JOINT CONSTRUCTION

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

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

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

H. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

I. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 23 05 19 "Meters and Gages for HVAC Piping."

3.7 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Installation: Pipe and fittings shall be installed as specified in this section unless specific installation instructions are provided in the individual sections covering the piping system. Install each run with a minimum of joints and couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated using reducing fittings. Align piping at connections within 1/16 inch misalignment tolerance.

C. Routing and Placement: Piping shall be run without traps or pockets and pitched a minimum 1 inch per 40 feet in the direction of flow, unless indicated or required to be pitched steeper. Grade piping so that air in the mains and risers will be carried up and discharged at venting points. Coordinate installation with structural features, and with other piping, equipment and the work of other trades. All piping shall be installed as close to the structure overhead as possible.

D. Prohibited Installation: Do not run piping through transformer vaults, elevator equipment rooms, other electrical or electronic equipment spaces and enclosures. Do not run piping over electrical panels. Where pipe joints or valves in water lines occur within two feet in horizontal directions from electrical panels or equipment, provide drip pans sized to afford protection. Pans shall be 20-gauge galvanized steel with edges turned up 2-1/2 inches on all sides, reinforced with galvanized steel angles or by rolling edges over 1/4-inch diameter steel wire. Provide a drain with

3/4-inch flange and pipe to nearest floor drain, and support the pan assemblies as required to prevent sagging or swaying.

E. Interior Piping: Interior piping shall be run parallel to the walls and ceilings; avoid diagonal runs. Provide a minimum 6 inch clearance between walls and horizontal piping.

F. Exterior Piping: Exterior piping (above and below grade) shall essentially be routed and located as indicated on the drawings; however, actual placement shall be verified by confirming exact location of structures and other utilities in the field and by careful layout prior to execution of the work.

G. Insulated Piping: Pipe requiring insulation shall be installed with sufficient clearances to permit proper application of insulation.

H. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

I. Perform the following before operating the system:

1. Open manual valves fully.
2. Set makeup pressure-reducing valves for required system pressure.
3. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type).
4. Set temperature controls so all coils are calling for full flow.

END OF SECTION 23 21 13

SECTION 23 21 16 - HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 230010, BASIC MECHANICAL REQUIREMENTS are a part of this Section.

1.2 SUMMARY

A. Section includes special-duty valves and specialties for the following:

1. Chilled-water piping.
2. Condenser-Water Piping
3. Air-vent piping.
4. Strainers
5. Suctions diffusers
6. Differential Pressure Controller
7. Treaded connections
8. Solder connections
9. Flanged connections
10. Grooved connections
11. Flexible connections
~~11.~~12. Ball joints

~~12.~~

1.3 ACTION SUBMITTALS

A. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
1. Product Data: Documentation for Leadership Extraction Practices in the following:
   a. Leadership Extraction Practices for Recycled Content
2. Product Data: Documentation for Low Emitting Materials
   a. Low Emitting Materials for Paints and Coatings
   b. Low Emitting Materials for Adhesives and Sealants
3. Product Certificates: Provide the following:
   a. Environmental Product Declarations (EPD’s)
   b. Corporate Sustainability Reporting (CSR’s)

B. Product Data: For each type of the following:

1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
2. Air-control devices.
3. Hydronic specialties.

~~1.3~~1.4 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the paragraph entitled "Code Compliance" in Section 230010.

~~1.4~~1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

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

1. Chilled & Condenser-Water Piping: 150 psig at 200 deg F.
2. Makeup-Water Piping: 80 psig at 150 deg F.
3. Air-Vent Piping: 200 deg F.
4. Condensate-Drain Piping: 150 deg F.

2.2 VALVES

A. Check, Ball, and Butterfly Valves: Comply with requirements specified in Section 230523 "General-Duty Valves for HVAC Piping.

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 230900 "Instrumentation and Control for HVAC.

2.3 AIR-CONTROL DEVICES

A. Manual and Automatic Air Vents: Comply with requirements specified in Section 230580 "Air Control and Accessories".

2.4 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, ASTM A536 or ASTM A395 Wye type shall be full line size of the connecting pipe, ductile iron ASTM A-395 Class 60-40-18, cast or ductile-iron or forged steel shall be used in steel piping and all bronze in copper piping systems. Flanged wye-type shall have bolted covers in 2-1/2 through 8 inches and hinged covers in 10 inch and larger. Grooved shall have coupled or T-bolt hinged cover (dictated by size). Threaded shall have threaded gasketed caps 2 inches and smaller with NPT blowdown outlet. Provide cover and bottom drain connection. Provide blowdown valve where indicated.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged or grooved ends for NPS 2-1/2 and larger.
3. Strainer Screen: Stainless-steel, 40-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig.

B. Suction Diffusers:
1. Body: Constructed of either cast iron or ductile iron, rated for a maximum allowable working pressure of 175 psig and a maximum temperature of 250 Deg. F. Flange or groved end connections. Flanged end connections shall be designed according to ANSI Class 150 standards.
2. Straightening vanes: full length, 4 plane, removable.
3. Strainer cylinder: 304 stainless steel with 3/16” perforations.
4. Startup strainer: full length, removable with 16 mesh screen.
5. Accessories:
   a. Adjustable support foot.
   b. Pressure Temperature ports on the inlet and outlet sides of the strainer cylinder.
6. Manufacturer:
   a. Xylem Inc, Bell & Gossett
   b. Armstrong Pump
   c. Aurora
   d. Flow Solutions International (FSI)

C. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area. Free area not less than three times inlet area.
4. CWP Rating: 125 psig.

D. Differential Pressure Controller
1. Manufacturer:
   a. IMI TA, Model TA-PILOT-R

2. Material: Valve body: Ductile iron EN-GJS-400 Pilot body: AMETAL® O-rings: EDPM rubber Seat seal: EPDM/Stainless steel Plug mechanism: Stainless steel

and brass Membrane: EPDM rubber Springs: Stainless steel Screws and nuts: Stainless steel
3. Surface treatment: Pilot body: Non treated Valve body: Electrophoretic painting.
4. Flanges: According to ASME/ANSI B16.42 Class 150.
5. Temperature: Max. working temperature: - with measuring points, standard: 245F - with measuring points, double secured: 300F Min. working temperature: -4F
6. Pressure class: Class 150 Max. differential pressure (ΔpV): 115Psi
7. Leakage rate: Tight sealing

E. Bronze Body with Threaded Connections:

1. Manufacturer:

a. Mueller Steam Specialties
b. Spirax/Sarco
c. Armstrong
d. O.C. Keckley Co.
e. Metraflex Co.

F. Bronze Body with Solder Connection: Solder type wye strainers shall be class 250 SWP/400 WOG.

1. Manufacturer:

a. Mueller Steam Specialties
b. Spirax/Sarco
c. O.C. Keckley Co.

G. Cast Iron Body with Threaded Connection: Y-type strainers shall be class 250 SWP/300 WOG.

1. Manufacturer:

a. Mueller Steam Specialties
b. Spirax/Sarco
c. Armstrong Machine Co.
d. O.C. Keckley Co.

H. Cast Iron Body with Flanged Connections:

1. Manufacturer:

a. Mueller Steam Specialties
b. Spirax/Saro
c. Armstrong Machine Works
d. O.C. Keckley Co.
e. Metraflex Co.

I. Grooved Connection: Ductile iron body, minimum 300 psi working pressure for 12” and smaller and 230 psi working pressure for 14” and larger.

1. Manufacturer:

   a. Victaulic
   b. Owner-approved substitution

J. Ball Joints: Wrought steel for the ball, case and retainer designed for Class 150, weld neck connections. The ball sealing surface shall be chrome plated and coated with molybdenum disulfide, with a minimum flex angle of 15°.
   1. Manufacturer:
      a. Hyspan Barco Type N Style I weld end ball joint
      b. Owner-approved.
      ~~b.~~

2.5 FLEXIBLE CONNECTORS

A. Stainless-Steel Bellow, Flexible Connectors:

   1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
   2. End Connections: Threaded or flanged to match equipment connected.
   3. Performance: Capable of 3/4-inch misalignment.
   4. CWP Rating: 150 psig.
   5. Maximum Operating Temperature: 250 deg F.

B. On grooved installations, three flexible couplings may be used in lieu of each flexible connector for vibration attenuation at major equipment. Couplings shall be placed in close proximity to the vibrating source in accordance with published guidelines.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.

B. Install check valves at each pump discharge and elsewhere as required to control flow direction.

C. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

A. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.

B. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

C. Install piping from air separator to expansion tank with a 2 percent upward slope toward tank.

D. Install piping from to drain point with a 2 percent downward slope toward closest drain point

E. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 and larger.

F. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.

G. Install expansion tanks on the floor on 4 inch high concrete housekeeping pad. Vent and purge air from hydronic system, and ensure that tank is properly charged with air or nitrogen to suit system project requirements. Charge the diaphragm/bladder type expansion tank with air prior to filling the piping system with fluid. The tank shall be charged to a pressure as indicated in the tank schedule on design documents.

END OF SECTION 23 21 16

SECTION 23 21 23 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Close-coupled, in-line centrifugal pumps.
2. Close-coupled multi-stage in-line centrifugal pumps
3. Separately coupled, vertical, in-line centrifugal pumps.
4. Separately coupled, base-mounted, end-suction centrifugal pumps.
5. Separately coupled, base-mounted, double-suction centrifugal pumps.
6. Separately coupled, vertical-mounted, turbine centrifugal pumps.
7. Automatic condensate pump units.

1.3 ABBREVIATIONS

A. Buna-N: Nitrile rubber.

B. EPT: Ethylene propylene terpolymer.

C. HI: Hydraulic Institute.

1.4 SUBMITTALS

A. Product Data: Include certified performance curves and rated capacities, power requirement, operating characteristics, furnished specialties, final impeller dimensions, material specifications, and accessories for each type of product indicated. Indicate pump's operating point on curves, including brake horsepower, pump efficiency and NPSH indicated on curves. Where two or more pumps are operating in parallel, submit combined pump curve with all pump operating points plotted, system curve indicated and brake horsepower and pump efficiency indicated on curves.

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.

1. Wiring Diagrams: Power, signal, and control wiring.

C. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."

C. Maximum suction velocity shall be less than 10 FPS. Pump discharge velocity shall be less than to 14 FPS

D. Pump selections shall be no more than 5% less than the scheduled pump efficiency.

E. Maximum impeller diameter shall not exceed 85% of the cutwater diameter.

F. Pump motors shall be NEMA Premium™ Efficiency. Motors for pumps with variable speed drive must have Class F insulation.

G. Pumps shall be factory tested, thoroughly cleaned and painted. Discharge and suction shall be factory covered to protect the volute/impeller from dirt and damage during shipment and storage.

H. Pumps shall be constructed with materials and standards which have been tested or proven and have published test data available if requested, stating that these materials and standards have been found acceptable for use in pump manufacturing by one or more of the following:

1. American Society for Testing and Materials (ASTM)
2. International Organization for Standardization (ISO)
3. American National Standards Institute (ANSI)
4. National Electrical Manufacturers Association (NEMA)

I. Provide full two year on-site parts and labor warranty including travel time and expense. Warranty period shall begin at date of Substantial Completion.

J. Provide shaft grounding rings on all pump motors driven by a VFD. Typically to an AEGIS – SGR.

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

L. UL Compliance: Comply with UL 778 for motor-operated water pumps.

M. Pump Performance: Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25% of midpoint of published maximum efficiency curve.

N. Pump tests: Manufacturer shall test pumps in the shop prior to shipment. For identical pumps, only one pump of each specified capacity need to be tested. Tests shall be in accordance with the Hydraulic Institute Test Code.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.

B. Store pumps in dry location.

C. Retain protective covers for flanges and protective coatings during storage.

D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

E. Comply with pump manufacturer's written rigging instructions.

1.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One mechanical seal for each pump.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2.2 GENERAL

A. Factory assembled, packaged and motor.

B. Centrifugal: Single stage, or multi-stage as noted.

C. Statically and dynamically balance rotating parts.

D. Pumps to operate at 1750 rpm unless specified otherwise.

E. Pump and motor capacities:

1. Minimum as scheduled on Drawings.
2. Suitable for parallel operation.
3. Motor to operate over entire head capacity range of pump without exceeding horsepower rating.
4. Motors shall be NEMA “Premium™-Efficiency” type specified in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

F. Pump characteristics:

1. Pump curve shall rise continuously from maximum capacity to shutoff.
2. Shutoff head shall be approximately 10% greater than design head.
3. Operation shall be at or near peak efficiency.
4. Capable of operating at 25% beyond design capacity in gpm without exceeding break off point.
5. Impeller diameter: Maximum 85% of the cutwater diameter.
6. Scheduled maximum NPSH required to apply over full operating range of pump.

G. Tested and guaranteed to withstand 1 1/2 times specified working pressures.

H. Pumps to be suitable for handling fluids at scheduled temperatures.

I. Abrasive Separator: Except as noted, provide seal flush piping connections with stainless steel abrasive separator.

2.3 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
~~3.~~4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and threaded companion-flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
5. Pump Bearings: Permanently lubricated ball bearings.

D. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

E. Capacities and Characteristics: As scheduled on Drawings.

2.4 CLOSE-COUPLED MULTI-STAGE IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers
   1. Goulds

B. Description: a non-self-priming vertical multistage pump coupled to a standard motor. The liquid end, located between the upper cover and the pump casing, is held in place by tie rods. The pump casing is available with different configurations and connection types. Temperature of pumped liquid: -20.0°F to 250.0°F standard version. Direction of rotation: clockwise looking at the pump from the top down (marked with an arrow on the adapter and on the coupling).

C. Pump Construction: Cast Iron/304SS ANSI Flange with Class 125 Flange Rating. Maximum Allowable Working Pressure of 200 Psi g. Seal housing chamber designed to prevent the accumulation of air in the critical area next to the mechanical seal. Mechanical seal according to EN 12756 (ex DIN 24960) and ISO 3069.

D. Motor: Standard NEMA 182TC Frame motor premium efficient totally enclosed fan cooled. 1800 RPM nominal. 3 phase version, 4 pole: 208-230/460 V, 60Hz.

E. Capacities and Characteristics: As scheduled on Drawings.

2.5 SEPARATELY COUPLED, VERTICAL, IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
~~3.~~4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically on a cast iron support stand. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Carbon steel, uniform diameter thru water chamber with 316 stainless steel shaft sleeves or 416 stainless steel continuous construction.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and EPT bellows and gasket. Include water slinger on shaft between motor and seal.
5. Pump Bearings: Radial and thrust bearings; single row, inboard and double row outboard, regreaseable ball bearings, 100,000 hours average life. Bearings to be removable without disassembling the pump.

D. Shaft Coupling: T.B. Woods Dura-Flex® flexible shock arresting coupling and coupling guard for pumps less than 100HP and a Falk Steelflex® Grid coupling and guard for 100HP and larger.

E. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; rigidly mounted to pump casing with lifting eye and supporting lugs in motor enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Outdoor applications shall have a TEFC (Totally Enclosed Fan Cooled) motor and indoor locations shall have an open drip-proof motor; voltage and horsepower as scheduled.

F. Capacities and Characteristics: As scheduled on Drawings.

2.6 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.

2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
~~3.~~4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and flanged connections. Provide integral mount on volute to support the casing, and attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Shaft Sleeve: Renewable ceramic coated stainless steel of minimum 600 Brinell hardness.
5. Mechanical Seal: Babbit filled carbon rotating ring against a tungsten carbide stationary seat held by a stainless steel spring, and Buna-N bellows and gasket. Water flush design to provide flush across face of mechanical seal.
6. Pump Bearings: Grease-lubricated ball bearings contained in cast-iron hosing with grease fittings, suitable for in-service lubrication. Rated life of bearings not less than 80,000 hours.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. EPDM coupling sleeve for variable-speed applications.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Baseplate: Cast iron or rolled steel, factory fabricated with raised lip and drain tappings. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to baseplate, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

H. Capacities and Characteristics: As scheduled on drawings.

2.7 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
~~3.~~4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Horizontally split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and ASME B16.1, Class 125 flanges. Casing supports shall allow removal and replacement of impeller without disconnecting piping.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Shaft Sleeve: Renewable hardened stainless steel or ceramic coated stainless steel of minimum 600 Brinell hardness.
5. Mechanical Seal: Babbit filled carbon rotating ring against a tungsten carbide stationary seat held by a stainless steel spring, and EPT bellows and gasket. Water flush design to provide flush across face of mechanical seal.
6. Pump Bearings: Radial and thrust bearings; single row, inboard and double row outboard, regreaseable ball bearings, 100,000 hours average life. Bearings to be removable without disassembling the pump.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. T.B. Woods Dura-Flex® flexible shock arresting coupling and coupling guard for pumps less than 100HP and a Falk Steelflex® Grid coupling and guard for 100HP and larger.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Baseplate: Cast or rolled steel, factory fabricated with raised lip and drain tappings. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to mounting frame, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Outdoor applications shall have a TEFC (Totally Enclosed Fan Cooled) motor and indoor locations shall have an open drip-proof motor; voltage and horsepower as scheduled.

H. Capacities and Characteristics: As scheduled on drawings.

2.8 SEPARATELY COUPLED, VERTICAL-MOUNTED, TURBINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
~~3.~~4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, single-stage, centrifugal, impeller-between-bearings, end-suction pump as defined in HI 2.1-2.2 and HI 2.3; designed for installation with pump and motor shafts mounted vertically and projecting into a sump. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Pump Bowl: Cast iron, with replaceable bronze wear ring, cone strainer, and suction bell.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance. All impellers shall be dynamically balanced, and shall be securely fastened to the shaft with tapered steel lock collars, threaded lock collars or double keys. The impellers shall be adjustable vertically by external means at the driver location.
3. Pump Shaft: AISI Type 416 stainless steel turned and ground, supported by bronze bearings above and below each impeller. The suction bell bearing shall be extra long and permanently lubricated and sealed with a bronze sand collar. The discharge case shall also contain an extra long support bearing. Provide in sections not over 10 feet in length. The size of the shaft shall be no less than determined by ANSI specification B58.1. Steel lineshaft couplings with a safety factor of 1-1/2 times shaft safety factor shall join the lineshafts; these threaded couplings shall have left-hand threads to tighten during pump operation.
4. Pump Bearings: Water-lubricated bronze and rubber sleeve bearings contained in cast-iron housing. A rigid type bearing retainer shall be provided at each column joint to support the lineshaft bearings at maximum 5 foot centers. 304 or 410 stainless steel sleeves shall be provided on the lineshaft at each lineshaft bearing location; these shall be field replaceable and securely fastened to the shaft.
5. Pump Column: ASTM A 53/A 53M, Grade B steel pipe.
6. Mechanical Seal: Mechanical seal consisting of AISI Type 416 stainless steel rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal. Flushing fit.: Utex or Owner approved substitution. Seal shall be replaceable without removing the motor or disturbing the piping.
7. Packed Seal: Heavy duty stuffing box, with a minimum of four rings of asbestos free graphite-impregnated braided yarn with bronze split lantern ring between center two graphite rings, and bronze packing gland.

D. Shaft Coupling: Keyed with locking collets.

E. Discharge Head: ASME B16.1, Class 250 discharge flange with threaded gage tapping. Top of discharge head shall have a registered fit to accurately locate the driver.

F. Drive Ratchet: Nonreversing ratchet.

G. Hollow Shaft Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to discharge head. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Electric motors for vertical turbine pumps shall be of the vertical solid shaft or vertical hollowshaft high thrust design. The motors shall be designed to carry the thrust load of the pump. The motor shall be keyed to the steel shaft, and shall have an adjustable coupling.

1. Enclosure: Totally Enclosed - Severe duty.
2. Enclosure Materials: Cast iron.
3. Motor Bearings: Grease lubricated.

H. Unusual Service Conditions:

1. Ambient Temperature: 95 deg F.
2. Altitude: 100 feet above sea level.
3. High humidity.

I. Capacities and Characteristics: As scheduled on drawings.

2.9 AUTOMATIC CONDENSATE PUMP UNITS

A. Manufacturers:

1. Aurora Pump; Division of Pentair Pump Group.
2. Beckett Corporation.
3. Flowserve Corporation; Div. of Ingersoll-Dresser Pumps.
4. Hartell Pumps Div.; Milton Roy Co.
5. Little Giant Pump Co.; Subsidiary of Tecumseh Products Co.

B. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and a 72-inch-minimum, electrical power cord with plug.

2.10 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig pressure rating, cast or ductile-iron body and end cap, flanged pump-inlet fitting with flanged or grooved system outlet fitting; with bronze or stainless steel startup and bronze or stainless-steel permanent strainers; bronze or stainless-steel straightening vanes; drain plug; and factory-fabricated support.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of work.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

C. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.

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

3.2 CONCRETE BASES

A. Install pumps on concrete bases of dimensions required for pumps and controllers. Refer to Division 23 Section "Common Work Results for HVAC" And see Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Cast-in-place concrete materials and placement requirements are specified in Division 03.

3.3 PUMP INSTALLATION

A. Comply with HI 1.4 or HI 2.4 as applicable.

B. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping. Provide supports under elbows on pump suction and discharge lines.

D. Install continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

E. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

F. Set base-mounted pumps on concrete foundation. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

1. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
2. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

G. Automatic Condensate Pump Units: Install units for collecting condensate and extend discharge as shown on drawings.

3.4 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

B. Comply with pump and coupling manufacturers' written instructions.

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation and HI 2.1-2.5, " Vertical Pumps for Nomenclature, Definitions, Application and Operation."

D. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.5 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles. Decrease to pump nozzles from line size with long radium reducing elbows or reducers.

E. Install silent spring loaded check valve and throttling valve on discharge side of pumps.

F. Install Y-type or T-type (grooved) strainer and shutoff valve on suction side of pumps.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gages on pump suction and discharge, at integral pressure-gage tapping.

I. Install check valve and ball valve on each condensate pump unit discharge.

J. Provide drains from baseplates and stuffing boxes, piped to spill over floor drains.

K. Provide vent valves and drain on pump casings.

L. Pipe up flush filter for mechanical seals, with bypass line from pump discharge to external gland connection and filter or cyclone separator in line.

M. Install electrical connections for power, controls, and devices.

N. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

O. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.6 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Check piping connections for tightness.
3. Clean strainers on suction piping.
4. Perform the following startup checks for each pump before starting:

    a. Verify bearing lubrication.

b. Verify that pump is free to rotate by hand. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
c. Verify that pump is rotating in the correct direction.

5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
6. Start motor.
7. Open discharge valve slowly.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Coordinate with the requirements of Sections 01 91 13 and 23 08 00.

END OF SECTION 23 21 23

SECTION 23 21 23 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10.01, Basic HVAC Requirements are part of this Section.

C. Comply with requirements in Section 23 05 48 "Vibration Controls for HVAC" for equipment isolation.

1.2 WORK INCLUDED

A. End Suction, Base Mounted Pumps.
B. Close Coupled, Vertical, In-line Centrifugal Pumps

1.3 QUALITY ASSURANCE

A. Maximum suction velocity shall be less than 10 FPS. Pump discharge velocity shall be less than to 14 FPS

B. Pump selections shall be no more than 5% less than the scheduled pump efficiency.

C. Maximum impeller diameter shall not exceed 85% of the cutwater diameter.

D. Pump motors shall be NEMA Premium™ Efficiency. Motors for pumps with variable speed drive must have Class F insulation.

E. Pumps shall be factory tested, thoroughly cleaned and painted. Discharge and suction shall be factory covered to protect the volute/impeller from dirt and damage during shipment and storage.

F. Pumps shall be constructed with materials and standards which have been tested or proven and have published test data available if requested, stating that these materials and standards have been found acceptable for use in pump manufacturing by one or more of the following:

1. American Society for Testing and Materials (ASTM)
2. International Organization for Standardization (ISO)
3. American National Standards Institute (ANSI)
4. National Electrical Manufacturers Association (NEMA)

G. Provide full two year on-site parts and labor warranty including travel time and expense. Warranty period shall begin at date of Substantial Completion.

H. Provide shaft grounding rings on all pump motors driven by a VFD. Typically to an AEGIS –

SGR.

1.4 SUBMITTALS

A. Submit dimensioned performance and product data for acceptance.

B. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

C. Additional submittal requirements:

1. Submit pump curves with pump operating point plotted, brake horsepower and pump efficiency indicated on curve.
2. Where two or more pumps are operating in parallel, submit combined pump curve with all pump operating points plotted, system curve indicated and brake horsepower and pump efficiency indicated on curve.
3. Where pumps are used in open type systems (i.e. condenser water) submit net positive suction head curve (NPSH) with the system requirements plotted.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Manufacturers:

1. Armstrong Pump Company
2. Aurora
3. Bell & Gossett

2.2 EQUIPMENT

A. End Suction, Base Mounted Pumps:

1. Type: Centrifugal, single stage, end suction, back pull out design, base mounted, flexible coupled.
2. Casing: Cast iron, end suction, rated for 250 psi, suction and discharge gauge tapping, casing taped for air vent, 250 psi ANSI flanged suction and discharge.
3. Impeller: Stainless steel fully enclosed, keyed to shaft and secured with locknut, hydraulically and dynamically balanced.
4. Shaft: Steel with aluminum bronze or stainless steel sleeve thru seal chamber.
5. Seals: Carbon rotating against a stationary ceramic seat.
6. Bearings: Regreaseable ball bearings.
7. Drive: Coupled with a T.B. Woods Sure-Flex® flexible shock arresting coupling, and OSHA approved coupling guard. Coupling for variable speed drive applications shall be T.B. Woods Dura-Flex® shock arresting coupling and OSHA approved coupling guard.
8. Motor: Outdoor applications shall have a TEFC (Totally Enclosed Fan Cooled) motor and indoor locations shall have an open drip-proof motor; voltage and horsepower as scheduled.
9. Range: 20°F to 225°F.

10. Base: Heavy structural steel welded or cast iron frame with mounts for motor pump and flexible coupler, open area for non-shrinking grout.

B. Close Coupled, In-line centrifugal Pumps

1. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.
2. Pump Construction:

   a. Casing: Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and threaded companion-flange connections.
   b. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
   c. Pump Shaft: Stainless steel.
   d. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
   e. Pump Bearings: Permanently lubricated ball bearings.

PART 3 - EXECUTION

3.1 GENERAL

A. Install in accordance with manufacturers written instructions.

3.2 CONCRETE BASES

A. Install pumps on concrete bases of dimensions required for pumps and controllers. Refer to Division 23 Section "Common Work Results for HVAC" And see Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Cast-in-place concrete materials and placement requirements are specified in Division 03.

3.3 PUMP INSTALLATION

A. Comply with HI 1.4 or HI 2.4 as applicable.

B. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping. Provide supports under elbows on pump suction and discharge lines.

D. Install continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

E. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

F. Set base-mounted pumps on concrete foundation. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

a. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
b. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

G. Provide mechanical equipment with vibration isolation according to the following schedule:

EQUIPMENT	ISOLATOR TYPE
Base mounted pumps	B-2 with Type K, and FC-2
Inline pumps	H

~~G.~~H. Automatic Condensate Pump Units: Install units for collecting condensate and extend discharge as shown on drawings.

3.4 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

B. Comply with pump and coupling manufacturers' written instructions.

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation and HI 2.1-2.5, " Vertical Pumps for Nomenclature, Definitions, Application and Operation."

D. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.5 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles. Decrease to pump nozzles from line size with long radium reducing elbows or reducers.

E. Install silent spring loaded check valve and throttling valve on discharge side of pumps.

F. Install Y-type strainer and shutoff valve on suction side of pumps.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gages on pump suction and discharge, at integral pressure-gage tapping.

I. Install check valve and ball valve on each condensate pump unit discharge.

J. Provide drains from baseplates and stuffing boxes, piped to spill over floor drains.

K. Provide vent valves and drain on pump casings.

L. Pipe up flush filter for mechanical seals, with bypass line from pump discharge to external gland connection and filter or cyclone separator in line.

M. Install electrical connections for power, controls, and devices.

N. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

O. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.6 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

    a. Complete installation and startup checks according to manufacturer's written instructions.
    b. Check piping connections for tightness.
    c. Clean strainers on suction piping.
    d. Perform the following startup checks for each pump before starting:

        a. Verify bearing lubrication.
        b. Verify that pump is free to rotate by hand. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
        c. Verify that pump is rotating in the correct direction.

e. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
f. Start motor.
g. Open discharge valve slowly.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION 23 21 23

SECTION 23 23 00 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 WORK INCLUDED

A. Refrigerant (RS/RL/RHG) Piping.

B. Valves and Specialties

1.3 DEFINITIONS

A. The pipe sizes given in this document shall be construed as nominal pipe sizes.

1.4 QUALITY ASSURANCE

A. All material provided under this section shall be standard catalogued products of recognized manufacturers regularly engaged in the production of such products, and shall be of the manufacturer's most recent design that is in regular production.

B. Each item provided under this section shall meet the requirements for that item as installed and used, in accordance with the following standards:

1. Metallic Piping Systems employing mechanical joints and grooved-end pipe - ASME/ANSI B-31.9
2. Refrigeration Piping and Heat Transfer Components - ASME/ANSI B31.5
3. Safety Code for Refrigeration Systems – ASHRAE 15
4. Refrigerant Containing Components and Accessories – UL 207

C. Each piping system shall be in accordance with the system design pressures shown in paragraph 2.1 - Materials, this specification section.

D. All materials provided under this section shall be new, except where the specifications and/or drawings permit the reuse of certain existing materials.

1.5 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this Section to the extent referenced. The publications are referenced in the text by the basic designation only.

B. The work and materials listed in this Section shall be provided in accordance with the standards and requirements set forth in the applicable portions of the latest editions of the referenced publications.

1. American National Standards Institute (ANSI) Standards
2. American Petroleum Institute (API) Specification
3. American Society of Mechanical Engineers (ASME) Publications
4. American Society for Testing and Materials (ASTM) Publications
5. American Welding Society (AWS) Publication
6. American Water Works Association (AWWA) Standards
8. The Manufacturer's Standardization Society of the Valve and Fittings Industry (MSS) Publications
9. National Fire Protection Association (NFPA) Standards
10. National Sanitation Foundation (NSF) Testing Laboratory Standards.
11. Plastic Pipe Institute (PPI) Manual.
12. Underwriters Laboratories (UL)

1.6 SUBMITTALS

A. All submittals shall be made in accordance with Division 01 requirements.

B. Materials List: Submit a list identifying the specific type of material that will be used for each piping system. Include pipe, pipefittings, valves and joints. Include the basic designation of the publication applicable for each type of material and method.

C. Refrigeration Piping Requirements: Submit a letter from the refrigeration equipment manufacturer stating that the refrigeration piping system, as shown on the contract documents, is acceptable for the equipment the manufacturer proposes to furnish, or submit drawings prepared by an authorized representative of the refrigeration equipment manufacturer.

PART 2 – PRODUCTS

2.1 PRODUCT, GENERAL

A. Recycled Content of Steel Products: Post-consumer recycled content plus one-half of pre-consumer recycled content not less than 25%.

B. Recycled Content of Copper Products: Post-consumer recycled content plus on-half of pre-consumer recycled content not less than 25%.

C. Refer to Section 01 81 13.14 “Sustainable Design Requirements – LEED v4 BD+C” for additional information and requirements for recycled content. Provide material cost data specific to this material.

D. Environmental Product Disclosure: Provide an Environmental Product Declarations (EPD) that conforms with one of the followings:

1. Product specific declarations in accordance to ISO 1404
2. Environmental Product Declarations conforming to ISO 14025, 14040, 14044 and EN 15804 or ISO 21930.
3. Industry Wide Product Specific Type III EPD Third Party Certification.

E. Provide detailed material cost data for this scope of work.

2.~~1~~2 MATERIALS

A. Refrigerant (RS/RL/RHG) Piping.

1. Piping carrying Refrigerants shall be ACR copper.
2. ACR Copper Refrigerant Piping:

a. Piping, 3" and smaller: Type ACR hard-drawn copper tubing, ASTM B88, ANSI H23.1.

b. Fittings, 3" and smaller, all types, wrought copper: ASTM B16.22, ANSI B16.22. All 90° elbows shall be the long radius type.

c. Brazing: Contractors Option:

(1) 5% silver, 6% phosphorus, balance copper, 1190°F melting point. AWS A5.8 number BCuP -3. J.W. Harris Stay-Silv® 5 or approved substitution.

(2) 15% silver, 5% phosphorus, balance copper, 1190°F melting point. AWS 5.8 number BCuP-5. J.W. Harris Stay-Silv® 15 or approved substitution.

(3) 6% silver, 6.1% phosphorus, balance copper, 1190°F melting point. QQ-B-654A number BCuP -5. J.W. Harris Dynaflow® 5 or approved substitution.

d. Unions used shall be specifically designed for refrigeration piping.

2.~~2~~3 VALVES AND SPECIALTIES

A. Solenoid Valves:

1. Liquid line shut off.
2. Normally closed.
3. Manual lift stem.
4. Pilot operated.
5. Synthetic seat for permanent tight shut-off.
6. 120 volt solenoid coil (interchangeable).
7. Top grade brass, bronze and/or semi-steel body materials.
8. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

B. Filter Drier:

1. Replaceable core type.
2. Heavy steel, cadmium plated with external coat of paint.

3. All internal parts cadmium plated.
4. Outlet seal gasket with spring to prevent bypassing.
5. Copper fittings brazed to steel shell, suitable for soldering with Sil-Fos or Phos-Copper solder.
6. Molded porous core elements.
7. Tie rod assembly to permit external assembly with one piece insert.
8. Bolt and nut attachment.
9. Size for refrigerant capacity and tonnage at 2 psi pressure drop.
10. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

C. Moisture and Liquid Indicators:

1. Suitable for R-407c.
2. Accurately calibrated to change color for indication of moisture.
3. Large full view sight glass.
4. Removable indicator element for sizes 1-3/8" and up. Remove before soldering.
5. Full line size for liquid lines up to 2-1/8" O.D. 3/8" bypass indicator with preformed installation kit on larger sizes.
6. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

D. Sight Glasses:

1. Similar to Sporlan "See-all" moisture and liquid indicator with solder type connections.
2. Install sight glass of the same size as the liquid line.

E. Miscellaneous Valves and Accessories:

1. Drain valves for all pressure vessels.
2. Dual pressure relief valves with manifold for all pressure vessels.
3. Refrigerant service valves where indicated.
4. Pressure - Temperature Test Ports and Test Kit:

   a. Brass or stainless steel body with threaded cap and gasket.
   b. Two self closing valves with intermediate pocket for added pressure protection.
   c. Pressure temperature test kits consisting of 0- 150 psi pressure gauge with adapter, 25-125°F testing thermometer, 0-220°F testing thermometer, gauge adopted and protective carrying case (two required).

F. Thermometers:

1. Red reading type, glass front, iron or phenol case, adjustable pattern, separable socket.
2. Shall have 9 inch scale and 12 inch case.
3. Operating range shall occur in middle half of total range
4. Acceptable Manufacturers: Mueller, Taylor, Rochester.

G. Gauges:

1. Liquid pressure gauges constructed with bronze tube, stainless steel movement, white dial, black micrometer, adjustable pointer, iron case with black flange iron or phenol screwed ring, bottom connection.
2. Case diameter size shall be 4-1/2 inches minimum.
3. Operating range shall occur in middle half of total gauge range.

4. Provide needle valve for all gauges.
5. Acceptable Manufacturers: Crosby-Ashton Type AAO, Ashcroft, Lonegran

H. Refrigerant Charge: Complete operating charge of R-407C.

I. High pressure receiver designed and constructed for 300 psi design working pressure with liquid seal float control, automatic liquid feed valve, drain and equalizer connections, liquid line filter-drier, moisture indicator, three service and bypass valves, charge valve and manual purge valve.

J. Locking Refrigerant Caps: Precision machined from high grade brass surrounded by a protective aluminum shroud. Provide a 3 year warranty. Provide one multi key per project to maintenance personnel.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Furnish and install piping, fittings and appurtenances required to complete the piping systems shown on the drawings. Elbows shall be long radius type. Tees may not be field fabricated.
2. Run piping to true alignment, generally parallel or perpendicular to building walls, floors and ceilings, and with uniform grades and spacing, so as to present a neat and workmanlike appearance.
3. Care shall be paid to the exact locations of piping with respect to equipment, ducts, conduits, slabs, beams, lighting fixtures, columns, ceiling suspension systems, etc. to provide maximum access to mechanical and electrical equipment in the building. Close coordination and cooperation shall be exercised with other trades in locating the piping in the best interests of the Owner. The drawings and specifications covering other work to be done in the building shall be carefully studied and arrangements made to avoid conflict.
4. Not all necessary pipe offsets are indicated on the drawings because of the small scale. The various runs of piping to be installed shall be studied and adjustments made in exact routings as may be required for proper installation.
5. Conflicts arising during the erection of piping shall be brought to the attention of the Owner's Representative. No improvising or field changes will be permitted without the approval of the Owner's Representative.
6. Use full lengths of pipe wherever possible. Short lengths of pipe with couplings will not be permitted. Cut to exact measurement and install without forcing or spring unless otherwise shown on the drawings or specified.
7. Avoid tool marks and unnecessary pipe threads. Burrs formed when cutting pipe shall be removed by reaming. Before installing any pipe, care shall be taken that the inside is thoroughly cleaned and free of cuttings and foreign matter. Measures shall be taken to preserve this cleanliness after erection.
8. Arrange pipe connections to valves and specialties so that there is clearance for easy removal of the valve or specialty from the line, and also for the removal of the valve bonnet and interior, and the specialty top and bottom and interior, except where otherwise approved by the Owner's Representative.
9. Erect piping in such a manner so as to obtain sufficient flexibility and to prevent excessive

stresses in materials and excessive bending movements at joints or connections to equipment. Make allowances throughout for expansion and contraction of piping. Provide each riser and horizontal run of piping with expansion loops, expansion joints, or expansion compensators where indicated and required. Securely anchor and adequately guide pipe as required or where indicated to force expansion to the expansion device without bending, binding, or misalignment of pipe. Branch connections from mains to risers shall be made with ample swing or offset to avoid undue strain on fittings or short pipe lengths. Where indicated, in lieu of expansion loops, expansion joints, or expansion compensators, horizontal runs of pipe shall be anchored at approximately midway of the run to force expansion, evenly divided, toward the mains and risers to provide for expansion and contraction of piping. Flexibility shall be provided by installing one or more turns in the line so that piping will spring enough to allow for expansion without straining.

10. Installed piping shall not interfere with the operations or accessibility of doors or windows and shall not encroach on aisles, passageways and equipment, and shall not interfere with the servicing or maintenance of any equipment. Adjacent pipelines shall be grouped in the same horizontal or vertical plane.
11. Where lines are purposely pitched for drainage, an accurate grade shall be maintained. No lines shall be supported in such a manner as to permit deflection, due to gravity, sufficient to pocket the lines when full of liquid. Grade mains as indicated by arrows on the drawings and in accordance with gradient as indicated in attached Piping Schedule.
12. Piping found to have water hammer or other objectionable vibrations which cannot be eliminated by proper grading or other natural means, shall be braced, trapped or hung with shock absorbing hangers and equipped with air chambers, mechanical shock absorbers, flexible pipe connections or otherwise silenced using approved means.
13. Use building steel wherever possible for supporting pipe hangers. Main structural steel shall not be drilled, cut or burned for hangers without the approval of the Owner's Representative. Expansion bolts shall be used only upon the approval of the Owner's Representative.
14. Install unions or flanges in piping connections to equipment, regulating valves, and wherever necessary to facilitate the dismantling of piping and/or removal of valves and other items requiring maintenance.
15. Avoid bushings. Reducing fittings shall be used wherever practical.
16. The drawings indicate the size of piping and connections, and if certain sizes are omitted or unclear, obtain additional information before proceeding.
17. The piping drawings have been worked out with a view to the most economical installation, taking into consideration accessibility and appearances, and the Contractor must follow the drawings accurately and if it is found impractical to install the work in accordance with the drawings and specifications, the Contractor shall notify the Owner's Representative before making any changes and get their approval or revised drawings before proceeding with the work. Verify all measurements on the job before cutting pipes or having piping fabricated, and be responsible for the correct location of all pipe connections, also check sizes and standard of outlets on the equipment, including the dimensions and drilling of flanges, etc.
18. Copper tubing and galvanized steel shall not be mixed in any one run of piping.
19. Change in direction shall be made with fittings, except that bending of steel and copper pipe 4 inches and smaller will be permitted, provided a pipe bender is used and wide sweep bends are formed. The center-line radius of bends shall be not less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations is not acceptable.
20. Threaded joints shall be made with tapered threads in accordance with ANSI B2.1, and made tight with an approved pipe thread joint compound or material, applied to the male threads only. Use compounds sparingly and apply with caution to ensure that compounds do not enter piping systems. When pipe joint is made up a maximum of 3 threads shall be

visible.

21. Joints for plastic pipe shall be made in accordance with PPI Piping Manual.
22. Connections between ferrous and nonferrous metallic pipe shall be made with dielectric unions or flanges.
23. Connections between plastic and metallic pipe, between plastic and glass pipe, and between metallic and glass pipe, shall be made with transition fittings manufactured for the specific purpose.
24. Unions and flanges shall not be concealed in walls, partitions, or above inaccessible ceilings.

B. Valve and Specialties Applications

1. Install service valves for gage taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.
2. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.
3. Install solenoid valves upstream from each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at top.
4. Install thermostatic expansion valves as close as possible to distributors on evaporators.

    a. Install valve so diaphragm case is warmer than bulb.
    b. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at bottom of the line. Verify proper location for the bulb with the valve manufacturer
    c. If external equalizer lines are required, make connection where it will reflect suction-line pressure at bulb location.

5. Install safety relief valves where required by ASME Boiler and Pressure Vessel Code. Pipe safety relief-valve discharge line to outside according to ASH RAE 15.
6. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube on each circuit.
7. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for device being protected:

    a. Solenoid valves.
    b. Thermostatic expansion valves.
    c. Hot-gas bypass valves.
    d. Compressor.

8. Install filter dryers in liquid line between compressor and thermostatic expansion valve on each circuit.
9. Install receivers sized to accommodate pump-down charge.
10. Install flexible connectors at compressors.
11. Locking Refrigerant Caps: Provide at all exterior refrigerant service access ports (Schrader valves).
12. Install gauges with dial in vertical position. Locate between shut-off valve and equipment directly adjacent to equipment within normal visual range of operator standing on floor.
13. Provide gauges where shown on drawings, including the following locations:

    a. Ice builders; leaving each builder on the pumped liquid return header.
    b. Barrel chiller; entering and leaving the pumped liquid lines.
    c. Compressor oil coolers; entering and leaving condenser water lines.

d. Evaporative condenser; entering and leaving refrigerant lines.
e. Refrigerant pumps; entering and leaving the pumped liquid lines.

14. Provide nickel plated brass escutcheons or floor plates, around pipes piercing floors and walls in finished spaces. Fit around insulation or around pipe if uninsulated. Secure to pipe with setscrew. Provide deep escutcheon where sleeve projects beyond finished surface

C. Refrigerant Systems Additional Requirements:

1. Installation shall be in accordance with ANSI B31.5 Refrigeration Piping, unless specified otherwise herein.
2. Brazing procedures and operators shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.
3. Refrigerant pipeline accessories that may be damaged by heat shall be disassembled prior to joint brazing. Reassemble accessories after joint brazing operations are completed.
4. Joints shall be made with solder-type fittings. The outside surface of the tube where engaged in the fitting, and the inside surface of the fitting in contact with the tube, shall be cleaned with an abrasive material before brazing. Self-cleaning compounds are not allowed. Care shall be taken to prevent annealing of tube and fittings when making connections. Brazed joints shall be made with flux and the previously specified silver-brazing alloy. The brazing alloy shall be applied and drawn through the full fitting length. Excess brazing alloy shall be wiped from the joint before the brazing alloy hardens. Joints shall be made with heat applied uniformly around the entire circumference of the tube and fittings. Remove all excess flux for a clear visual inspection of all brazed connections.
5. Refrigerant piping installed below concrete slab- on-grade shall be installed in continuous runs without joints, and shall be encased in SCH 40 PVC ~~plastic~~ conduit. Ends of conduit shall be sealed watertight.

3.2 BRAZING AND SOLDERING

A. Operator and Procedure Qualifications: All brazing operators and all brazing procedures shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

B. Brazing: Silver braze joints in accordance with MSS-SP-73 "Silver Brazing Joints for Wrought and Cast Solder Joint Fittings".

C. Soldering:

1. Joints in copper tubing shall be made with solder- type fittings. Outside surface of the tube where engaged in the fitting, and inside surface of the fitting in contact with the tube, shall be cleaned with an abrasive material before soldering. Self- cleaning compounds shall not be used. Care shall be taken to prevent annealing of tube and fittings when making connections. The solder joint shall be made with flux and wire form solder, except brazed joints. The flux shall be a mildly corrosive liquid or a petroleum based paste containing chlorides of zinc and ammonium. Solder shall be applied and drawn through the full fitting length. Excess solder shall be wiped from joint before solder hardens. Joints in copper tube sizes 2-1/2 inches and larger shall be made with heat applied uniformly around the entire circumference of the tube and fittings by a multi-flame torch. Use of oxy-acetylene cutting torch in lieu of multi-flame torch is not permitted. Disassemble valves and other accessories that may be damaged by heat before soldering.

3.3 TESTING OF PIPING SYSTEMS:

A. Each piping system, after erection, shall be subjected to a pressure test. The test requirements shall be as follows:

1. General: Furnish everything required for the tests. Notify Architect/Engineer at least 48 hours before any testing is performed. Independent Agent/Owner shall verify pressure test and sign off. Report to be furnished to Architect/Engineer. Testing shall be performed at the completion of each phase of the project.
2. Refrigerant Piping Systems shall be tested with dry carbon dioxide, or nitrogen, at 315 psig for the high side, and at 245 psig for the low side. If leaks are to be detected by use of an electronic halogen detector, or a halide torch, the system shall be pressurized with refrigerant gas prior to introduction of dry carbon dioxide or nitrogen into the system. Pre-charging of system with refrigerant gas is not necessary for soap bubble leak detection method.
3. Leaks, if any, shall be located, repaired, and retested in accordance with the test method specified for the system in which the leaks are located.

B. Prior to testing a system, the Contractor shall provide the proper Building Official and the Owner's Representative with not less than 72 hours notice of the proposed test. The Contractor shall obtain approval of the test results. Where written approval is required, the Contractor shall obtain such written approval, and submit a copy of the approval.

C. Work requiring testing shall not be covered, or otherwise concealed, until testing is completed and approval is granted.

D. Work, or portions of work, that is altered in any way after testing and approval shall be retested, witnessed, and approval obtained.

E. Systems requiring hydrostatic tests shall be protected from damage caused by freezing. After tests are completed drain all sections of pipe, including traps, or fill undrained sections and traps with antifreeze solution. Vent all high points to release vacuum and ensure complete drainage of closed systems, and blow out piping with compressed air to remove trapped water.

F. Duration of tests, unless specified otherwise, shall be the time required to examine each joint in the system being tested.

G. During tests, isolate system components that have test pressures less than pressures specified for system tests.

H. Use clean soapy water applied to exterior of joints to locate leaks in systems using compressed air, dry carbon dioxide, or nitrogen, under positive pressure as a test medium.

END OF SECTION 23 23 00

SECTION 23 25 00 - HVAC WATER TREATMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following HVAC water-treatment systems:

1. Bypass chemical-feed equipment and controls.
2. Biocide chemical-feed equipment and controls.
3. Chemical treatment test equipment.
4. HVAC water-treatment chemicals.
~~5.~~

1.3 WORK INCLUDED

A. Feeding and Control Equipment with all Piping and Wiring for each System.

B. Closed Loop Temporary Filter.

C. Pre-Operation Cleaning of each System.

D. Initial Water Analysis and Recommendations.

E. Water Treatment Chemicals for each System.

F. Test Equipment.

G. Training of Operating Personnel Including Written Instructions, Log Sheet and Record Forms.

H. Follow-up Service for One Full Year from date of Start-up including Laboratory Assistance.

1.4 SYSTEMS TO BE TREATED

A. Chilled Water (CHS/CHR).

B. Condenser Water - Open Loop (CWS/CWR).

1.5 DEFINITIONS

A. EEPROM: Electrically erasable, programmable read-only memory.

B. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

C. RO: Reverse osmosis.

D. TDS: Total dissolved solids.

E. UV: Ultraviolet.

F. NTU: Nephelometric turbidity units

G. uS/cm: Microsiemens per centimeter

1.6 PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

C. Closed hydronic systems, including chilled water, shall have the following water qualities:

1. pH: Maintain a value within 8.3 to 10.1.
2. Turbidity: Maintain a value less than 15 NTU.
3. Boron Nitrite: Maintain a value within 600 to 1000 ppm.
4. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
5. Soluble Copper: Maintain a maximum value of 0.30 ppm.
6. Iron: Less than 0.5 ppm,
7. TDS: Maintain a maximum value of 4000 uS/cm.
8. Free Caustic Alkalinity: Maintain a maximum value of 20-40 phenol alkalinity.
9. Microbiological Limits:

a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.

10. Treatment:
    a. Chilled water: Mixture of sodium nitrite, borax and molybdate with other copper alloy inhibitor; non-oxidizing, non cationic biocide.

D. Open hydronic systems, including condenser water, shall have the following water qualities:

1. pH: Maintain a value within 7.0 to 9.0.
2. Langelier Saturation Index: Maintain a maximum value of +2.5 ppm.
3. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
4. Soluble Copper: Maintain a maximum value of 0.30 ppm.
5. Conductivity: Maintain a maximum value of 1500 michromhos.
6. Free "OH" Alkalinity: Maintain a maximum value of 0 ppm
7. Silica: Maintain a maximum value of 125 ppm
8. Microbiological Limits:

    a. Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
    b. Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
    c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
    d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
    e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.

9. Polymer Testable: Maintain a minimum value within 10 to 40.

10. Treatment: organic phosphonate and polymeric dispersant with copper alloy inhibitor, or other chromate- free treatment in liquid form; suitable for pumping from containers directly to water system.
    a. Alternate two biocides, one oxidizer and one non-oxidizer; increase dosage when significant amount of algae or slime are detected after system operations.
    b. Compounds of mercury, copper or arsenic shall not be permitted.

11. Bleed off:
    a. Automatic control by condenser water conductivity and water meter signals.
    b. To maintain maximum chloride concentration to 7 times concentration of make-up water to minimize corrosion and scale formation.

E. Passivation for Galvanized Steel: For the first 60 days of operation.

1. pH: Maintain a value within 7 to 8.
2. Calcium Carbonate Hardness: Maintain a value within 100 to 300 ppm.
3. Calcium Carbonate Alkalinity: Maintain a value within 100 to 300 ppm.
4. Phosphate level: Maintain a value within 4-12 ppm after initial passivation with 400-600 ppm phosphate for 24-48hours.

1.7 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Inhibitor injection timers.
4. pH controllers.
5. TDS controllers.
6. Biocide feeder timers.
7. Chemical solution tanks.
8. Injection pumps.
9. Chemical test equipment.
10. Chemical material safety data sheets.
11. Multimedia filters.
12. Self-cleaning strainers.
13. Bag- or cartridge-type filters.
14. Centrifugal separators.

B. Shop Drawings: Pretreatment and chemical, treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.

1. Record actual locations of equipment and piping, including sampling points and locations of chemical injectors.

2. Wiring Diagrams: Power and control wiring.

C. Field quality-control test reports to indicate inhibitor levels, pH, conductivity, equipment conditions, chemical inventory and water usage data.

D. Operation and Maintenance Data: For sensors, injection pumps, water softeners/demineralizers and controllers to include in emergency, operation, and maintenance manuals.

E. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.

2. Water Analysis: Illustrate water quality available at Project site.
3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.
4. Certification of compliance: Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposal disposal.

1.8 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider with certified water technologists, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

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

C. All wiring shall conform to the NEC.

D. The pre-cleaning and chemical charging shall be by or supervised by personnel trained in the field of water treatment. Chemicals shall be charged into the system within 24 hours of flushing and during circulation.

E. All chemicals shall be compatible with system materials of construction and shall comply with all applicable EPA and regulatory agency standards.

F. After charging of the system and for a period of one (1) full year after the date of start up the water treatment supplier shall periodically inspect the system and perform all necessary tests (minimum of 4) to properly evaluate the chemical concentration.

G. After completion of the system the water treatment supplier shall train the owner in the proper maintenance procedures and future system requirements.

H. After completion of the system water treatment, the contractor shall provide a water analysis and certify in writing to the Owners Representative that the system or systems have been properly flushed, cleaned and charged with the proper chemical concentration and that the Owner has been instructed in proper maintenance procedures.

I. Corrosion coupon analysis by manufacturer's laboratory with test report at the end of the first year of operation.

1.9 MAINTENANCE SERVICE

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for chilled-water piping, condenser-water piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion, and shall include the following:

1. Initial makeup and system water analysis with HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with disinfectant detergents, and initially fill systems with required chemical treatment prior to operation.
3. Minimum 4 hours of on-site training of plant engineers to use water treatment equipment, to handle and administer treatment chemicals.
4. Monthly field service and consultation.
5. Customer report charts and log sheets.
6. Laboratory technical analysis.
7. Analyses and reports of all chemical items concerning safety and compliance with government regulations.
8. Summary review reports with graphs every six months.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Kibler Chemical Corporation.
   2. Betz Entec.
   3. Premier Water Technology.
   4. The Nalco Chemical Company.
   5. Garratt-Callahan Company.

2.2 CLOSED LOOP MANUAL CHEMICAL-FEED EQUIPMENT

A. General: Manual feeding of chemicals into filter style shot feeder and in turn into system in accordance with initial water evaluation and continuing test result requirements.

B. Bypass Filter Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

   1. Five-gallon combination filter-feeders, quantity as shown on drawings. Efficiency Dynamics, Ft. Worth, TX 76101, FF- 100 Owner approved substitution, including steel shell with stainless steel basket, filter bag capable of 40 gpm flow with filter efficiency of 5 microns at 3 psi pressure drop and hand removable cap. Suitable for 150 psi and temperatures to 200°F.
   2. Twelve filter bags or provide one if filter is cleanable.

3. Corrosion coupon rack including corrosion probe connection fittings, one carbon steel and one copper corrosion coupon with holders and two (2) corrosion coupon tees.
4. Totalizing make-up water meter equal to Master Meter Multi-Jet or Owner approved substitution for installation in make-up water line. Meter to be sized per the plumbing drawings and shall have contacts for monitoring by the Building Control System.
5. Installation accessories including piping, fittings, shut off valves, drain valves, pressure gauges to measure pressure loss thru filter and automatic flow control valve set for 8 GPM.

2.3 CLOSED LOOP TEMPORARY FILTER

A. Provide an HPF-1665-1-CL ANCOPureTM HPF Closed Loop Filter on the chilled water system. The filter must be installed and operational from the start-up of the chillers through substantial completion. The Owner shall be provided with a sample of the water each month from the contractor and the filter shall not be removed until the Owner and Engineer have signed off on the water quality.

B. Provide 1-one 16”x65” Polyglass filter tank, rated for 100 PSI maximum design pressure

C. Piping shall be 1” with a 1” multiport control valve

D. 100 lbs. of gravel per tank

E. Filter Media: HPF

F. Filtered Particulate Size: 5 Microns

G. Quantity of Filter Media Per Tank: 4 FT3

H. Inlet/Outlet Gauge Set w/ Sample Valve: 0-160 PSI

I. Normal Service Flow Rate: 17 GPM

J. Peak Flow Rate: 14 GPM

K. Backwash Flow Rate: 100

2.4 SIDE STREAM CARTRIDGE FILTER SYSTEM

A. Housing: A round multi-filter housing constructed of carbon steel with a 150 psi pressure rating at 300°F. The housing design shall include a large rounded bottom sump area so that the filter baskets may have a rounded bottom for particulate accumulation. The top portion of the fixed housing shall be equipped with a carbon steel plate with holes cut for the filter baskets. Filter basket holes shall be equipped with buna o-ring gaskets to prevent bypass around filter. Housing shall include a davit swing arm to remove the top for access to filter housings. Access to the housing shall be through the use of swing bolts with eye-nuts. Housing shall also include the following features: vent and drain port and gauge ports to measure differential pressure across the filter media. Piping connections shall be either ANSI 150# flanges or grooved for mechanical joint connection. The entire assembly shall be sand blasted and finished inside and out with a two part epoxy finish.

B. Filter Baskets: A 316 stainless steel basket with perforations. Basket shall be designed to accept standard liquid bags.

C. Liquid Filter Bags: Heavy duty filter media designed to filter at least 46 GPM of water per square foot of filter area with a maximum pressure loss of 8 psig at this valve. Filter media shall be suitable for intended fluid and shall have a filter rating of 5 microns absolute. Provide two complete spare sets of filters.

D. Based on Krystil Klean Multi-Round Liquid Bag Housing.

2.5 OPEN LOOP AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Maximum Temperature: 120 F
4. Minimum Working-Pressure Rating: 150 psig.
5. Maximum Pressure Loss at Design Flow: 3 psig.
6. Registration: Gallons.
7. End Connections: Threaded.
8. Control: Low-voltage signal capable of transmitting 1000 feet.

B. Feeding and Control Equipment:

1. Microprocessor controller: To control conductivity, pH and chemical treatment and to include:

   a. Chemical resistant membrane key pad control for access to all measurements, setpoints, calibration adjustments, program data and real time.
   b. LCD display to digitally indicate all measurements, setpoints and program data. Individual screens with prompting for normal operation, conductivity setpoints, pH setpoints, alarm status, feed limit timers, calibration, temperature setpoints, drum levels, real clock time and auxiliary analog/digital inputs as required.
   c. Conductivity Monitor: To provide linear, temperature compensated measurements over the full range of 0-20,000 micromhos. Accuracy will be 1% of reading, with a hysterisis of ±30 micromhos over a temperature compensated range of 5-60 deg. C. Bleed-off shall be controlled for standard operation by

the conductivity controller, which actuates solenoid bleed-off valve when cooling water system dissolved solids level reaches or exceeds the setpoint, and for biocide operation where a secondary bleed-off setpoint will be used to lower system conductivity levels prior to biocide feed. This circuitry shall ensure increased bleed-off prior to biocide feed so that the dissolved solids levels will not rise above standard operation setpoint during biocide feed, when bleed-off lock- out timer is activated. In both operating modes, an independent bleed limit timer with alarm shall safeguard against excessive bleed-off.

d. Chemical Feed Controls: Each of the four (4) chemical feeds will be capable of operating as a percentage timer where chemical is fed on an adjustable time- proportioning basis initiated by bleed- off, a counter/timer where chemical is fed proportional to make-up water rate. (A water meter with an electric contactor shall pulse a solid state reset counter with an adjustable range of 0-99 counts. Completion of counter cycle will initiate solid state reset timer for chemical feed with an adjustable range of 0-10 minutes); and as a clock timer where chemical feed is programmed by a 24 hour timer with 1, 7, or 28 day repeating cycle. Each chemical feed interval will be programmed for start time and duration with up to 16 intervals per function. Each mode shall be individually field programmable.

e. Auxiliary Analog/Digital Inputs: Seven auxiliary channels will be available for other analog input signals as required (ORP corrosivity, flow rate, etc.). Four digital input channels will be available for water flow interlock make-up water meter, bleed-off water meter and printer out of paper.

f. Security Code: Controller programming changes can be accessed only by entering an authorized security code.

g. Printer: Capable of printing operating data at rate of 20 characters per second on standard adding machine roll paper (2- 3/4" wide). Printer can be manually activated to print each display screen. Also, with each alarm occurrence, the printer will automatically print all analog operating data for the previous 30 minutes (in 5 minute increments) prior to that alarm occurrence.

h. Operating Data History: Controller will retain in memory all operating data for the minimum, maximum and average of all analog input data recorded each hour for the previous 24 hours and for each day for the previous twenty days; the first and last occurrence of each alarm condition recorded, including the day and time of each occurrence for the previous seven days; and the daily total running time in hours and minutes recorded for bleed-off and all chemical feeds, including acid and/or caustic, if applicable. The water flow volume in gallons of water through the make-up and bleed-off water meters will be recorded on both a daily and accumulative basis.

i. Drum Level Monitoring: Each chemical drum used shall be monitored by a drum level sensor which will continuously sense the amount of chemical remaining and alarm when the level has dropped to a predetermined, adjustable level (setpoint). The LCD display shall show the level remaining in each drum and the drum level alarm setpoint. This setpoint is to be adjustable from 0-100% in the field. Low drum level alarms shall display low drum level, lockout chemical pump and activate alarm buzzer.

j. Power Outage Protection: A lithium cell battery will provide power for real time clock/calendar up to two years. Setpoints, calibrations, feed schedules and all other user option inputs and software shall not require battery back-up and shall be maintained in the control system for a minimum of 10 years without power. Each unit shall be shipped from the factory pretested and calibrated. Each unit shall also be preprogrammed to "default" setpoints to prevent overfeeds prior to user programming.

k. Remote Communications: Modem capable of two way communications with local or remote IBM (or compatible) personal computer furnished with the energy monitoring system. All operating data history as recorded in memory shall be retrievable and upon occurrence of specific alarms, shall be capable of dialing a programmable list of 8 numbers for annunciation.

2. A key-lock, NEMA 12 enclosure, fabricated from 14 gauge cold rolled steel, primed and painted with polyurethane enamel paint for corrosion protection. All components in the NEMA 12 enclosure shall be pre-plumbed and pre-wired to form an operational and ready to use system which shall include:

   a. One (1) sample stream piping assembly consisting of two (2) 3/4" inlet/outlet shut off valves rated for 125 psi service; one (1) flow switch rated for 125 psi service; four (4) 3/4" PVC chemical injection tees. Conductivity probe of PVC construction, with stainless steel and temperature compensated elements, mounted in a Mogul Flo-Tee with probe fitting. The conductivity probe shall be easily removed from the probe fittings by loosening the lock nut. pH probe which shall utilize a combination (measuring/reference) sealed glass electrode with pH measuring range of 0-14 and temperature operating range of 32^{o} - 140^{o}F. The electrode shall also be mounted in line with an O-ring sealed mounting adapter that does not require tools to remove or install electrode. pH temperature compensation electrode shall have temperature operating range of 32^{o} - 140^{o}F. The electrode shall also be mounted in line with an O-ring sealed mounting adapter that does not require tools to remove or install electrode.

   b. Four (4) chemical feed pumps of the positive displacement type, with ball type check valves and necessary polyethylene discharge tubing for the feed of corrosion inhibitor and two biocides. Pump materials of construction shall be compatible with chemicals being used.

   c. Dividing panel to isolate and protect microprocessor from chemical feed equipment.

3. Two (2) water meters, complete with electric contacting register sized to meter twice the volume of the maximum makeup and bleed-off water rates of the system.

4. One (1) prepiped bleed-off piping assembly consisting of inlet shut off valve, wye strainer, flush valve, throttling valve and 0 psi differential brass solenoid valve. Bleed off piping assembly shall be sized to bleed twice the maximum bleed off rate of the system.

5. One (1) sample stream injection assembly, with stainless steel diffuser tube for injecting sample stream flow into the recirculating line.

6. Corrosion coupon bypass assembly including inlet outlet shut off valves. Line strainer with 20 mesh s.s. screen, and corrosion probe connection fittings, one carbon steel and one copper corrosion coupon with holders, two (2) corrosion coupon tees and automatic flow control valve (8 gpm).
7. Four (4) drum level sensor assemblies each with a PVC bung hole adapter to mount directly into a 55-gallon chemical drum bung hole. Each sensor will measure amount of chemical remaining in drum and transmit a signal to the micro-processor.

C. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: 120 gal.

D. Chemical Solution Injection Pumps:

1. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

E. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints.

F. Injection Assembly:

1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: Three-piece, stainless steel as described in "Stainless-Steel Pipes and Fittings" Article below; and selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.
5. Materials of construction: Stainless steel 316, Nickel alloy, Carpenter 20, PVC.

G. Fail-Safes and Alarms
1. Corrosion safety interlock: Alarm indication, lock-out all chemical feed, open bleed-off valve to flush corrosive water from system.
2. PH interlock: Alarm indication, lock-out all chemical feed, open bleed-off valve to reduce total dissolved solids in cooling tower water.
3. Flow interlock (on loss of flow): Alarm indication, lock-out all control outputs and chemical feeds.

H. Low Level Alarms

1. Low level alarm system to monitor chemical solution level in inhibitor, ph modifier (acid or alkali), biocide, and dispersant drums.
2. Alarm probes, suitable for use in 55 gal drum and connected with flexible cable.
3. Signal output suitable for remote alarm function in addition to local alarm.

2.6 STAINLESS-STEEL PIPES AND FITTINGS

A. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.

B. Stainless-Steel Fittings: Complying with ASTM A 815/A 815M, Type 316, Grade WP-S.

C. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and 150-psig SWP and 600-psig CWP rating.

2.7 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test equipment to properly evaluate the chemical levels within the system. The test equipment shall include but not be limited to: Carrying case or cabinet, all necessary reagents for determination of corrosion inhibitor level pH, P & M, alkalinity and chlorides as well as microbiological colony population and biocide effectiveness.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons in accordance with ASTM D2688. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. Two-station rack for closed-loop systems.
2. Four-station rack for open systems.

2.8 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1 "Performance Requirements" Article.

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2.9 FILTRATION EQUIPMENT

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

a. Alamo Water Treatment; Ecodyne Water Treatment, Inc.
b. Culligan International.
c. Griswold Controls.
d. LAKOS; a div. of Claude Laval Corporation.
e. PEP Filters, Inc.
f. Puroflux Corporation.
g. Rosedale Products, Inc.
h. USFilter.

2. Description: Simplex separator housing with baffles and chambers for removing particles from water by centrifugal action and gravity.
3. Housing: With manufacturer's proprietary system of baffles and chambers.

a. Construction: Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
b. Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
c. Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
d. Collection Chamber: Designed to hold separated particles.
e. Outlet: Near top of unit.
f. Purge: At bottom of collection chamber.
g. Pipe Connections NPS 2 and Smaller: Threaded according to ASME B1.20.1.
h. Pipe Connections NPS 2-1/2 and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.

4. Motorized Purge Valve: Gate or plug pattern valve.

a. Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with EPDM valve seat and stem seal; with ASTM B 148 aluminum bronze disc.

5. Strainer: Stainless-steel basket type mounted on pump suction.
6. Piping: ASTM A 53, Type S or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
7. Piping: ASTM B 88, Type L copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
8. Vertical Lift Check Valves shall be provided at the discharge of each pump. Valves shall comply with these requirements:
a. Size 3/8" thru 2". Bronze body, threaded or sweat connection, renewable teflon disc and seat, copper or stainless steel spring loaded, stainless steel or silicone bronze stem, Class 125.
b. Size 2-1/2" thru 10". Iron wafer type body, taped lug connection, renewable bronze disc and seat, stainless steel spring loaded, bronze guide pin, Class 125

9. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.

    a. Casing: Radially split, cast iron.
    b. Pressure Rating: 125 psig minimum.
    c. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
    d. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
    e. Seal: Mechanical.
    f. Motor: ODP motor for indoor use and TEFC motor for outdoor use, supported on the pump-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

10. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.

    a. Panel: NEMA 250, Type 4 enclosure.
    b. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
    c. Separator Purge: Automatic and manual.
    d. TDS Controller Interlock: Open separator purge valve with bleed-off control.

11. Support: Skid mounting.

PART 3 - EXECUTION

3.1 GENERAL

A. Each piping system is to be provided with the specified hardware. Where multiple evaporative condensers or closed circuit fluid coolers are specified, each is to be provided with its own chemical feed equipment.

B. All products shall be installed or services performed in strict accordance with the manufactures written installation/procedure instructions.

C. All piping systems and related equipment shall be thoroughly flushed with pre-cleaning detergent and dispersant designed to remove deposition from construction, such as pipe dope, oils, most loose mill scale, and other extraneous materials. The products used shall inhibit corrosion of the various metals in the system and shall be safe to handle and use. Effectiveness of the product shall be such that the water need only be at ambient temperatures. Contractor is cautioned to be sure temperature and pressure in system during flushing does not cause rupture disc on chiller or relief valves etc. to blow.

D. Recommended Flushing Sequence:

1. Fill system with clear water and flush at a minimum velocity of 5 feet per second, until the water is relatively clear, bleeding out at low points, strainer blow-downs, etc, while circulating to help remove any debris that has been dislodged. Piping should be isolated or bypassed to prevent flow through coils, control valves and balancing valves, especially during the initial flush of heavy debris.
2. For systems that do not contain aluminum or galvanized metal, add detergent in concentration recommended by water treatment manufacturer and flush with detergent for 12-24 hours, frequently flushing at all low point drains, and blowing down pipe strainers with the piping isolated to prevent flow through coils.
3. When the cleaning time is complete, open high point vents and drain the system completely to a location acceptable to DEP and local jurisdictions.
4. Refill the system with fresh water and circulate to mix.
5. Initiate bleed-and-feed and flush the system until the water is clear from detergent foam. To prevent air from entering the system, be sure to never bleed water faster than make-up water is being added.
6. Drain system. Remove and clean all strainer baskets. During the draining process, the circulating pumps shall be in continuous operation to prevent settling, and circulation and draining shall continue until the total alkalinity and pH of the water is equal to the makeup water.
7. Refill system and add passivation chemicals and circulate for 5-7 days to coat inside of cleaned pipe with inhibitor.
8. Initiate bleed-and-feed and flush until phosphate level is below 10 parts per million. As soon as target phosphate level is reached, immediately add the recommended amount of corrosion inhibitor to the system.

E. Install chemicals required for treatment of each system within 24 hours of completion of cleaning prior to start-up and operation of the system. Contractor shall measure water quantity required to fill system and provide this information to water treatment equipment supplier and tabulate this data in the operation and maintenance manuals.

F. After cleaning and filling the mechanical system, operate the system for a period of one year, one visit per month during that time. Testing and sampling shall continue until the graph indicates the water treatment is maintaining the specified levels of 800 PPM to 1200 PPM of Nitrites and a maximum of 1 PPM of total iron levels of chemical within plus or minus 10% under all conditions of load. T.T. Cobra Tech and Biostat shall also be added to the system.

G. After the system is flushed, pre-cleaned and chemically stabilized the Contractor shall:

1. Turn the test kits over to the owner.
2. Instruct the owner in proper maintenance procedures.
3. Fulfill all obligations for the specified period of 1 year from the date of startup including four (4) service calls during the cooling season and two (2) service calls during the heating season.

3.2 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.3 INSTALLATION

A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.

B. Install water testing equipment on wall near water chemical application equipment.

C. Install interconnecting control wiring for chemical treatment controls and sensors.

D. Mount sensors and injectors in piping circuits.

E. Bypass Feeders: Install in closed hydronic systems, including chilled water, and equipped with the following:

1. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
2. Install side stream filter in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
3. Install water meter in makeup water supply.
4. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
5. Install a full-port ball isolation valves on inlet, outlet, and drain below feeder /filter inlet.
6. Install a swing check on inlet after the isolation valve.
7. Install a [flow meter] at outlet of filter.

F. Install automatic chemical-feed equipment for condenser water and include the following:

1. Install makeup water softener.
2. Install water meter in makeup water supply.
3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.

   a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into condenser water piping as shown on drawings.

4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
5. Install TDS controller with sensor and bleed valves.
    a. Bleed valves shall cycle to maintain maximum TDS concentration.
6. Install pH, conductivity and orp sensors with integral controller, injection pumps and solution tanks.
    a. Injector pumps shall operate to maintain required pH and orp.
7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
    a. Injection pumps shall operate to feed biocide on an alternating basis.

G. Install corrosion resistant drip pan, a minimum of 3 inches high, under tanks and pumps. Intent is to contain minor leaks.

3.4 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to equipment to allow service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Common Work Results for HVAC."

D. Install unions, shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in other Division 23 Sections.

E. Refer to Division 22 Section "Domestic Water Piping Specialties" for backflow preventers required in makeup water connections to potable-water systems.

F. Confirm applicable electrical requirements in Division 26 Sections for connecting electrical equipment.

G. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

H. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

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

B. Perform tests and inspections and prepare test reports.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing. Install and retrieve corrosion coupons every 90 days to generate quarterly reports on corrosion rates of steel and copper with photographic images of the coupons.

C. Tests and Inspections:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials and retest piping until no leaks exist.

D. Remove and replace malfunctioning units and retest as specified above.

E. Comply with ASTM D 3370 and with the following standards:

1. Silica: ASTM D 859.
2. Steam System: ASTM D 1066.
3. Acidity and Alkalinity: ASTM D 1067.
4. Iron: ASTM D 1068.
5. Water Hardness: ASTM D 1126.
6. Chloride: ASTM D4458
7. Copper: ASTM D1688
8. pH: ASTM D5464

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

B. Training: Provide a minimum of 4 hours of training on handling and testing of treatment chemicals with "how-to-use" video that details exact operating procedures of equipment.

END OF SECTION 23 25 00

SECTION 23 25 00.01 - PCA WATER TREATMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 WORK INCLUDED

A. Feeding and Control Equipment with all Piping and Wiring for each System.

B. Closed Loop Temporary Filter.

C. Pre-Operation Cleaning of each System.

D. Initial Water Analysis and Recommendations.

E. Water Treatment Chemicals for each System.

F. Test Equipment.

G. Training of Operating Personnel Including Written Instructions, Log Sheet and Record Forms.

H. Follow-up Service for One Full Year from date of Start-up including Laboratory Assistance.

1.3 SYSTEMS TO BE TREATED

A. Glycol Water (GWS/GWR).

B. Chilled Water (CHS/CHR).

C. Condenser Water - Closed Loop (CWS/CWR).

1.4 QUALITY ASSURANCE

A. All electrical components shall be UL or ETL listed or labeled.

B. All wiring shall conform to the NEC.

C. The pre-cleaning and chemical charging shall be by or supervised by personnel trained in the field of water treatment. Chemicals shall be charged into the system within 24 hours of flushing and during circulation.

D. All chemicals shall be compatible with system materials of construction and shall comply with all applicable EPA and regulatory agency standards.

E. After charging of the system and for a period of one (1) full year after the date of start up the water treatment supplier shall periodically inspect the system and perform all necessary tests (minimum of 4) to properly evaluate the chemical concentration.

F. After completion of the system the water treatment supplier shall train the owner in the proper maintenance procedures and future system requirements.

G. After completion of the system water treatment, the contractor shall provide a water analysis and certify in writing to the Owners Representative that the system or systems have been properly flushed, cleaned and charged with the proper chemical concentration and that the Owner has been instructed in proper maintenance procedures.

H. Corrosion coupon analysis by manufacturer's laboratory with test report at the end of the first year of operation.

1.5 SUBMITTALS

A. Submit schedule indicating make, model and size by system.

B. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

C. Submit letter of certification as described in 1.4.G.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Kibler Chemical Corporation

B. Betz Entec

C. Premier Water Technology

D. The Nalco Chemical Company

E. Garratt-Callahan Company

2.2 PIPING SYSTEMS AND WATER TREATMENT SYSTEMS

A.	Glycol Water (GWS/GWR)	:	Closed Loop
B.	Chilled Water (CHS/CHR)	:	Closed Loop
C.	Condenser Water (CWS/CWR)	:	Closed Loop

2.3 WATER TREATMENT REQUIREMENTS

A. Closed Loop:

1. General: Manual feeding of chemicals into filter style shot feeder and in turn into system in accordance with initial water evaluation and continuing test result requirements.
2. Feeding and Control Equipment:
   a. Five gallon combination filter-feeders, quantity as shown on drawings. Efficiency Dynamics, Ft. Worth, TX 76101, FF- 100 Owner approved substitution, including steel shell with stainless steel basket, filter bag capable of 40 gpm flow with filter efficiency of 5 microns at 3 psi pressure drop and hand removable cap. Suitable for 150 psi and temperatures to 200°F.
   b. Twelve filter bags or provide one if filter is cleanable.
   c. Corrosion coupon rack including corrosion probe connection fittings, one carbon steel and one copper corrosion coupon with holders and two (2) corrosion coupon tees.
   d. Totalizing make-up water meter equal to Master Meter Multi-Jet or Owner approved substitution for installation in make-up water line. Meter to be sized per the plumbing drawings and shall have contacts for monitoring by the Building Control System.
   e. Installation accessories including piping, fittings, shut off valves, drain valves, pressure gauges to measure pressure loss thru filter and automatic flow control valve set for 8 GPM as specified in Section 230523 – General-Duty Valves for HVAC Piping.
3. Closed Loop Temporary Filter:
   a. Provide an HPF-1665-1-CL ANCOPure™ HPF Closed Loop Filter on the chilled water system. The filter must be installed and operational from the start-up of the chillers through substantial completion. The Owner shall be provided with a sample of the water each month from the contractor and the filter shall not be removed until the Owner and Engineer have signed off on the water quality.
      1) Provide 1-one 16”x65” Polyglass filter tank, rated for 100 PSI maximum design pressure
      2) Piping shall be 1” with a 1” multiport control valve
      3) 100 lbs. of gravel per tank
      4) Filter Media: HPF
      5) Filtered Particulate Size: 5 Microns
      6) Quantity of Filter Media Per Tank: 4 FT3
      7) Inlet/Outlet Gauge Set w/ Sample Valve: 0-160 PSI
      8) Normal Service Flow Rate: 17 GPM
      9) Peak Flow Rate: 14 GPM
      10) Backwash Flow Rate: 100
4. Water Treatment Chemicals:
   a. All chemicals necessary for flushing and pre- cleaning.
   b. All chemicals, in liquid form, necessary to control scale, corrosion, microbiological growth and water PH. Quantity to last 1 full year from date of start up.
5. ~~Side Stream Cartridge Filter System:~~
   a. ~~Housing: A round multi-filter housing constructed of carbon steel with a 150 psi pressure rating at 300°F. The housing design shall include a~~

~~large rounded bottom sump area so that the filter baskets may have a rounded bottom for particulate accumulation. The top portion of the fixed housing shall be equipped with a carbon steel plate with holes cut for the filter baskets. Filter basket holes shall be equipped with buna o-ring gaskets to prevent bypass around filter. Housing shall include a davit swing arm to remove the top for access to filter housings. Access to the housing shall be through the use of swing bolts with eye-nuts. Housing shall also include the following features: vent and drain port and gauge ports to measure differential pressure across the filter media. Piping connections shall be either ANSI 150# flanges or grooved for mechanical joint connection. The entire assembly shall be sand blasted and finished inside and out with a two part epoxy finish.~~

~~b. Filter Baskets: A 316 stainless steel basket with perforations. Basket shall be designed to accept standard liquid bags.~~

~~c. Liquid Filter Bags: Heavy duty filter media designed to filter at least 46 GPM of water per square foot of filter area with a maximum pressure loss of 8 psig at this valve. Filter media shall be suitable for intended fluid and shall have a filter rating of 5 microns absolute. Provide two complete spare sets of filters.~~

~~d. Based on Krystil Klean Multi-Round Liquid Bag Housing.~~

2.4 GLYCOL SOLUTION

A. The glycol piping system shall be filled with a brine solution made up of 3 parts water and 1 part ethylene ~~propylene~~ glycol (25 percent mixture).

B. Manufacturer: Refer to the paragraph entitled "MANUFACTURERS" in Section 230100.

1. Union Carbide
2. Dow Chemical

2.5 TEST EQUIPMENT

A. Test equipment to properly evaluate the chemical levels within the system. The test equipment shall include but not be limited to: Carrying case or cabinet, all necessary reagents for determination of corrosion inhibitor level pH, P & M, alkalinity and chlorides as well as microbiological colony population and biocide effectiveness.

PART 3 - EXECUTION

3.1 GENERAL

A. Each piping system is to be provided with the specified hardware. Where multiple evaporative condensers or closed circuit fluid coolers are specified, each is to be provided with its own chemical feed equipment.

B. All products shall be installed or services performed in strict accordance with the manufactures written installation/procedure instructions.

C. All piping systems and related equipment shall be thoroughly flushed with pre-cleaning detergent and dispersant designed to remove deposition from construction, such as pipe dope, oils, most loose mill scale, and other extraneous materials. The products used shall inhibit corrosion of the various metals in the system and shall be safe to handle and use. Effectiveness of the product shall be such that the water need only be at ambient temperatures. Contractor is cautioned to be sure temperature and pressure in system during flushing does not cause rupture disc on chiller or relief valves etc. to blow.

D. Recommended Flushing Sequence:

1. Fill system with clear water and flush at a minimum velocity of 5 feet per second, until the water is relatively clear, bleeding out at low points, strainer blow-downs, etc, while circulating to help remove any debris that has been dislodged. Piping should be isolated or bypassed to prevent flow through coils, control valves and balancing valves, especially during the initial flush of heavy debris.
2. For systems that do not contain aluminum or galvanized metal, add detergent in concentration recommended by water treatment manufacturer and flush with detergent for 12-24 hours, frequently flushing at all low point drains, and blowing down pipe strainers with the piping isolated to prevent flow through coils.
3. When the cleaning time is complete, open high point vents and drain the system completely to a location acceptable to DEP and local jurisdictions.
4. Refill the system with fresh water and circulate to mix.
5. Initiate bleed-and-feed and flush the system until the water is clear from detergent foam. To prevent air from entering the system, be sure to never bleed water faster than make-up water is being added.
6. Drain system. Remove and clean all strainer baskets. During the draining process, the circulating pumps shall be in continuous operation to prevent settling, and circulation and draining shall continue until the total alkalinity and pH of the water is equal to the makeup water.
7. Refill system and add passivation chemicals and circulate for 5-7 days to coat inside of cleaned pipe with inhibitor.
8. Initiate bleed-and-feed and flush until phosphate level is below 10 parts per million. As soon as target phosphate level is reached, immediately add the recommended amount of corrosion inhibitor to the system.

E. Install chemicals required for treatment of each system within 24 hours of completion of cleaning prior to start-up and operation of the system. Contractor shall measure water quantity required to fill system and provide this information to water treatment equipment supplier and tabulate this data in the operation and maintenance manuals.

F. After cleaning and filling the mechanical system, operate the system for a period of one year, one visit per month during that time. Testing and sampling shall continue until the graph indicates the water treatment is maintaining the specified levels of 800 PPM to 1200 PPM of Nitrites and a maximum of 1 PPM of total iron levels of chemical within plus or minus 10% under all conditions of load. T.T. Cobra Tech and Biostat shall also be added to the system.

G. After the system is flushed, pre-cleaned and chemically stabilized the Contractor shall:

1. Turn the test kits over to the owner.
2. Instruct the owner in proper maintenance procedures.
3. Fulfill all obligations for the specified period of 1 year from the date of start up including four (4) service calls during the cooling season and two (2) service calls during the heating season.

H. Where the owner provides the chemicals for treatment, notify the owner well in advance of the cleaning process and when completed advise in writing that it is recommended that the chemicals be charged immediately to prevent damage to the system.

3.2 GLYCOL SYSTEM FILL

A. Coordinate with the Owner for shut-down and isolation of the branch piping to be effected by this scope of work. Capture drained glycol for proper disposal, and use new pre-mixed solution to fill system. The glycol system serves both the Preconditioned Air Units (PCA), and the Boarding Bridge AHUs; therefore, the contractor is responsible for the entire system water treatment, glycol levels, and air management as impacted by this work.

END OF SECTION 23 25 00.01

SECTION 23 3113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round and flat-oval ducts and fittings.
4. Double-wall round and flat-oval ducts and fittings.
5. Sheet metal materials.
6. Duct liner.
7. Sealants and gaskets.
8. Hangers and supports.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

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

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7.

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.4 SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.

B. LEED V4 BD+C Submittals:

1. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
   a. Product Data for Metal Ductwork: Documentation for Leadership Extraction Practices in the following:
      1. Leadership Extraction Practices for Recycled Content
      2. Provide material cost breakout for this scope of work

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top and bottom of ducts.
5. Dimensions of main duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment and vibration isolation.

D. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.

3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items penetrating finished ceiling including the following:

    a. Lighting fixtures.
    b. Air outlets and inlets.
    c. Speakers.
    d. Sprinklers.
    e. Access panels.
    f. Perimeter moldings.

E. Welding certificates.

F. Field quality-control reports.

1.5 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to: AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

D. Mockups:

1. Before installing duct systems, build mockups representing static-pressure classes in excess of 3-inch wg. Build mockups to comply with the following requirements, using materials indicated for the completed Work:

    a. Five transverse joints.
    b. One access door(s).
    c. Two typical branch connections, each with at least one elbow.
    d. Two typical flexible duct or flexible-connector connections for each duct and apparatus.
    e. One 90-degree turn(s) with turning vanes.
    f. One fire damper(s).
    g. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

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

B. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

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

1. McGill AirFlow LLC.
2. Semco Manufacturing, Inc.
3. Sheet Metal Connectors, Inc.

B. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.

C. Outer Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

D. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

F. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Coat insulation with antimicrobial coating.
4. Cover insulation with polyester film complying with UL 181, Class 1.

G. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

1. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

H. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent.

I. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible (2005)," Figure 2-1, "Rectangular Duct/Traverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

J. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SINGLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

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

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

   a. Lindab Inc.
   b. McGill AirFlow LLC.
   c. SEMCO Incorporated.
   d. Sheet Metal Connectors, Inc.
   e. Spiral Manufacturing Co., Inc.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

C. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

D. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

E. Tees and Laterals: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.4 DOUBLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

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

1. Lindab Inc.
2. McGill AirFlow LLC.
3. SEMCO Incorporated.
4. Sheet Metal Connectors, Inc.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.

C. Outer Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

1. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

   a. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

2. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

   a. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
   b. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

3. Tees and Laterals: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible (2005)," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for

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

D. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent.

E. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Coat insulation with antimicrobial coating.
4. Cover insulation with polyester film complying with UL 181, Class 1.

F. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

1. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

2.5 FLUSH FLAT SEAM RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class, except use sheet metal 2 gauge numbers heavier than required for classification with normal standing seam construction.

B. Transverse Joints: Fabricate joints in accordance with transverse joint detail shown on drawings. Provide all joints and seams, smooth, and alighted with no projections. In other aspects conform to the latest edition of SMACNA's "HVAC Duct Construction Standards" for applicable sealing requirements, duct-support intervals and other provisions.

C. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." Install ducts with longitudinal seams at lop of ducts.

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct

Construction Standards - Metal and Flexible," Chapter 2, "Rectangular Duct Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Reinforcing: Install vertical stays for interval reinforcement at transverse joints and at 2 foot intervals along run of duct, as follows:

1. Ducts up to 60 inches wide: Provide 1 vertical stay at mid-point of duct.
2. Ducts 61 inches to 90 inches wide: Provide 2 vertical stays at third points of duct.
3. Ducts over 90 inches wide: Provide 3 vertical stays at quarter points of duct.
4. Vertical Stays: 10 USSG galvanized steel, free of burrs and rough edges, with both ends bent and fastened to the top and bottom of ducts.

2.6 SHEET METAL MATERIALS

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

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

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

C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Minimum Thickness for Factory-Applied PVC Coating: 4 mils on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil thick on opposite surface.
3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

D. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.

E. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

F. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

G. Factory- or Shop-Applied Antimicrobial Coating:

1. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested according to ASTM D 3363.
4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
5. Shop-Applied Coating Color: Black.
6. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.

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

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

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

J. Recycled Content of Metal Ductwork : Postconsumer recycled content plus one-half of pre-consumer recycled content not less than 30 percent.

1. Refer to Section 01 81 13.14 “Sustainable Design Requirements - LEED v4 BD+C” for additional information and requirements for recycled content.

2.7 DUCT LINER

A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

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

   a. CertainTeed Corporation; Insulation Group.
   b. Johns Manville.
   c. Knauf Insulation.
   d. Owens Corning.
   e. Maximum Thermal Conductivity:

1) Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2) Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

2. Factory- and Shop-Applied antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

   a. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

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

   a. Aeroflex USA Inc.
   b. Armacell LLC.
   c. Rubatex International, LLC

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

   a. For indoor applications, use adhesive that has a VOC content of 30 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length

to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick galvanized steel; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

D. Shop Application of Duct Liner: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm or higher.
7. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

   a. Fan discharges.
   b. Intervals of lined duct preceding unlined duct.
   c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

9. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.

   a. Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

10. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.8 SEALANT AND GASKETS

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

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: As per manufacturer’s written instructions.
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
10. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
11. Sealant shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers.” Retain one of first two paragraphs below. If retaining second paragraph, verify acceptability with authorities having jurisdiction.

C. Water-Based Joint and Seam Sealant:

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

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

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.

4. Class: 25.
5. Use: O.
6. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

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

F. Round Duct Joint O-Ring Seals:

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

2.9 HANGERS AND SUPPORTS

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

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

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

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

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

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

H. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.

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

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

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

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

C. Install round and flat-oval ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

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

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

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

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

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

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

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with the latest edition of SMACNA's "Duct Cleanliness for New Construction Guidelines" and in accordance with specification section 01 34 46, which ever is more stringent.

3.2 INSTALLATION OF EXPOSED DUCTWORK

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

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

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

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

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

3.3 INSTALLATION OF DUCTS OUTDOORS

A. Ducts shall be made completely watertight.

B. Construct ducts as follows to assure water run-off.

1. Arrange standing seams so as not to act as dams.
2. Erect ducts with longitudinal seams at bottom of duct.
3. Slope entire top of duct down towards side.
4. Provide vertical struts within duct to bow tap panels of duct into convex shape.
5. Erect ducts with mastic sealant within sheet metal joints.

3.4 DUCT SEALING

A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Mastic sealant shall comply with California Department of Public Heath (CDPH) Standard Method v1.1 – 2010, and evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Envirnomental Chambers and VOC requirements.

C. Seal ducts to the following seal classes according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Outdoor, Supply-Air Ducts: Seal Class A.
3. Outdoor, Exhaust Ducts: Seal Class A.
4. Outdoor, Return-Air Ducts: Seal Class A.
5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
7. Unconditioned Space, Exhaust Ducts: Seal Class A.
8. Unconditioned Space, Return-Air Ducts: Seal Class A.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
11. Conditioned Space, Exhaust Ducts: Seal Class A.
12. Conditioned Space, Return-Air Ducts: Seal Class B.

3.5 HANGER AND SUPPORT INSTALLATION

A. Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

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

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

C. Hanger Spacing: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

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

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

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

3.6 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."

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

3.7 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

3.8 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with the latest edition of SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Test the following systems:

    a. All ducts which are (1) under positive or negative pressure and (2) which are connected to an air moving device (air handling unit, exhaust fan, supply fan or similar air moving equipment) and (3) which convey 1000 cfm or greater through their largest portion.
    b. All ducts which are (1) under positive or negative pressure and (2) which are part of a supply, return, outside and exhaust air system and (3) which are equal to or greater than 25 feet in length and (4) which may or may not be directly connected to an air moving device.

c. All supply ducts which are (1) connected to an air moving device (air handling unit, exhaust fan, supply fan or similar air moving equipment) and (2) which convey 1000 cfm or greater through their largest portion.
d. All return ducts which are (1) which are part of a return and outside air system and (2) which are equal to or greater than 25 feet in length and (3) which may or may not be directly connected to an air moving device.
e. All exhaust ducts which are (1) which are part of a general and toilet room exhaust air system and (2) which are equal to or greater than 25 feet in length and (3) which may or may not be directly connected to an air moving device.
f. All exhaust ducts which make up a part of the smoke management system including return air ducts for air handling systems which are converted into smoke exhaust ducts.

3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
4. Test for leaks before applying external insulation.
5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
6. Give seven days' advance notice for testing.

C. Test Procedure:

1. Test at the time of duct installation, prior to installation of any field-applied insulation and prior to any concealment in chases or similar enclosures.
2. Duct entry and outlet openings shall be capped or sealed prior to pressurizing the duct. The seal shall be of adequate strength and thickness to withstand the test pressures.
3. Use a fan having a minimum capacity of 300 cfm or 10 percent of the particular duct system design capacity, whichever is greater and which is capable of producing a static pressure equal to the duct test pressure.
4. Test fan shall be connected to a flow measuring assembly consisting of straightening vanes and an orifice plate mounted in a straight section with appropriately located pressure taps. Orifice assembly shall be calibrated with its own calibration curve. Pressures shall be measured with U-tube manometers and corresponding flow rates shall be obtained from the orifice performance curve.
5. Connect test fan and orifice flow measuring assembly to the duct to be tested with a section of flexible duct.
6. Test for audible leaks as follows:

a. Close off and seal all openings in the duct section to be tested.
b. Start the blower with its control damper partially closed.
c. Gradually open the control damper until the duct pressure reaches the designed duct operating pressure.

d. Survey all joints for audible leaks. Mark each leak and repair after shutting down blower. Do not apply a retest until sealing has been repaired and allowed to set.

7. After all audible leaks have been sealed, the remaining leakage should be measured with the orifice section of the test apparatus as follows:

a. Start blower and open damper until the pressure in duct reaches the designed duct operating pressure.
b. When partial sections (such as supply section, return section, etc.) of the duct system are tested, the summation of the leakage for all sections shall not exceed the total allowable leakage.

8. Correct any duct leaks which are detected either audibly or by touch regardless of whether leakage through duct system is less than allowable test leakage.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.9 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing. Submit duct cleaning procedures and methodologies for review.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

    a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

    b. Submit test results to Owner for review and approval. Any test results failed to comply with Acceptable Cleanliness Level shall be cleaned and retested.

3.10 START UP

A. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC."

3.11 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

1. Underground Ducts: Concrete-encased PVC-coated, galvanized sheet steel with thicker coating on duct exterior.

2. Ducts serving Agriculture Lab and Bird Quarantine: Rigid aluminum duct.

B. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 10 feet downstream of all terminal units. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Constant-Volume Air-Handling Units and DOAS Units:

a. Pressure Class: Positive 4-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Variable-Air-Volume Air-Handling Units:

a. Pressure Class: Positive 4-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

4. Ducts Connected to Equipment Not Listed Above:

    a. Pressure Class: Positive 4-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 3.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.
    e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

C. Return Ducts and AHU, DOAS Return/Exhaust Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.
    e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Air-Handling Units, DOAS units:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.
    e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Equipment Not Listed Above:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 3.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.
    e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

a. Pressure Class: Negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Air-Handling Units and DOAS units:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

a. Exposed to View: Type 304, stainless-steel sheet, No. 4 finish.
b. Concealed: Type 304, stainless-steel sheet, No. 2D finish.
c. Welded seams and joints.
d. Pressure Class: Positive or negative 4-inch wg.
e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
f. SMACNA Leakage Class: 3.
g. Slope ductwork towards equipment/source.
~~g.~~h. Duct shall be insulated with a field-applied grease duct enclosure in accordance to ASTM E 2336, refer to Section 23 07 19 HVAC Insulation.

4. Ducts Connected to Dishwasher Hoods:

a. Type 304, stainless-steel sheet.
b. Exposed to View: No. 4 finish.
c. Concealed: No. 2D finish.
d. Welded seams and flanged joints with watertight EPDM gaskets.
e. Pressure Class: Positive or negative 4-inch wg.
f. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
g. SMACNA Leakage Class: 3.
h. Slope ductwork towards equipment/source.
i. Duct shall be insulated with a field-applied grease duct enclosure in accordance to ASTM E 2336, refer to Section 23 07 19 HVAC Insulation.
~~h.~~j.

5. Ducts Connected to Smoke Exhaust Systems:

a. Pressure Class: Positive or negative 6-inch wg.

b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round: 3.
e. Duct materials and joints shall be capable of withstanding the probable temperatures and pressures to which they are exposed as determined by the IMC. Ducts shall be leak tested to 1.5 times the maximum design temperature. Measured leakage shall not exceed 5 percent of design flow.

6. Ducts Connected to Fans Exhausting Process (ASHRAE 62.1, Class 3 and 4) Air:

a. Type 316, stainless-steel sheet.
   1) Exposed to View: No. 4 finish.
   2) Concealed: No. 2B finish.

b. Pressure Class: Positive or negative 3-inch wg (750 Pa).
c. Minimum SMACNA Seal Class: A, welded seams, joints, and penetrations.
d. SMACNA Leakage Class: 3.

7. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.

2. Ducts Connected to Air-Handling Units:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.

3. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel.
2. PVC-Coated Ducts:

   a. Exposed to Airstream: Match duct material.
   b. Not Exposed to Airstream: Galvanized.

3. Stainless-Steel Ducts:

   a. Exposed to Airstream: Match duct material.
   b. Not Exposed to Airstream: Match duct material.

4. Aluminum Ducts: Aluminum.

G. Liner:

1. Duct liner shall meet or exceed insulation “R” values. See Specification Section 23 07 19 “HVAC Insulation.”

2. Supply Air Ducts: Flexible elastomeric, 2 inches thick.

3. Return Air Ducts: Flexible elastomeric, 1 inches thick.

4. Exhaust Air Ducts: Flexible elastomeric, 1 inch thick.

5. Supply Fan Plenums: Flexible elastomeric, 2 inches thick.

6. Return- and Exhaust-Fan Plenums: Fibrous glass, 2 inches thick.

7. Transfer Ducts: Fibrous glass, Type I, 1 inch thick.

H. Elbow Configuration:

1. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

   a. Velocity 1000 fpm or Lower:

      1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
      2) Mitered Type RE 4 without vanes.

   b. Velocity 1000 to 1500 fpm:

      1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.

2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

c. Velocity 1500 fpm or Higher:

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
c. Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

3. Round Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

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

1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
4) Radius-to Diameter Ratio: 1.5.

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

I. Branch Configuration:

1. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

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

2. Round and Flat Oval: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

   a. Velocity 1000 fpm or Lower: 90-degree tap.
   b. Velocity 1000 to 1500 fpm: Conical tap.
   c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 23 31 13

SECTION 23 33 00 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Backdraft dampers.
2. Manual volume dampers.
3. Fire dampers.
4. Smoke dampers.
5. Combination fire and smoke dampers.
6. Turning vanes.
7. Remote damper operators.
8. Duct-mounted access doors.
9. Flexible connectors.
10. Duct security bars.
11. Duct accessory hardware.
12. Wire mesh grilles.

B. Related Sections:

1. Division 23 Section "HVAC Gravity Ventilators" for roof-mounted ventilator caps.
2. Division 28 Section "Fire Detection and Alarm" for duct-mounted fire and smoke detectors.

1.3 SUBMITTALS

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

1. For all accessories specified, include construction details, dimensions, materials, finishes, bearings and compliance with applicable codes.
2. Performance: Show compliance with pressure drops or specific requirements noted.
3. Provide manufacturer’s installation instructions.
4. For duct silencers/sound attenuators, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. LEED V4 BD+C Submittal:
   1. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
      a. Product Data for Metal Ductwork: Documentation for Leadership Extraction Practices in the following:
         1. Leadership Extraction Practices for Recycled Content
         2. Provide detailed material cost data for this scope of work.

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

   1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

      a. Special fittings.
      b. Manual volume damper installations.
      c. Control damper installations.
      d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
      e. Duct security bars.
      f. Wiring Diagrams: For power, signal, and control wiring.

D. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

E. Source quality-control reports.

F. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.4 QUALITY ASSURANCE

A. All products provided for enhancement of Life Safety shall be UL listed and bear the appropriate label stating compliance.

B. All Products to have a Florida Product Approval Number, as required by the Florida Building Code (FAC 9N-3).

C. All products located in the conditioned air stream or located in return air plenums shall conform to the NFPA 90A Flame/Smoke/Fuel Contribution of 25/50/0 and all other applicable requirements of NFPA 90A.

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

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

F. Demonstrate resetting of fire dampers to authorities having jurisdiction and Owner’s representatives.

G. Smoke and Smoke/Fire dampers shall be provided with a 60 month from the date of shipment parts only warranty, including freight for all components, including damper operators.

1.5 EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fusible Links: Furnish quantity equal to 10 percent of amount installed, or a minimum quantity of five of each type installed.

2. Fire Smoke Damper Actuators: Furnish quantity equal to 10 percent of amount installed, or a minimum quantity of five of each type installed.

3. Fire Smoke Dampers: In addition to quantity indicated on drawings furnish ten (10) additional fire smoke dampers 24x24 or equivalent size per each floor in Landside and 10 per each floor In Airside.

4. Fire Dampers: In addition to quantity indicated on drawings furnish ten (10) additional fire dampers 24x24 or equivalent size per each floor in Landside and 10 per each floor In Airside.

PART 2 - PRODUCTS

2.1 MATERIALS

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

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

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

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2D finish for concealed ducts and a No. 2B finish for exposed ducts.

D. Aluminum Sheets: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

E. Extruded Aluminum: Comply with ASTM B 221, Alloy 6063, Temper T6.

F. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

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

2.2 BACKDRAFT DAMPERS

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

1. Air Balance Inc.; a division of Mestek, Inc.
2. Duro Dyne Inc.
3. Greenheck Fan Corporation.
4. Ruskin Company.
5. Vent Products Company, Inc.
6. Nailor Industries, Inc.

B. Description: Gravity balanced.

C. Maximum Air Velocity: 2000 fpm.

D. Maximum System Pressure: 1-inch wg.

E. Frame: Minimum 16 gauge (0.064-inch thick) galvanized sheet steel or extruded aluminum, with welded corners and mounting flange.

F. Blades: Multiple single-piece blades, maximum 6-inch width, minimum 16 gauge (0.064-inch thick) galvanized steel or extruded aluminum, with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: Neoprene, mechanically locked.

I. Blade Axles:

1. Material: Galvanized steel or aluminum.
2. Diameter: 0.20 inch minimum.

J. Tie Bars and Brackets: Aluminum or galvanized steel.

K. Return Spring: Adjustable tension.

L. Bearings: Steel ball or synthetic pivot bushings.

M. Accessories:

1. Adjustment device to permit setting for varying differential static pressure.
2. Counterweights and spring-assist kits for vertical airflow installations.
3. Electric actuators.
4. Chain pulls.
5. Screen Mounting: Front mounted in sleeve.
    a. Sleeve Thickness: 20-gauge minimum.
    b. Sleeve Length: 6 inches minimum.
6. Screen Mounting: Rear mounted.
7. Screen Material: Galvanized steel or aluminum.
8. Screen Type: Bird.
9. 90-degree stops.

2.3 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Air Balance Inc.; a division of Mestek, Inc.
    b. McGill AirFlow LLC.
    c. Ruskin Company.
    d. Greenheck, Inc.
2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:
    a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
    b. Mitered and welded corners.
    c. Flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:
    a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
    b. Opposed-blade design for multiple blades dampers.
    c. Round or oval ducts: butterfly type.
    d. Stiffen damper blades for stability.
    e. Galvanized-steel, 0.064 inch thick.
6. Blade Axles: Galvanized steel.

7. Bearings:

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

8. Tie Bars and Brackets: Galvanized steel.

B. Standard, Aluminum, Manual Volume Dampers:

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

   a. Air Balance Inc.; a division of Mestek, Inc.
   b. McGill AirFlow LLC.
   c. Ruskin Company.
   d. Greenheck, Inc.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames: Hat-shaped, 0.10-inch-thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

   a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
   b. Opposed-blade design for multiple blades dampers.
   c. Stiffen damper blades for stability.
   d. Roll-Formed Aluminum Blades: 0.10-inch- thick aluminum sheet.
   e. Extruded-Aluminum Blades: 0.050-inch- thick extruded aluminum.

6. Blade Axles: Nonferrous metal.
7. Bearings:

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

8. Tie Bars and Brackets: Aluminum.

C. Low-Leakage, Steel, Manual Volume Dampers:

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

   a. Air Balance Inc.; a division of Mestek, Inc.
   b. McGill AirFlow LLC.
   c. Ruskin Company.
   d. Vent Products Company, Inc.

e. Greenheck, Inc.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
3. Suitable for horizontal or vertical applications.
4. Frames:

   a. Hat, U or Angle shaped.
   b. Galvanized-steel channels, 0.064 inch thick.
   c. Mitered and welded corners.
   d. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

   a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
   b. Opposed-blade design for multiple blades dampers.
   c. Stiffen damper blades for stability.
   d. Galvanized, roll-formed steel, 0.064 inch thick.

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

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

8. Blade Seals: Neoprene.
9. Jamb Seals: Cambered stainless steel.
10. Tie Bars and Brackets: Galvanized steel.
11. Accessories:

    a. Include locking device to hold dampers in a fixed position without vibration.

D. Low-Leakage, Aluminum, Manual Volume Dampers:

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

   a. Air Balance Inc.; a division of Mestek, Inc.
   b. McGill AirFlow LLC.
   c. Ruskin Company.
   d. Vent Products Company, Inc.
   e. Greenheck, Inc.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
3. Suitable for horizontal or vertical applications.

4. Frames: Hat, U or Angle-shaped, 0.10-inch- thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

   a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
   b. Opposed-blade design for multiple blades dampers.
   c. Roll-Formed Aluminum Blades: 0.10-inch- thick aluminum sheet.
   d. Extruded-Aluminum Blades: 0.050-inch- thick extruded aluminum.

6. Blade Axles: Nonferrous metal.
7. Bearings:

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

8. Blade Seals: Neoprene.
9. Jamb Seals: Cambered stainless steel.
10. Tie Bars and Brackets: Aluminum.
11. Accessories:

    a. Include locking device to hold dampers in a fixed position without vibration.

E. Jackshaft:

1. Size: 1-inch diameter.
2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

F. Damper Hardware:

1. Zinc-plated, die-cast core with quadrant and lever handle made of 3/32-inch- thick zinc-plated steel, and a lockscrew.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform to clear insulation for insulated duct mounting.

2.4 FIRE DAMPERS

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

1. Air Balance Inc.; a division of Mestek, Inc.
2. Arrow United Industries; a division of Mestek, Inc.
3. McGill AirFlow LLC.

4. Ruskin Company.
5. Greenheck, Inc.
6. Prefco Products, Inc.

B. Type: Dynamic; UL listed and rated and labeled according to UL 555 by an NRTL. Conformance with NFPA 90A and authorities having jurisdiction.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 hours (UL approved for installation in 2 hour walls).

E. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: UL listed minimum gauge galvanized steel with welded construction corners. Rollformed sleeves will not be acceptable unless contractor guarantees in writing to seal voids in sleeve with UL approved sealer to limit air leakage. Length to suit application.
2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

G. Mounting Orientation: Dynamic spring closure type, vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch-thick, galvanized-steel blade connectors. At locations where duct size exceeds fire damper manufacturer’s height limit for Type B fire dampers, multiple blades fire dampers with the same ratings and construction requirements shall be used. Where installed in stainless steel or aluminum ductwork, use Type 304 stainless steel.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

J. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links constructed to UL Standard 33.

K. Heat-Responsive Device: Electric resettable link and switch package, factory installed, 165 deg F rated.

2.5 SMOKE DAMPERS

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

1. Air Balance Inc.; a division of Mestek, Inc.
2. Ruskin Company.
3. Prefco Products, Inc.
4. Greenheck, Inc.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: Integral, factory wired for single-point connection.

D. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.

E. Blades: Roll-formed, horizontal, interlocking, 0.034-inch-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch-thick, galvanized-steel blade connectors.

F. Leakage: Class II.

G. Rated pressure and velocity to exceed design airflow conditions.

H. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

I. Damper Motors: Modulating or two-position action as noted.

J. Damper and actuator shall be provided with a 60 month warranty.

K. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Electric motor actuator to be UL listed with damper assembly. Motor furnished with all connecting linkage and mounting hardware.
3. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC" and Division 26 Sections.
4. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
5. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
6. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
7. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.

8. Electrical Connection: 115 V or 24 V single phase, 60 Hz; or signal from smoke detector alarm circuit as required.

L. Accessories:

1. Auxiliary switches for signaling, fan control or position indication.
2. Test and reset switches, damper or remote mounted as required.

2.6 COMBINATION FIRE AND SMOKE DAMPERS

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

1. Air Balance Inc.; a division of Mestek, Inc.
2. Ruskin Company.
3. Cesco Products.
4. Prefco Products, Inc.

B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 4000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Multiple-blade type; fabricated with roll-formed, 0.064-inch-thick galvanized steel frame; with mitered and interlocking corners.

F. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

G. Heat-Responsive Device: Electric resettable link and switch package, factory installed, rated. Conform to NFPA 90A and NFPA 92A for fire and smoke dampers.

H. Smoke Detector: Integral, factory wired for single-point connection.

I. Blades: 14 gauge true airfoil design constructed of galvanized steel of low leakage non-heat degradable design with friction free inflatable silicone coated fiberglass material to maintain smoke leakage rating to a minimum of 450°F and galvanized steel for flame seal to 1900°F.

J. Leakage: Minimum UL Class II metal to metal, non-degradable, seals rated to minimum of 350°F.

K. Rated pressure and velocity to exceed design airflow conditions.

L. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking. Operator located exterior of sleeve.

M. Master control panel for use in dynamic smoke-management systems.

N. Damper Motors: Modulating or two-position action as noted.

O. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC" and Division 26 Sections.
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: 115 V or 24 V single phase, 60 Hz; or signal from smoke detector alarm circuit as required

P. Accessories:

1. Provide two (2) sets of auxiliary switches for monitoring FSD positions for FAS and BMS.
2. Test and reset switches, damper or remote mounted as required.

2.7 TURNING VANES

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

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. METALAIRE, Inc.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized steel, aluminum or stainless steel sheet, to match duct material; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

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

D. Vane Construction: Double wall.

2.8 REMOTE DAMPER OPERATORS

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

1. Ventfabrics, Inc.
2. Young Regulator Company.

B. Description: Cable system designed for remote manual damper adjustment.

C. Tubing: Brass.

D. Cable: Stainless steel.

Wall-Box Mounting: Recessed, 2 inches deep. Wall-Box Cover-Plate Material: Stainless steel.

E. Ceiling Mounting: Concealed ceiling mounting brackets, with cover plate and all necessary hardware for a complete installation. Cover plate finish to match ceiling finish.

1. High security areas: Provide tamper-proof threaded cap.

2.9 DUCT-MOUNTED ACCESS DOORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Ductmate Industries, Inc.
2. McGill AirFlow LLC.
3. Ventfabrics, Inc.
4. Ruskin.

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

1. Door:

a. Double wall, rectangular.
b. Sheet metal, to match duct material, with insulation fill and thickness as indicated for duct pressure class.
c. Vision panel.
d. Hinges and Latches: 2-by-2-inch butt or piano hinge and cam latches.
e. Fabricate doors airtight and suitable for duct pressure class.

f. Size: Not less than 16 inches by 14 inches. Ducts less than 16 inches in height, install with one dimension 16 inches and other dimension 2 inches less than duct width. Install larger sized doors where required for access.

2. Frame: Same material as door, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
b. Access Doors up to 18 Inches Square: Two hinges and two sash locks.
c. Access Doors up to 24 by 48 Inches: Three hinges and two compression latches with outside and inside handles.
d. Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

~~C. Pressure Relief Access Door:~~

~~1. Door and Frame Material: Sheet steel, to match duct material.~~
~~2. Door: Double wall with insulation fill with metal thickness applicable for duct pressure class.~~
~~3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.~~
~~4. Factory set at 10-inch wg.~~
~~5. Doors close when pressures are within set-point range.~~
~~6. Hinge: Continuous piano.~~
~~7. Latches: Cam.~~
~~8. Seal: Neoprene or foam rubber.~~
~~9. Insulation Fill: 1-inch- thick, fibrous-glass or polystyrene-foam board.~~

2.10 DUCT ACCESS PANEL ASSEMBLIES

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

1. Ductmate Industries, Inc.
2. Flame Gard, Inc.
3. 3M.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness 0.0528-inch carbon or 0.0428-inch stainless steel to match duct.

D. Fasteners: Carbon or Stainless steel to match. Panel fasteners shall not penetrate duct wall.

E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F.

F. Minimum Pressure Rating: 10-inch wg, positive or negative.

2.11 FLEXIBLE CONNECTORS

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

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. Ventfabrics, Inc.

B. Materials: Flame-retardant or noncombustible fabrics.

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

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide for all ducts except those with any size 13" and larger under positive pressure which shall be 5-3/4 inches wide attached to 2 strips of 2-3/4-inch- wide, 0.028-inch-thick, galvanized sheet steel or 0.032-inch-thick aluminum sheets. Provide metal compatible with connected ducts.

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

1. Minimum Weight: 30 oz./sq. yd.
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.
4. Pressure: 10" wg positive or negative.

F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to abrasion and damage due to repeated flexing, UV rays and ozone, waterproof and airtight.

1. Minimum Weight: 30 oz./sq. yd..
2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F.

G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.

1. Minimum Weight: 16 oz./sq. yd..
2. Tensile Strength: 285 lbf/inch in the warp and 185 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.

1. Minimum Weight: 14 oz./sq. yd..
2. Tensile Strength: 450 lbf/inch in the warp and 340 lbf/inch in the filling.

3. Service Temperature: Minus 67 to plus 500 deg F.

I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.

1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

2.12 DUCT SECURITY BARS

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

1. Carnes.
2. KEES, Inc.
3. Lloyd Industries, Inc.
4. Metal Form Manufacturing, Inc.
5. Price Industries.

B. Description: Factory-fabricated and field-installed duct security bars.

C. Configuration:

1. Frame: 10 gage by 2 inches.
2. Sleeve: 3/16-inch, bent steel frames with 1-by-1-by-3/16-inch angle frame factory welded to 1 end. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
3. Horizontal Bars: 2 by 1/4 inch.
4. Vertical Bars: 1/2 inch.
5. Bar Spacing: 6 inches.
6. Mounting: Metal deck or roofing. Bolted or welded with masonry anchors. Ductwork or other framing. Poured in place or set with concrete block. Welded or bolted to one wall (one side only).

2.13 WIRE MESH GRILLES

A. Construction: 1/2 inch (12.5 mm) mesh screen with 1 inch (2.5 mm) sheet metal frame, bolted to flanged duct connection.

B. Materials:

1. Screen: Minimum 18 gauge galvanized steel or 14 gauge aluminum.
2. Frame: Minimum 0.040 inch thick galvanized sheet steel or aluminum sheet.

2.14 Bolts and nuts: Indoors, galvanized steel; exposed to weather, stainless steel.DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

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

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all products in strict accordance with the manufacturer's written installation instructions.

B. Coordinate the installation of products provided within other sections of Division 23 including but not limited to control dampers, airflow measuring stations, etc.

3.2 INSTALLATION

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

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

C. Install backdraft or control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, outside air, and exhaust systems where branches extend from larger ducts and as indicated. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

1. Install volume dampers at the following locations:

    a. At all splits, except grease exhaust ducts.
    b. In ducts serving single supply, return, outside air, and exhaust outlets.
    c. In open return ducts above ceiling.
    d. In ducts connecting to a common plenum.
    e. Where indicated on drawings and in details.
    f. Where required for balancing.
2. Install a 24” long yellow strip of material to each damper handle for easy visual location. These strips must be in place prior to Substantial acceptance.
3. Install remote damper operators for volume dampers above ceilings which are non-accessible or without access panels.
4. Install steel volume dampers in steel ducts.
5. Install aluminum volume dampers in aluminum ducts.
6. Do not install volume dampers in grease ducts.

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

F. Install test holes at fan inlets and outlets and elsewhere as indicated and in ductwork where required for testing and adjusting.

G. Install fire, smoke and combination fire/smoke dampers according to UL listing in ducts and openings in the following:

1. Shaft walls.
2. Floors and ceilings.
3. Fire walls.
4. Fire resistance partitions.
5. Fire rated ceilings.
6. Exit corridor walls.
7. Elsewhere as indicated on drawings.

H. Install duct security bars. Install where indicated on drawings. Provide 12-by-12-inch hinged access panel with cam lock in duct in each side of sleeve.

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

1. On both sides of duct coils.
2. Upstream and downstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire, smoke or combination fire/smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers

having fusible links shall be ~~pressure relief access doors and shall be~~ outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.

~~7. At each change in direction and at maximum 50-foot spacing.~~
~~8.~~7. Upstream from turning vanes.
~~9.~~8. Upstream or downstream from duct silencers.
~~10.~~9. Control devices requiring inspection, including smoke detection heads.
~~11.~~10. At fan bearings enclosed in ducts.
~~12.~~11. Inlet side of each single width centrifugal fan.
~~13.~~12. At inlet and outlet sides of each in-line centrifugal and axial fan.
~~14.~~13. At duct humidifiers.

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

K. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
3. Head and Hand Access: 18 by 12 inches.
4. Head and Shoulders Access: 21 by 14 inches.
5. Body Access: 25 by 14 inches.
6. Body plus Ladder Access: 25 by 17 inches.

L. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

M. Install flexible connectors at duct connections to equipment, at building expansion joints, at connections between ducts of dissimilar metals and at penetrations of mechanical equipment room walls.
1. Install flexible connections with 2 inches slack in fabric and minimum movement of 1 inch.

N. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

O. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct as detailed on drawings. Do not use flexible ducts to change directions.

P. Connect diffusers or light troffer boots to ducts directly or with maximum 60-inch lengths of flexible duct clamped in place.

Q. Install duct test holes where required for testing and balancing purposes.

R. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

S. Install wire mesh screen grilles at return air ducts in hung ceilings and in other places where indicated. Bolt grilles to flanged connections or ducts at terminations.

T. Air Flow Measuring Stations

1. Install air flow measuring stations where indicated, or as directed by engineer.
2. Install all interconnecting tubing between measuring station, companion meter and control systems, in accordance with the manufacturer’s printed instructions.

3.3 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

3.4 MANUFACTURER’S FIELD SERVICES

A. Provide services of a testing agency to take noise measurements per section 23 0593. Use meters meeting requirements of ASA 47 (ANSI S1.4).

B. After start-up, and final corrections and balancing of systems, take octave band sound measurements over full audio frequency range in areas adjacent to mechanical equipment rooms, duct and pipe shafts, and other critical locations, as directed.

C. Provide one-third octave band measurements of artificial sound sources in areas indicated as having critical requirements.

D. Submit complete report of test results including sound curves.

END OF SECTION 23 33 00

SECTION 23 34 13 - AXIAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Tubeaxial fans.
2. Vaneaxial fans.
3. Mixed-flow fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

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

1. Certified fan performance curves with system operating conditions clearly plotted and including:

    a. Sound power levels for both fan inlets and outlet at rated capacity.
    b. Manufacturer’s data for adjustable fan blades for at least five (5) blade settings, including maximum.
    c. Minimum “turn down” CFM for controllable pitch fans.

2. Certified fan sound power ratings, including:
    a. Fan manufacturer’s published sound power, level data based on actual test, on the fan sizes being furnished, conducted in accordance with current AMCA standards. Such data is to define sound power levels (PWL) re: 10-12 watts for each of the eights (8) frequency bands.
    b. Manufacturer’s estimated data will not be acceptable.

3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.

5. Dampers, including housings, linkages, and operators.
6. Fan speed controllers.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

D. System Effect Calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fans capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions the vendor is responsible for calculating the “System Effect” pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, top speed and other required capacity data to be cored to account for the “System Effect” pressure drop and for a minimum of 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horse power to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

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

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final locations, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer’s wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Belts: One set for each belt-driven unit.

PART 2 - PRODUCTS

2.1 TUBEAXIAL FANS

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

1. Aerovent; a Twin City Fan Company.
2. American Fan Company (Flakt/Woods).
3. Barry Blower Div.; Penn Ventilation Companies, Inc.
4. Greenheck.
5. Loren Cook Co.

B. Description: Fan wheel and housing, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

C. Housings: Hot rolled steel ASTM A-283, 0.187 inch thick for fans up to 28 inches ID, and 0.250 inch for larger fan ID’s.

D. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

E. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft.

F. Wheel Assemblies: Cast aluminum, machined and fitted to shaft.

G. Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, heavy duty, pillow block type, self-aligning ball or roller bearings.

    a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
    b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
    c. Extend lubrication lines to outside of casing and terminate with grease fittings.

H. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
3. Propeller Access Section Door: Short duct section bolted to fan inlet and outlet allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.

8. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
9. Backdraft Dampers: Ultra-low leakage type, for bolting to the discharge of fan or outlet cone, of same material as housing. Maximum leakage not to exceed 0.07% at 3 inches W.C. static pressure.
10. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F.
11. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
12. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
13. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
14. Inlet Cones: Round-to-round transition of same material as housing.
15. Outlet Cones: Round-to-round transition of same material as housing.
16. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

I. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.

J. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

    a. Apply to finished housings.
    b. Apply to fan wheels.

K. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.2 VANEAXIAL FANS

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

1. Aerovent; a Twin City Fan Company.
2. American Fan Company (Flakt/Woods).
3. Barry Blower Div.; Penn Ventilation Companies, Inc.
4. Greenheck.
5. New York Blower Company (Jay).
6. Loren Cook Co.

B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

1. Variable-Pitch Fans: Internally mounted electronic actuator

    a. Fan blades shall be automatically controllable through full design pitch range to vary volume and pressure characteristics across this range.
    b. Each blade to be index marked for various pitch settings and shall be capable of stepless control across the complete pitch range with the motor operating at full speed.
    c. Blades in the controllable pitch hub shall be remotely-controlled by an actuator furnished by the fan manufacturer.

C. Housings: Hot rolled steel ASTM A 283, 0.187 inch thick for fans up to 28 inch ID and 0.250 inch for larger fan ID's, continuously welded.

1. Inlet and Outlet Connections: Flanges.
2. Guide Vane Section: At least 8 stationary integral guide vanes, 3/16 inch thick, downstream from fan wheel designed to straighten airflow.

D. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft.

E. Wheel Assemblies: Cast-aluminum hub assembly, machined and fitted with threaded bearing wells to receive blade-bearing assemblies with replaceable, cast-aluminum blades; factory mounted and balanced.

F. Drives for belt driven fans: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, heavy duty, pillow black type, self-aligning ball or roller bearings.

    a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
    b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
    c. Extend lubrication lines to outside of casing and terminate with grease fittings.

G. Direct Motor Driven Fans:

1. Arrangement 4 with motor inside fan housing.

2. Fan rotor assembly attached directly to motor shaft, properly keyed and secured by means of a ball bearing locknut and washer for a positive locking method of securing rotor to fan shaft.
3. Motor Mount: Flange mounted, with motor flange recessed into motor support plate to preclude any shear effect on bold misalignment.
4. Motor Support Plate: Steel plate, 0.75 inch thick, welded to fan housing by means of motor support ring and names.
5. Motor Support Ring: Steel, at least 0.25 inch thick on hub sized up to 17 inch and at least 0.375 inch thick on hub sizes 21 inch and larger. Continuously welded to motor support plate.

H. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
3. Propeller Access Section Door: Short duct section bolted to fan inlet and outlet allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
8. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
9. Backdraft Dampers: Ultra low leakage type for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing. Maximum leakage not to exceed 0.07% at 3 inches W.C. static pressure.
10. Stall Alarm Probe: Sensing probe capable of detecting fan operation in stall and signaling control devices. Control devices and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."
11. Flow Measurement Port: Pressure measurement taps installed in the inlet of fan to detect and signal airflow readings to temperature-control systems. Control devices and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."
12. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F.
13. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
14. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
15. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
16. Inlet Cones: Round-to-round transition of same material as housing.

17. Outlet Cones: Round-to-round transition of same material as housing.
18. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

I. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream.

a. Flange mounted NEMA standard totally enclosed air over, single speed single winding continuous duty variable torque type.
b. High efficiency type with ball bearings AFEMA “PP,” and Class “F” insulation using thermosetting insulating varnish fortified with water repelling silicone ambient.
c. Provide external copper grease leads for lubrication of motor bearings.
d. Suitable for operation in vertical, horizontal or angular position.

J. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

a. Apply to finished housings.
b. Apply to fan wheels.

4. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.3 MIXED-FLOW FANS

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

1. Loren Cook Company.
2. Greenheck.

B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive, and accessories.

C. Housings: Galvanized steel.

1. Inlet and Outlet Connections: Outer mounting frame and companion flanges.
2. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
3. Mixed-Flow Outlet Connection: Flanged discharge(s) perpendicular to fan inlet.

D. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

E. Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Motor Mount: Adjustable base.
7. Shaft Bearings: Radial, heavy duty, pillow block type, self-aligning ball or roller bearings.

   a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
   b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
   c. Extend lubrication lines to outside of casing and terminate with grease fittings.

F. Accessories:

1. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
2. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
3. Backdraft Dampers: Low leakage type for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing.
4. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
5. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
6. Inlet Cones: Round-to-round transition of same material as housing.
7. Outlet Cones: Round-to-round transition of same material as housing.
8. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

G. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.

H. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.

2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

    a. Apply to finished housings.
    b. Apply to fan wheels.

I. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.4 SOURCE QUALITY CONTROL

A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install axial fans level and plumb.

B. Support floor-mounting units. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

    1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Support suspended units from structure using threaded steel rods. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. Install units with clearances for service and maintenance.

G. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Drawings indicate a specific configuration of ductwork at each unit. If configuration of the units furnished differs from that indicated on the drawings (whether or not the units are scheduled units, or of a listed manufacturer, or an acceptable substitute), it shall be the Contractor's responsibility to modify ductwork, etc., as required to accommodate the actual configuration of the units furnished.

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

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

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
9. Disable automatic temperature-control operators, energize motor and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.
10. Shut unit down and reconnect automatic temperature-control operators.
11. Remove and replace malfunctioning units and retest as specified above.

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

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

END OF SECTION 23 34 13

SECTION 23 34 16 - CENTRIFUGAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Airfoil centrifugal fans.
2. Backward-inclined centrifugal fans.
3. Forward-curved centrifugal fans.
4. Tubular and in-line centrifugal fans.
5. Utility/vent sets.
6. Cabinet fans.
7. Plenum fans.
8. Plug fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

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

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings, based on actual test on the fan sizes being furnished, and conducted in accordance with current AMCA standards. Data shall define sound-power levels (PWL) re: 10-12 watts for each of the eight (8) frequency bands. Manufacturer's furnishing estimated data will not be accepted.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

D. System Effect Calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fans capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions the vendor is responsible for calculating the "System Effect" pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, tip speed and other required capacity data to be corrected to account for the "System Effect" pressure drop and for a minimum of 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horsepower to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: Instructions for lubrication, motor and drive replacement, spare parts list and wiring diagrams, for centrifugal fans to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

C. AMCA certification in accordance with AMCA Standard 210 and AMCA Standard 2408 for centrifugal fans. Class I, II, or III, as required for operating conditions.

D. Where variable inlet vanes are used, fan performance characteristics must be manufacturer's published catalog rating data of fan with vanes.

E. NEMA Compliance: Motors and electrical accessories shall comply with NEMA 1.

F. UL/cUL Power Ventilator for Smoke Control Systems.

G. UL/cUL 705, Power Ventilators.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer's wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Belts: Two sets for each belt-driven unit.

PART 2 - PRODUCTS

2.1 GENERAL

A. Units furnished shall be complete with all components assembled. All features considered standard by the manufacturer and which are required to complete the system, and to make it functional, shall be included without respect to specified detailing in these specifications.

B. Drawings indicate a specific configuration of ductwork at each unit based on required discharge and intake requirements and taking into account fan rotation. If configuration of the units furnished on the project differs from that indicated on the drawings (whether or not the units furnished are the scheduled units, a listed manufacturer or an acceptable substitute), it shall be the Contractor's responsibility to modify ductwork, etc., as required to accommodate the actual configuration of units furnished on the project.

C. Fan manufacturer shall provide all ultra-low leakage type motorized backdraft dampers of type indicated on drawings.

1. Frames: Galvanized steel, not less than 0.09 inch thick.
2. Blades: Galvanized steel, not less than 0.064 inch thick and not more than 8 inches wide.
3. Bearings: Oiltite, ball bearing or nylon, with 0.50 inch shafts.
4. Side seals: Stainless steel of the tight-seal spring type.
5. Maximum leakage not to exceed 0.07% at static pressure of 3 inches W.C.
6. Submit leakage and flow characteristic date for all backdraft dampers with fan manufacturer's submittals.

D. Spark Resist and Construction for fans as noted.

1. Spark Arrestance Class:

   a. Class A: All parts in contact with air, non-ferrous.
   b. Class B: Fan wheel and rubbing, non-ferrous.
   c. Class C: Inlet cone and rub ring, non-ferrous.

2. Motor: Explosionproof, Class I, Group D, Division 2.
3. Belt Drive: Non-sparking.
4. Fan arrangement with bearings out of air stream.
5. No inlet vanes or outlet dampers.
6. Verify corrosive characteristics of materials being handled, operating temperatures and whether fumes are wet or dry. Fan manufacturer to determine the material, number and thickness of coats, preparation of metal surfaces, baked or air dried, etc.
7. Assure that corrosion resistant construction does not conflict with spark-resistant requirements.

E. Corrosion Resistant Construction for fans as noted.

1. Fan shall be completely corrosion resistant, equipped with fan blades best suited for corrosion protection method.
2. Scroll and Wheel: Type 304, 316 stainless steel.

2.2 AIRFOIL CENTRIFUGAL FANS

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

1. Aerovent; a Twin City Fan Company.
2. Barry Blower Co.

3. Chicago Blower Corporation.
4. Greenheck Fan Corp.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff, with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Airfoil Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing. For fans 24" and larger, bearings housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

    a. Adjustable pitch diameter:

        1) For fans with motors up to 5 hp.
        2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

    b. Fixed pitch diameter:

        1) Fans with motors 25 hp and larger.
        2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
        3) All fans with variable inlet vanes or variable frequency drives.
        4) Supply and install on fixed pitch pulley per fan to balance systems.

    c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant non-sparking and non-static matched sets for multiple belt drives.

5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.

7. Inlet Screens: Grid screen of same material as housing.
8. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
13. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.3 BACKWARD-INCLINED CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.
2. Barry Blower Co.
3. Chicago Blower Corporation.
4. Greenheck Fan Co.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Backward-Inclined Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearings housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

   a. Adjustable pitch diameter:

      1) For fans with motors up to 5 hp.
      2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

   b. Fixed pitch diameter:

1) Fans with motors 25 hp and larger.
2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
3) All fans with variable inlet vanes or variable frequency drives.
4) Supply and install on fixed pitch pulley per fan to balance systems.

c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.
7. Inlet Screens: Grid screen of same material as housing.
8. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
13. Bearing Lubricating: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.

2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Capacities And Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.4 FORWARD-CURVED CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.
2. Barry Blower Co.
3. Chicago Blower Corporation.
4. Greenheck Fan Corp.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Forward-Curved Wheels: Black-enameled or galvanized steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, horizontally split cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

    a. Adjustable pitch diameter:

        1) For fans with motors up to 5 hp.
        2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

    b. Fixed pitch diameter:

        1) Fans with motors 25 hp and larger.
        2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
        3) All fans with variable inlet vanes or variable frequency drives.
        4) Supply and install on fixed pitch pulley per fan to balance systems.

4. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation.

Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

7. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.
7. Inlet Screens: Grid screen of same material as housing.
8. Outlet screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
13. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Galvanized steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.5 TUBULAR (INLINE) CENTRIFUGAL FANS

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

1. Aerovent, a Twin City Fan Company.
2. Barry Blower Company.
3. Greenheck Fan Corporation.
4. Loren Cook Company.

B. Description: Factory-fabricated~~,~~ -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed steel panels to make tubular housings, continuously welded, with doors or panels to allow access to internal parts and components.

1. Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Spun inlet cone with flange.
3. Inlet and outlet flanges.
4. Straightening Vanes: Downstream from fan wheel designed to straighten airflow.

D. Airfoil Wheels: With curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

E. Backward-Inclined Wheels: With curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast steel hub riveted to backplate and fastened to shaft with set screws.

F. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan’s speed range.

G. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Heavy duty, self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

I. Grease-Lubricated Shaft Bearings: Heavy duty, self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

J. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

   a. Adjustable pitch diameter:

      1) For fans with motors up to 5 hp.
      2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

   b. Fixed pitch diameter:

      1) Fans with motors 25 hp and larger.
      2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
      3) Supply and install on fixed pitch pulley per fan to balance systems.

   c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

K. Accessories:

1. Access Doors: Shaped to conform to housing, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan housing, of same material as housing.
3. Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan housing.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.

5. Mounting Brackets: For horizontal floor or ceiling mounting and for vertical mounting.
6. Drive chamber and Belt Tube: Isolate belts and drives from air stream, of same material as housing.
7. Inlet and Outlet Screens: Where no connecting ductwork is indicated, grid screen of same material as housing.
8. Shaft Seals: Airtight seals around shaft or drive side, of felt or neoprene.
9. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone, extended to outside of housing.
10. Spark-Resistance Construction: AMCA Type B.

L. Motors: Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. Enclosure Type: Totally enclosed, fan cooled.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

N. Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

2.6 UTILITY VENT SETS

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

1. Aerovent: a Twin City Fan Company.
2. Chicago Blower Corporation.
3. Greenheck Fan Corp.
4. Loren Cook Company.
5. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and –finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly and common bare structure, with bearing pedestal, in fan arrangement 10.

C. Fans shall be UL listed as “Power Ventilators for Smoke Control Systems” (by maximum temperature for a minimum number of hours of operation) for one of the following:

1. 500°F (260°C) maximum temperature for a minimum of 4 hours of operation
2. 572°F (300°C) maximum temperature for a minimum of 2 hours of operation.
3. 750°F (400°C) maximum temperature for a minimum of 2 hours of operation.
4. 1000°F (538°C) maximum temperature for a minimum of 15 minutes of operation.
5. The UL Power Ventilators for Smoke Control sticker shall be fixed to the fan housing

D. Housings: formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Bearing pedestal: Steel angle, integral with fan bracing for mounting bearings. Fan motor mounted under bearing pedestal.
3. Housings: Field rotatable to standard discharge positions.
4. Inlet cone.
5. Outlet and inlet flanges.

E. Fan Wheels:

1. Under 12 inch (305 mm): Forward curved wheels, steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
2. 12 inch (305 mm) and larger: Backward inclined wheels, steel construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened shaft with set screws.

F. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

G. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.

3. Motor Pulleys: Cast iron or cast steel. Adjustable pitch diameter for use with motors up to 5 hp; fixed pitch diameter for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use to tachometer with guard in place
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Discharge Dampers: Assembly parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control level of same material as housing.
6. Inlet Screens: Grid screen of same material as housing.
7. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
8. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
9. Spark-Resistant Construction: AMCA 99.
10. Shaft Seals: Airtight seals installed around shaft on drive side of fans.
11. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing and support base.

K. Motors: Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. Enclosure Type: Totally closed, fan cooled.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.7 CABINET FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Greenheck Fan Corporation.
2. Loren Cook Company.
3. Penn Ventilator Company.
4. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and –finished, units, consisting of insulated cabinet containing filter box, fan wheel(s), fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Cabinet: Galvanized sheet steel, at least 0.08 inch thick, reinforced and braced with angles, with hinged or bolted access panels to allow access to internal parts and components.

1. Internal Bracing: Steel angle or channel-iron supports for mounting fan wheels(s), shaft, motor and accessories.
2. Inlet and outlet duct connection flanges.
3. Internal Insulation: Coated fiberglass board insulation, NFPA 90 approved, 1 inch thick, 1.5 lb density.

D. Fan Wheels: Galvanized steel construction forward curved in direction of air flow or backward inclined blades mounted on a common shaft and secured with keyways.

E. Shafts: Solid steel selected for continuous operation at maximum rated fan speed and motor horsepower.

1. Shaft mounted on ball bearings.
2. Motor and drive frame isolated on shock mounts.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Cast iron or cast steel. Adjustable pitch diameter for use with motors up to 7 1/2 hp; fixed pitch diameter for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

H. Accessories:

1. Access Panels: hinged or bolted gasketed panels allowing access to internal parts and components in cabinet, of same material as cabinet.
2. Companion Flanges: Flanges for duct connections of same material as cabinet.
3. Spark-Resistant Construction: AMCA 99.
4. Bearing Lubrication: Lubricating fittings and pressure relief fittings extended to accessible locations.
5. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.

I. Motors: Ball bearing type. Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. Enclosure Type: Totally enclosed fan cooled.

J. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

K. Filter Box: Galvanized sheet steel fabricated as specified for cabinet, to mate with fan cabinet, with side access panels for filter replacement.
1. Filters: 2 inch (50 mm) thick throwaway pleated type.

2.8 PLENUM FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Mfg. Corp.
2. Aerovent; a Twin City Fan Company.
3. Chicago Blower Corporation.
4. Greenheck Fan Corporation.
5. Loren Cook Company.
6. Trane.
7. Owner approved substitution.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

D. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.

2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

H. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

I. Accessories:

1. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
2. Spark-Resistant Construction: AMCA 99.
3. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

J. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.

K. Characteristics:

1. Wheel Material: Steel.
2. Special Wheel Coating: Powder-baked enamel.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

M. Spark Arrestance Class: A.

2.9 PLUG FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Mfg. Corp.
2. Aerovent; a Twin City Fan Company.
3. Chicago Blower Corporation.
4. Loren Cook Company.
5. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure for installation into a fan plenum or duct.

C. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped, backward inclined, blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

D. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

I. Accessories:

1. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
2. Spark-Resistant Construction: AMCA 99.
3. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
4. Spun inlet cone with flange.
5. Safety Guard: Heavy wire screw cage to enclose moving parts of fan where required for personnel protection.
6. Inlet Vane and Econocone Actuators: with separate access section, minimum 21 inches (530 mm) long, with door for upstream access to vanes.

J. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.

K. Characteristics:

1. Wheel Material: Steel.
2. Special Wheel Coating: Powder-baked enamel.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

M. Spark Arrestance Class: A.

2.10 SOURCE QUALITY CONTROL

A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install centrifugal fans level and plumb.

B. Support floor-mounting units using spring isolators having a static deflection of 1 inch. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. All roof-mounted equipment shall be properly secured to the building structure to withstand local Coastal Windstorm criteria, ie., minimum 115 MPH hurricane force winds.

G. Install units on raised supports where so noted. Furnish platform and all supports and bracing, and provide suitable vibration isolation.

H. Overhead suspended unites and units on raised supports shall be provided with access platforms, railings and ladders.

I. Install units with clearances for service and maintenance.

J. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Install ducts adjacent to fans to allow service and maintenance.

C. Install line-sized piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain.

D. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

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

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning, including ductwork, and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
9. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.
10. Remove and replace malfunctioning units and retest as specified above.

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

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain centrifugal fans.

3.5 FINAL CLEANING

A. Refer to Section 01 74 23 for final cleaning.

END OF SECTION 23 34 16

SECTION 23 34 23 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:
1. Centrifugal roof ventilators.
2. Axial roof ventilators.
3. Upblast propeller roof exhaust fans.
4. Centrifugal wall ventilators.
5. Ceiling-mounting ventilators.
6. In-line centrifugal fans.
7. Propeller fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

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

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Roof curbs.
7. Fan speed controllers.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1. Roof framing and support members relative to duct penetrations.
2. Ceiling suspension assembly members.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

D. System Effect calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fan capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions, the vendor is responsible for calculating the “System Effect” pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, tip speed and other required capacity data to be corrected to account for the “System Effect” pressure drop and for a minimum 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horse power to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. Sound-Power Level Ratings: Comply with AMCA 301, “Methods for Calculating Fan Sound Ratings from Laboratory Test Data.” Factory test fans according to AMCA 300, “Reverberant Room Method for Sound Testing of Fans.” Label fans with the AMCA-Certified Ratings Seal.

C. AMCA Compliance: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, “Laboratory methods of Testing Fans for Rating.” Label fans with the AMCA Certified Ratings Seal...

D. American Society for Testing Materials (ASTM): Standard E84, Surface Burning Characteristics of Building Materials.

E. National Fire Protection Association (NFPA): Standard 255, Test Methods, Surface Burning Characteristics of Building Materials.

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

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

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer’s wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Belts: Two sets for each belt-driven unit.

PART 2 - PRODUCTS

2.1 General

A. Units furnished shall be complete with all components assembled. All features considered standard by the manufacturer and which are required to complete the system, and to make it functional, shall be included without respect to specific detailing in these specifications.

B. A specific configuration of the duct at each unit has been indicated on the drawings based on required discharge and intake requirements. If the configuration of the units furnished on the project differs from that indicated on the drawings (whether or not the units furnished are scheduled units, a listed manufacturer or an acceptable substitute), it shall be the Contractor's responsibility to modify duct, etc. as required to accommodate the actual configuration of units furnished on the project.

C. Low leakage motorized backdraft dampers: The fan manufacturer shall provide ultra low leakage type motorized backdraft dampers as indicated on the plans. Frames shall not be less than 0.093 inch thick galvanized steel. Blades must not be over 8 inches wide galvanized steel roll formed with edge seals. Bearing shall be Oiltite, ball bearing or nylon with ½" shafts. Side seals shall be stainless steel of the tight-seal spring type. Dampers and seals shall be suitable for temperature ranges of 40°F to 200°F. Dampers shall be minimum (ultra-low leakage) leakage type to conserve energy and the manufacturer shall submit leakage and flow characteristic data for all backdraft dampers with the fan manufacturer temperature control submitted. Maximum leakage shall be 0.07% at static pressure of 3 inches of WC.

D. Preview safety disconnects shall be mounted on the fans at the fan motor with flexible conduit and shall conform to requirements of ~~Division 16~~specification section 23 05 33. Roof mounted fans with three phase motors shall have NEMA-3R disconnects pre-wired.

E. Three phase motors 1 ½ hp and larger shall be TEFC premium plus high efficiency.

F. Furnish and install curb mounted outside air intake hoods, exhaust fan discharge air hoods, relief hoods, and curb mounted rook exhaust fans on roof curbs where indicated on the drawings.
   1. Openings in roof and supporting miscellaneous steel and structural framing as required for support of all roof mounted outside air intake hoods, roof mounted relief hoods, roof mounted discharge hoods for ceiling exhaust fans, and roof mounted exhaust fans shall be by the General Contractor.
   2. HVAC Contractor must furnish to the General Contractor exact curb outside dimensions, exact roof opening sizes and dimensioned location of roof curbs on roof.
   3. Roof curbs for aluminum fans shall be minimum 18" tall, factory pre-fabricated all welded aluminum construction, factory insulated with built in cant, 1 ½" by 1 ½" wolmanized and fire treated wooded nailer strip, 1 1/2" wide by 1/8" thick neoprene full perimeter curb gasket. Roof curbs shall be furnished with damper trays for ease of mounting damper and duct connection. Roof curbs for galvanized steel fans

shall be same as for aluminum curbs, except factory pre-fabricated all welded galvanized construction.

4. Where fans are installed on sloping roofs, the fan manufacturer shall provide a roof curb that matches the roof slop or curvature to allow the fan to be installed level and shall be responsible for coordination with Architectural drawings for exact roof slop and for flashing and sealing details.
5. Where fans are installed on standing seam metal sloping roofs, the standing seam metal roofing manufacturer shall provide the roof curb.
   a. The standing seam metal roofing manufacturer shall provide a 12" high insulated, welded, galvanized, steel roof curb with 1 ½" by 1 ½" wolmanized and fire treated wooden nailer strip for all roof mounted outside air intake goods, roof mounted discharge hoods for ceiling exhaust fans, roof mounted exhaust fans to match slope and roofing material corrugations and standing seam configuration. Roofing manufacturer must coordinate with Architectural drawings for exact roof slope and for flashing sealing details.
   b. Roofing manufacturer must coordinate with HVAC Contractor for exact curb outside dimensions, exact backdraft damper tray opening and dimensions, and exact roof opening size for fans furnished by the contractor.
   c. General Contractor must install roof curbs in manner as recommended by standing seam metal roofing manufacturer furnished on the project and as detailed by the Architect.

G. Corrosion Resistant Construction: For fans so indicated or specified, entire fan shall be completely corrosion resistant, and shall be provided with a scroll drain, shaft seal and flanged inlet and outlets.
   1. Shaft shall be made of stainless steel.
   2. Scroll and wheel shall be stainless steel.

2.2 CENTRIFUGAL ROOF VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Carnes Company HVAC.
   2. Greenheck.
   3. Loren Cook Company.
   4. Penn Ventilation.

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

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

   1. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains and grease collector.
   2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

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

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Fan and motor isolated from exhaust airstream.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   a. Fan pulley: Fixed pitch diameter.
   b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an internal aluminum conduit.
3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
4. Dampers: Counterbalanced, rattle free, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
5. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

G. Roof Curbs: Aluminum; mitered and welded corners; 1-1/2-inch-thick, rigid, fiberglass insulation adhered to inside walls, damper tray and 1-1/2-inch wood nailer and neoprene curb sealing gasket. Size as required to suit roof opening and fan base.

1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 18 inches.
3. Sound Curb: Curb with sound-absorbing insulation matrix.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Aluminum.
6. Burglar Bars: 1/2-inch- thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.
8. Vented Curb: Unlined with louvered vents in vertical sides.

H. Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

2.3 AXIAL ROOF VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Aerovent; a Twin City Fan Company.
   2. Carnes Company HVAC.
   3. Greenheck.
   4. Loren Cook Company.
   5. Penn Ventilation.

B. Description: Direct- or belt-driven axial fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.

   1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

D. Fan Wheel: Aluminum hub and blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   3. Pulleys: Cast-iron or cast steel.
      a. Fan pulley: Fixed pitch diameter.
      b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   4. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

   1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an internal aluminum conduit.
   2. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   3. Dampers: Counterbalanced, rattle free, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   4. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

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

1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 18 inches.
3. Sound Curb: Curb with sound-absorbing insulation matrix.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Aluminum.
6. Burglar Bars: 1/2-inch- thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

H. Capacities and Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

2.4 UPBLAST PROPELLER ROOF EXHAUST FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carnes Company HVAC.
2. Greenheck.
3. Loren Cook Company.
4. Penn Ventilation.
5. Owner approved substitution.

B. Description: Direct- or belt-driven propeller fans consisting of housing, wheel, butterfly-type discharge damper, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Wind Band, Fan Housing, and Base: Reinforced and braced galvanized steel, containing galvanized-steel butterfly dampers and rain trough, motor and drive assembly, and fan wheel.

1. Damper Rods: Steel with bronze bearings.
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

D. Fan Wheel: Replaceable, cast or extruded-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing; weatherproof housing of same material as fan housing with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   a. Fan pulley: Fixed pitch diameter.
   b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed

controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matches, etc. for multiple belt drives.
5. Motor Mount: On outside of fan cabinet, adjustable base for belt tensioning.

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

1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 18 inches.
3. Sound Curb: Curb with sound-absorbing insulation matrix.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Galvanized steel.
6. Burglar Bars: 1/2-inch-thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

G. Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

H. Special Applications:
1. Kitchen Exhaust Fans:
   a. Up-blast type centrifugal with non-sparking aluminum wheel and hub.
   b. Stainless steel piano hinge on one side to permit service and maintenance.
   c. Ventilated extended height roof curb to meet NFPA 96 minimum discharge height above roof of 40 inches.
   d. U.L. 762 listed for grease removal.
   e. Grease trough.
   f. Without backdraft damper.
   g. Flexible electrical connector with pre-wired NEMA 3R disconnect switch.
2. Smoke Exhaust Fans:
   a. Up-blast type, all steel construction, with heat slinger wheel and seal.
   b. High temperature bearings and bearing grease.
   c. Motor and belt outside of air stream with insulated belt housing.
   d. Bifurcated housing for direct drive motor outside of air stream.
   e. U.L. 792 listed for high temperature operation and duration, i.e. 1,000°F with minimum operation of 15 minutes and 500°F with 4 hours minimum operation.
   f. Ultra-low leakage motorized back-draft damper.
   g. Inlet bell with debris screen.
   h. Flexible electrical connector with pre-wired NEMA 3R disconnect switch.

2.5 CENTRIFUGAL WALL VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Carnes Company HVAC.
   2. Greenheck.
   3. Loren Cook Company.
   4. Penn Ventilation.

B. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.

C. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.

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

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   3. Fan and motor isolated from exhaust airstream.
   4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
      a. Fan pulley: Fixed pitch diameter.
      b. Motor pulley: variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   5. Belts: Oil-resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
   3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   4. Wall Grille: Ring type for flush mounting.
   5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
   6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

G. Characteristics:
   1. Drive Arrangement: Direct or Belt drive as scheduled.
   2. Sound: As scheduled.
   3. Damper: Yes.

2.6 CEILING-MOUNTING VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Broan Mfg. Co., Inc.
   2. Carnes Company HVAC.
   3. Greenheck.
   4. NuTone Inc.
   5. Penn Ventilation.
   6. Loren Cook Co.
   7. Owner approved substitution.

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

C. Housing: Steel, lined with acoustical insulation.

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

E. Grille: Painted aluminum, louvered grille with flange on intake and thumbscrew attachment to fan housing.

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

G. Accessories:

   1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   2. Manual Starter Switch: Single-pole rocker switch assembly with cover and pilot light.
   3. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
   4. Motion Sensor: Motion detector with adjustable shutoff timer.
   5. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
   6. Filter: Washable aluminum to fit between fan and grille.
   7. Isolation: Rubber-in-shear vibration isolators.
   8. Manufacturer's standard roof jack or wall cap, and transition fittings.

2.7 IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Carnes Company HVAC.
   2. Greenheck.
   3. Loren Cook Company.

4. Penn Ventilation.
5. Owner approved substitution.

B. Description: In-line, direct or belt-driven (as scheduled) centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

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

D. Rectangular and Square Housing: steel with factory applied baked enamel paint on exterior, internally insulated with 1 inch thick, 3 lb. PCF density coated fiberglass insulation secured with welded insulation speed clips. Insulation shall comply with ASTM E84 and NFPA 255 for maximum ratings of flamespread 25 and smoke developed 50. Housing shall have mounting brackets at each corner.

E. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing with wheel, inlet cone, and motor on swing-out service door.

F. Belt-Driven Units: Motor mounted on adjustable base, with adjustable motor sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.

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

H. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
3. Companion Flanges: For inlet and outlet duct connections.
4. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

I. Vibration Isolators:
1. Type: Elastomeric Hangers.
2. Static Deflection: 1/4 inch.

J. Spark Arrestance Class: As scheduled.

2.8 PROPELLER FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.

2. Carnes Company HVAC.
3. Chicago Blower Corporation.
4. Loren Cook Company.
5. Penn Ventilation.
6. Greenheck, Inc.

B. Description: Direct- or belt-driven propeller fans consisting of fan blades, hub, housing, orifice ring, motor, drive assembly, and accessories.

C. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.

D. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.

E. Fan Wheel: Replaceable, cast or extruded-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

F. Belt-Driven Drive Assembly: Resiliently mounted to housing, statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.

    a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.

4. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
5. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
6. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
7. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

G. Accessories:

1. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.
2. Motor-Side Back Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
3. Wall Sleeve: Galvanized steel to match fan and accessory size.
4. Weathershield Hood: Galvanized steel to match fan and accessory size.
5. Weathershield Front Guard: Galvanized steel with expanded metal screen.
6. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

7. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

H. Vibration Isolators: Refer to Division 23 Section "Vibration and Seismic Control for HVAC Equipment and Piping."

1. Spark Arrestance Class: As scheduled.

2.9 MOTORS

A. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Enclosure Type: Totally enclosed, fan cooled.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.

B. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Secure roof-mounting fans to roof curbs with stainless steel hardware. Refer to Division 07 Section "Roof Accessories" for installation of roof curbs.

1. Contractor shall coordinate all required roof openings with the roof structural plans and shall provide a roof opening shop drawing with the required roof openings dimensioned and sized for the General Contractor to frame out and provide roof openings. Refer to structural plans for required roof opening framing.
2. Roof curbs shall be furnished and located by the Contractor for the General Contractor’s or Owner’s bonded roofing contractor to install.
3. Secure unit curb cap to roof curb with stainless steel or cadmium-plated screws a maximum of 12” on center minimum four per side.

4. All roof-mounted equipment must be properly secured to the building structure to withstand local Coastal Windstorm criteria, i.e., minimum 145 MPH hurricane force winds and required seismic criteria.

F. Support suspended units from structure using threaded steel rods. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

G. Install units with clearances for service and maintenance.

H. Label units according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

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

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

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

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
10. Shut unit down and reconnect automatic temperature-control operators.
11. Remove and replace malfunctioning units and retest as specified above.

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

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension and align motor belt drive sheaves with fan sheaves.

C. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

D. Replace fan and motor pulleys as required to achieve design airflow.

E. Lubricate bearings.

END OF SECTION 23 34 23

SECTION 23 34 33 - AIR CURTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes air curtains with electric heat.

1.3 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, fan curves, discharge nozzle velocity profile, furnished specialties, and accessories for each unit.

B. Shop Drawings: .

1. Design Calculations: Calculate requirements for selecting vibration isolators.
2. Include plans, elevations, sections, details, and attachments to other work.
3. Wiring Diagrams: Power, signal, and control wiring.

C. Coordination Drawings: Plans and details drawn to scale and coordinating penetrations of exterior walls.

D. Samples for Initial Selection: For units with factory-applied color finishes.

E. Operation and Maintenance Data: For air curtains to include in maintenance manuals.

F. Warranties: Special warranties specified in this Section.

1.4 QUALITY ASSURANCE

A. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of air curtains that are similar to those indicated for this Project in material, design, and extent.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of air curtains and are based on the specific product indicated. Refer to Division 01 Section "Product Requirements."

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

D. Comply with AMCA 220, "Test Methods for Air Curtain Units," for airflow, outlet velocity, and power consumption.

E. Comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating. Certify coils according to ARI 410

F. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

1.5 STORAGE AND HANDLING

A. Protect unites from physical damage by storing in protected areas and leaving factory covers in place.

1.6 COORDINATION

A. Coordinate layout and installation of air curtains and suspension system components with other construction, including light fixtures, fire-suppression-system components, and partition assemblies.

B. Coordinate installation of wall penetrations and louvers. These items are specified in Division 08 Section "Louvers and Vents."

1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air curtains that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below, before construction begins, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Furnish one set of filters and fan belts for each unit.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers:
   1. Berner International Corp.
   2. Powered Aire, Inc.
   ~~2.~~3. Loren Cook Company.
   ~~3.~~4. Marley Engineered Products.
   ~~4.~~5. Mars Air Products; Dynaforce Division.
   ~~5.~~6. MesTec AG; L. J. Wing Division.

2.2 MATERIALS

A. Housing Materials: Heavy-gage, electroplated-zinc steel with welded construction and polyester-coated finish.

   1. Mounting Brackets: Steel, for wall or ceiling mounting.

B. Intake Louvers: Integral part of the housing, mechanically field adjustable and capable of reducing air-outlet velocity by 60 percent with louver in totally closed position.

C. Discharge Nozzle: Integral part of the housing, containing adjustable air-directional vanes with 40-degree sweep front to back.

2.3 FANS

A. Fans: Galvanized steel, Centrifugal, forward curved, double width, double inlet, statically and dynamically balanced.

B. Fan Drives: Direct or Belt, equipped with belt guards and adjustable sheaves and pulleys for adjusting air-outlet velocity.

2.4 MOTORS

A. Motor Type: Multispeed, resiliently mounted, continuous duty, open, dripproof, with integral thermal-overload protection.

B. Bearings: Permanently sealed, lifetime, prelubricated, ball bearings.

C. Disconnect: Internal power cord with plug and receptacle for fractional hp motors and toggle disconnect for control power. Provide NEMA 3R disconnect switch for 3 phase motors.

~~2.5 ELECTRIC HEATING COILS~~

~~A. Coil Assembly: Comply with UL 1995.~~

~~B. Frame: Galvanized-steel frame.~~

~~C. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.~~

~~D. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or unit.~~

~~1. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.~~

~~E. Control Panel: Unit mounted with disconnecting means and overcurrent protection. Include the following controls:~~

~~1. Magnetic contactor.~~
~~2. Solid-state stepless pulse controller.~~
~~3. Time-delay relay.~~
~~4. Pilot lights.~~
~~5. Airflow proving switch.~~

~~2.6~~2.5 FILTERS

A. Washable Panel Filters: Removable, stainless-steel, baffle-type filters with spring-loaded fastening; with minimum 0.0781-inch-thick, stainless-steel filter frame.

B. Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

~~2.7~~2.6 ACCESSORIES

A. Field-Installed Thermostat: Line voltage, factory installed and wired to the junction box on air curtain.

B. Automatic Door Switch: Plunger type installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.

C. Start-Stop, Push-Button Switch: Manually activates and deactivates air curtain.

D. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 0.5 seconds to 10 hours.

E. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, Type 3R enclosure.

F. Mounting Brackets: Adjustable mounting brackets for drum-type roll-up doors.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions where air curtains will be installed for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for electrical systems to verify actual locations of electrical power and controls connections before air-curtain installation.

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

3.2 INSTALLATION

A. Install air curtains with clearance for equipment service and maintenance.

B. Install air curtain discharge nozzle a manufacturer's recommended height above door opening and properly centered within door width opening.

3.3 CONNECTIONS

A. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

B. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

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

1. After installing air curtains completely, perform visual and mechanical check of individual components.
2. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Repair or replace malfunctioning units and retest as specified above.

3.5 ADJUSTING

A. Adjust belt tension.

B. Adjust motor and fan speed to achieve specified airflow.

C. Adjust discharge louver and dampers to regulate airflow.

D. Adjust air-directional vanes.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air curtains.

END OF SECTION 23 34 33